Field Trip Guide Book - P14

Florence - Italy
August 20-28, 2004

Volume n° 4 - from P14 to P36

32nd INTERNATIONAL GEOLOGICAL CONGRESS

HISTORICAL-GEOLOGICAL EVENTS AND THEIR IMPACT ON MAN

Benevento: the Trajan's Arch (or Golden Door) in old print.

Leaders: T.S. Pescatore, A. Cinque

Associate Leaders: M.R. Senatore, C. Rosskopf

Post-Congress **P14**

The scientific content of this guide is under the total responsibility of the Authors

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Front Cover:
Benevento: the Trajan’s Arch (or Golden Door)
in old Print

Leaders: T. S. Pescatore, A. Cinque
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Introduction

The main goal of this field trip is to highlight the mutual relationship between the occurrence of recent geological events and the course of historical events, mainly during Greek and Roman times, in southern Italy.

We will examine the geological and archaeological evidence of events that were able to modify the environmental conditions of specific sites and areas. Some of the historical events considered had catastrophic effects, like -for example- the Plinian eruption from Mt. Vesuvius in 79 A.D. This destroyed and buried completely the Roman towns resting at the foot of Vesuvius (4th day); furthermore, it had catastrophic indirect effects also far away from the volcano (on the morning of the 5th day). The field trip will also take into account: the high magnitude earthquake which occurred in 360 A.D. (2nd day afternoon); the significant floods that affected the Benevento area in the Late Roman times (morning of the 2nd day); the events of colluvial and alluvial deposition that punctuated the history of the Greek-Roman town of Elea-Velia (3rd day, afternoon); as well as the geomorphic change that affected some coastal plains during historical times (3rd and 4th days).

Some of the sites we will be visiting are located in Quaternary intermountain basins of the Southern Apennine chain. Namely, Saepinum is located on terraced deposits belonging to a Quaternary tectonic lake (Morcone palaeo-lake), while Benevento is located on fluvial terraces created by the Calore River. The other sites rest along the Tyrrhenian coast of Campania and belong to varied scenarios: the sea-cliffs at the base of the Vesuvius western flank (Herculaneum, Oplontis and *pro parte* Pompeii); the faulted northern coast of the Surrentine Peninsula (Marina di Equa and Sorrento); the coastal plains of the Alento-Fiumarella, Sarno and Sele rivers where the archaeological sites Velia, Pompei and Paestum are, respectively, located. For the various sites to be visited, the environments that existed –and the natural events that occurred there- during Greek or Roman times can be understood by reading the available geomorphological and stratigraphical records and by taking into account the results of some sedimentological and palaeo-ecological analyses, radiocarbon datings, and archaeological age constraints as well.

The planned schedule for the field trip is in table 1.

Field References

Topographic maps:

Touring Club Italiano – Carta Stradale d'Italia – *Campania e Basilicata* – scale 1:200,000

City Map – *Benevento* - scale 1:65,000 - Litografia Artistica Cartografica, Firenze.

Geological Maps:

Consiglio Nazionale delle Ricerche - Modello strutturale d'Italia - scale 1:500,000

Carta Geologica d'Italia - Foglio 173 - Benevento

Carta Geologica d'Italia - Foglio 183-184 - Isola d'Ischia - Napoli

Carta Geologica d'Italia - Foglio 198 - Eboli

Carta Geologica d'Italia - Foglio 209 - Vallo della Lucania

Guidebooks:

Gallimard Guide, *Naples et Pompéi.* Italie p. 335

Ministero per i Beni e le Attività Culturali & Soprintendenza per i Beni Archeologici delle Province di Salerno, Avellino e Benevento (2002). *Il Museo narrante del Santuario di Hera Argiva alla foce del Sele* (G. Greco & B. Ferrara eds). Arti Grafiche Sud, p. 40.

Greco G. (2002)–*Velia. La visita della città*. Naus, Pozzuoli (Napoli).

Other archaeological guidebooks (Saepinum. Paestum, Hera Argiva, Pompei, Herculaneum, Oplontis) will be available at the site reception desk

Table 1

First day: from Naples to Benevento
17.00-17.30 - Naples - Meeting point: Napoli Centrale Railway Station
18.00-18.30 - Naples - Meeting point: Napoli Capodichino Airport
18.30-19.30 - Transportation from Naples to the hotel in Benevento
20.30 - Dinner
Second day: Benevento and Saepinum
08.20-08.30 - Travel from Benevento to Cellarulo
08.30-09.45 - Cellarulo (Stop 1)
09.45-10.30 - Roman Amphitheatre (Stop 2)
10.30-11.15 - Roman Theatre (Stop 3)
11.15-12.15 - Arch of Trajan (Stop 4)
12.15-13.15 - Lunch

13.15-14.10 Travel from Benevento to Sepino
14.10-17.00 - Saepinum - Altilia (Stop 5)
17.00-20.00 - Travel from Sepino to the hotel at Capaccio Scalo
20.30 - Dinner

Third day: Sele coastal plain (Paestum and the Hera Argiva Sanctuary) and Velia

08.00-08.30 - Travel from Capaccio Scalo to the Hera Argiva Sanctuary
08.30-10.30 - The Hera Argiva Sanctuary (Stop 1), Museum of Hera Argiva (Stop 2)
10.30-12.15 - Pier along the beach at Paestum (Stop 3)
12.15-13.15 - Lunch
13.15-14.15 - Travel from Paestum to Velia
14.15-14.45 - The seaside town-walls (Stop 4)
14.45-15.30 - The Triportico area (Stop 5)
15.30-16.30 - The Asklepieion (Stop 6)
16.30-17.15 - Via del Porto and the Roman Necropolis (Stop 7)
17.15-18.15 - Travel from Velia to the hotel at Capaccio Scalo
18.15-19.15 - The Temples of Paestum
20.30- Dinner

Fourth day: Herculaneum, Oplontis and Pompeii

08.20-09.30 - Travel from Capaccio Scalo to Herculaneum
09.30-11.00 - Herculaneum: Belvedere (Stop 1); beach of Herculaneum (Stop 2)
11.00-11.30 - Travel from Herculaneum to Oplontis
11.30-12.15 - Oplontis (Stop 3)
12.15-13.15 - Lunch
13.15-13.45 - Travel from Oplontis to Pompeii
13.45-18.30 - Pompeii: Via dell'Abbondanza (Stop 4), Casina dell'Aquila (Stop 5); Porta Nocera (Stop 6); the walls of the city (Stop 7)
18.30-19.00 - Travel to the hotel in Pompeii
20.30- Dinner

Fifth day: Surrentine Peninsula

8.30-9.15 - Travel from Pompeii to Vico Equense
9.15-10.15 - Quaternary geology and the geomorpho logy of Vico Equense (Stop 1)
10.15-12.15 - Roman ruins of Marina di Equa (Stop 2)
12.15-12.45 - Travel from Marina di Equa to Sorrento
12.45-13.15 - Lunch
13.15-14.30 - Visit to the coastal remains of Menenio Agrippa Villa (Stop 3)
14.30-16.00 - Walk around Sorrento
16,30 - 17.15 - Hydrofoil trip to Naples
17.15 - Travel by bus from the Naples harbor to the Napoli Centrale Railway Station and to Napoli Capodichino Airport.

Regional geological setting

The Southern Apennines are a N150°-striking and NE-verging fold and thrust belt mainly derived from the deformation of the African-Apulia passive margin. It is typical of the Apennines to show compressional features (piles of thrust sheets and duplex structures) cut by subsequent extensional and transtensional faults. This style can be recognized all along the chain, but the ages of onset and/or termination of the compressional and extensional stages vary remarkably from place to place (e.g., younger and younger onset of final extension moving from Tuscany to Calabria and from the inner to the outer portion of a single segment). As far as the Campanian segment is concerned, the piling up of thrusts occurred between the Early Miocene , in the inner (i.e. southwestern) areas, and the Early Pleistocene, as found in the outermost portions of the chain.
Four wide belts have been identifed in the chain area. From east to west the following units outcrop: a) successions characterized by basinal to marginal facies, ranging in age from Cretaceous to Miocene, tectonically lying on Plio-Pleistocene deposits; b) successions characterized by shallow water, basinal and shelf-margin facies, ranging in age from Middle Triassic to Miocene (Lagonegro units) overthrust on the previous one; c) Triassic to Miocene carbonate platform successions (Apenninic platform units), overthrust on the Lagonegro units; d) Jurassic-Cretaceous to Miocene deep water successions (ophiolite-bearing units and associated siliciclastic wedges) overthrust on the Apenninic platform units. All these units tectonically lie on the buried Apulia platform (Apulia chain; Fig. 1).
Mesozoic palaeogeography and Neogene structural evolution still represent the keys for understanding western Mediterranean geodynamics. The extension, which follows the compression, is still active along the Apennine axis.

The passage to an extensional regime has not yet been dated with precision, but it is not older than the Late Pliocene near the Tyrrhenian coast, and Middle Pleistocene in the axial part of the chain, which is nowadays the place of the most active tectonism and seismicity. The major morphostructural effects of the Tyrrhenian extension were (a) the formation of wide and deep grabens along the coast (e.g. the one hosting the Campania Plain and the Gulf of Naples; the one occupied by the Sele River Plain and the Gulf of Salerno) and (b) the collapse of intermountain basins which then directed the main river valleys (e.g. the

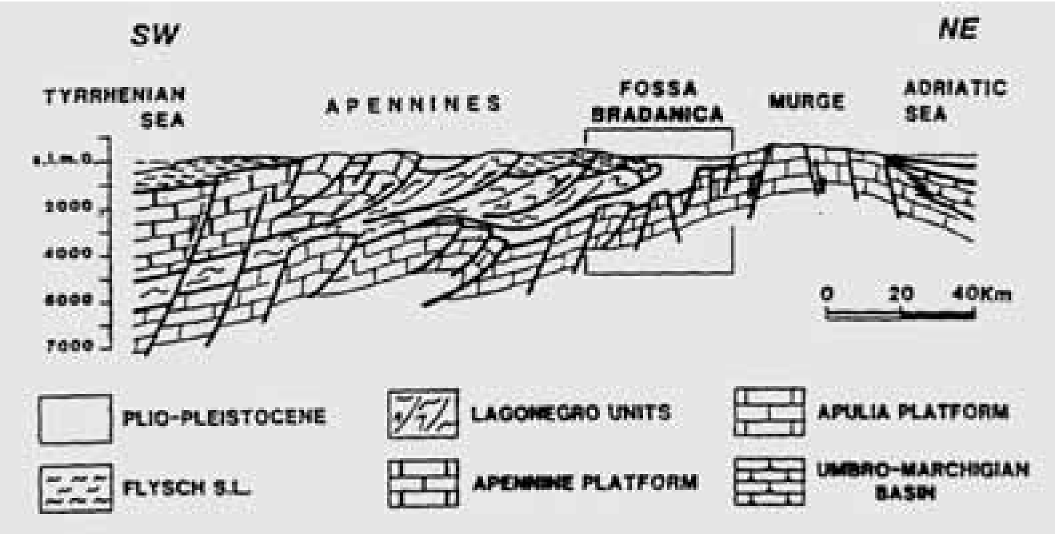

Figure 1 - Cross-section of the Southern Apennines (from Doglioni and Flores, 1997). Read "Apennine platform" as "Campania-Lucania platform"

Volturno and the Calore in Benevento), and/or which created tectonic lakes which were subsequently pirated and dissected by the powerful rivers that drain the steep south-western flank of the chain (e.g. the basins of Morcone and Vallo di Diano).

It was on these fertile coastal and intermountain plains that the Greeks and Romans founded important settlements, among which the ones to be visited during our excursions.

Variations in sea level, linked to climatic fluctuations, are evident along the coastal plains where the sand ridges of relict beaches can be found. On the interveining promontories , glacio-eustatic variations have been noted by the presence of steps of marine terraces (sometimes remarkably uplifted), by cycles of downcutting, aggradation and re-dissection of the lower valley reaches and, where the relief is made of limestone, by series of solution notches and alternations of marine and subaerial stages in karstic caves.

Furthermore, the major climatic changes in the chain are reflected in (i) the discontinuous accumulation of cryogenically-produced gravel deposits at the base of some rocky cliffs, (ii) alternating phases of alluvial fan growth and dissection along some mountain fronts, and (iii) alternating phases of aggradation and dissection along some river valleys.

DAY 1

Travel from Naples to Benevento

See table 1

DAY 2

Benevento (*T. Pescatore, M.R. Senatore, M. Boscaino, G. Tocco, G. Bisogno*) and Saepinum (*F. Pinto, V. Ceglia*)

Introduction

In Benevento, the Roman settlements were affected several times by natural events: mainly earthquakes and floods.

The Roman Theatre and Amphitheatre are located on alluvial terraces of the Calore River outside the Roman city walls (Fig. 2). Both structures are dated to I century B.C. While the Theatre has been known about for a long time, the Amphitheatre was only discovered in 1985. Before this discovery it was thought to have been built in wood, as no stone structures had been found. According to Tacitus in A.D. 63, a very important gladiatorial performance in honour of Nero took place in the Amphitheatre.

Stop 1:

Cellarulo

The main synorogenic units cropping out around Benevento show that the town is situated in a tectonic depression inside the Apenninic chain that

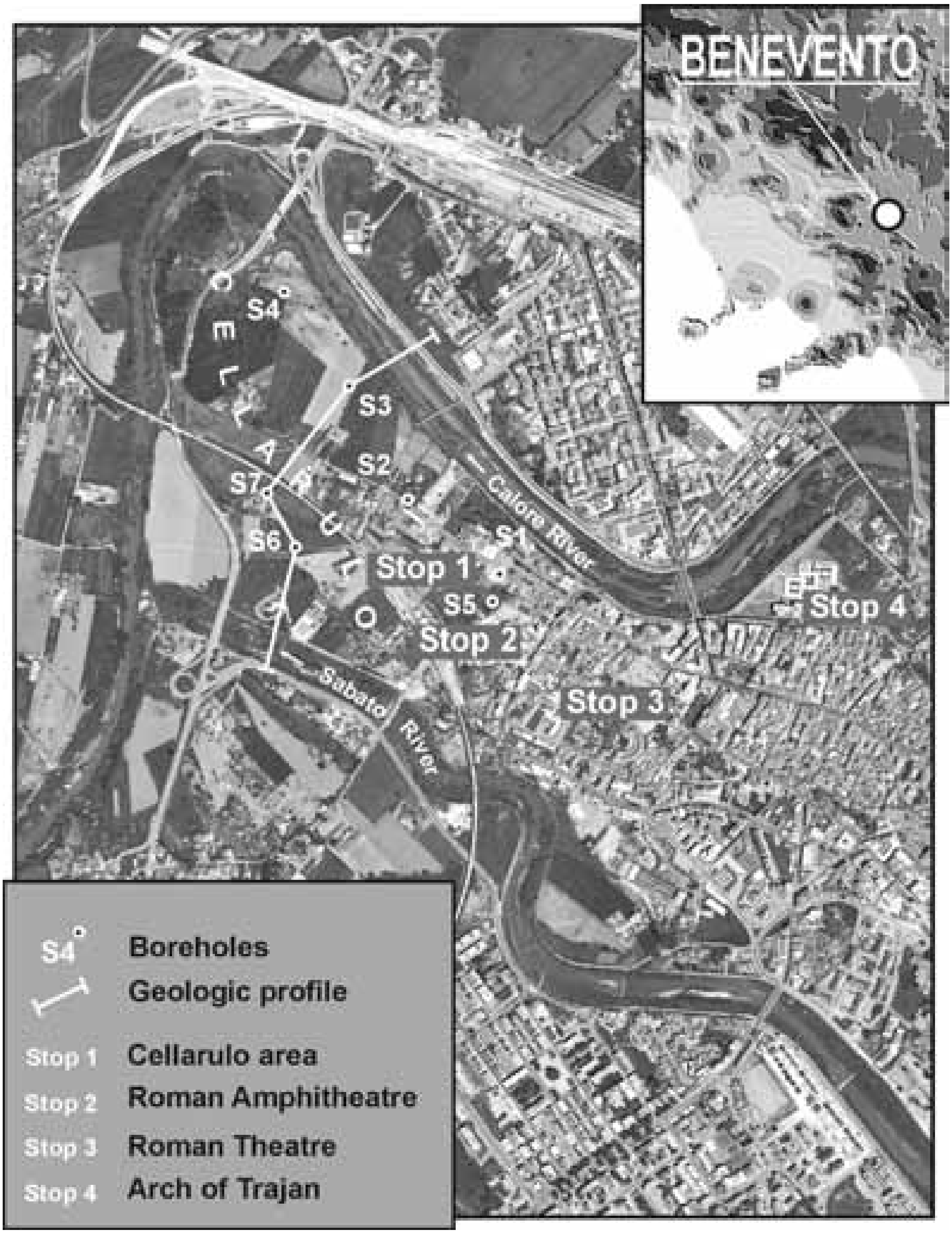

Figure 2 - Map of Benevento with Cellarulo area and stops location.

must have already existed in the Messinian. During the Messinian and the Middle Pliocene a sequence made up of several units separated by discontinuous and discordant limits was deposited. These units

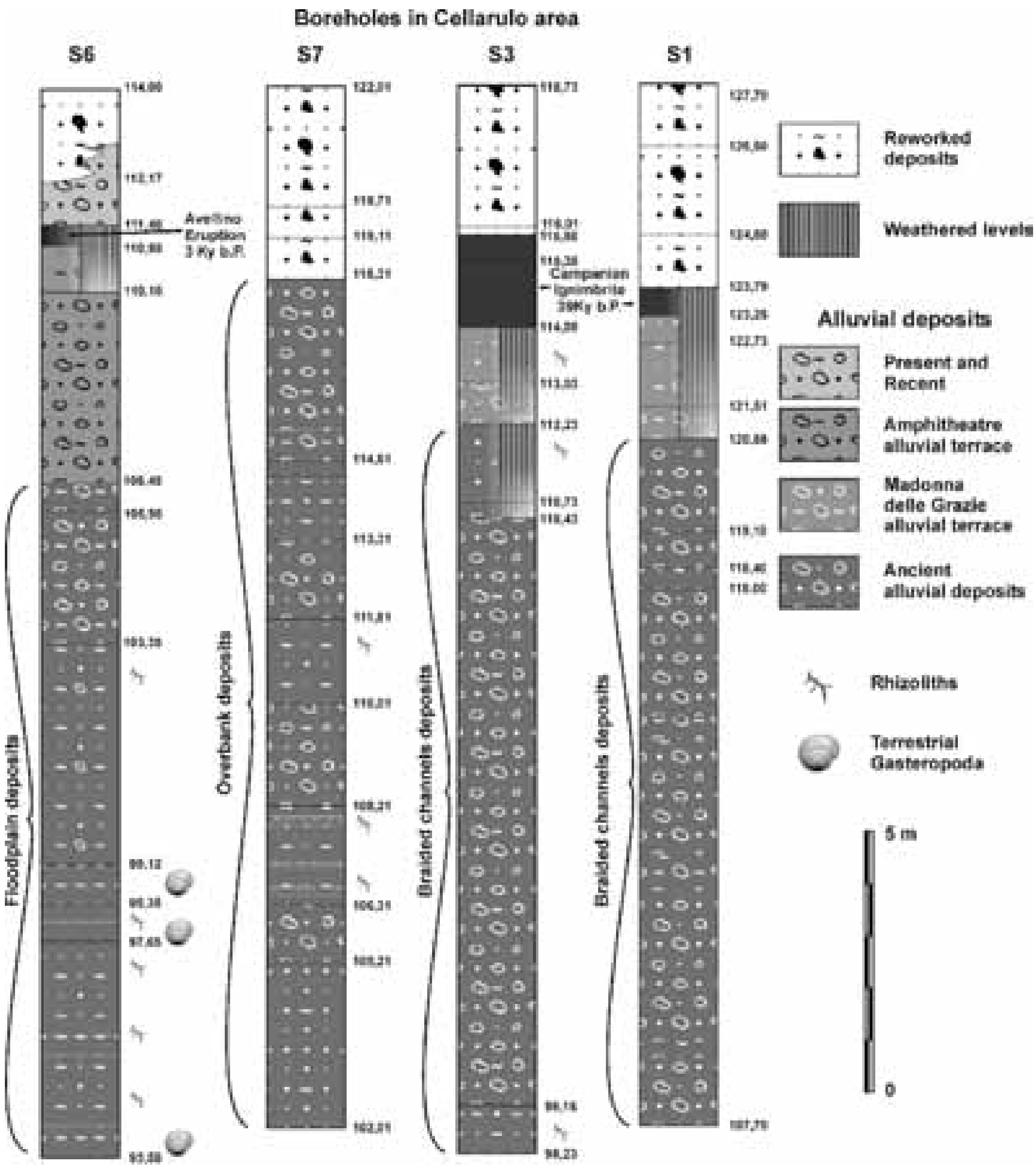

Figure 3 - Stratigraphy of the boreholes carried out in the Cellarulo area (see Fig. 1 for location).

show subsequent tectonic phases that deformed this interchain basin. In the Late Pliocene and the Pleistocene, the uplift of the chain led the area into a continental environment with an alluvial system.

The Quaternary deposits (Fig. 3-4), recognizable from both the geological maps of the area and from seven boreholes, consist of the following:

1 - Ancient alluvial deposits, with gravel facies (braided alluvial plain deposits); gravel and silty sand facies (bank deposits); silty sand and clayey sand facies (flood plain deposits with swamp areas). These deposits are significantly thick and the lower limits have never been evaluated. The deposits are considered by many researchers to be Rissian in age, but this date is not certain.

2 – Alluvial deposits on the terrace of the Madonna delle Grazie Church. These are made up of a fining up sequence with a basal gravel with a silty sand matrix

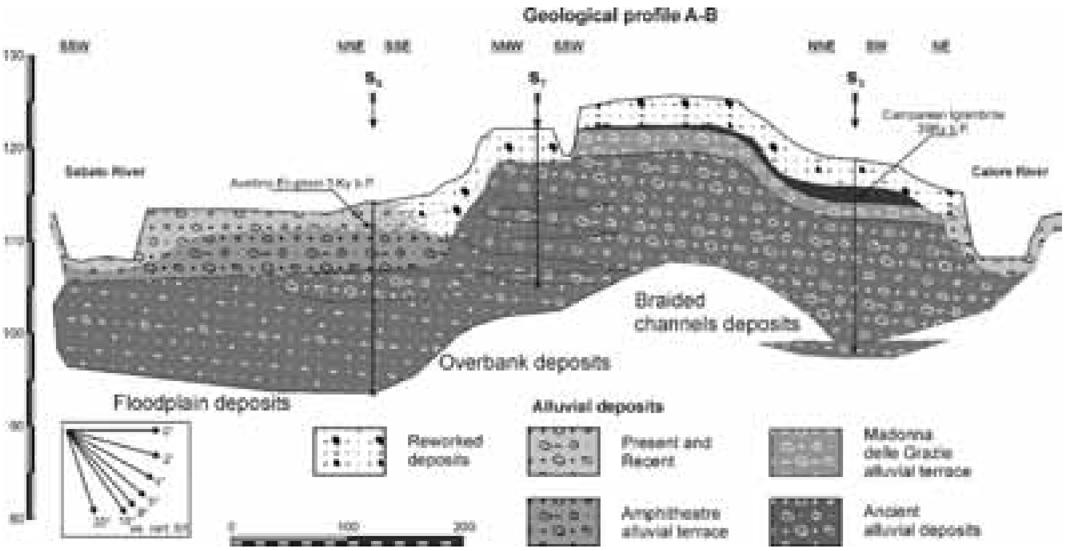

Figure 4 - Geological cross section in Cellarulo area (see Fig. 1 for location).

more or less clayey passing up to siltstone with clayey sand. These deposits, associated with the terraced deposits placed about 15 metres over the riverbed, are covered by the Campanian Ignimbrite (39 ka B.P.).

3 - Present-day flood deposits. On the terrace of the Amphitheatre a palaeosoil with inside a pumice layer coming from Vesuvius named the "Avellino Pumice layer" (3 ka B.P.) can be seen clearly. Present-day alluvial deposits follow. These were mainly deposited between the eruption of Avellino (3 ka B.P.) and circa 1600 years B.P., when the area around the Amphitheatre was abandoned.

4 – Pyroclastic deposits. The Campanian Ignimbrite (39 ka B.P.) and the Avellino Pumice have already been mentioned. Research has shown that there is evidence of more recent eruptions. In the Amphitheatre, D'Argenio et al. (2002) report the presence of pyroclastic deposits attributed to the Pollena eruption coming from Vesuvius dated A.D. 472.

5 – Eluvial-colluvial deposits with elements of anthropic origin. These are made up of reworked pyroclastic deposits in which various anthropic elements can be found: fragments of brick, earthenware, bone (also human), mortar and plaster. These can be attributed to settlements from Roman (and possibly pre-Roman) to Medieval times. The deposits containing these fragments may have been reworked in more recent times.

6 – Present-day anthropic deposits. These are made up of rubble.

Stop 2:

The Roman Amphitheatre

The visible part of the Amphitheatre is a fraction of the whole structure, as well as an offset of the boundary wall. The structure consists of eight radial walls, a terracotta floor on the first inner side, the "ambulacrum", and two other walls in the direction of the arena. These structures have been preserved up to a height of two metres. The structures are made of stone and their forms, while the walls are in a mixed structure of "opus reticulatum" with calcareous "cubilia" and tiles. The materials used are mainly little calcareous blocks with a grey mortar binder. The best-known section of the Amphitheatre shows the presence of alluvial deposits at the bottom of the foundations (Fig. 5). This deposit contains reworked Avellino Pumice, which erupted from Vesuvius about 3.000 yr B.P. In A.D. 369 Benevento was hit by a high intensity earthquake. The earthquake, described by Simmaco Seniore, damaged the Theatre and the Amphitheatre, which were then abandoned, even if used until the V century, as testified by the presence of a level of bricks in fragments. Between the end of the V century and the beginning of the VI century floods occurred and the alluvial deposits of the Sabato River covered and hid the Amphitheatre, whereas the Theatre was only partially covered. In the VI century the area of the Amphitheatre was occupied by a "tardo antica" (Late Roman) Necropolis. In the VII century, at the edge of the older terrace, which was higher than during Roman times, the Longobards built city walls,

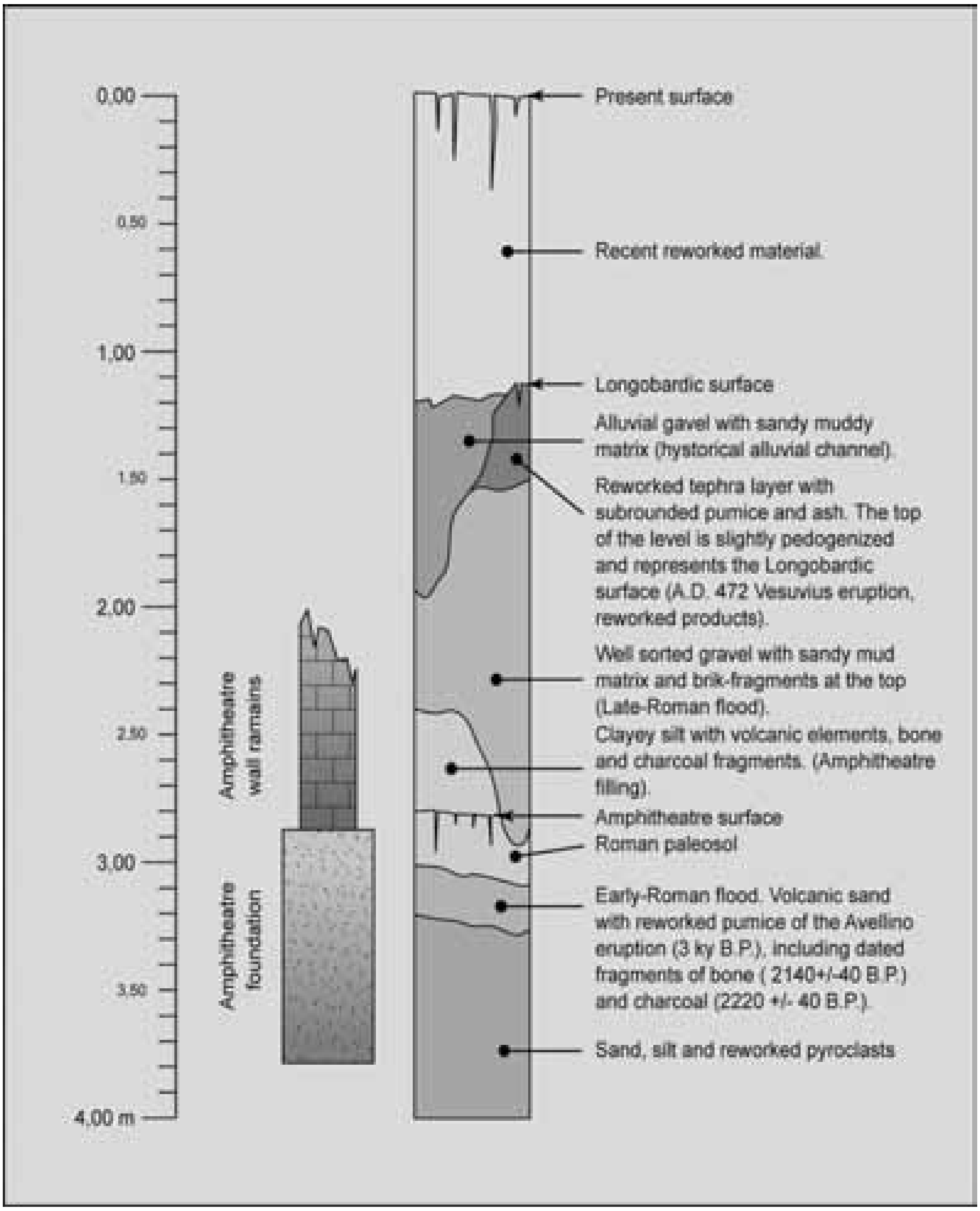

Figure 5 - Stratigraphy of the section outcropping in the Roman Amphitheatre of Benevento (from D'Argenio et al., 2002).

and the stonesof the Roman buildings were used to build new buildings. The Longobard walls protected the city from other floods, while the lower terrace with the Amphitheatre and Necropolis on top was affected by floods: in this section younger alluvial deposits have been found below a level of modern reworked material.

Stop 3:

The Roman Theatre

The Theatre location has always been known. Even if its structure was later incorporated into Middle Age buildings, it has still kept its original plan.

This structure lies on the alluvial deposits of the Sabato River, outside the walls of the Roman-era city. Restoration started in the '20s and ended in the '60s; this brought the original structure back to light almost completely. The archaeological excavation has almost been completed, except for a small area on which the "Santa Maria della Verità" Church was built in the XVI century.

Of the original theatre, the "ima cavea", the "media cavea" are visible, although only portions of the "summa cavea" remain. Moreover, eleven arcades piled up in three different orders are now evident; the bottom and some of the second one are in the "tuscany" style. The "cavea" is circular and is connected to the scene by three entrances.

Stop 4:

The Arch of Trajan

The Arch of Trajan, inaugurated on 13th May 113 A.D., was built to celebrate the construction of the "Via Traiana". This meant that, compared to using the "Via Appia", Brindisi could now be reached one and a half days earlier.

The arch, chosen to cover the first part of the road, is of the simplest type, with only one vault, similar to the Arch of Titus. Its structure is made of limestone blocks, covered with Carrara marble on the outside. This decorative arch is one of the finest in existence.

The historical reliefs can be divided into four groups:

- the panels on the side facing the countryside portraying Trajan's relationships with the Empire's different provinces;
- the panels facing the city where the Emperor's actions in favour of Rome are represented;
- the panels on the inside of the vault where the Emperor's goodwill to the city of Benevento is illustrated;
- the small frieze that celebrates Trajan's triumph at the end of the second war against the Dacians in 107 A.D.

The triumphal procession that runs along the inside of the monument is a true work of art, as well as marvellous evidence of everyday life in the Trajan era.

From Benevento to Saepinum

Leaving Benevento, first heading northwards along the main road, S.S. 17, and then going along the provincial road to Sepino, we'll reach the archeological site of Saepinum-Altilia, close to Sepino's centre. Sepino has had three locations over the centuries between Mount Muschiaturo and the Campitello Plain: the Samnite city in Terravecchia; the Roman-era city in Altilia and, finally, the medieval and present-day town on a hill, close to the Tappone stream.

In the pre-Roman period, the first Samnite settlement sprung up on the plain of the Tammaro River valley, an important area for commercial trading. To protect the site, a settlement was founded (IV, V century B.C.) on Terravecchia hill (953 m). The fortified Samnite city, Ocre Saipinatz, better known as Saipins, lies between the valleys of the Magnaluna stream to the north and the Saraceno River to the south, both tributaries of the Tammaro River. With this fortification, the Samnites took control of trade between Apulia and Campania and the Sannio Pentro, as well as of the pastures towards the mountain.

The Samnite settlement is still recognisable from its defence structures: a circular megalithic wall with a trapezoidal layout, the longest side facing northeast, behind the slope overlooking the natural enbankment of Castelvecchio town. Three gates have so far been identified by archaeologists: The "Postierla del Matese" gate, facing southwest and opening towards the mountains; the "Acropoli" gate, facing northwest and opening towards Civitella di Campochiaro and *Bovianum Undecumanorum*; and the "Tratturo" gate, probably the most important, to the east of the walls and opening towards the plain and the Saepio site. It was this route, in fact, that became the "*cardo maximus*" of the future Roman Saepinum. The centre was intended for trading, and so it was enclosed to protect it from enemy attacks. It was occupied by the consul C. Papirius Cursor during the third Samnite war, and at the end of the II century B.C. it was upgraded to "municipality" status.

At the end of the II century B.C., during the Roman period, the city underwent a radical change in its construction, developing more around the crossroads between the main track, the "decumano", and the Matese cartroad, the "cardo". Following the Civil War (91-88 B.C.), the area was then laid out according to the Roman town plan. Public buildings, private dwellings and monuments gave Saepinum the stamp of an Imperial Roman city.

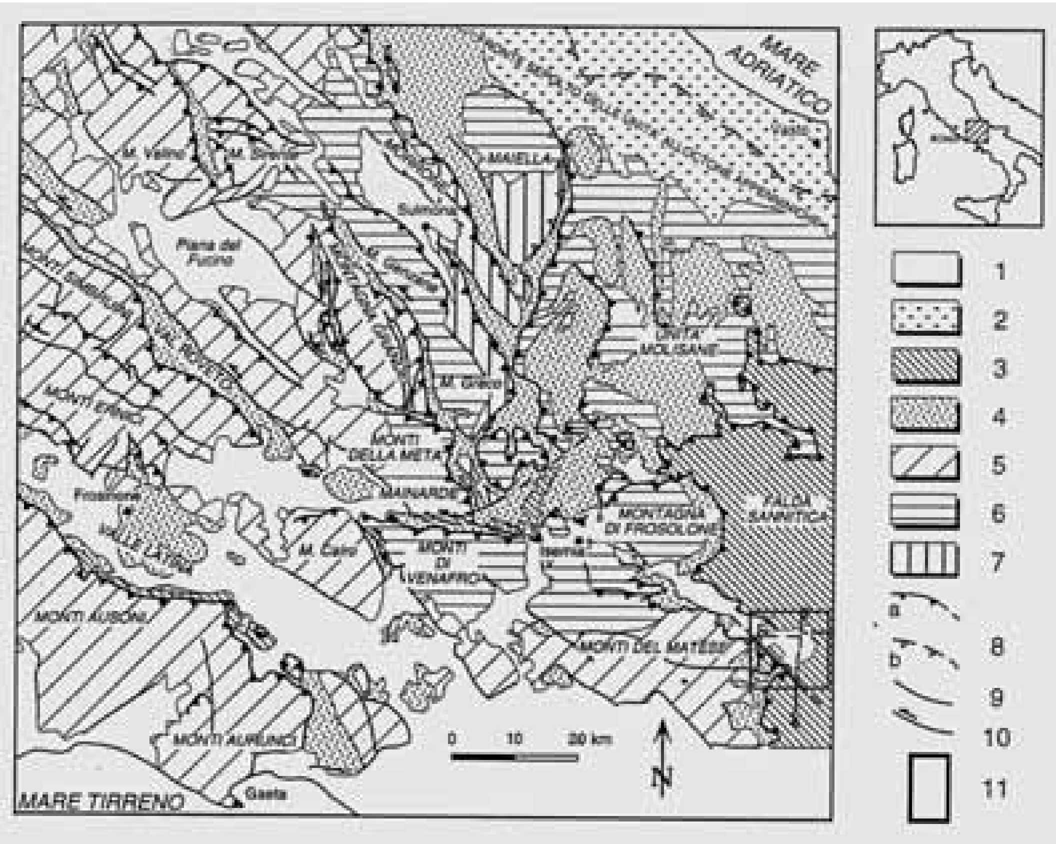

Figure 6 - Geological sketch of the central-southern Apennine Chain with location map of the Sepino Plain (modified from De Corso et al., 1998). Legend: 1) Plio-Quaternary marine and continental deposits; 2) marine deposits ranging from Lower Pliocene to Lower Pleistocene; 3) pelagic deposits of the "Falda sannitica"; 4) terrigeneous and siliciclastic deposits ranging from Upper Miocene to Pliocene; 5) limestone succession of the Matese Unit ranging from Upper Triassic to Middle Miocene; 6) slope-basin deposits ranging from Upper Triassic to Middle Miocene; 7) Apulian Unit l.s. (Upper Triassic – Middle Miocene); 8) Thrust sheets (a – outcropping, b - buried) ; 9) faults; 10) strike-sleeps; 11) studied area.

The fall of the Roman Empire had an effect on Saepinum, too. The demographic and political collapse, aggravated by the Goth-Byzantine war (A.D. 535-553) and natural disasters such as earthquakes and floods, favoured the spreading of marshy and wooded areas, which caused progressive abandonment of the area. Saepinum, which in the meantime had taken the name Altilia, was annexed to Gastaldato di Boiano under Longobard reign. From the IX century to the XV-XVI century, Sepino became two different towns: Present-day Sepino and Castelvecchio.

The old town centre of Sepino

The old town centre is the medieval village. The area was surrounded by an almost elliptical-shaped wall, with four gates and towers on which the castle stood. Some of the towers and three of the gates still exist today: the "Meridionale", the "Orientale" and the "Corte" or "Borrelli" gate. The castle, which was greatly damaged during the 1805 earthquake, was progressively demolished.

Geological aspects and historical seismicity

The southern Apennines is a chain generated by thin-skinned tectonics. The massif of the eastern Matese, together with the whole mountain group, is part of an external structural level of the chain. It is quite a complex structural level with translative, rotational and transcurrent effects, whose geometric and temporal relations are not yet clear. As far as the structural style is concerned, there has been more than one interpretation, which we can summarise into two fundamental hypotheses. One hypothesis sees the tectonic unit of the Matese mountain group (the eastern Matese Unit) detached from the crystalline basement (Ietto, 1969; Patacca et al., 1992) over several contractional phases, and therefore characterised by a very complex arrangement. The other describes a homogenous tectonic unit characterised by buckling and fault-related folding (De Corso et al, 1998). Such differences in style implies a different ratio of contraction in a NE-SW direction between the Late Tortonian and the Middle Pliocene. The evolution between the Late Pliocene and the Early Pleistocene is much clearer when, as a result of compressive tectonics, NE-vergent movements gave rise to widespread WSW-ENE to W-E left-lateral and N-S right-lateral strike-slip faulting (Corrado et al., 1997; Ferranti, 1997), in accordance with what has been noted all over the southern Apennines for the Late Pleistocene (Caiazzo, 2000).

From the Middle Pleistocene the Matese Massif became a wide complex mosaic of horst and graben that raised and depressed the carbonatic and terrigenous successions of the Miocene transgression. Continental intermountain basins developed. This produced the formation of normal faults that controlled the physiography of the continental sedimentary basins, as in the case of the Sepino Plain basin.

A meso-structural and morphotectonic study was carried out in the Sepino Plain area, around the slopes of the Morgia del Monaco (eastern Matese Massif), where calcareous-clastic successions of continental slope facies outcrop. These successions laterally pass to pelagic basin successions. The age is from Cretaceous to Palaeogene. The basal limit is a W-vergent thrust sheet named “Falda Sannitica” (Fig. 6). The Sepino Plain is at the foot of the slopes and is bounded by the Tammaro River to the east, while the Toppola, Saraceno and Magnaluna streams cut transversely deposits, distinguishing the current phase of erosion. The plain is made up of detrital-alluvial deposits and sandy mud from a fluvial and lacustrine environment. The detrital-alluvional deposits outcrop westward to isolated or coalescent alluvial fans while, in the eastern side of the plain they aggrade the slopes directly. The substratum of the detrital-alluvional deposits is constituted by the succession of the Molisano-Samnita depression. This latter is made up mainly of calcareous-clastic and clayey-marly sandstone, and it is referred to a Meso-Caenozoic basin unit and to siliciclastic synorgenic successions of the deformed Miocenic foredeep. The physiography of the Sepino Plain has a NW-SE trending and continues, with structural solutions, towards NW in the Bojano Plain, where there are contemporary alluvial and lacustrine deposits.

The structural analysis was integrated with geomorphologic-stratigraphic research. We can thus deduce the relationships between the border features of the Sepino Plain basin and put forward a proposal on the space-time distribution of the Pleistocene-Holocene faulting, as well as outline the kinematic-structural setting in which the sedimentary basin of the Sepino Plain developed.

First off, the borders of the plain are structural and make a triangular area with the fault system of the Morgia del Monaco to the west, the fault system of Campochiaro-Cercepiccola (W-E) to the north and the fault system of the Tammaro River (SSW-NNE) to the southwest. The Campochiaro-Cercepiccola fault system (W-E) and Tammaro River fault system (SSW-NNE) are older than the Sepino fault system (Fig. 7). These probably were actived by a N-E vergent compressional tectonic system which caused left W-E dislocations and right horizontal N-S dislocations, not only in the Matese area. The NW-SE Sepino fault system is linked to the phase occurring during the Middle Pleistocene that drastically caused prevailing extension in the NE/SW direction (Patacca et al., 1992; Corrado et al., 1997).

Furthermore, the Sepino fault system, is a Middle Pleistocene synthetic normal fault that, as described by Di Bucci et al. (1999), disarticulates the wide areas of peneplain previously formed during the Early Pleistocene.

The orientation of the stress fields in the Middle Pleistocene seems to correspond to the active stress field identified by the analysis of focal mechanisms for recent earthquakes in the southeast of the Molise region (Federici et al.,1992; Speranza et al., 1998; Montone et al., 1999). Similarly, Cello et al. (1982), using regional seismologic data and focal mechanisms of earthquakes in southern Italy, detect a NE-SW orientation of the T-axis, corresponding to the extension direction from the seismicity of southern Italy (Gasparini et al., 1985). The works of Galli et al. (2002) scrutinises the historical seismicity of the area, particularly the Bojano Plain; here we’re reporting the most important earthquakes which affected the Sepino

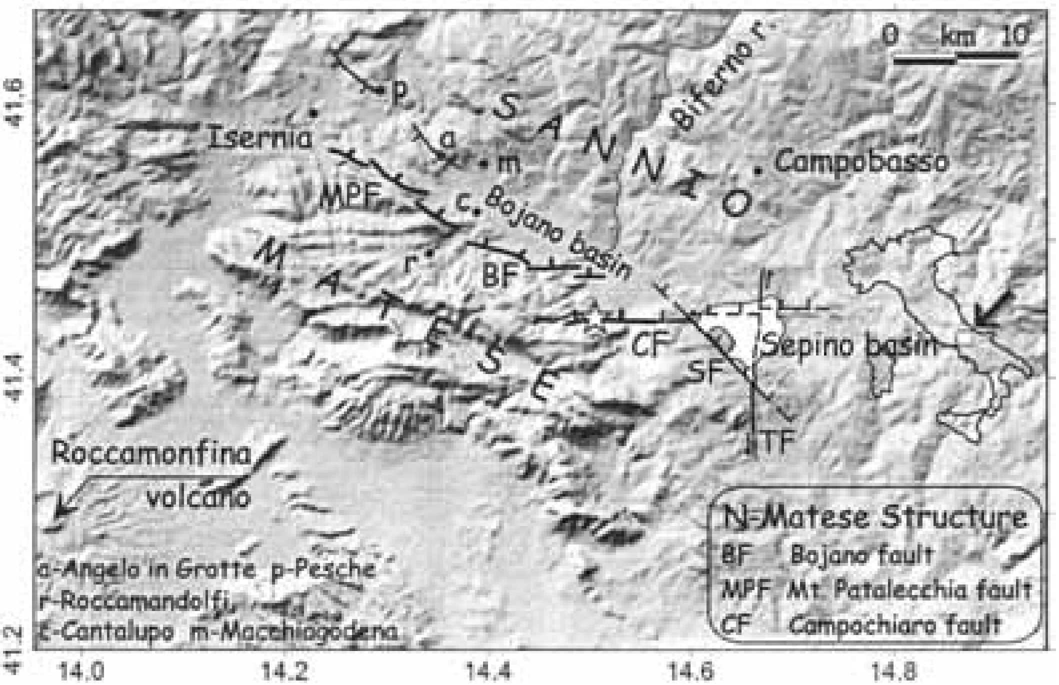

Figure 7 - Digital elevation model of the region between Molise and Campania (after Galli et al., 2002). Bold lines show the north-easthern Matese massive structure, composed of the Mt. Patalecchia-Bojano-Sepino fault (SF) system and the Campochiaro -Tammaro fault (TF) system.

Plain: those of 346 A.D., 1456 A.D. and 1805 A.D.
The 346 A.D. earthquake, mentioned by Jerome (ca. 340-420) in his modified version of Eusebio di Cesarea's *Chronicom*, was the one which, according to a reconstruction by Galli et al. (2002), affected the Roman site of Saepinum. The exact location of the depocentre is uncertain, as the tombstones that mention it explicitly have been found in a wide area of the Sannio.
The 1456 earthquake that destroyed Sepino, among other towns, was the most destructive medieval event in the whole area.
The 1805 earthquake caused serious damage to many towns in the Bojano Plain and neighbouring areas.
At the present time, we do not know the temporal frequency of the co-seismic effects in the Sepino area. The archaeological site of Saepinum is situated on an alluvial fan of weathered silt, sand and sandy mud of fluvial and lacustrine origin. These deposits cover a wide depositional/erosive peneplain surface, slightly sloping towards the Tammaro River. There are no breaks or natural terraces in the peneplain surface which evidence palaeoseismic effects both outside and within the archaeological site.

Figure 8 - Three examples of disconnected structures due to earthquakes: a) off-setting of lithons in an arc; b) block rotation in a pillar; c) increase of spacing between blocks in a wall.

Historical and archaeological research to discern any reconstruction or restoration due to earthquake damage is in progress, with the goal of dating the destructive seismic events. A preliminary investigation highlighted the state of preservation of the structures and the architectural continuity of foundations and elevations of the buildings in the area around the Altilia-Saepinum archaeological site. Some areas show traslation and rotation of parts of the buildings. These should be considered archaeoseismic evidence, for the above mentioned reasons. Some examples are shown in Figure 8.

DAY 3

Sele Coastal Plain - Paestum and the Hera Argiva Sanctuary (*T. Pescatore, M.R. Senatore, G. Greco, G. Tocco G. Avagliano*) and Velia (*A. Cinque, C. Rosskopf, G. Robustelli, G. Tocco, C.A. Fiammenghi*)

Introduction

The Sele Coastal Plain is hosted in a wide structural depression which is located along the continental margin of the Southern Tyrrhenian Sea and contains also the nearby Gulf of Salerno (Fig. 9).

The geological history of the Sele Plain began in the Late Miocene with the formation of a wide gulf. Following the uplifting of the Apennine Chain, during the Early Pleistocene up to the Middle Pleistocene, a coarse, clastic, alluvial fan developed (the “Conglomerati di Eboli” formation, Russo, 1990). In the Late Pleistocene (130,000-75,000 yrs ago), the Tyrrhenian coastal ridges of Ponte Barizzo (isotopic stage 5e), Masseria Stregara (isotopic stage 5d) and Gromola (isotopic stage 5a) were deposited, giving rise to a progradation of the coastal system of more than 3 km (Brancaccio et al., 1986; Russo, 1990). With the Late Pleistocene regression (75,000-18,000 yrs ago) the continental environment was extended more than 15 km, leaving a greater part of the continental shelf exposed. The Holocene sea level rise and the influence of man determined the present-day environments. A pumice fall deposit, from the eruption of Mt. Vesuvius in A.D. 79 (Pompeii Pumice, Lirer et al., 1973), was found in the sediments of the plain. From Roman times and the Middle Ages, up to the beginning of this century, the coastal plain was unliveable due to the presence of ponds and marshes. Drainage systems subsequently dried up these marsh areas

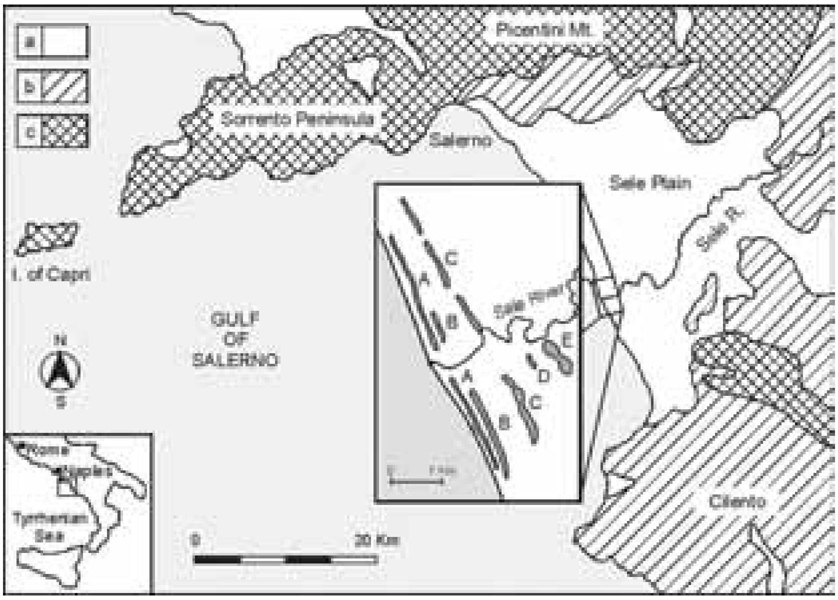

Figure 9 - Geological framework of the Sele coastal plain and of the Gulf of Salerno, a) Quaternary deposits of the coastal plain; b) Caenozoic sandstones and clays (flysch deposits) ; Mesozoic carbonate rocks. The insert shows the outcropping coastal ridges (Late Pleistocene and Holocene) at the mouth of the Sele river: Sterpina (A), Laura (B), Gromola (C), Masseria Stregara (D), Ponte Barizzo (E) (from Barra et al., 1999).

Stop 1:

The Hera Argiva Sanctuary

In the 1930s Zanotti Bianco and Zancani Montuoro discovered the Hera Argiva Sanctuary at the mouth of the Sele River. It is considered one of the most famous of antiquities: Plinius the Elder defined it as “renowned”; Strabo traced its origins back to Jason and to the mythical expedition of the Argonauts. The multiform goddess Hera lived in a “Kepos” (luxuriant natural garden) surrounded by aquatic plants and by animals such as cattles, horses and aquatic birds.

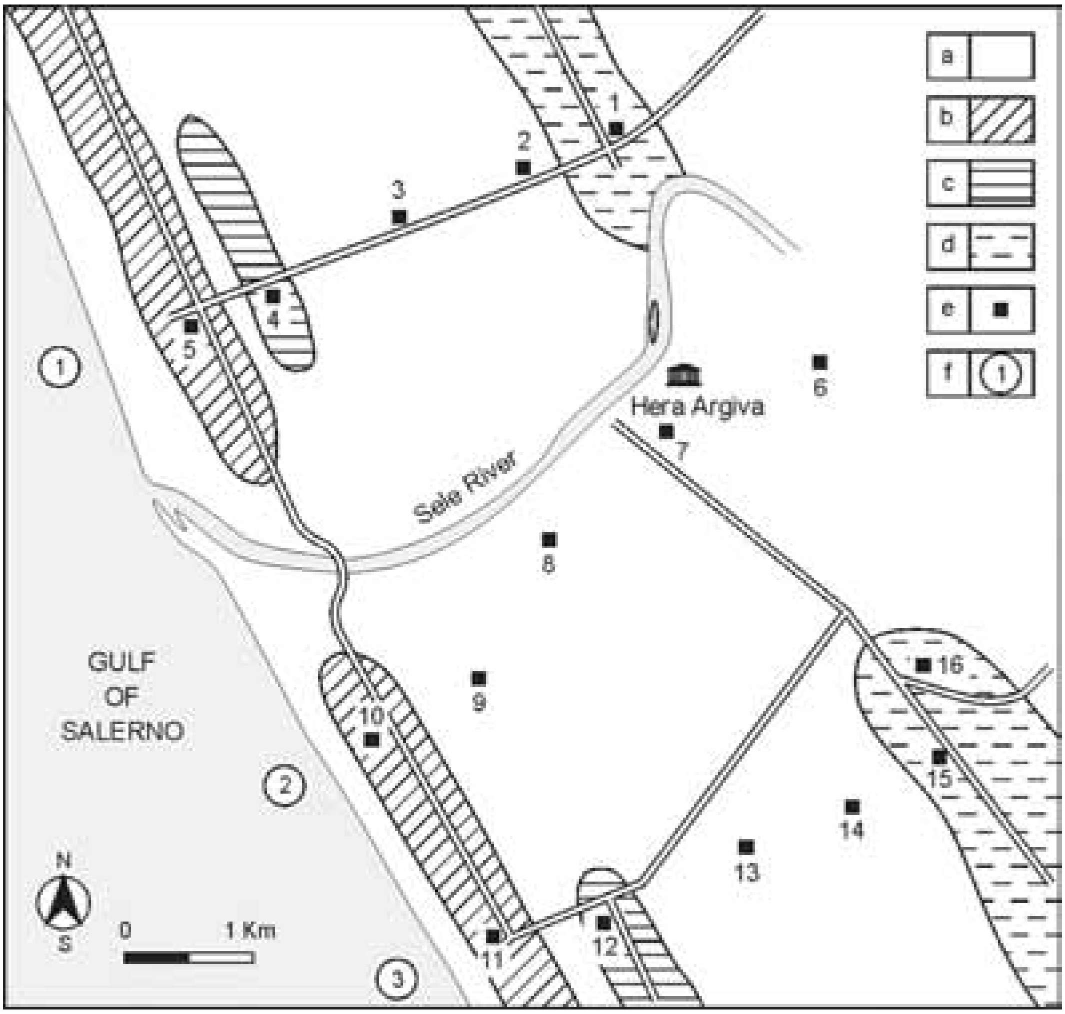

Figure 10 - Geological framework of the Sele coastal plain and the boreholes' location: a) Alluvial deposits and present-day beach; b) the Sterpina coastal ridge (about 2100 yr B.P.); c) the Laura coastal ridge (about 4000 yr B.P.); d) the Gromola coastal ridge (75,000 yr B.P.); e) boreholes; f) transects (from Barra et al. 1999).

Stop 2:
The Hera Argiva Museum

The history of the Hera Argiva Sanctuary is outlined in the museum; the exhibit includes the archaeological excavations and the reconstruction of the building as well (Fig. 10).

Stop 3:
The Pier along the beach at Paestum

The stratigraphic succession of the Upper Pleistocene – Holocene was reconstructed through samples collected from 16 boreholes located in three transects perpendicular to the coastline (Fig. 10-11; Barra et al., 1999). The more landward boreholes (FS1, FS15, and FS16) are located on the dune ridge of Gromola (75,000 yrs ago) while the more seaward ones (FS5, FS10, and FS11) are on the present-day coastal dune. The stratigraphic succession (Fig. 12) has been divided into two fourth order sequences, separated by a continental erosive surface (SB). The lower sequence, constituted by Tyrrhenian deposits, includes another erosive surface (T1/R1) separating the sub-sequences of Masseria Stregara and Gromola. The upper sequence, constituted by Upper Pleistocene-Holocene deposits, has been called Hera Argiva.

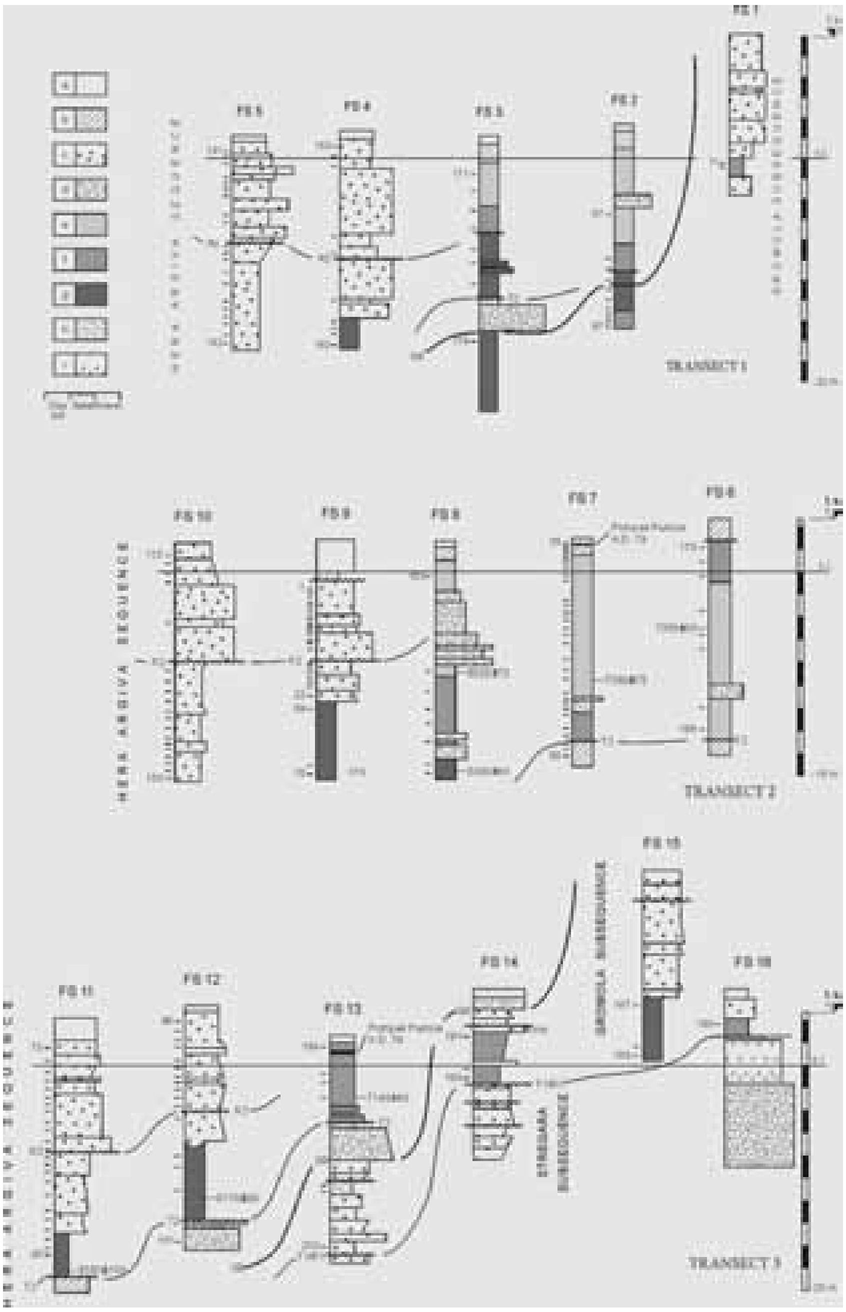

Figure 11 - Core logs: a) Recent cover; b) weathered (soils and paleosoils); c) beach and dune sand; d) fluvial sand and gravel; e) mud with freshwater fauna; f) mud with brackish faunae; g) mud with brackish fauna and peat levels; h) clay with open marine fauna; I) travertine. C14 ages are on the right side of the core logs: SB is a fourth order sequence boundary, and transgressive (T) and/or regressive (R) surfaces are also depicted. Pompeii Pumice is a tephra level. The number on the left side of the logs indicate the samples studied. (from Barra et al., 1999)

2.1 The Masseria Stregara Sub-Sequence

This outcrops in the Masseria Stregara dune ridge (Fig. 10) and is present at the bottom of borehole FS1, FS13 and FS14 (Fig. 11-12). The age is Tyrrhenian. This sub-sequence consists of:

a) sand with thick, low angle laminae: medium to fine sand with low angle, parallel laminae passing upward to:

b) rounded and windblown sand: medium sand with well-rounded and windblown grains.

The thickness is not significant as the boreholes were stopped before reaching the base of the unit. The sedimentary characteristics of the succession show beach deposits passing upward to aeolian dune deposits. An erosive surface (R1) separates this sub-sequence from the upper one.

The Masseria Stregara sub-sequence, accumulated during a highstand phase of ca. 100,000 yrs, isotopic stage 5d, is made up of a transgressive depositional system (beach sands) and by a highstand system (aeolian dunes).

2.2 The Gromola Subsequence

This outcrops in the Gromola dune ridge and is present in boreholes FS1, FS2, FS3, FS13, FS14, and FS15 (Fig. 11). The age is Tyrrhenian isotopic stage 5a. This interval is made up of, from the bottom:

a) Dark clay, silt and peat: dark gray clay, silty clay and silt, and peat or bed rich in organic matter. The thickness ranges from 1 to 3 metres. Unbroken or fragmented terrestrial gasteropods (*Planorbis*) are frequent.

The clay sedimentary characteristics and microfauna show a sub-aerial environment or the existence of a transitional environment with shallow oligohaline to mixohaline waters. In general the ostracod fauna assemblages are typical of brackish environments of the Mediterranean Sea (Barra et al., 1999).

b) Sand with thick, low angle laminae: medium to coarse sand with thick, sub-horizontal or low angle laminae intercalated with rounded pebbles. The thickness is 2/3 metres. Shells of *Cardium* and *Venus* are found. These deposits are substituted seaward by clay and silt clay with marine fauna (FS13).

The sand sedimentary characteristics and microfauna in the clay define littoral to sublittoral deposits. The frequency of the planktonic foraminifers reveals exchanges with the open sea (Barra et al., 1999).

c) Rounded and windblown sand: red, medium to fine sands with well-rounded and windblown grains. These deposits can be correlated to the sands at the top of the Gromola Ridge, which are brown in colour and show a large-scale cross-bedding with high-angle foreset laminae (up to 35°). The thickness of these sediments changes from a few to tens of metres. These deposits are aeolian dunes.

An erosional surface (R1) separates this unit from the upper one. The Gromola sub-sequence is represented by sediments of ca. 75,000 yrs above the R1 surface and is made up of a transgressive system: pelitic sediments deposited in a freshwater marsh passing upward to lagoon and beach sands, substituted seaward by clayey deposits of an infralittoral environment; a

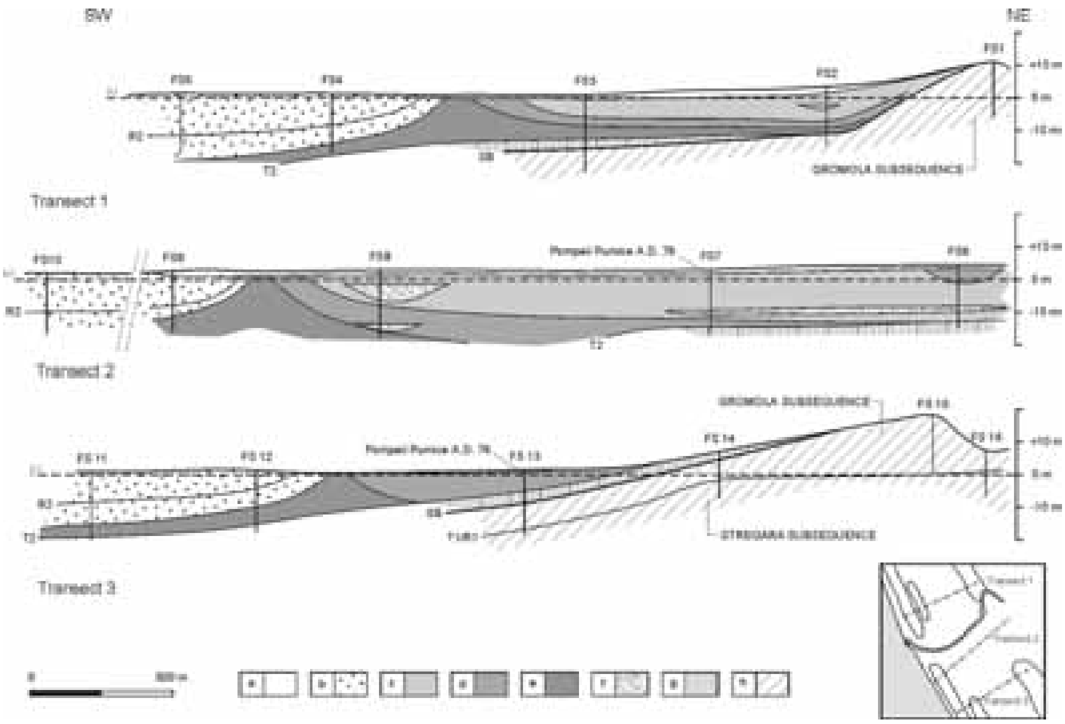

Figure 12 - Geological cross-sections (see the insert for location and Fig. 10 for symbols; from Barra et al., 1999). The Hera Argiva Sequence (Late Pleistocene – Holocene): a) recent cover; b) beach and dune sand; c) mud with freshwater fauna; d) mud with brackish fauna; e) mud with brackish and marine fauna and peat levels; f) fluvial sand and gravel; g) weathered mud (paleosols); The Masseria Stregara and Gromola subsequences (Middle - Late Pleistocene).

highstand depositional system: aeolian dunes passing seaward to beach deposits. The trasgressive surface (T1) coincides with the erosional one (R1).

2.3 The Hera Argiva Sequence

This represents the Upper Pleistocene-Holocene and is made up of (Fig. 11-12):

a) A lower interval of alluvial deposits and palaeosoil: polygenic pebbles (up to 10 cm) with sandy matrix, passing upward to a green clay with sandy or gravely beds. Their thickness reaches 2.5 m. A palaeosoil rich in calcium carbonate nodules ends this interval. This palaeosoil, up to 1 m thick, marks a surface dipping 1°- 2° seaward.

b) Dark clay, silt and peat: grey and dark grey clay and silty clay, with peaty layers. The clay interval constitutes the base of the Holocene succession in FS9, FS10, FS11, and FS12, and the whole succession in FS6, FS7 and FS8.

The ostracod fauna indicate a fresh water-oligohaline environment. On the other hand, the assemblages with *C. torosa* co-occur with species characterising freshwater, mixohaline and shallow marine environments (Barra et al., 1999).

Benthic foraminiferal assemblages ranging from oligotypic to very oligotypic are respectively dominated or constituted only by brackish to marine euryhaline species (Barra et al., 1999). The decrease and disappearance, landward and upward, of marine species indicates a gradual decreasing in salinity, which corresponds to the transition from a brackish environment (open lagoon) still influenced by the sea, to a sheltered lagoon, or a salt marsh to a freshwater environment. Only in the FS6 borehole deposits does an oligohaline environment pass upward to a brackish marsh deposits. A 1-m-thick sandy bed with parallel laminae and fragments of molluscs such as *Cardium* is found in the FS8 borehole. This level can be interpreted as a storm event that introduced beach sands into the lagoon environment.

c) Sand with thick low angle laminae: medium to coarse sand, with sub horizontal laminae up to several centimetres in thickness. The sand grains are rounded and with low sphericity. Rounded and flat pebbles are interbedded in the sands. Mollusc shells are both unbroken and fragmented; valves of *Venus* are dominant.

The ostracod fauna are of shallow marine environments; benthic foraminiferal assemblages are poorly diversified and dominated by clearly marine species, mainly from the infrallittoral zone; the planktonic species are absent (Barra et al., 1999).

The above-described characteristics indicate that the deposits were formed in littoral or sublittoral environments.

d) Rounded and windblown sand: medium to fine sands with windblown grains. These deposits outcrop at the Laura and Sterpina ridges. These aeolian sands change seaward into sand and gravel beach.

e) Upper interval of alluvial deposits: brown and dark grey clay and silty clay, with calcium carbonate nodules. Medium sands are intercalated with pelitic sediments. The thickness of this interval is up to 5 m. Pelitic deposits can be attributed to natural levees of the river, occasionally flooded by alluvial sands.

f) Pompeii Pumice event. The Pompeii Pumice layer, from the 79 A.D. Vesuvius eruption, is found in a thickness of 15 cm all over the Sele Coastal Plain, more than 60 km southeast of the volcano. Such a pyroclastic level is characterized by angular pumice, 2 or 3 cm in size, in the FS7 borehole, and by rounded and graded pumice in the FS13 one.

Summing up, the Hera Argiva Sequence is made up of: a lowstand system made up of sand and gravel alluvial deposits that ends with a palaeosoil; a transgressive system above surface T2, made up of pelitic deposits from marshes and lagoons passing upwards to beach deposits; a highstand system above surface R2, represented by a beach-dune complex and by bogs and ponds behind a barrier beach.

3. Radiocarbon Dating.

The radiocarbon datings were made by Barra et al. (1999). All the reported ages are corrected for carbon isotope fractionation and expressed in year before present (yr B.P.); their uncertainty is of the 1st level. The conventional C^{14} ages measured, as well as sample identification and location are listed in Table 2.

4. Pollen analysis

Palynological analyses (Barra et al., 1999) were carried out on samples collected from core FS7 and on sample FS11/93, the latter is dated 9850±100 B.P. The results of the analyses suggest the existence of two distinct phases during the Holocene environmental evolution: a lower phase and an upper one.

The lower phase

Characterized by a general prevalence of herbaceous plants suggesting a wet environment. Aquatic plants sporadically appear, indicating the existence of stagnant or low-energy water. Therefore the results show the Sele Plain was marshy and lacking of any arboreal cover, except sporadic periods when *A. glutinosa* was abundant. Allochthonous pollen from mountain and sub-mountain forests is not frequent and, when so, always in low percentages.

Table 2

Core #	*Lab. # Rome*	*Depth below s.l.*	C^{14} *(yr B.P.)*	*Analysed organic matter*
FS6	- 662	6.0-6.2	7050+/-80	Humifiedwood debris
FS7	- 663	8.8	7360+/-75	Humified wood debris
FS8	- 664	7.0	6330+/-70	Humified wood debris
FS8	- 665	15.5-16.0	8300+/-80	Organic clay + wood
FS9	- 666	17.6-17.8	8360+/-80	Humified wood debris
FS11	- 667	17.1-17.5	9850+/-100	Organic clay
FS12	- 668	14.0-14.5	9170+/-90	Organic clay
FS13	- 669	5.0-5.5	7140+/-80	Organic clay

Probably, moving away from marshy areas, there were transition formations towards either mesophilous woods, from planes to hill vegetation, or xerophitic vegetation of coastal areas.

The upper phase

Herbaceous plants are overwhelmingly prevalent in the upper layers, with most of them from open and largely dry environments.

The results suggest a gradual drying out of the environment. The area might therefore have been covered with meadows with widespread weeds.

The sample (FS7/25), from above the A.D. 79 pumice layer, shows the sudden appearance of a significant percentage of *Myrtus* pollen. Sometimes its grains were grouped, indicating the strictly local presence of the plant. The sudden high percentage of this pollen and its occurrence in groups, besides its local presence, may also suggest an introduction by man.

5. XRD Analysis of Clay Minerals

The different clay components identified by Barra et al. (1999) ranked as follows:

a) - Kaolinite (K), largely predominant over the other clay components; this was generally a well-crystallized mineral.

b) - the three varieties of Illite (I) (Ilp, Io and locally, Iap).

c) - The “anonymous” smectite (Sm) of the “crystallinity” classes (CD, D, E) (Thorez, 1976) which more suitably correspond to random mixed layers of illite-smectite with predominant swelling (inter)layers than to simple smectite mineral. Moreover, the swelling did not exceed 35%.

The clay mineral content does not show sensitive qualitative or quantitative variations from one sedimentary layer to another.

6. Recent uplift and the Holocene sea level rise at the Sele Coastal Plain

The Sele Coastal Plain was affected by tilting phenomena starting from the Tyrrhenian time (ca. 125,000 yrs ago), with uplifting of the land and subsidence of the sea. Similar phenomena were also reported in other areas of the Italian Tyrrhenian coast.

Furthermore, close to the river mouth, an uplifting of about 0.25 m per 1000 yrs has been recorded in recent times, as the Tyrrhenian beach of Ponte Barizzo Ridge has been found about +20 m (Brancaccio et al., 1990), and beach deposits of the Laura Ridge (ca 4000 yr) were found at about +1 m (Russo, 1990).

7. Late Pleistocene-Holocene evolution (Fig. 13**).**

During the regressive phase of the Late Pleistocene-Holocene, the sea level dropped to -120m and then the continental deposits of the lowstand system of the Hera Argiva sequence were accumulated; the Holocene transgression follows.

Two phases can be distinguished in the Holocene sea level rise: the first phase is transgressive, between 10,000 and 8000 yrs ago, and the second is aggradating, between 8000 and 4000 yrs ago. The transgressive succession is typical of the barrier-lagoon model (Oertel et al., 1992), in which the rate of the sea-level rise is ca. 10mm/yr. During this phase, beach and marsh-lagoon environments shifted landward, forming a retrogradational architecture, characterised by the absence of aeolian coastal dunes (Fig. 13A). The second phase began with the decrease of the sea-level rise at about 8000 yrs ago. The curve calculated by Bellotti et al., (1995) indicates a rate of about 10mm/yr at 10,000 yrs B.P.; such a rate

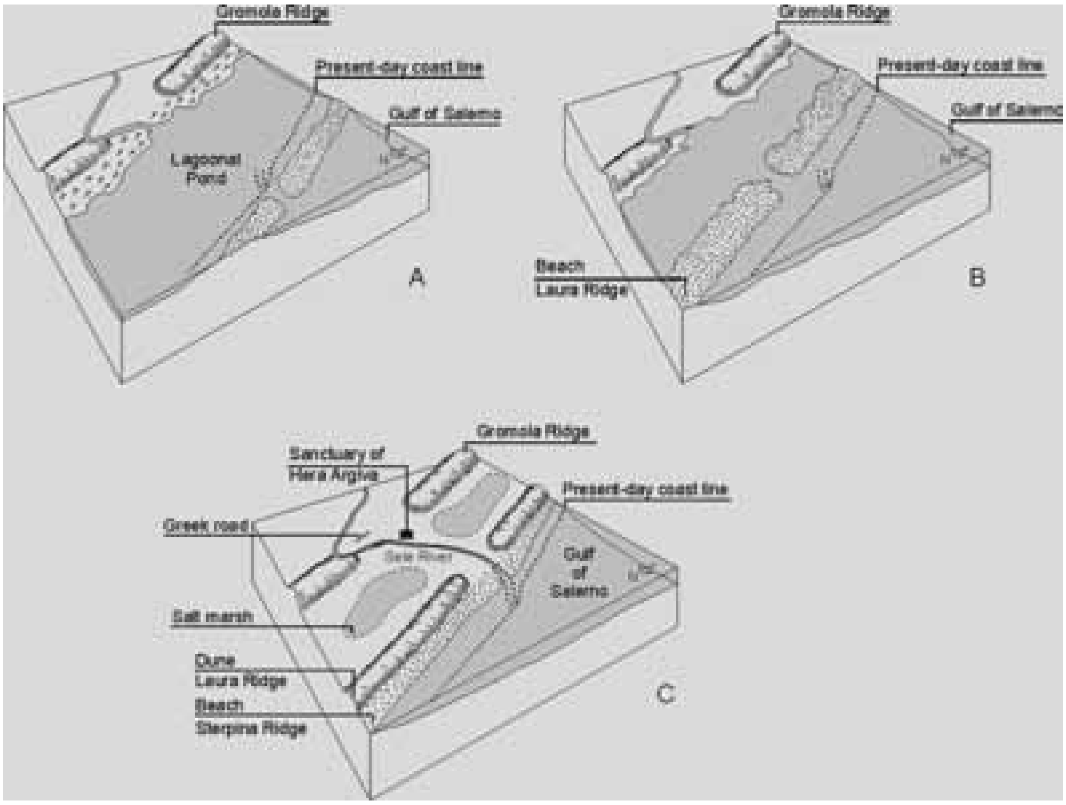

Figure 13 - Reconstruction (not to scale) of Holocene coastal geomorphic features during the transgression (A), progradation (B), and at the time of Hera Argiva settlement (C).
A) Between 10,000 and 8000 yrs B.P. the sea-level rise is the dominant controlling factor of the sedimentary process: the continental shelf is submerged and the coastline shifted landward. The transgressive succession is characterised ,from sea to land, by a beach, lagoon and a freshwater marsh. The decrease in rate of the sea-level rise at about 8000 yrs B.P., leads into a phase of aggradation between 6000 and 4000 yrs B.P.
B) At about 4000 yrs B.P., during the maximum flooding of the sea, a beach (the Laura ridge) was formed with a lagoon behind. The rate of sea-level rise then decreased, and the sediment supply induced beach progradation, filling up of the lagoon and the freshwater marshes.
C) 6th century B.C. -- environmental reconstruction. An active beach (the Sterpina ridge), the coastal dune (the Laura ridge), and salt marshes and bogs are present. The Hera Argiva Sanctuary, surrounded by luxuriant vegetation, was built on the Sele river margin, at the edge of marshes. A Greek road found near the last meander of the Sele river is shown; the reconstruction of the trend of this road along the Gromola ridge toward the city of Poseidonia suggests that a harbour may have been located at the last meander of the river (from Barra et al., 1999).

decreases to about 1mm/yr at 5000 yrs ago. The low rate of the sea-level rise determined the beginning of the infilling of the lagoon and the expansion of the marsh zones.

A highstand system follows, represented by a beach dune complex with bogs and ponds behind, that prograded seaward until reaching its present day position (Fig. 13 B), and characterized by a very low rate of sea-level rise. During the last 4000 yrs, values of some mm/yr are indicated in our curve and in the Tevere plain. The land uplifting, estimated at about 2.5 mm/yr, and an increase in sediment supply, led to the seaward progradation of the coastline until its present-day position. During this phase the dune deposits at the top of the Laura Ridge and the Sterpina Ridge were formed, while landward salt marsh, bogs and ponds extensively invaded the area behind the barrier beach. The change from a wet environment to a drier one is recorded in the pollen spectrum, where *A. glutinosa*, *Salix* and *Populus* diminish and then disappear altogether, with a concomitant progressive expansion of Chenopodiaceae. Together with Cichorioideae and microfauna (foraminifers and ostracods), this indicates a gradual change from a brackish to freshwater and dry environment.

9. Palaeoenvironments and the Magna Grecia settlements

When the Hera Argiva Sanctuary was built (ca. 2500 yrs ago), the shoreline was displaced about 250 m landward with respect to the present-day one. In contrast, some authors believe that, at that time, the coastline was located landward, while for others, seaward. We believe the existing environments were as follows (Fig. 13 C):

- a beach area with sand deposits located in the area of the Sterpina Ridge;
- a coastal dune system, located behind the beach and formed by the aeolian sands of the top of the Laura Ridge;
- a coastal marsh environment, with bogs and ponds in the area behind the dunes; the Gromola Ridge limited this environment landward.
- a natural levee of the river limiting the salt marsh towards NW. The Hera Argiva Sanctuary was on this natural bank, protected from floods.

Bogs and ponds were spread out in the areas surrounding the sanctuary and created quite a favourable environment for the setting up of a garden rich in aquatic vegetation and fauna, typical of the Hera cult. The area, however, was covered with meadows. Some plants, such as *Myrtus*, may have been introduced by man.

The lagoons were partly filled and the harbour of the city was probably situated along the bank of the Sele River, possibly in its last meander. This hypothesis seems to be confirmed by a Greek road found close to the last meander of the river.

From Paestum to Velia

While going by bus from Paestum to Velia, we'll cross the southernmost part of the Sele Plain and enter the hilly landscape of the Cilento area: a structural high forming a wide headland between the two Quaternary tectonic gulfs of Salerno and Policastro. A N120 trending fault zone depresses the Cilento area compared to the more internal part of the Campanian Apennines, whose mountains made of Mesozoic platform carbonates (Alburno-Cervati thrust sheet unit) are visible in the foreground. Borehole and seismic data prove that the top of those carbonates is depressed at a thousand metres below s.l. in Cilento. In fact, here only some higher units of the accretionary wedge are exposed: namely the so called North Calabrian units (Cretaceous to mid-Tertiary basinal deposits including the Ascea Flysch we will see in Velia) and, disconformably deposited on that, the Miocene siliciclastic turbidites of the Cilento Group.

The last part of our trip to Velia runs along the final stretch of the Alento River valley, which appears considerably aggraded by Upper Quaternary fluvial and transitional deposits. An initial fill dates back to the Last Interglacial period, and was partly covered by tributary fans during the Last Glacial period. The peaking stage of the Versilian ingression transformed the lower Alento valley into a *ria*, penetrating about 2.5 km inland of the present shoreline (Cinque et al., 1995). During the last millennia, this gulf has been gradually filled, and the coastline moved forward, thanks to high rates of fluvial supply and substantial stability of the sea level after the end of the Post-Glacial rise. The same evolution was recorded in the nearby lower valley of the Fiumarella River, whose outlet in the Tyrrhenian Sea is only a few kilometres to the SE of the Alento one. The coastal hill separating these two valleys is the place where the Greek city of Elea was built in the VI century B.C. At that time, the SW spur of the hill was partly protruding into the sea as a rocky promontory that hosted first a rich quarter of the initial settlement and then, at the beginning of the V century B.C., the sacred monumental area of the city, the Acropolis. As narrated by ancient writers and backed up by some archaeological findings, Elea had two ports on the two sides of the said promontory. But nowadays the Acropolis spur appears entirely absorbed into the sandy plain, due to historical phases of progradation of both the Alento and the Fiumarella coastal plains (Fig. 14).

Velia

Elea (initially Hyele or Ele) was founded around 540-535 B.C. by Greeks fleeingPhocaea (on the Aegean coast of present-day Turkey) when their town was put under siege by the mighty Persian army. Elea's economy rested principally on long-range maritime commerce, but some earnings came also from the production of olive oil and salted fish. In the early III century B.C. the city became an ally of Rome, but it continued to use the Greek language and to coin its own money. In 88 B.C. Elea became a Roman *municipium* and its name changed to Velia. The city started to suffer a slow, progressive decline

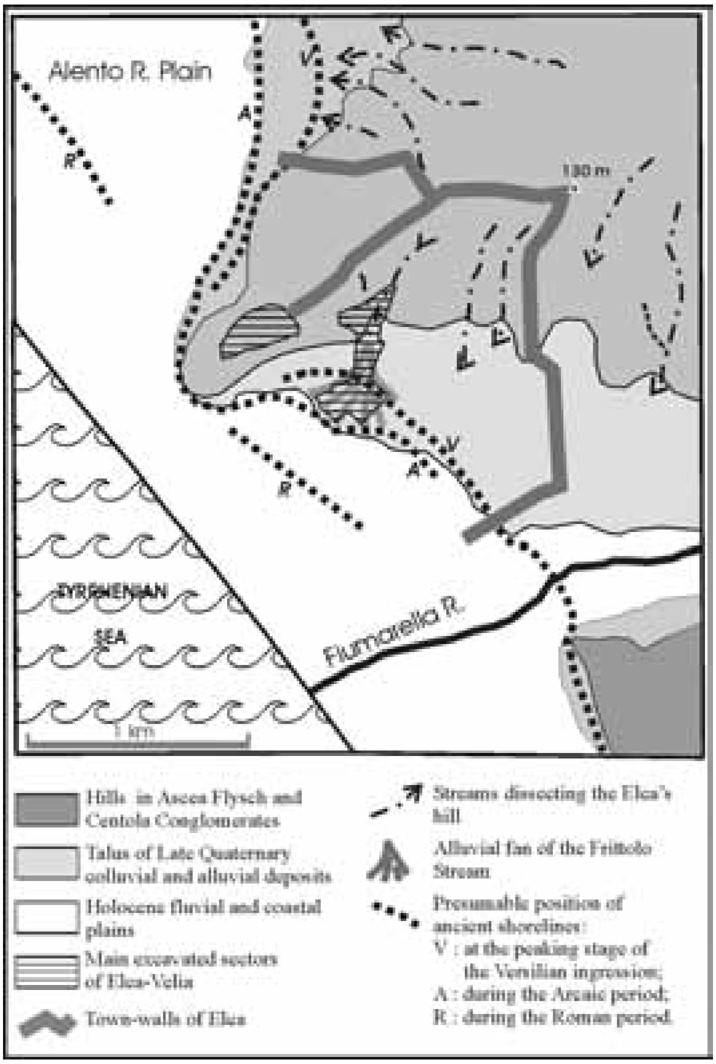

Figure 14 - Geomorphological sketch map of the Velia area.

during the Roman Imperial Age, supposedly because the Tyrrhenian trade routes toward the Eastern Mediterranean area were in competition with new ones exploiting ports on the Adriatic Sea, which were by then connected to Rome and Northern Italy by good, safe roads. The contemporaneous filling of Velia's harbour with silt was certainly a concomitant contributor to their troubles. Velia's lower quarters (those on the coastal plain) were largely abandoned in the V century, but a village on the area of the previous Acropolis (Castellamare della Bruca) survived and maintained a certain local importance up until the IX century.

Stop 4:
The seaside town-walls

Entering the town through the gate of *Porta Marina Sud* (Fig. 15) we note two construction phases in the city walls. The first one (in even, squared blocks) dates back to the first half of the V century B.C. They emerge very little from the present excavation floor, but deeper investigations in the past followed it down to about 1.5 m below sea level, without even reaching the foundation level. The walls were reconstructed higher during the last quarter of the IV century B.C. (walls in bossed, squared blocks). As we shall see later on during the visit, a phase of ground aggradation affected the area in the interval between the two wall construction phases. According to some authors, the southern port of Elea was just outside these walls. Another hypothesis locates it at the base of the Acropolis spur, where the main parking area is now. Possibly the first location is true for the Archaic period, while the second one may be valid in the Hellenistic period. Such dislocation of the port was probably made necessary by progradation during the V and IV centuries.

Stop 5:
The Triportico area

Inside the town-walls excavations have largely re-exhumed the urban levels of the Hellenistic and Roman phases. On reaching the NE end of Insula II, we'll stop to discuss a poster illustrating the results of past diggings made both inside the *Triportico* (a complex edifice of the late I century BC) and below an adjacent paved road of the late IV century BC (present elevation 5.5 m above sea-level). Exactly in this spot, drilling data permit us to locate the foot of a palaeo-sea cliff that marks the local inner limit of the Versilian ingression. The correlative beach-face sediments rest below the present zero and are followed by slightly weathered supralittoral sands interfingering with thin alluvial and colluvial beds. On these materials (at about 1m above sea-level) traces of the first Archaic settlement (wooden huts of the late VI century B.C.; Archaic Phase I) were found. These are followed by two phases of house building (Archaic Phases IIa and IIb) that were built by the second generation of Phocaean immigrants. A few decimetres of alluvial materials were deposited in the area during Archaic-period . When the brick houses had already been abandoned, there was the accumulation of some littoral sand (wind blown?), followed by the falling in of the walls and the burial of the ruins by alluvial deposits rich in charcoal fragments. After a short-lived reconstruction (Archaic Phase III), around 450 B.C., the site received some more littoral sands (a tempestite, according to Ortolani, 1994) and was aggraded by 2.5-3 metres of alluvial deposits. Ortolani et al. (1991) interpret as palaeo-sismites two thin, convoluted layers within this sequence. Between the mid-V and the late-IV century B.C. all the lower quarters of Elea were probably troubled by alluvial events, as no building activity is recorded there in that time span.

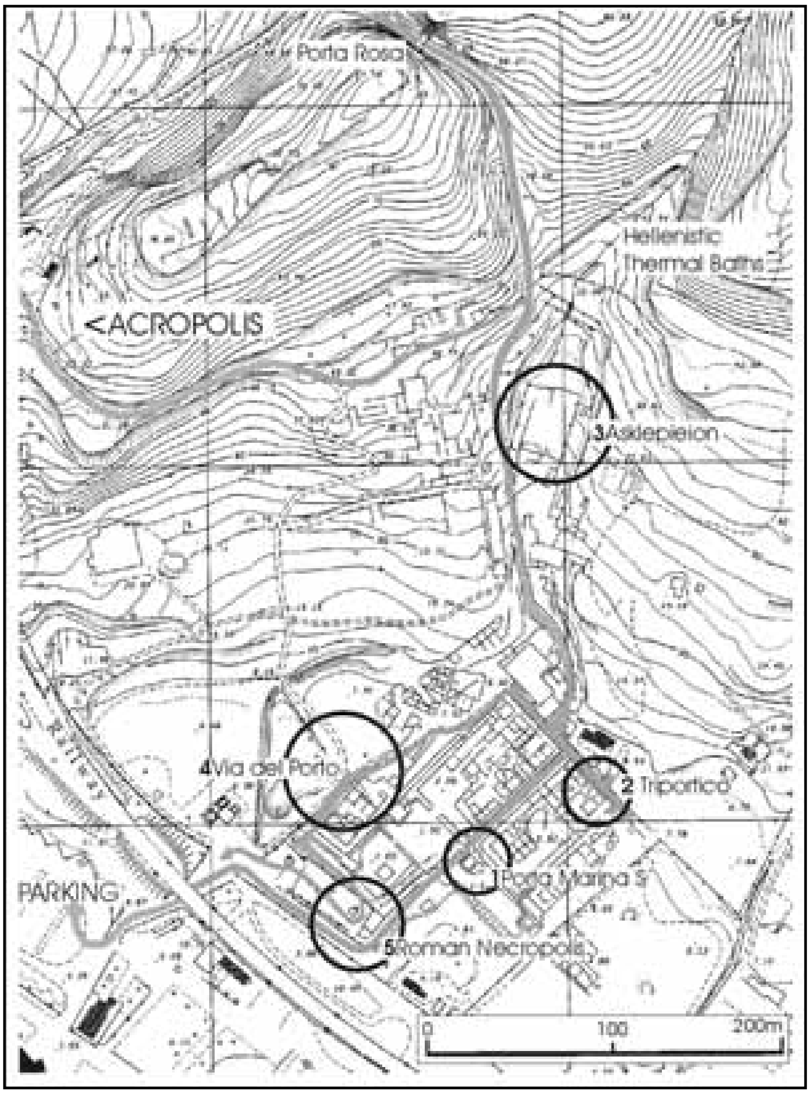

Figure 15 - A contour map of the Velia area highlighting the route of our visit to the ruins (gray line) and the sites to be commented during the visit (circles).

Stop 6:

The Asklepieion

Walking along *Via di Porta Rosa* we climb up to the *Asklepieion*. This belongs to a sequence of Hellenistic buildings that were built right on the floor of the *Vallone Frittolo* dale; this dale is the largest torrential incision converging toward the southern lower quarter of Elea, and surely the main source area of the alluvial deposits found there. Probably this strange location was decided not only to scenographically exploit the landforms and to use a spring upstream for fountains and baths, but also to stabilize the valley by terracing its flanks and floor and by directing the water into an underground channel. The fact that these works only temporarily stabilised the dale is evident in the damage suffered by some walls of the *Asklepieion* and, further upstream, by the Hellenistic Thermal Baths (upset during the II century B.C.).

Stop 7:

Via del Porto and the Roman Necropolis

After a look at the splendid *Porta Rosa* and the *Acropolis*, we'll go back down to the lower city to visit an excavation in progress in the area of *Via del Porto* (Fig. 16). Here some fresh vertical cuts allow us to examine a 3-metre-thick sequence of alluvial deposits covering roads and houses of the Hellenistic period. Here we are on the alluvial fan of the Frittolo stream, which had aggraded the urban area also during the late Archaic period. The youngest sequence, which is now being exposed by new excavations, includes at least three intervals to be ascribed to debris flow events (massive, sheet-like, non-erosive based, poorly-sorted, matrix-supported conglomerates of pebble to fine boulder grade). Besides stones up to 2 dm^3 large, they contain many fragments of pottery, tiles, bricks, carbonised wood and bones. These beds (each up to 70 cm thick) alternate with intervals that are composed of horizontally-stratified, laterally continuous sheets of sandy silt, sand and pebbly sand referring to unconfined sheetflood pulses (alternating couplets of different clast size).

The presence of walls and floorings that witnessed at least three building phases (repair and/or rebuilding of houses) during pauses in the sedimentation is of great interest. The sequence accumulated mostly between the II and the III century (personal communication from Prof. Giovanna Greco).

Visiting the nearby Roman Necropolis, we see evidence that the coastal strip resting immediately outside the city walls (nowadays 3 to 5m higher than during the III century B.C.) suffered about two metres of aggradation (aeolian plus alluvial) by the I century B.C., another metre or so by the II century and, finally, up to two metres more (maximum value close to the colluvium-releasing Acropolis slope) after that date.

What we have seen in Velia re-proposes the old problem of differentiating the human causes of erosion/alluviation from the climatic ones. The fact that only small portions of the city have been excavated and geo-stratigraphically interpreted, coupled with some chronological uncertainties, does not permit safe conclusions. As a contribution to the discussion, we can recall that we are in a morphoclimatic scenario where susceptibility to erosion is high and quite sensitive to minor

Figure 16 - A new excavation front along Via del Porto road shows the alluvial sequence that covered the Southern Quarter of Velia starting from the II century. The remnants of walls attest to the occurrence of building activity during pauses in sedimentation.

environmental change (especially when hillslopes are deforested, overgrazed and/or artificially terraced and then left abandoned). Also to be noted is the fact that the town-walls reached up to the hill top and, therefore, the source of the sediments we have seen was always intra moenia territory: an area that was most likely much impacted by man, but also so hemmed in and so limited as to make the control of soil erosion and slope failures relatively easy. Even though we cannot exclude that a role was played by short-lived social crises in the history of Elea-Velia (with neglect of both terrac and drainage systems), it appears probable that periods of exceptionally severe storms were at least a concomitant cause of the observed alluvial events.

We'll finally leave Velia and return to Capaccio by bus to visit the magnificent Greek temples of Paestum by the light of the sunset.

DAY 4

Herculaneum, Oplontis and Pompeii
A. Ciarallo, T. Pescatore, M.R. Senatore, G. Capretto

Introduction

The Sarno Coastal Plain represents the southern side of the Campania Plain (Fig. 17) and is dominated by the Somma-Vesuvius volcano. Along the volcano's slopes some of the most famous Roman settlements

Figure 17 - Campania Plain showing the Somma-Vesuvius volcano, ancient Pompeii and other Roman settlements (from Pescatore et al., 2001).

buried by the A.D. 79 eruption are Pompeii, Herculaneum and Stabiae.

The Sarno plain is part of a Pliocene-Quaternary basin bordered by NW-SE and NE-SW normal faults, along which the Mesozoic-Cenozoic calcareous rocks of the Apenninic units are down-faulted towards the Tyrrhenian Sea. During the last 2 Ma, an active subsidence lowered the top of the carbonate substratum to a depth of 5000m in the northern part (Volturno Plain), and to 2000m in the southern part (Sarno Plain; Cinque et al., 1987).

The Sarno plain is bounded towards the sea by a structural high made up of Mesozoic calcareous units; the offshore Rovigliano Rock (Fig. 31) represents its surface expression.

The Pliocene-Quaternary succession filling the Sarno basin mostly consists of marine sediments and epiclastic and pyroclastic continental sediments (Trecase 1 borehole; Cinque et al., 1987). In the inner plain, beach deposits correlated to the Upper Pleistocene (Tyrrhenian - isotopic stage 5e in Chappell and Shackleton, 1986) were found at 25m below sea level. In the outer plain, beach deposits of Holocene age were found between –4 m and +1 m of present sea level (Cinque et al., 1987); the different elevations of these beach deposits testifies active volcano-tectonic phenomena.

Since Roman times, soil fertility, favourable climatic conditions, and water abundance encouraged both agriculture and commerce, as well as the building of many villas. Samnitic and Roman villas (II and I century B.C.) along the route from Pompeii to Oplontis and Herculaneum, together with the villas of Stabiae, were built in choice settings on the seaside, near the edge of a relatively stable cliff.

Pliny the Elder, in his treatise *Historia Naturalis*, exalted the Campania coast for its "invigorating and permanent salubrity, the pleasant climate, rich fields and gentle hills". He also celebrated "Pompeii, on Vesuvius' slope, close to the Sarno River". Pliny the Elder did not understand, however, that Vesuvius was an active volcano. In fact, during his time, volcanic eruptions were considered to be a supernatural phenomenon, rather than a natural event, so the towns and villas were not envisioned as being at high risk.

The A.D. 79 eruption deposits, which almost instantaneously covered the area surrounding Vesuvius, constitute an easily-recognizable stratigraphic marker that facilitates palaeogeographical reconstruction.

Several authors (Ruggiero, 1879; Ward-Perkins, 1979; Cinque and Russo, 1986; Malandrino, 1988; Furnari, 1994; Pescatore et al., 1999, 2001) proposed different reconstructions for the shoreline trend prior to A.D. 79, although the data was insufficient to solve the controversy.

Eruption History of the Somma -Vesuvius

The Somma-Vesuvius history has been characterized by eight eruptive cycles, separated by long quiescence periods, since the Late Pleistocene. The first cycle occurred about 17,000 yrs B.P., and each cycle begins with a Plinian eruption followed by effusive eruptions. The 79 A.D. eruption represents the beginning of a cycle after a 300-400 yr quiescence period (Sigurdsson et al., 1985).
The eruption was described by Pliny the Younger, who lived in Baiae, 30 km west of the volcano (Fig. 17). He wrote two letters to the historian Tacitus to inform him of the death of his uncle, Pliny the Elder, who went to the Pompeii area both to aid residents and to observe the volcanic activity.

After the A.D. 79 eruption, subplinian explosive eruptions occurred. In 1631 an explosive and effusive phase was followed by minor events. The last eruption occurred in 1944.

The Course of the 79 A.D. Eruption

The eruption started on the night of the 24th of August with a very intense Plinian explosive phase, leading to the formation of a plume that was about 32 km high and elongated toward the southeast by stratospheric winds (Carey and Sigurdsson, 1987). Pliny the Younger wrote that this volcanic cloud resembled a Mediterranean pine. The Plinian fall deposits, named Pompeii Pumice (Lirer et al., 1973), covered the pre-existing topography like a blanket, decreasing in thickness downwind from Vesuvius (Fig. 18, 19, and 20). On the 25th of August, the volcanic activity changed, and flows and surges were produced (Fig. 20, 21, and 22). They spread along the volcano slopes at 400°C (Kent et al., 1981) and at more than 100 km/h; when they reached the Sarno Plain, they destroyed everything. The products of these flows and surges completely buried Herculaneum and caused major destruction and high mortality in Pompeii, Oplontis and Stabiae. The volcanic activity probably continued for some weeks, with phreatomagmatic explosions (Sheridan et al., 1981).
The volcanological interpretation of the deposits and the historical evidence presented by Pliny's letters provide a framework to a reconstruction of the eruption in A.D. 79 (Figs. 19 and 23).

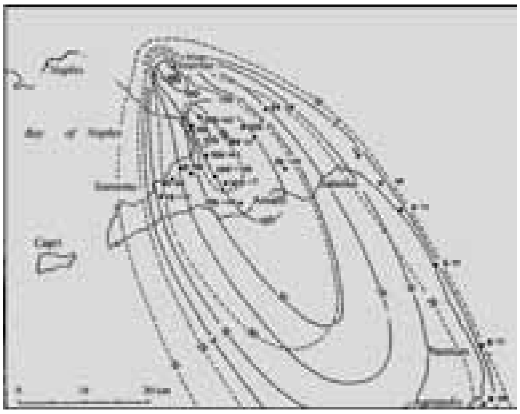

Figure 18 - Extent (in centimetres) of pumice-fall. Numbers on the isopachous lines were extrapolated from values at datum points. White pumice-fall: continuous line. Grey pumice-fall: dotted lines (from Sigurdsson et al. 1985).

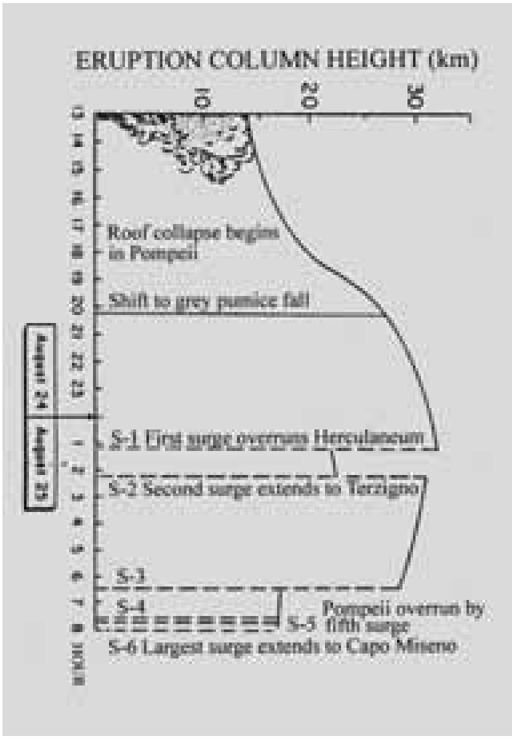

Figure 19 - Evolution of column height during the A.D. 79 eruption (from Carey and Sigurdsson, 1987).

The proposed chronological scheme is based on four assumptions:
1) the beginning of the Plinian phase is taken as 1 p.m.;

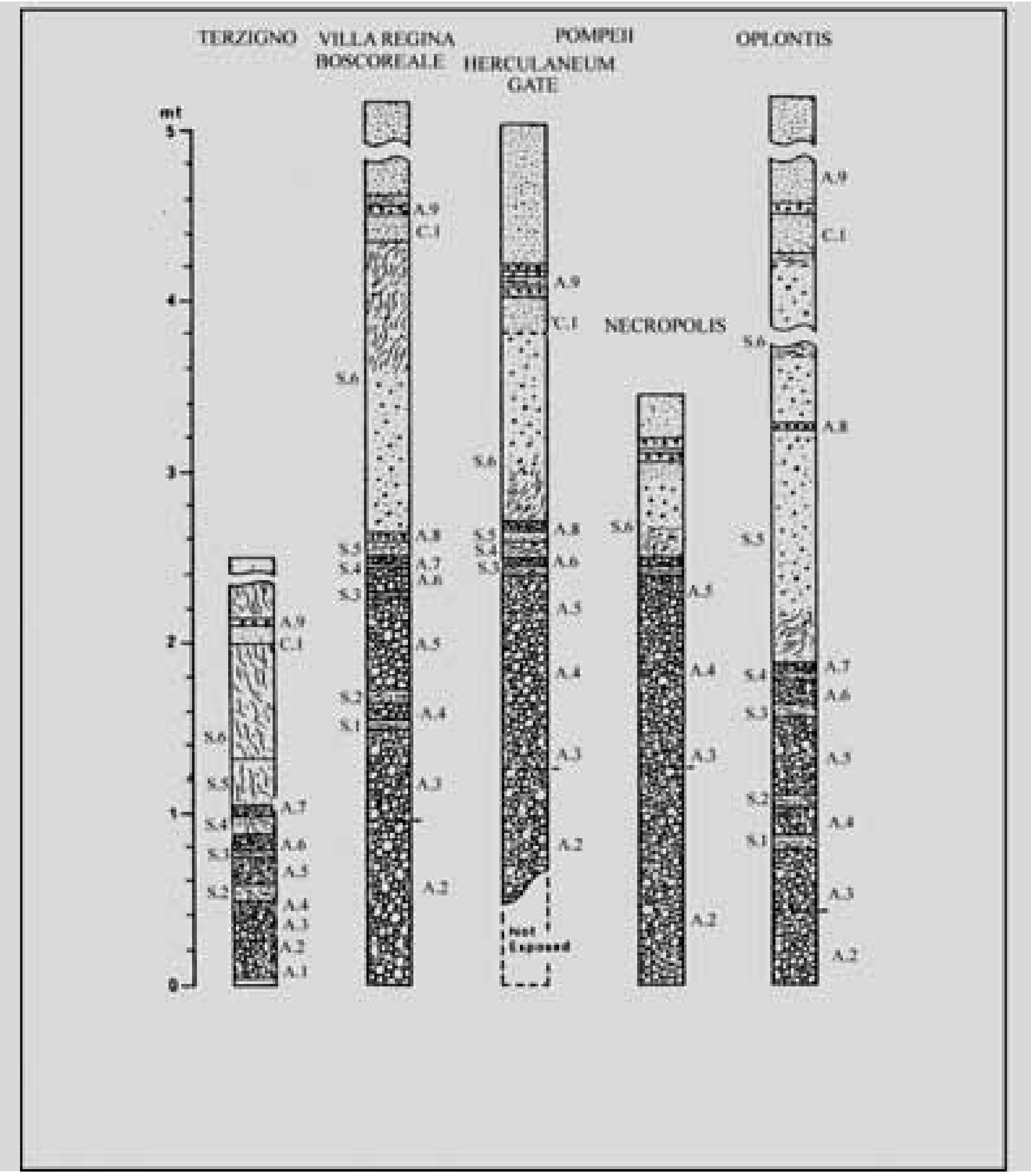

Figure 20 - Stratigraphic sections of the A.D. 79 eruption (from Sigurdsson et al., 1985). At Villa Regina the initial fall of fine ash (A-1) did not occur. The A-2 and A-3 pumice fallout layers were followed by an S-1 surge that broke the branches of the tree (Jashemski, 1979) and by a reverse-graded fall deposit of grey ash (A-4). An alternation of surge and fallout deposits occurs upwards in the sequence. The most destructive surge was probably the S-6 layer. Overlying this layer is the first appearance of accretionary lapilli (C-1), indicating the transition to phreatomagmatic activity.

2) the most widespread surge (S-6) is taken as corresponding to the surge which Pliny the Younger watched spreading across the Bay of Naples and which made him flee Misenum shortly after daybreak (about 8 a.m.);
3) the rate of accumulation is assumed to have been uniform during the fall-out;
4) the surges are regarded as an instantaneous event and their thickness is excluded from this chronology.
The first eruptive activity was a phreatomagmatic one that generated a low eruption cloud. The ash plume spread to the East resulting in the deposition of ash-

Figure 21 - Distribution of the six surge layers from the 79 A.D. eruption (from Sigurdsson et al., 1985).

Figure 22 - The thickness of the total surge deposits (in meters) with isopachous lines. Distribution of pyroclastic flows (dotted lines) is also shown (from Sigurdsson et al., 1985).

fall layer A-1. Probably the ash fell on the morning of the 24th of August or during the previous night.

Around 1 a.m. on the 25th of August the style of the activity changed, and six pyroclastic flows and surges were produced during the next seven hours. The first surge affected Herculaneum, Oplontis and Boscoreale, the second surge reached Terzigno and had severe effects on Herculaneum. The third surge, with a similar distribution, reached the northern city wall of Pompeii, and the following pyroclastic flow buried the city of Herculaneum; a fourth surge was generated and killed about 2000 people in Pompeii (Maiuri, 1958). The fifth surge and the successive pyroclastic flow were distributed to the South. The sixth and largest surge reached Stabiae at about 8 a.m. on the 25th of August and probably caused the death of Pliny the Elder.

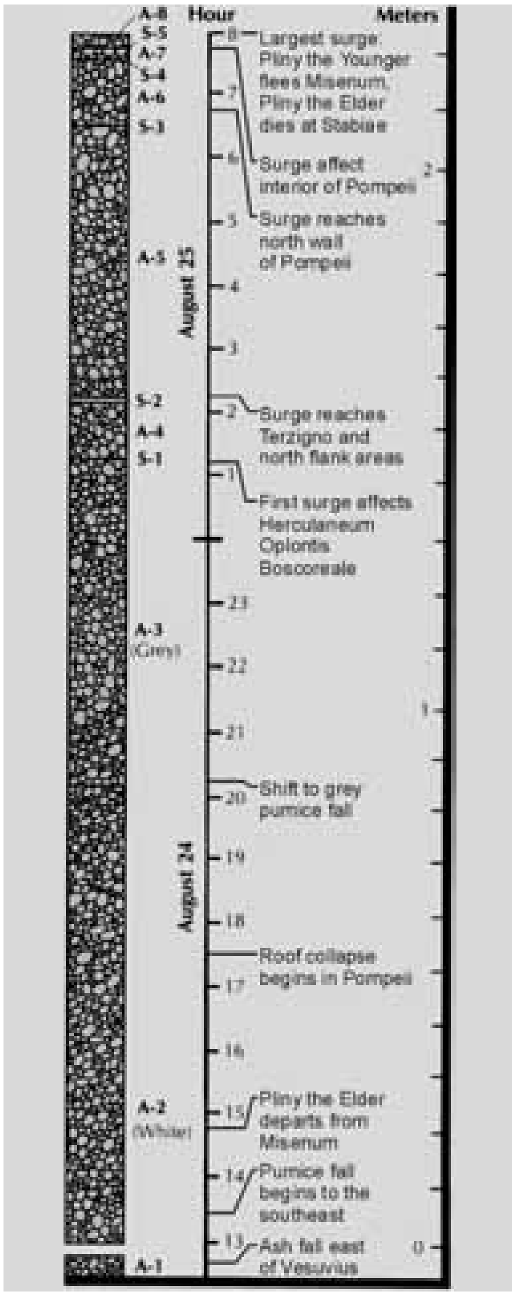

Figure 23 - Chronology of the A.D. 79 eruption, based on correlation of events described in the letters of Pliny the Younger with the volcanic stratigraphy at Villa Regina, Boscoreale. The stratigraphic section shows the thickness of the fall layers as a measure of duration. The thickness of the surge layers is omitted, as surges are considered to be nearly instantaneous events (from Sigurdsson et al., 1985).

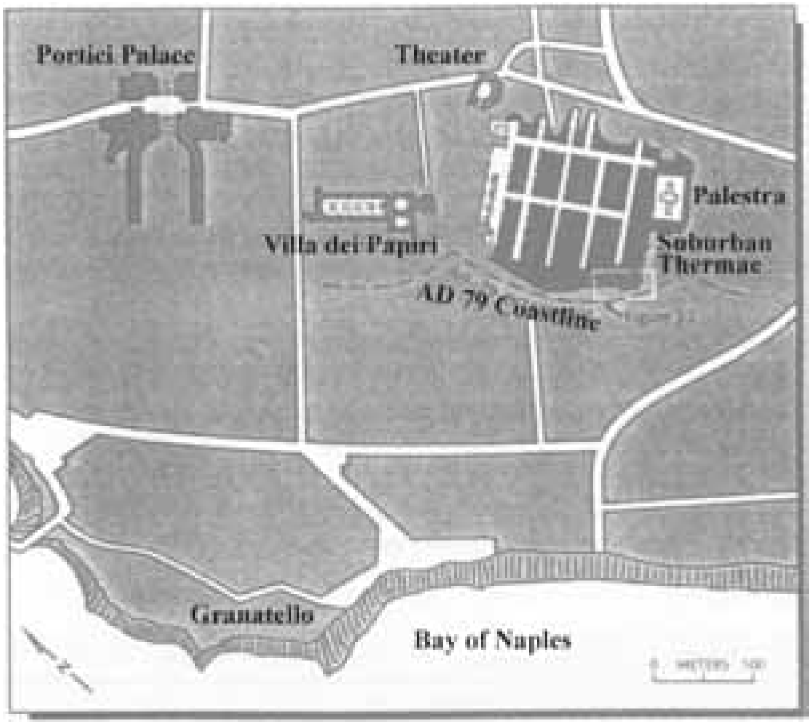

Figure 24 - The Herculaneum area (from Sigurdsson et al., 1985)

This surge travelled across the Bay of Naples and reached the city of Misenum. Deposits left by this surge are present in the area of the city of Naples and perhaps in the Bay of Pozzuoli.

Later activity of the volcano laid down other surge and accretionary lapilli beds. These deposits were probably formed by a large number of small phreatomagmatic explosions resulting from the interaction of ground water and magma (Sheridan et al., 1981). This activity may have persisted for days or weeks.

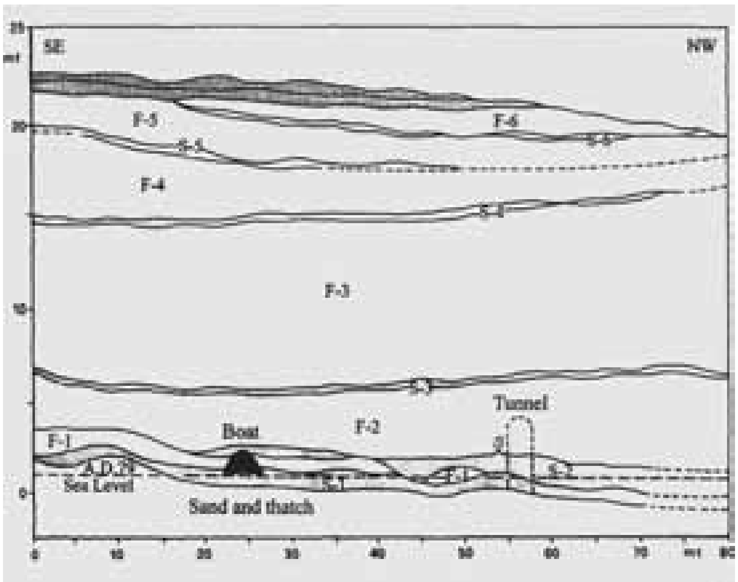

Figure 25 - Stratigraphy of the A.D. 79 volcanic deposits at Herculaneum. Note that the vertical scale is based on datum that originates 5 m below present sea level (from Sigurdsson et al., 1985)

Stop. 1:

Herculaneum - Belvedere

(Fig. 24, 25)

From the belvedere it is possible to see the whole excavation. Herculaneum was founded, probably in the 4th century B.C., near the sea, on a promontory situated between two streams at the foot of Vesuvius. The city, as member of the Oscan League based in Nocera, took a great part in the Greek culture of Naples.

Herculaneum was conquered by Silla's troops during the Civil War (89 B.C.) and became a Roman *municipium,* acquiring the dimensions of a residential city and a centre of leisurely holidays for many high-ranking Romans.

The eruption of Vesuvius in A.D. 79 has undergone systematic excavations which,

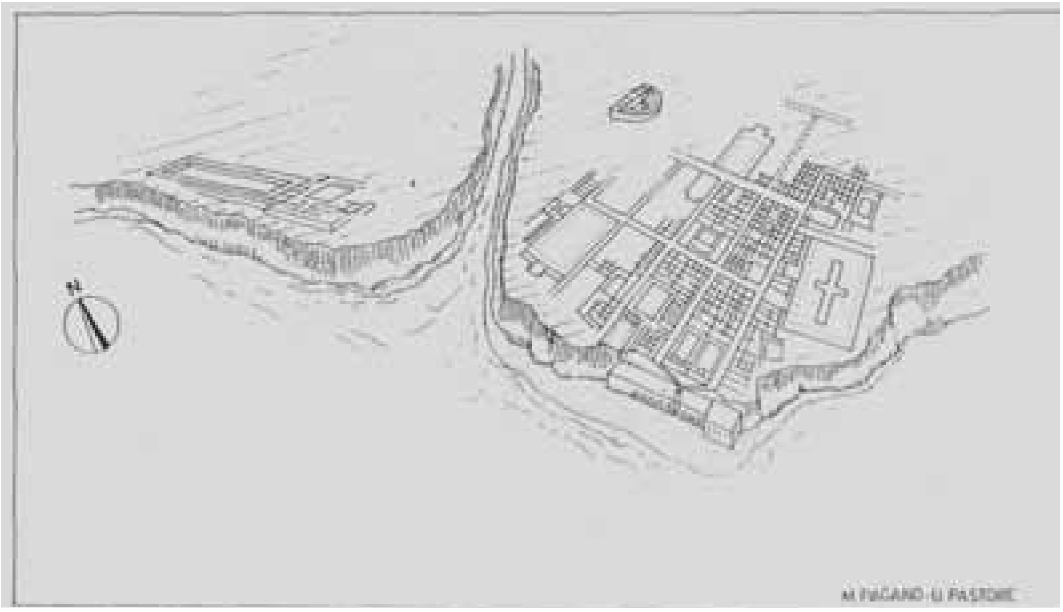

Figure 26 - Old topography of Herculaneum and of the Villa dei Papiri with a river separating them (from Pagano et al., 1997).

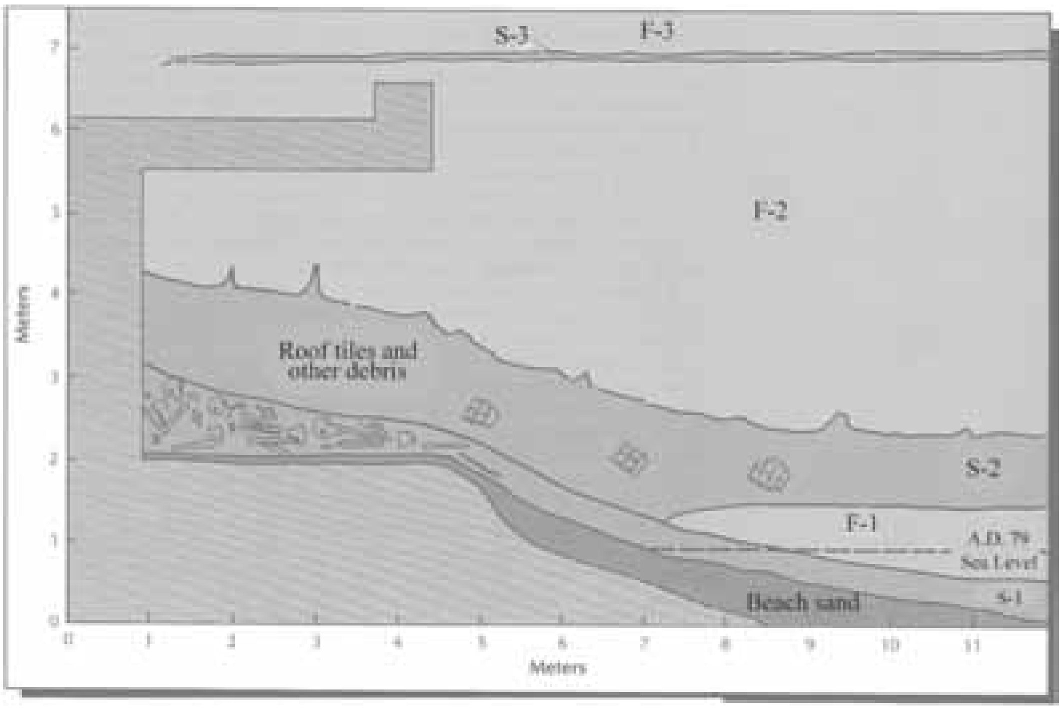

Figure 27 - The Herculaneum beach and one of the chamber, showing the sequence of the A.D. 79 volcanic deposits (from Sigurdsson et al., 1985)

from 1738 to the present time, have brought to light many acres of urban plan, still lying, for the most part, buried under the modern city.
The city of Herculaneum, only 7 km west of the crater of Vesuvius, was buried under more than 20 m of pyroclastic deposits.

Stop 2:

Beach deposits in Herculaneum (Figs. 26 and 27)
The latest excavation permits the reconstruction of the beach of Herculaneum prior to the A.D. 79 eruption. The beach consists of three types of deposits: a pumice-rich tuff formed by an early eruption of Vesuvius; a black beach sand with cross bedding; a gravel layer composed of rounded pebbles of limestone, lava and rubble. These sediments are located about 5 metres below the present sea level.
The best exposure of pyroclastic deposits overlaying the beach is in the 23m-high wall toward the sea.
Generally, the first deposit from eruption is an unconsolidated grey surge layer (S-1). This layer contains a high proportion of wood, both carbonised and uncarbonised, and many human skeletons. Inside the chambers located in front of the beach the layer is virtually crammed with skeletons. On the beach the surge is overlain by a pyroclastic flow (F-1). The third layer deposited in Herculaneum is a pyroclastic surge (S-2). This poorly consolidated layer contains a high proportion of building material, including bricks, roof tiles, plaster, column parts and wall portions. This layer is also overlain by a massive pyroclastic flow (F-2). The upper part of the section is composed of four more couplets of surge and pyroclastic deposits. The S-5 is characterized by large-scale cross bedding.
Studies of the flow emplacement temperature made by Maury (1976) and by Kent et al., (1981) suggest a temperature of 350-400° C.

Stop 3:

Oplontis (Fig. 28)
One of the most interesting villas of suburban Pompeii was brought to light at Oplontis, the present-day Torre Annunziata. Belonging probably to Poppea, wife of the Emperor Nero, the villa shows a decorative, architectonic magnificence that allows the viewer to discern the immense economic power of the ruling classes of Rome.
The succession of the volcanic deposits at Oplontis is, in general, similar to that at Boscoreale, up until emplacement of the S-5 surge. The colonnade and the roof over the portico collapsed during the deposition of the grey pumice (A-3), while the first surge (S-1) destroyed the vegetation.

At Oplontis a lithic-rich A-7 fall was interrupted by the emplacement of a powerful surge (S-5), followed almost immediately by pyroclastic flows confined to the large courtyard facing Vesuvius. The subsequent surge (S-6) and flow (F-6) completely buried the villa.
At Oplontis, as elsewhere around Vesuvius, the S-6 layer is capped by a bed rich in accretionary lapilli indicating the beginning of pheatomagmatic activity (C-1).
The deposits of the A.D. 79 eruption are more than 5 m thick.

From Oplontis to Pompeii

Introduction:
The History of the City (Fig. 29)

The ancient city of Pompeii is located in the alluvial plain of the Sarno River on a morphological high created by a lava flow of unknown age. The northern part of the city is topographically higher, the southern

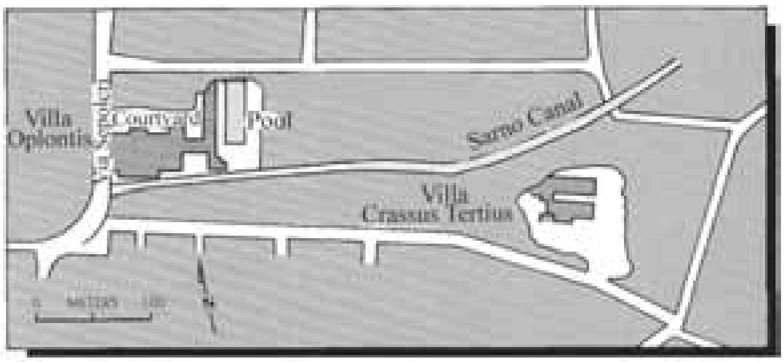

Figure 28 - Oplontis (after Jashemski, 1979). The villa reputed to have belonged to Poppea Sabina and the villa of Crassius Tertius are shown (from Sigurdsson et al., 1985).

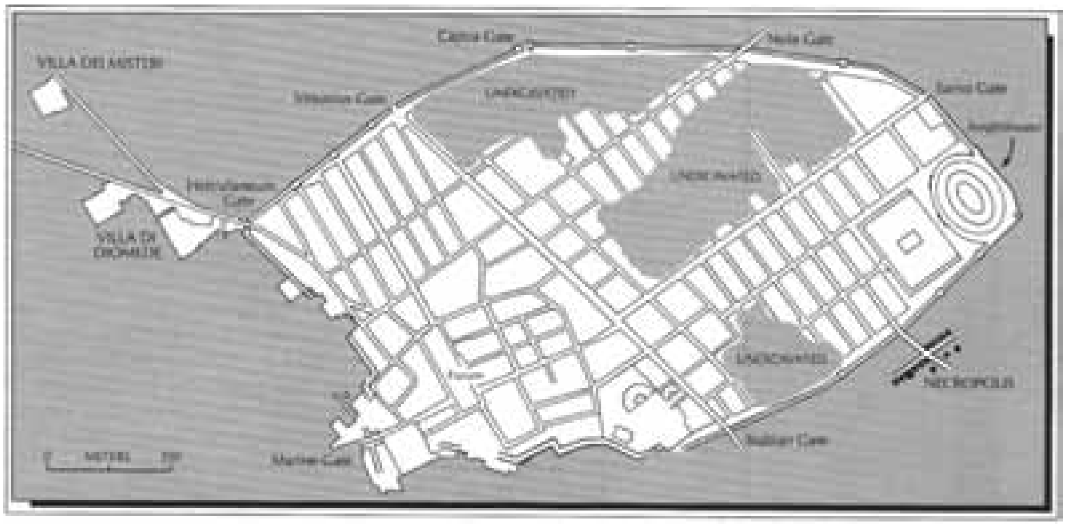

Figure 29 - Pompeii, excavated and unexcavated (from Sigurdsson et al., 1985).

part is topographically lower and develops at the edge of the lava flow. at present, all of the territory of Pompeii appears highly modified by human actions.
The first settlement (the archaic city) of Pompeii probably goes back to the 6th century B.C. The archaic city developed around two sanctuaries dedicated to the cult of Apollo and Minerva or of Hercules. The archaic part, because of its irregular urban plan, contrasts with the more organized expansion of the populated zones that were subsequently added on.
According to some recent hypotheses, between the 5th and 3rd centuries B.C. there was no construction of public buildings. However, the 2nd century B.C. brought on the beginning of important building activity that produced a remarkably developed city and many new public buildings. This period of economic flourishing lasted until the earthquake of A.D. 63, which considerably damaged the buildings and structures. The city was still under restoration at the time of its dramatic destruction caused by the eruption of A.D. 79.
Studies of the walls that surround the city highlighted different phases in their construction. The first walls were constructed in the second half of the 6th century B.C. with leucite lava blocks ("pappamonte"). These walls were low and probably used to provide protection and defence for agricultural and pastoral activities. Subsequently, at the beginning of the 5th century B.C., the city walls were reinforced and raised with travertine slabs. In the 4th century B.C. the walls were raised even higher, using more travertine. At the end of the 3rd century B.C., the external wall was reinforced and an internal wall was added; the material used was mostly volcanic tuff, the so-called Ignimbrite Campana, which is dated about 39 ka B.P. In the 2nd century B.C. parts of the external walls were substituted using various materials: lava, cobble, bricks and mortar. In this period, immediately before the Civil War, twelve guard towers were placed between the two walls.

Stop 4:
Pompei - Via dell'Abbondanza

Since 1987, the Soprintendenza Archeologica of Pompeii has been engaged in the systematic excavation of the most important street of the city, the *decumanus inferior* (Via dell'Abbondanza).
The excavation revealed two distinct units. The southernmost one was found to be a bakery with an attached shop and living room, one of which contains a cycle of splendid banquet pictures, the most celebrated of these, the one of "the chaste lover", has give its name to the building.
The more northerly one, on the other hand, was found to be a rich, private dwelling.

Stop 5:
Pompeii - Casina dell'Aquila

1. Holocene evolution (Fig. 30**)**

The Holocene succession of the Sarno River Coastal Plain and the natural scenery in the area around Pompeii were reconstructed by integrating all the information available from 18 new boreholes which show the framework of reference and the stratigraphy of ca. 400 boreholes drilled in the area since the 1800s. The A.D. 79 eruption deposits were a chrono-stratigraphic marker. The archaeological sites known in the plain, mostly villas and harbour warehouses in use prior to the A.D. 79 eruption, were taken into account as their location facilitated the geological reconstruction of the palaeo-environments.

After the Tyrrhenian highstand (isotopic stage 5e in Chappell and Shackleton, 1986), a series of regressions began, from the 5a (75,000 yrs B.P.) to 2 (about 18,000 yrs B.P.) isotopic stages. During the last phases of the sea level fall (isotopic stages 3 and 2), an erosional phase began on the Sarno Coastal Plain and alluvial material was deposited, giving rise to progradation of the coastal plain and the growth of alluvial fans. Pyroclastic deposits, dated

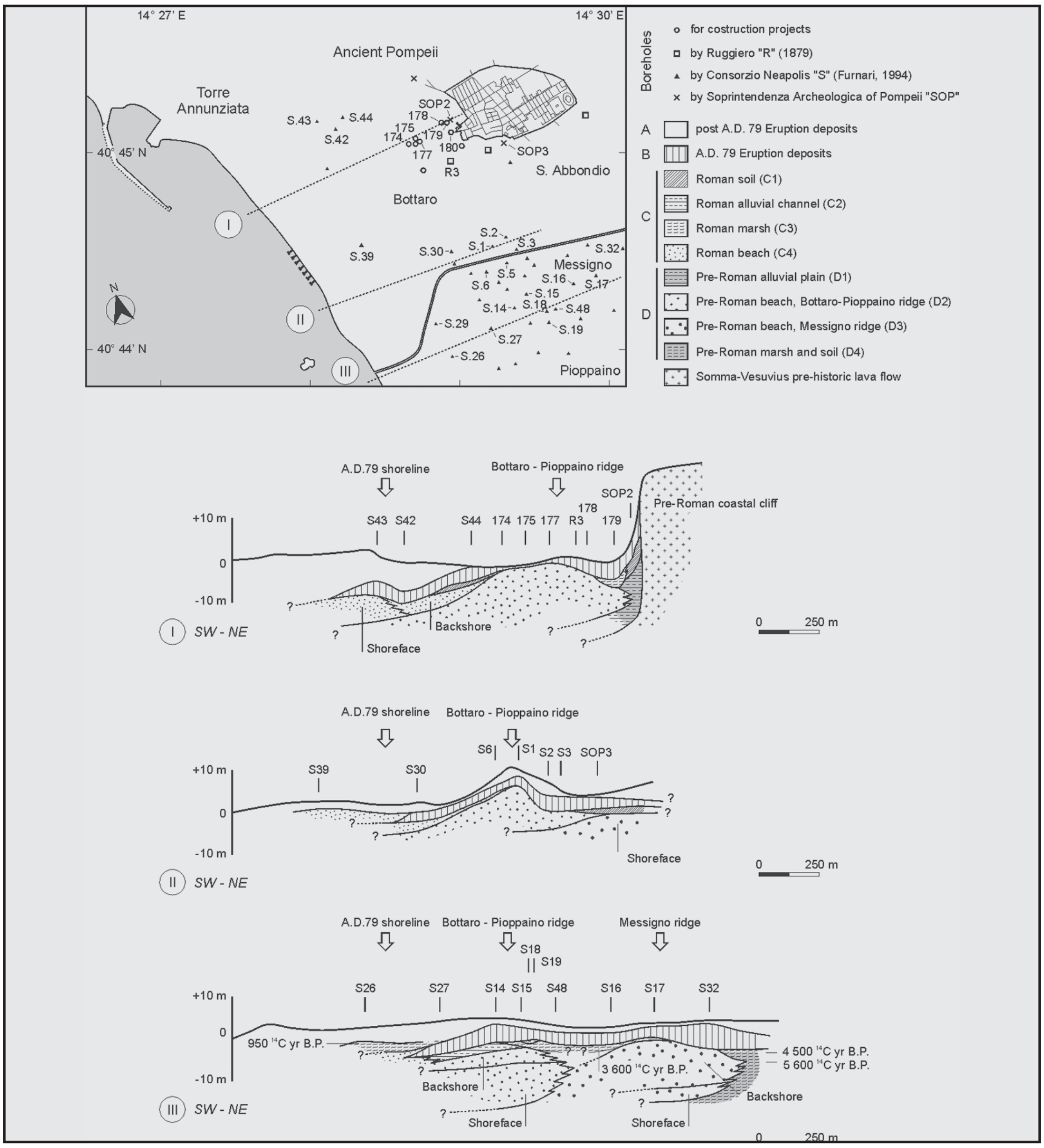

Figure 30 - Geologic cross-sections of the Sarno coastal plain (from Pescatore et al., 2001).

39,000 yrs B.P. (Tufo Grigio Campano; De Vivo et al., 2001), provide age control for the interbedded alluvial deposits. The erosion caused the incision and formation of a scarp, either in pyroclastic and lava deposits or in calcareous and alluvial fan deposits. During the Holocene transgression, up to the climatic optimum, the sea flooded the areas previously exposed in a continental environment.

The Somma-Vesuvius lava flow on which ancient Pompeii is located, specifically between the Marina Gate and the Stabiae Gate, has a near vertical margin, and probably represents a coastal cliff (Cinque and Russo, 1986). Together with the other scarps formed during the latter phases of sea level fall, the cliff underwent coastal erosion during the maximum flooding of the sea related to the Holocene climatic optimum (Fairbridge, 1961; Lambeck, 1990). In the boreholes the beach sand deposits under the Roman soil may be related to this time. Thus, during the climatic optimum, the sea reached the lava flow edge, the Messigno Ridge, which has been dated 5600 - 4500 yrs B.P. (Barra, 1991; Cinque and Russo, 1986; Pescatore et al., 1999, 2001) and the erosional scarps toward the southwest.

The shoreline prograded westward during the highstand reaching the Bottaro-Pioppaino Ridge, dated at 3600 yrs B.P. (Barra, 1991) before reaching its present-day position. Ancient Pompeii was built during the last phase of seaward shoreline progradation.

In the boreholes located north of the city, a thick interval of fluvial sand underlies the Roman soil. These deposits confirm that the area northwest of the ancient city has always had a continental environment and that a river flowed at the lava flow edge between the Capua Gate and the Marina Gate.

A.D. 79 environmental reconstruction around Pompeii (Fig. 31**)**

The integration of all the data led to the reconstruction of the natural environments present around Pompeii, the location of the shoreline, and the Sarno River distal segment in A.D. 79.

The areas surrounding the western and southern part of the city, at the lava flow's edge, were capped by a soil in which many pottery fragments were found, suggesting that the Romans used this area for waste disposal. This soil represents a land area, bordered on the seaward side by marshes with mud rich in organic matter and, near the Marina Gate, by beach sand deposits from the Bottaro-Pioppaino Ridge. The muddy deposits of the marsh areas confirm the presence of coastal bogs and ponds located between the morphological highs of the Bottaro-Pioppaino and Messigno Ridges. The bogs and ponds were separated from dry areas by poplars and cypresses (Ruggiero, 1879).

The Bottaro-Pioppaino Ridge near the Sarno River floodplain was interbedded with alluvial sand and gravel and marsh clay. The distribution of alluvial deposits has allowed reconstruction of the distal segment of the Sarno River, which exhibits meandering pattern and some meander cut-offs. The Roman harbour could have been located in a meander close to the end of the Bottaro-Pioppaino Ridge where there are harbour warehouses (Ruggiero, 1879) and pottery fragments (D'Ambrosio, 1984).

The boreholes without A.D. 79 eruption deposits and with shoreface sand mark an area completely submerged by the sea in which the reworking prevented the deposition of pyroclastic products. Following this interpretation, the Roman shoreline was about 1 km landward with respect to the present-day one and about 1 km southwest from the Marina Gate. It seems possible to infer that the shoreline trend was basically parallel to the present-day one.

Stop 6:

Porta Nocera section (the Necropolis)

A good section of A.D. 79 eruption deposits is visible here (Fig. 20)

Stop 7:

The walls of the city

Human history is often influenced by natural catastrophic phenomena, such as floods, earthquakes and eruptions, that damage constructions and cause periods of crises in the economic development of cities.

It is well known that Pompeii was hit by a strong earthquake in A.D. 63 which, as evidenced by building restorations, conditioned the life of the inhabitants. Soon after, Pompeii was covered and destroyed by pyroclastic deposits from the 79 A.D. Vesuvius eruption. Less known is the presence of a river that flowed north of the city. A catastrophic flood between the 4th and 3rd centuries B.C. hit Pompeii strongly enough to slow down and even stop its development for some time.

The study of alluvial deposits is based on the stratigraphy of both boreholes areas along the walls of the ancient city of Pompeii and excavations inside

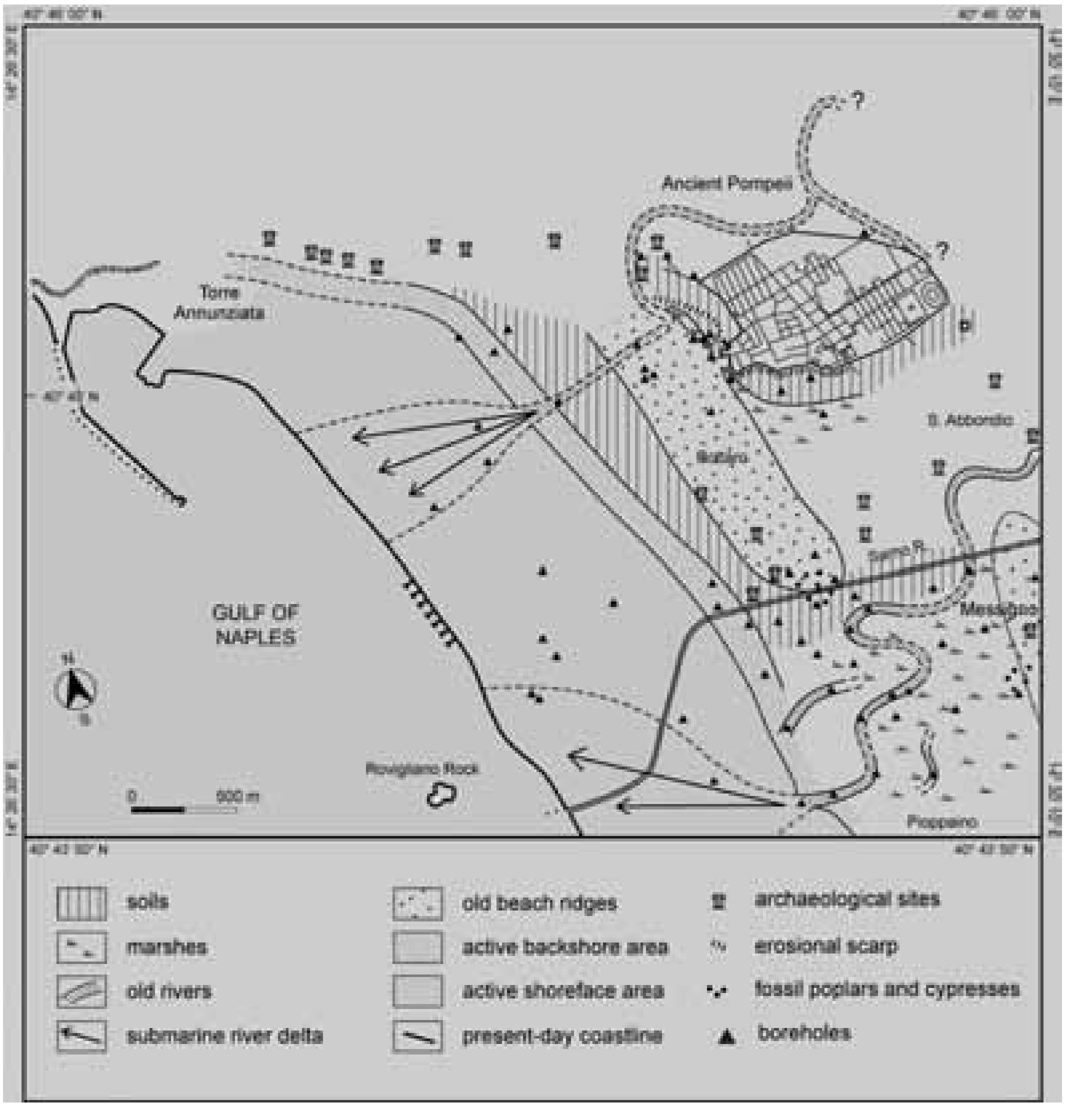

Figure 31 - Environmental reconstruction for the time of the A.D. 79 eruption (from Ciarallo et al., 2003).

the city, as well as on the radiometric dating of such deposits.

The two rivers surrounding the city (Fig. 31**)**

The Conte Sarno Canal

Studies of the existing natural environment around Pompeii before the eruption of A.D. 79 have been carried out by various authors. At first they were based on historical sources; then, more recently, on geological data and sediment analysis from boreholes carried out in areas surrounding the city. Among these authors, Ward-Perkins (1979) has hypothesized the presence of a river, that he believed to be the Sarno River, based on the current path of the Conte Sarno Canal, located northeast of the ancient city. Before the lava flow, the river flowed north of the site where the city of Pompeii rose in the 6th century B.C. The lava flow, on which is built the city of Pompeii, then would havecaused its diversion. According to historical sources, in contrast, this canal was believed to be artificial and constructed in A.D. 1500 for

irrigation.
Rich documentation testifies the existence of the canal, probably all the way back to the first settlement of Pompeii. These same documents also state that, after its creation, it was partly modified in order to divert it to supply water to the city.
In some boreholes carried out west of the city, the type and character of sediments found underneath the A.D. 79 eruption deposits can be attributed to a submerged river delta that was linked to a river which was active before the eruption, but non-existent today. The presence of such a river is also evident from the analysis of several plants that were discovered and gathered in this area: poplars, willows and irrigated crops.
Since an artificial canal was discovered outside the walls close to Porta Capua, it is thus probable that most of this river segment was artificial, starting from the large bend that still exists in the Conte Sarno Canal northeast of the city. This canal was probably diverted, as necessary, into canals that were constructed even in the lava banks upon which the city itself was built. The reconstruction of the course of this river segment seems to be the following: from the large bend, it came down to brush Porta Capua, from which it flowed towards Villa dei Misteri, and then towards the city, probably where it picked up the city's drainage run-off, and flowed to the sea a few hundred metres further on, where it formed a delta.

The Sarno River.
This river is still present today in the plain even though it has had variations, mostly during the Bourbon period (16^{th} century), which changed its final segment It now flows to sea in front of the Rovigliano Rock. Boreholes have allowed the reconstruction of the final river segment and the submerged delta, active at the time of the A.D. 79 eruption (Fig. 31).

Catastrophic floods.
Alluvial deposits distinguishable in several boreholes along the walls of the city and in excavations inside the archaic part of Pompeii are distributed across a wide area with a north-south trend almost orthogonal to the river flowing north of the city. These are lenticular volcanic sand, rich in silt matrix, with a thickness that varies from a few centimetres to several metres. The layers either have a massif structure or a cross or planar bedding, up to a few decimetres in length. The sand contains rounded calcareous or volcanic pebbles, oriented according to the cross-bedding, as well as fragments of plaster, ceramics and animal bones. The base of the layers is sharp, highly erosive, and sometimes amalgamated. These deposits can be interpreted as mud or debris flows left by particularly intense flood events, rather than material carried out by humans, as they had been interpreted as up til now.
Three different levels have been identified in this type of sediment, from the top:

level a) is widespread only outside the city in its northern sector, with an average width of 1 m, and in borehole S3 under the road that has been used since A.D. 79 and below this flood level another older road was found. Along the northern walls, the doors of the towers used in A.D. 79 are under the road. The towers were probably added to the city walls right before this flood event and subsequently, by removing flood sediments, the doors were brought back to light. Animal bones taken from flood sediments at the side of one of the tower doors was radiocarbon dated and their calibrated age is 170 years B.C.

level b) is widespread both inside and outside the city, with an average width of 2 m. Within the archaic city, level b shows a highly erosive trend. It seems that the flow caused the collapse of the wall structure and the destruction of the house. It was subsequently rebuilt, bringing the trampling above the flood deposits.

level c) is widespread over the entire area with an average width of 2 m. It is a thin layer above the lava flow on which Pompeii was built. A piece of animal bone found in this level during sampling done in a house of the archaic city was radiocarbon dated, and its calibrated age is 764 years B.C.

These studies attest to the existence of flood river deposits :
- a first alluvial event (level c) occurred before Pompeii was founded;
- a second event (level b), exceptionally intense, seems to have caused remarkable damage including building collapses. After this flood, the city was covered by a mud blanket of irregular thickness, thus the need to reconstruct, raising the trampled surface. This flood event, whose age is still unknown, might have occurred between the 4th and 3rd centuries B.C., during which a halt in the city's development was recorded.
- a third event (level a) occurred 170 years B.C., and involved only the external, northern parts of the city. Most likely the city walls, raised after the previous flood event, prevented the flow from invading the city.
The thickness of the three levels diminishes towards the south, and the presence of rounded, calcareous cobble demonstrates that these floods came from calcareous reliefs bounding the Sarno plain.

DAY 5

From Pompeii to Sorrento and Naples
A. Cinque, C. Caiazzo, G. Robustelli, M. Russo

From Pompei to Vico Equense.
Travelling by bus from Pompeii to Castellamare di Stabia (*Stabiae* is another of the towns destroyed by the A.D. 79 eruption), we cross the Holocene coastal-alluvial plain of the Sarno River transversally. This is an area of very fertile pyroclastic soils that gives up to four harvests per year, thanks also to the mild climate and the abundance of water. But this important resource has been largely compromised by the unplanned pseudo-urbanization that has occurred over the last four decades.
The first part of the motorway runs very close to the place where the Roman coastline and the harbour of ancient Pompeii were located. Drilling data from this area demonstrate that a subsidence of about 4 metres has occurred since A.D. 79. Notwithstanding this, the coast has been advancing because the arrival of pyroclastics (both primary and fluvially reworked) has allowed high rates of aggradation on the plain (Cinque, 1991).
Approaching Castellammare di Stabia, we see the horst of the Lattari Mountains (the backbone of the Surrentine Peninsula) bounded by high fault scarps and dissected by steep catchments. At the base of this calcareous ridge we see a number of coalescing alluvial fans that formed during the last glacial period (Würm), as streams were overcharged by gelifraction clasts. Mass wasting and washing away of the loose pyroclastic material repeatedly flung onto the Lattari Mountains by the Phlegrean and Somma volcanoes also contributed to the growth of those fans, whose deposits do in fact show frequent pyroclastic and volcanoclastic beds alternating with fanglomerates rich in pyroclastic matrix. The Würmian fans appear dissected by the creeks and frontally truncated by a palaeo-sea cliff that marks the peaking stage of the Versilian (i.e. Post-Glacial) transgression on this side of the Sarno River Plain. Chronologically speaking this sea cliff couples with the one we have seen on the opposite side of the Sarno Plain, i.e. the abandoned cliff cut at the base of the volcanic hill onto which ancient Pompeii had been built (Cinque et al., 1991)
After passing some tunnels cut into the above mentioned fans, we reach the town of Vico Equense.

Stop 1:
Quaternary geology and the geomorphology of the Vico Equense area (Fig. 32).
At the first stop we observe the terraces onto which the villages of Vico Equense and Seiano have been built. These terraces are the result of the fluvial dissection of an ancient alluvial fan that formed at the mouth of the Rivo d'Arco stream before the eruption of the Campanian Ignimbrite (39 ka). In fact, the roadside outcrop below the Vico Equense Hospital allows us to observe that the fanglomerates are followed by many metres of yellowish tuffs (some of which are primary volcanic deposits, while others are reworked pyroclastics) with subordinate lenses of calcareous pebbles. Further up in the section is the Campanian Ignimbrite, to which we can ascribe a final smoothing of the fan topography.
Towards the sea, the terraces appear cut by an 80-m-high sea cliff that evolved from a NE trending fault scarp formed soon after the emplacement of the Campanian Ignimbrite. This feature is the southern limit of a tectonic collapse (accompanied by a tilt to NE) that gave the Gulf of Naples its present basicshape (Milia, 1996). It was this collapse that causedthe deep dissection of the Rivo d'Arco terminal fan by creating a high step along its profile. The sea-floor topography of the Rivo d'Arco mouth shows the existence of a younger alluvial fan that grew on the downthrown sector, most likely during the Last Glacial regression (OIS 2).
On land, the apex of this submerged Upper Pleistocene fan is buried under more recent alluvial deposits (Equa Alluvium) that will be the subject of our next stop. From the bridge between Vico and Seiano we can see this youngest unit forming an order of converging fluvial terraces in the terminal reach of the Rivo d'Arco valley. At its inner end (1.5 km from the river mouth) the terrace is about 70 m a.s.l. and rests on a sequence some 20 m thick that has been entirely dissected by the stream (whose bed is in fact on the Cretaceous limestone). Near the coast the same terraces are at 6-7 m a.s.l. and they terminate with a sea-cliff of almost the same height.

Stop 2:
The post- A.D. 79 eruption alluvial fan of Marina di Equa (Fig. 33).
From Seiano we'll take a road descending down to Marina di Equa and, once on the beach, we'll walk 250 m NE following the base of the sea-cliff cut into the Equa Alluvium. These sediments are perfectly visible in the cliff, which also exposes a geo-archaeological site which is very useful for deciphering and dating

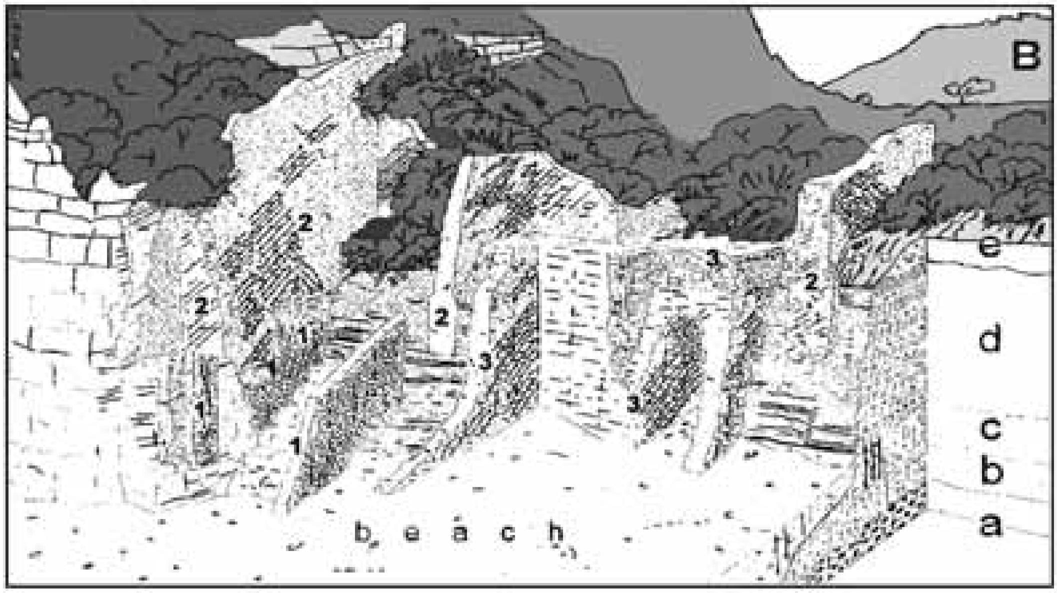

Figure 32 - Above: the Roman ruins of Marina di Equa in a photograph taken from the beach. Below: a simplified representation of the relations between the terrace forming deposits and the Roman ruins (a: beach deposits of the 1st century A.D.; b: A.D. 79 pumice fall; c: A.D. 79 ash; d: pyroclastic-alluvial deposits of the late 1st – 2nd century A.D.; e: younger colluvium and soil; 1, 2, 3: remnants of the three phases of construction which occurred between the 1st century B.C. and the 3rd century A.D.

the geomorphic events that occurred in the area during the first centuries A.D. (Cinque et al., 2000). The geo-archaeolohical site consists of the ruins of a complex building in which three phases of construction have been identified. With the aid of the photographs and drawings in this guidebook, we'll analyse these ruins, proceeding from the oldest to the youngest building stages.

At the point where the Equal Alluvium terrace terminates against the Upper Cretaceous limestone of the eastern valley-side slope, there are the ruins of a flight of steps which were the access to a seaside villa that was erected on the calcareous slope. Very few, small remnants of the villa's main body can be seen nowadays along that slope, because of the dense vegetation and the superimposition of other ruined

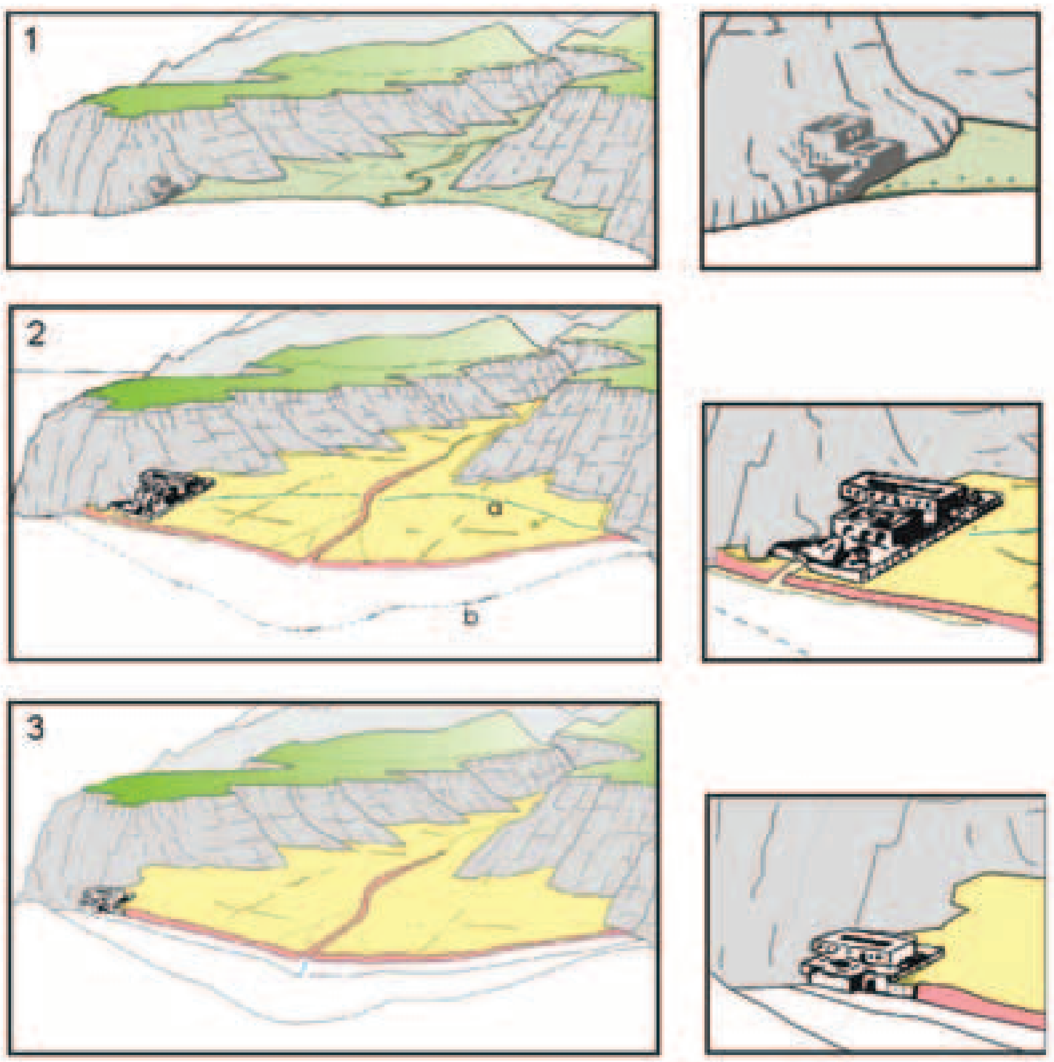

Figure 33 - Block-diagrams reconstructing the physiography of the Marina di Equa bay in three different moments.
1: before the 79 A.D. eruption. Low-lying coastal plain with a beach running close to the modern coastline. The first villa was only on the valley-side calcareous slope.
2: at the moment of the 2nd building phase. Terraced coastal plain (the stream was re-dissecting the Equa Alluvium and a sea-cliff was eroding the fan-deltaic body). Dotted lines "a" and "b" mark respectively the coast-line before the A.D. 79 eruption and the maximum extent of the fan-deltaic body;
3: at the moment of the 3rd building phase. The retreating sea-cliff had reached its present position and new solutions were necessary to defend the villa and to connect it with the beach.

buildings from the Middle Ages and modern times. Because of the materials and techniques used in the above mentioned stairs, the construction of the villa (1st building phase) can be framed between the I century BC and the beginning of the I century A.D. These stairs are buried under the materials from the A.D. 79 eruption, which are followed by linguoids of slope waste materials and well-stratified alluvial deposits. The former are restricted to the vicinity of the limestone slope, while the latter facies dominates the remaining part of the sea cliff section.

Facies and facies associations in the Equa Alluvium

The alluvial deposits are almost wholly made up of reworked, but unweathered, pyroclasts of the same A.D. 79 eruption; they also include rare fragments of pottery, tiles, bricks and plaster coming mostly from buildings of the I century. Their typical facies association is an almost monotonous sequence of broad sheets of pumice-rich conglomerates (PGm, where P is to stress the pumiceous, and thus very light nature of clasts) alternating with pelitic (Fl) and sand sheets (Sb). Closer to the Rivo d'Arco mouth, this association changes to a coarsening up sequence that starts with sandy, hyper-concentrated flood-flow deposits (Sh) interbedded with rare, scour-fill, cross-bedded sandstones (Ss) and debris-flow deposits (Gm). Subordinate small lenses of PGm and Fl are also present. Upward there are gravely, hyper-concentrated flood-flow deposits (Gm rich in calcareous clasts) that are organised in lenses up to 50 cm thick and 15 to 20 m wide in the cross-section.

Near the ruins, the basal part of the post-79 A.D. succession is normally buried by the sands of the modern beach, but when re-exposed by storm erosion, it shows a basal debris-flow unit up to one metre thick. This unit is made up of a massive, grey conglomerate which is supported by an abundant matrix of volcanic ash (*Dd*). The clasts are subangular fragments of white and light grey pumices, scoria and lava, with a minor percentage of baked *ejecta* of Mesozoic limestone (all materials typical of the A.D. 79 eruption). This basal debris-flow unit is also exposed 1.5 km upstream, but here the debris flow deposit reaches almost 20 m in thickness, because it lies closer to the source area, and because here the flows were confined in a narrow v-shaped valley.

The aggradational phase witnessed by the Equa Alluvium is interpreted as the result of a phase of rapid wasting of the A.D. 79 fall-out deposits soon after they had accumulated in the watershed. The stratigraphic sequence shows that the first dismantling was by landslides evolving into wet debris flows. After the steepest slopes of the catchment (>35°) had been denudated or almost so, accelerated soil erosion (gulling) and, possibly, minor slides continued to give abundant detrital supply to running waters, especially during rainstorm-induced flash floods. At the river mouth this aggradational phase corresponded to the growth of a fan that protruded into the sea at least 500 metres beyond the present coastline. It is likely that the lost, outer part of this body had a crudely developed fan-deltaic structure.

The high rate of sedimentation that characterised this alluvial phase can be deduced from the fact that a few decades after the eruption (probably at the beginning of the II century) the phenomenon had already calmed down, encouraging the reconstruction of the villa. In this second building phase the residence was also extended on top of the recently accumulated alluvial body. The foundations of these new rooms, today truncated by the sea cliff, appear laid out in the trenches excavated in the alluvial beds (Fig. 32). At the time when the villa was restored and extended, the fan had already started to be dissected by the Rivo d'Arco and consumed frontally by a retreating sea cliff. But the latter must still have been far enough away from the villa to encourage its owner to build onto the coastal alluvial terrace. This was excessively optimistic, because the sea cliff reached and damaged the second building not later than the III century, when a third building phase occurred. This consisted of protective walls leaning against the sea cliff, and an inclined tunnel to connect the buildings left on the terrace with the beach formed in front of the sea cliff itself (Fig. 32).

Worthy of note is the fact that also in Positano and Amalfi (two towns located at the mouth of steep torrential catchments belonging to the southern side of the Surrentine Peninsula) there are ruins of Roman villas that were destroyed and buried by huge alluvial events that occurred shortly after the A.D. 79 eruption and the reworking of the pyroclastics of that volcanic event. In those two cases the villas were destroyed and buried by the huge debris flows (10 to 18 m thick) that marked the onset of the phase of instability to which the following flood deposits also belong. Therefore, it is evident that the Apenninic reliefs surrounding the Neapolitan volcanic district are not to be regarded as completely unexposed to the hazards related to volcanic eruptions, especially if the exogenic phenomena that can be triggered by the accumulation of pyroclastic covers are considered.

From Marina di Equa to Sorrento.

The landscape visible along the road to Sorrento gives us the opportunity to note the sequence of minor transversal (NW-SE) horsts and grabens that articulate the ENE-trending Sorrento Peninsula. Descending from Montechiaro, we can see, in particular, the depression extending from Meta to Sorrento, whose floor is smoothed out by a huge (up to 70 m thick) body of Campanian Ignimbrite (CI). Because of both tectonic truncation (post-CI collapse of the Gulf of Naples) and wave impacts during the Post Glacial transgression, the ignimbritic prism appears bounded by an active sea-cliff up to 50 m high. The resulting tuffaceous terrace is also cut by very narrow gorges (often with vertical flanks) that mark the borders between the various towns resting on the terrace itself.

The Campanian Ignimbrite.

This pyroclastic formation is a grey, poorly to moderately welded, trachytic tuff that consists of rounded pumices and angular lithic fragments dispersed in a devitrified matrix containing sanidine, lesser plagioclase rimmed by sanidine, clinopiroxenes, biotite and magnetite. Recent high-precision datings (using single-crystal, laser fusion Ar/Ar methods) indicate that it erupted around 39 ka ago. Based on distribution and thickness of the residual outcrops, it was calculated that the eruption covered some 30,000 square km and laid down about 500 cubic km of deposits (the largest eruption in the Mediterranean region in the last 200,000 yrs). The mechanism of emplacement was probably composed of: (i) a transport system made up of expanded and decompressing turbulent currents that moved radially away from the source area and were more than 600 to 1,000 m thick when they reached the mountains surrounding the Campana Plain, and (ii) gravity-driven depositional systems draining off ridges and down valleys in directions dictated by local topography.

Even though there is no doubt that the CI originated within the Campanian Depression, the exact location and type of vent (or vents) is still controversial. Many authors locate it within the Flegrean Fields and some of them relate the emission of the CI to the first phase of the Flegrean Fields Central Caldera's collapse. Others proffer the hypothesis of fissural eruptions from pre-existing regional faults extending well outside the Flegrean area.

The edge of the tuffaceous sea cliff was punctuated by luxurious villas during the First Imperial Roman age. Each of them had private access to the shore (i.e. the cliff base) cut into the solid tuff either in the form of inclined tunnels and/or external flights of stairs. At sea level the most important villas also had one or more *ninfeos* as well as fish breeding pools (*peschieras*), which were also cut into the tuff. The present condition of these seaside ruins shows the changes that have occurred since their construction.

Stop 3:

The ruins of Agrippa's Villa in Sorrento (Fig. 35).

In Sorrento we'll visit the Roman ruins located below the historical Bellevue-Syrene Hotel. These make up the seaside structure of a large villa (owned by Agrippa Postumo, Augustus' son-in-law) sitting, as usual, on the

***Figure 34** - The sea-cliff cut in the Campanian Ignimbrite at S. Agnello di Sorrento. Also here, like in other places between Meta and Sorrento, there was a Roman villa on the terrace and the rock was sculptured to obtain ninfeos, peschieras and passages from the villa down to the beach.*

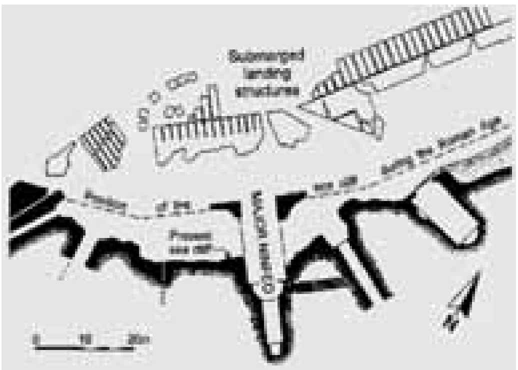

Figure 35 - Sorrento. Partial plan of the ruins belonging to the small port, ninfeos and underground passages of the large Menenio Agrippa Villa.

terrace above the cliff. The villa had a number of ways down to the shore and ninfeos, all sculpted into the tuff. These works appear locally cancelled by post-Roman phases of cliff retreat. A backwearing of more than ten metres can be appreciated in front of the *Mainninfeo* , whose original seaward extent is attested to by the remains of the wall sustaining the ancient entrance arch (originally built against the tuff cliff and now emerging from the sea water). As elsewhere along the coast, the amount of post-Roman recession of the sea cliff appears to vary considerably from place to place. This variability seems to be ascribed to local changes in the cliff-foot geometry (sometimes influenced by man) rather than to natural, lateral variations of the rock strength or differing exposure to waves. The whole array of geo-archaeological constraints present between Meta and Sorrento allows us to conclude that the post-Roman retreat of the tuffaceous sea cliff has occurred at rates that vary between almost zero and about 6 mm/year from place to place, with an average value towards the lower limit of the range. Much higher rates of retreat probably occurred during the first half of the Holocene, when the sea level was lower than that of the base of the tuffaceous bank and the waves were therefore assailing the much less resistant formations on which the CI rests (i.e. Upper Pleistocene, loose to poorly cemented fanglomerates known from a number of water-holes drilled on Sorrento's terrace).

The seaside quarters of Agrippa's villa are also interesting because we can appreciate the relative sea level rise that has occurred since the Roman age. Laid down on the abrasion platform cut into the tuff and partly buried by the sand of the modern beach, there are the *in situ* ruins of a complex landing system (typically made of hydraulic concrete poured into wooden cases) covered by about 70 cm of sea water. The exact amount of relative sea level rise cannot be calculated because we do not know (i) the thickness of the finishing top layer that has been eroded (or stolen?) from the concrete basement, and (ii) how much the jetties originally emerged from the sea. However, the rise should have been between one metre and a metre and a half. Submergence in the order of one metre is suggested by the situation shown in the nearby cavern *peschiera* of Agrippa's villa, as well as by the *peschiera* below Villa Niccolini (Fig. 34).

After the third stop, we'll take a short sightseeing walk around Sorrento, and then we'll take the hydrofoil to Naples, where the field trip ends.

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