Field Trip Guide Book - D01

Florence - Italy
August 20-28, 2004

Volume n° 3 - from D01 to P13

32nd INTERNATIONAL GEOLOGICAL CONGRESS

SIENA (CENTRAL ITALY): URBAN GEOLOGY, ART AND HISTORY OF A MEDIEVAL HILLTOP TOWN AND ITS BOTTINI (UNDERGROUND AQUEDUCT) AND MONUMENTAL FOUNTAINS

Leader: A. Costantini

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During-Congress D01

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

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Front Cover:
The Virgin Mary protects Siena during the earthquakes of 1466-67. Detail of a painted wooden cover of a Bicherna – the medieval, annual, account registry. (Archivio di Stato di Siena, tavoletta di Biccherna n. 34: Francesco di Giorgio Martini e fiduciario, "La Vergine protegge Siena in tempo di terremoti", anno 1467. Autorizzazione n°540 del 10/9/2003 su concessione del Ministero per i beni e le attività culturali. The illustration is 54 x 41 cm in size.)

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Introduction

Siena is located on a hilltop of porous, shoreface, Pliocene sandstone. It became an important town in medieval times (1100-1400 AD) because it was on a major route for pilgrims travelling from France to Rome the Via Francigena. It suffered from an absence of readily available water because no large river flows nearby. It was also involved in continuous fights with neighbouring Florence and the territory was not readily defendable. The solution for the medieval town was to build an underground aqueduct consisting of a 25 km-long network of tunnels, called Bottini, which collected water from hills to the northwest and brought it to public fountains (fonti). The underground aqueduct was used for drinking water until the early 1920s. It is now being refurbished to provide water for general use and particularly for watering gardens and city parks.

The objectives of the field trip are to examine the geomorphology and geology to determine the main characteristics of the aquifer (shore sandstones and conglomerates), aquifuge (offshore and lagoonal silty clays), and water potential of the area; to consider the historical-sociological conditions that led to the construction of the underground aqueduct; to marvel at some of the engineering and architectural constructions of the aqueduct itself and at the monumental fountains; and, finally, to savor, albeit briefly, the enchanting atmosphere, architecture and cuisine of Siena, one of the best preserved medieval towns of Tuscany, in both its buildings and way of life,.

The trip includes surface views but also one 1.5 hour-long stop in narrow tunnels utilizing portable artificial lights. This is a rare – for most people, unique – opportunity to visit the Bottini. However, the latter stop is unsuitable for persons not comfortable in narrow, closed spaces. An alternative surface activity has been scheduled for them. For those visiting the Bottini, field or running shoes and a light pullover or field-jacket with long sleeves are recommended. Similarly, a powerful flashlight is suggested to take pictures underground. The surface stops will not require any special equipment except for a hat against the sun.

Permission and a guide (bottinere = person working in the Bottini) from the Municipality of Siena are required to visit any part of the Bottini, but they are rarely, if ever, obtained other than for the occasional school field trip. This is done to avoid deterioration of the fragile underground environment. In any case, requests to enter the Bottini need to be made well in advance because there are waiting lists of more than two years. Good information can be obtained from the Diana Association (http://www.comune.siena.it/diana) that also provides alternative underground and surface trips. Useful references are: Douglas (1902, 2000) and Hook (1979) for the history of Siena; Bargagli Petrucci, F. (1992), Balestracci et al. (1993), and Serino (1998) for the Bottini; a virtual tour of part of Bottino Maestro di Fonte Gaia is being prepared as an Italian and English CD-ROM by the Laboratorio di Ricerca e Progettazione Siena città dell'Acqua (Comune di Siena); *http://faculty.washington.edu/kucher/diana/english/biblio.htm* for a bibliography of water in Siena; *http://www.neogeo.unisi.it/e_geo/home.htm* for maps of area; *http://www.sienaol.it* for city and surrounding maps and other information; *http://www.comune.siena.it* is the official site of the Municipality of Siena.

Regional historic-geologic setting

Like any other town, the development of Siena has been conditioned by the geomorphologic and geologic characteristics of its territory. The town is located in a Neogene basin (Siena Basin) (Fig. 1; Bossio et al., 1998) of the inner part of the Northern Apennines, on hills of Pliocene sandstones and conglomerates underlain by silty clays. The Siena Basin is a 20 km wide and 40 km long trough parallel to the trend of the Apennines chain. The sediments of the Siena area derived from both the Chianti to the north and the Montagnola Senese to the west. The first source is demonstrated by cobbles found in the Bottini under the town, of quartzo-feldspathic sandstone of the Macigno formation that crops out in the Chianti area. Siena is bounded on three sides by deeply dissected hill flanks, and on one side by topographically irregular highlands underlain by Pliocene deposits and pre-Neogene substrate rocks (Fig. 2). No major river flows nearby, and the few seasonal streams run in deep valleys, making it impossible for the Sienese to bring water to the city by gravity. During early times (Etruscan, Roman and early medieval times) sufficient water existed for small settlements. However, starting in the 1100s, Siena grew and reached a population of more than 60,000 inhabitants over an area of 2 km^2 at its apex, in the early part of the XIV century. The thriving city needed water – a lot of it. Bringing it from the distant hilly flanks of the basin by gravity would have required construction of subaerial aqueducts, which would have been very expensive and perhaps difficult to defend against enemies. So it was decided that water would have to be sought in the immediate

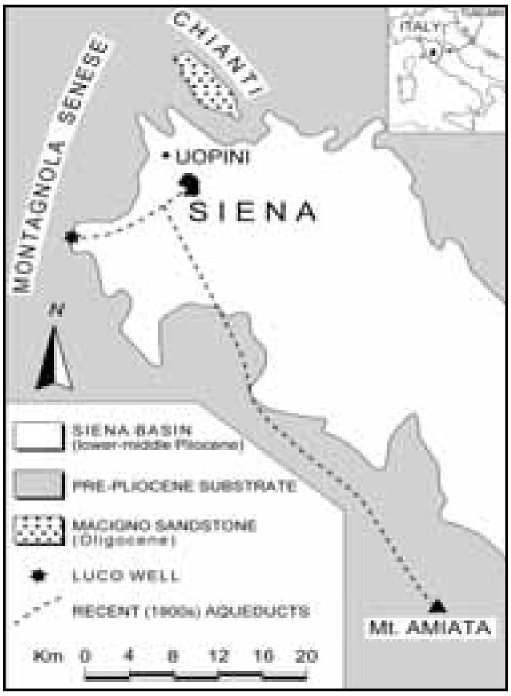


Figure 1 - Schematic geological map of the Siena Basin. A modern aqueduct was built during the early part of the 1900s getting water from Mt. Amiata (about 60 km from Siena). During the 1960s, waters from the Luco Well were added to augment the aging Mt. Amiata aqueduct

vicinity of the town, and collected and transported to public fountains inside the walled city through a more readily defendable underground aqueduct.

The construction of such an aqueduct was feasible because the weakly cemented sandstone (locally called *tufo*) can be readily excavated and maintains vertical walls. The aquifers are lower-middle Pliocene bioturbated shoreface sandstones and conglomerates, interlayered with impermeable lagoonal fine-grained deposits, and underlain by offshore silty clays. About 70 m of the coarser-grained deposits are fairly well exposed in the tunnel walls and on surface outcrops. The occurrence of at least four major shoaling-upward sequences can be recognized (Fig. 3). They are composed of the following facies. *Facies 1*: Bluish-gray sandy, silty clay with abundant marine macrofossils with thin shells, and sparse fine-grained plant fragments. It is interpreted as a distal offshore deposit (Terzuoli, 1997). *Facies 2*: Gray, argillaceous, silty, fine-grained sandstone, weakly cemented, with local small-scale cross-laminations. This sandstone contains abundant marine macrofossils with both thin and thick shells, and shows *Ophiomorpha* bioturbations and occasional vertical burrows. The sandstone is locally interlayered with thin (up to 5 cm) clay layers bioturbated by *Planolites.* This facies is interpreted to represent a proximal offshore setting. *Facies 3:* Yellow, fine-grained sandstone, weakly cemented, massive. It contains abundant marine shell fragments (mostly ostraee and pectinids), few isolated small (up to 2 cm) pebbles, and rare clay clasts. It shows bioturbations by *Ophiomorpha, Thalassinoides* (up to 10 cm long*), Terebellina*, *Rosselia*, and sub-vertical burrows 0.5-1 cm in diameter and up to 15 cm long, possibly of *Skolithos*. This sandstone is considered to be a lower shoreface deposit. *Facies 4:* Interlayering of medium-grained, yellow sandstone in 10-40 cm thick lensing beds, and conglomerate in layers 2-15 cm thick. The sandstone layers contain few disseminated small pebbles and some small cuts with sandy, pebbly fills. The conglomerate layers show thickening upward in the succession. Plane- and cross-beds are present. Shell fossils, some encrusted on pebbles, most frequently fragmented, are found in the conglomerates. Bioturbations by *Ophiomorpha, Skolitos*, *Macaronichnus segregatis, Conichnus* occur in the sandstone. This facies is interpreted to have formed in an upper shoreface setting. *Facies 5:* Clast-supported conglomerate, with various amounts of sandy matrix, occasionally with open framework. The clasts vary from small pebbles to cobbles, all well rounded. The finer-grained clasts tendentially have a disk shape, and the coarser-grained ones generally are sub-spherical. Imbrication of flat clasts occurs. The clasts are frequently separated into fairly well sorted, lenticular layers. Amalgamated, conglomeratic units of up to approximately 2 m occur. Lenses of sandstone are present and are bioturbated by *Macaronichnus*. This facies is thought to record a beach face ranging from subaerial to shallow-water settings.

The lower sequence is characterized, from the bottom up, by the offshore facies (*Facies 1, 2*) overlain by thick (up to 6 m) sandy conglomerates (*Facies 5*). The overlying sequences are composed by a repetitive superimposition of *Facies 3, 4, and 5*. Additional lagoonal facies are well developed at the top of the third sequences (Fig. 3), mostly characterized by fossiliferous silts and clays with brackish water microfauna and macrofossils such as *Cardium, Ceritium and Natica*. Marlstones, medium-grained sandstone; local thin lignite layers occur as well. The deposits of the northern part of the Siena Basin represent an overall regression. The lowermost sequence shows a major change from offshore to shore settings. This is capped by sequences reflecting fluctuations generally indicating a rapid, relative sea level rise and a slower filling of the accumulation-space so created. Among

Figure 2 - Old print depicting medieval Siena built on a hill bounded on three sides by steep slopes. Fortresses protected the town to the north (foreground) where the town had expanded along a hillcrest. Eventually the town was conquered in the mid 1500s from this vulnerable side. (The original print is in the Biblioteca Comunale di Siena).

other hypotheses, it is interesting to speculate that some of these high-frequency fluctuations may be partly associated with eustatic movements driven by Antarctic glaciers that developed at that time. The basal contact between the offshore clays and the shore sandstones and conglomerates determines the elevation of the principal groundwater table. The impermeable caps of the various sequences and some thin, intercalated, very fine-grained deposits establish the existence of secondary hanging water tables. The whole system has basin-centered (southwestward) polarity; that is, the bed dip, and groundwater and surface flows are all in the same direction. Therefore, the steep flanks of the deeply-incised valleys bounding Siena intercept the groundwater flow, and major springs occur at the base, with secondary springs at higher elevations. This overall simple groundwater setting is complicated by numerous normal faults that cut and displace the various aquifer-aquifuge contacts to various altitudes. The early fountains were built near the springs, particularly the largest, lowermost ones, such as at Fontebranda (also called Fonte Branda), and their flow was enhanced by digging tunnels (an early version of the Bottini) following the aquifer-aquifuge contact.

Archeological investigations have established that Siena was first an Etruscan site, and later a small Roman colony (*Sena Julia*). Siena was an important town during medieval times; it became one of the first free *comuni* (city states), and flourished during the XII-XIV centuries when it reached its maximum territorial extension and political power. It is during these times that innovations were first established in Siena, such as a fire brigade to combat one of the scourges of medieval times. Siena developed rapidly because of two major factors. First, besides being great traders in distant foreign markets, the people of Siena became bankers to the Pope and various religious prelates, and, second, the town was located on one of the major routes for pilgrims going to Rome: a branch of the Via Francigena. Indeed the pilgrims who had followed for some time the easier valley-bottom roads, switched to the hilly route when the lowlands became paludified and infested with malaria-carrying mosquitoes. Siena was located on the hilly route. Furthermore, Siena ensured protection and safety to the travellers while in its territory, as well as good accommodations, trading and banking – the town had also struck its own valuable silver coin. With wealth, the population and industries grew, and the need for water increased. As a result, the Bottini were constructed. Not everything was fine though. First, Siena, like most other medieval towns, was dealt a terrible blow by the plague (*peste*) that decimated its population in 1348: one out of three people died. Siena was never able to recover from that loss. Second, economic and political antagonism emerged with neighbouring .Florence. The people of Florence eventually replaced those of Siena as bankers to the Pope, and they struck a new golden coin (*fiorino*), more valuable and sought after than the silver one of Siena. After several intricate historical events, eventually the two towns found themselves in opposite camps: the *ghibellina* (Ghibelline) Siena allied with France, and the *guelfa* (Guelph) Florence allied with Spain. After several wars, King Charles V of Spain conquered Siena in 1555 and gave it to Florence. Siena was never again an independent entity.

Field itinerary

~Km (time) Notes

0 (8.00 hr) Fortezza da Basso. The Medici family built this in 1534. Florence is located at the southeastern edge of the intermontane, Pliocene-Pleistocene Firenze-Pistoia Basin. It is crossed by the Arno River that has experienced several large floods throughout the ages, the latest most-damaging one occurring in 1966.

- Follow the Viali di Circonvalazione to Porta Roma-

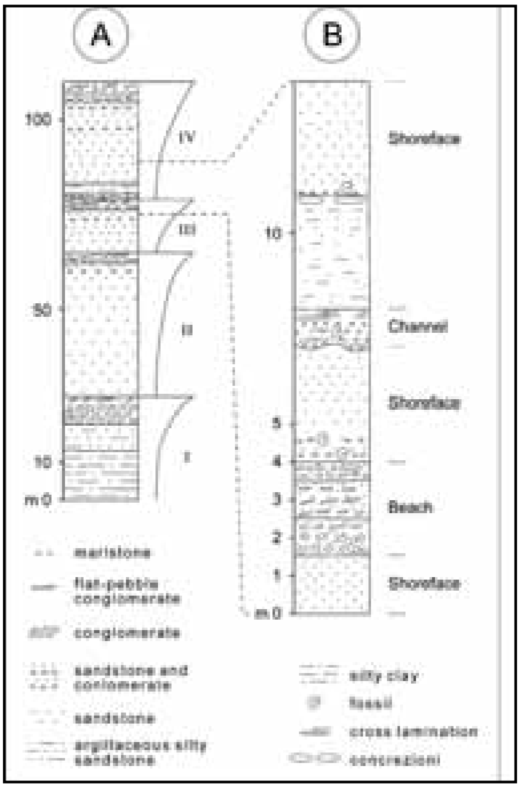


Figure 3 - Generalized stratigraphy of the Siena area: A. Four coarsening-upward sequences (I - IV) recognized in the western part of the city area (after Terzuoli, 1997); B. Enlarged portions of the two topmost sequences exposed on the walls of the Bottini visited during stop 4. Paleoenvironment interpretation is indicated on the right column

na and take the highway (superstrada) to Siena.
5 Certosa del Galluzzo (Florence) was built in 1342. Originally it housed Certosini monks, recently the Benedictine Cicestensis monks. It is located on the southern edge of the Florence-Pistoia Basin, on carbonate turbidites of the Ligurides (a tectono-stratigraphic unit of the pre-Neogene substrate).
7 Start of the highway (superstrada) for Siena. Along the route note Oligo-Miocene turbidites of the Tuscan unit (a tectono-stratigraphic unit of the pre-Neogene substrate) and of the Ligurides, and Pliocene conglomerates, sandstones and clays of Neogene basins.
31 Frontal view of S. Gimignano in the foreground. The S. Gimignano site was first occupied by the Etruscans (III-II century BC). There are historical documents indicating that it had been one of the medieval villages along the Via Francigena starting from 929 AC. Because of this route, as well as its money lending, and commercial activities (including saffron production) with several European and Middle Eastern communities flourished, the town grew, reaching its maximum prosperity during the XII century. At its economic apex the town had 75 towers, which were symbols of power, of which 15 are left. It became part of the Republic of Florence in 1351.
41 Poggibonsi.
49 Colle Val d'Elsa. Ancient Etruscan and Roman settlement that became a free commune during medieval times (XII century). It became prosperous during the XIV century because of the wool, glass and paper industries. In the second half of the XV century it developed one of the first printing establishments in Italy. The glass industry is still very active: its crystal is famous worldwide.
57 Monteriggioni castle is visible to the south of the road. It was built by Siena in 1203 to protect its territory against Florence. It suffered various battles and rebuildings of the walls, the latest being the reconstruction of 1260-1270 after the walls were destroyed by Florence in 1244. The walls have 14 square towers.
- Continue on the superstrada toward Siena crossing Miocene breccias and carbonates. It is possible to see the Montagnola Senese Ridge to the south in the background, which is part of the Mid- Tuscany Ridge (MTR).
63 Basciano. Start of the Siena Basin.
69 Siena: Take the "Siena Ovest" exit and follow signs to Porta S. Marco though the first and second turnarounds. At the intersection do not climb to S. Marco, rather continue straight to the gas stations. Past the gas stations turn left and go along the road (a sort of a U-turn) and then turn right, taking the road to Montalbuccio. Along the road note exposures of upper Pliocene sandstone (shoreface facies).
71 Stop at a suitable lookout along the road, at/or near the Montalbuccio restaurant (Back-cover map).

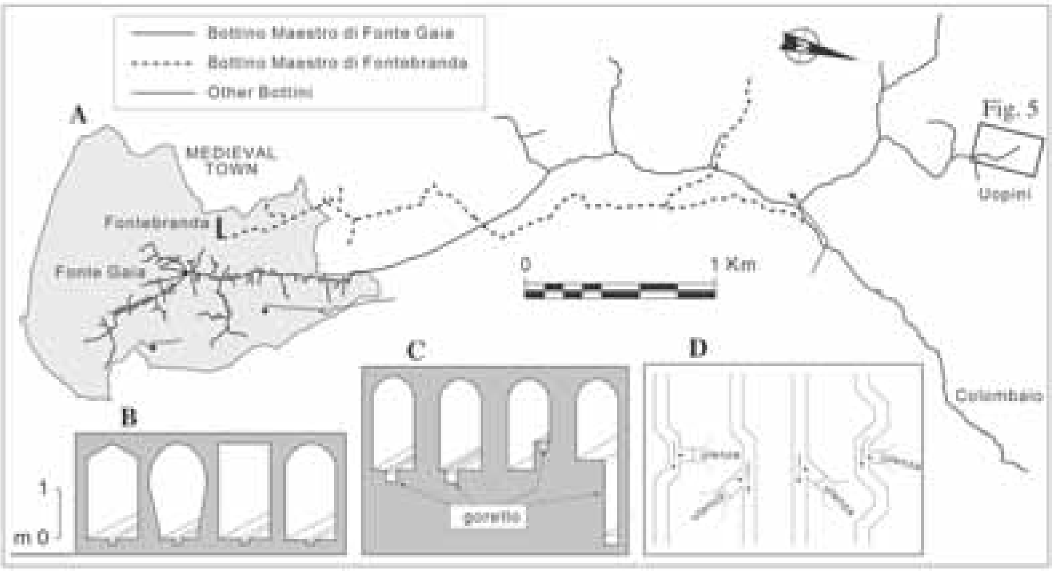
Stop 1:
(9.30 hr) Montalbuccio - Introduction; geology and history of the Siena area; *coffee break***.**

Siena is located on a morphological high, with its highest point to the northwest and the lowest to the southeast, underlain by porous sandstones and conglomerates. This is one of the reasons for the lack of a large supply of water. Since the XIX century the inhabitants have learned water conservation and optimized use of what they have. They also doggedly searched for water near the town through numerous wells and underground aqueducts (Bottini). For many centuries, despite derision like that leveled by Dante, they even dreamt about and sought a mythical river

– la Diana – flowing under the town. Starting in the early part of the XX century, modern technology has allowed the use of distant water supplies, from Mt. Amiata first, and then from wells from other parts of the Siena Basin later (Pozzo del Luco = Luco well).
The high Torre del Mangia (city-hall tower), the Campanile del Duomo (cathedral bell tower), and bell towers of several other churches dominate the city skyline. During medieval times, each large palace had its own high tower for security reasons, but mostly as a status symbol, as indicated in old prints and even in the painting of the *Effetti del Buon Governo* by Ambrogio Lorenzetti. Only one of these towers, the Mignanelli tower, can now be seen towering on the skyline; the others were cut down to the height of the palaces. Walking around town, however, you can recognize the old towers because a very porous Triassic limestone (*Calcare cavernoso*; in Siena called also *pietra da torre*) was used for their construction, whereas bricks were used for most other constructions.
The following stops of the trip are designed to show: major geomorphologic and geological features of the area (most stops), a water-source area of the Bottini (stop 2), the underground aqueduct (stop 4), various types of fountains (stops 5, 11), and architectural features of the town (most stops).
- *Continue northward on the same road. To the right (NW) note Mt. Maggio composed of the Calcare cavernoso (the rock type used in the construction of the towers of Siena). Mt. Maggio marks the northwestern edge of the Siena Basin. The Chianti highlands are visible in the foreground to the north.*
71.5 T-intersection. Turn right toward the Cassia Road (SS 2). On the right view a modern suburb of Siena.
73.3 Intersection, continue toward the Cassia (SS 2).
75.4 Junction with the Cassia (SS 2); turn right (E) onto the Cassia (SS2) toward Siena.
77.0 Intersection; turn left (NNW) toward Uopini, exiting off the Cassia (SS2).
77.2 Intersection: continue toward the Badesse (do not enter the village of Uopini).
75.5 Stop just before the 3-way road junction.

Stop 2:
(10.15 hr) Uopini - Introduction to the Bottini; a water-source area.

The term *Bottini* is used in Siena to refer to the tunnels of the underground aqueducts that bring water to the public fountains. Other underground excavations exist under the town and they are referred to as *cavitá*, some originally used as dwellings, now either abandoned or used for storage, wine cellars and the like. The sewers of Siena consist of large pipes that follow other tunnels.
The Bottini are 25 km long (Fig. 4). They consist of several local Bottini that bring water to special fountains such as Fontenuova, Fontanella and Fonte di Pescaia, and two principal (*maestri*) ones. The two principal Bottini are the older, 7500m-long Bottino Maestro di Fontebranda, and the newer, 15,700m-long Bottino Maestro di Fonte Gaia. Each one gets water from smaller tributary Bottini (*influenti*) like the one visible at Uopini. Originally the main Bottini were built to bring water only to public fountains; then later, starting in the early 1500s, secondary tunnels were built to bring water also to wells of private homes (that is, to clients called *utenze*) and institutions, such as convents and monasteries. The main Bottini system was built between the latter years of the XII century and 1460. Prior to that smaller excavations may have existed to enhance the output of local fountains. Uopini is one of the water-source areas for the Bottini. It is located in the northern part of the Siena Basin where sand and clay were deposited during the early and middle Pliocene. Sandstones form the hill where the village of Uopini is located (Fig. 5). They are underlain by, and have thin interlayers of, silty clays, providing for a main water table at the base and suspended water tables higher in the hill. These are, and most likely were in the past, revealed by small springs. Furthermore, the layers dip to the south, toward Siena, and it is along this flank of the hill that the maximum recharge area occurs, and the groundwater flow is downdip. Appropriately this is the flank the medieval people selected to build the *influenti* tunnels to intercept the highest, largest water source (the highest aquifuge overlain by the topmost thickest sandstone). Here the tunnels are small (narrow and low), just high enough for a person to walk in a crouched position. Openings (chimneys – *smiragli*) to the surface were dug at regular intervals to verify the direction of and to aerate the tunnels, to remove material from them, and to provide workers with access to tools and food. Three *smiragli* are still visible on the hillslope below Uopini. To ensure integrity of the tunnels and therefore good-quality water, the surface of this locality as well as of areas all along the route of the Bottini was protected, and no plant or crop cultivation was allowed, to prevent roots penetrating the roof of the tunnels. This land could not be used for grazing either, or for any other activity. Furthermore, the Bottini were kept clean and the flow unimpeded by special workers (*bottinieri*), to ensure good potable water. It is said that King Charles V of Spain visited the Bottini (at the time strategic for water supply and potential passageways for enemies and conspirators) and stated that Siena was "better"



(or “prettier” according to another version) inside than outside. The exact original Spanish phrase uttered by the King was not recorded. The people of Siena state that he said something like (translated into Italian): *“Siena la parte migliore* (better) *ce l’ha al di sotto”* or, another version, “*Siena é piú bella* (prettier*) dentro che fuori”*. If indeed the Spanish King visited the Bottini and stated anything, most likely he was referring either to the fact that the Bottini were more readily-defendable than the town outside, or he used the term *lindo* or perhaps *limpio* to indicate that the medieval town was cleaner underneath (in the Bottini) than above, as it really was!

- Retrace your route back to the Cassia (SS2) - that is, toward Siena.

78.6 Intersection with the Cassia (SS2); turn left (E) onto the Cassia (SS2) toward Siena.
79.2 Road turnabout: follow indications to “Siena centro”. The road follows the old Francigena route along the crest of the hill.
80.8 Continue straight ahead entering Viale Vittorio Emanuale II toward Antiporto di Camollia. This was one of the fortifications built on the more vulnerable (flat) side of Siena.
81.6 Antiporto di Camollia; continue straight following the “centro” sign.
81.8 Porta Camollia famous also for the sculpted Latin script “Cor magis tibi Sena pandit” (“Siena ti apre un cuore più grande” (…di questa porta); that is, “Siena opens its heart wide to you” (…wider than this door).

Figure 4 - Map and diagrams of the Bottini: A. The medieval town at is largest, and paths of the various Bottini (maestro ~ main ones); B. Various tunnel shapes; the small rectangular channel in the floor is the gorello (open channel) carrying the water; C. Different positioning of the gorello in the Bottini, to maintain the required slope for regular water flow; D. Maps of intersections between gorello of main Bottino and of secondary Bottini (utenze). The path of the main gorello is modified or dammed to ensure local deeper flow and thus continous delivery of water to the utenze (arrows = flow direction). (Rectangle on the upper right of the figure indicates the locations of Figure 5 and Stop 2).

- Turn right along the medieval walls. Follow Via Biagio di MontLuc, then Via Armando Diaz, then the road along the walls of Fortezza Medicea, and turn onto Viale dei Mille heading toward the church of S. Domenico. The Fortezza Medicea was built soon after the 1555 defeat of Siena by the Medici, the rulers of Florence.
83.4 Stop at suitable lookout.

Stop 3:

(10.45 hr) S. Domenico - Cityscape; causeway across a valley.

This stop allows a view of one of the most characteristic parts of Siena, with its ancient medieval houses built on a steep hillslope. The white- (marble) and black- (ophiolite) striated Duomo is located on one of the original three hilltops Siena was built on. The highest, and the first to be occupied, hilltop was that of Castelvecchio, located behind the Duomo; the

other hilltop is that of the Castellare (an old, partially- preserved castle), near the Piazza del Campo (Back-cover map). Farther to the east, note the Torre del Mangia of the Town Hall, and even farther to the east, the only remaining massive, high, private tower (the tower of the Mignanelli family) in Siena. Ambrogio Lorenzetti depicted this tower at the center of his painting the "*Effetti del Buon Governo"*. The church of S. Domenico and the Duomo were both affected by the earthquake of 1798: the bell tower of S. Domenico was damaged and two of the six marble columns of the Duomo were broken. This earthquake was associated with one of the closely spaced, normal faults that cross the town from NW to SE.
The deep, steep valley separating S. Domenico from the area of the Duomo is typical of the southern part of Siena. These valleys conditioned the lifestyle of Siena, in terms of both the roadways and the location of the fountains. Fontebranda is located at the bottom of the valley, about 30 m below the observation point at stop 3. It was a very inconvenient location to get water from, and the many industries that developed there (mainly wool, cloth, and slaughterhouses) were constricted by the limited space available.
In several instances the head portion of the valleys has been separated off and brought to good use. A case in point is the building of a causeway (completed in 1920) with dump fill between S. Domenico and the Fortezza Medicea. This allowed for faster communication (Viale dei Mille) and the creation of a sunken space nowadays used for car parking and a sports field.
- Coffee break.
- From this point on, follow the route indicated on the back-cover map.
- [Next full stop will be in a ~ 800-m-long tunnel starting at Fontegiusta (also referred to as Fonte Giusta). People uneasy in tight, underground places are advised to go directly to Stop 4b].

Stop 4:

(11.15 hr) Bottino Maestro di Fonte Gaia from Fontegiusta to Fonte Gaia (Piazza del Campo).
Construction of the Bottini was done by hand at various depths (2 to 30 m) below the surface to maintain the 2‰ gradient necessary for water to flow smoothly. Specialized miners (*guerchi*) did the work. They used simple tools (picks, shovels, and the like). Due to the narrow passages, only one man at a time could work at the tunnel face. To accelerate construction of the newer Bottino Maestro di Fonte Gaia, two crews were utilized in various segments, one working from the fountain side backward, and the other on the opposite side. Alignment errors were made, and adjustment

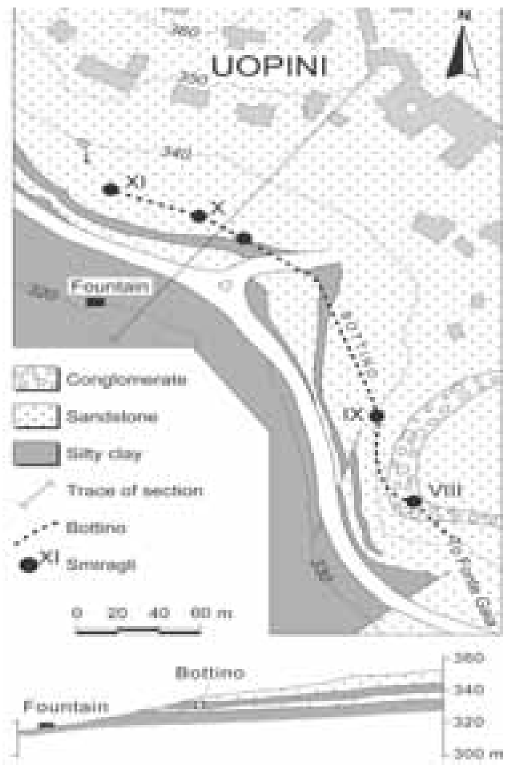


Figure 5 - Uopini area: A. Schematic geological map with trace of the Bottino and location of the smiragli; B. Schematic cross-section with location of the Bottino intercepting the groundwater flow of the largest topmost aquifer. Note optimum position of Bottino in respect to surface morphology and dip of the strata.

to the tunnels had to be made at the meeting points. No particular rock bed was followed for the Bottino Maestro di Fonte Gaia. When hard concretions (highly cemented sandstone blocks) were encountered, which made the excavation difficult, the tunnels were reduced from an average width of 80 cm and a height of 1.80 m to the minimum necessary for a person to go through. The tunnels were built differently at different times and places, as is shown by roofs with hut, barrel, square, and arc shapes (Fig. 4B). Starting in the early 1500s, secondary tunnels were built by private citizens and institutions in order to get water from the main Bottini. The secondary tunnels varied in size greatly, depending on the wealth of the people involved.
The main Bottini were slanted to be lined with bricks. It was a valiant and costly enterprise that was never executed, mainly because of the economic crisis that followed the decimation of the population by the 1348 plague. Only those parts of the Bottini that

were in danger of slumping, had water infiltrations, or required extra support because of the weight of the overlying palaces were reinforced with brick covers. More than 65% of the Bottini are not covered by bricks and they provide a good view of the geological features.

Smiragli (chimneys) were built along the Bottini at almost-regular intervals. The *smiragli* vary in shape from square to circular, in size from 2.5 to 3 meters, and in depth down to 30 m below the surface. The traces of the ropes used to lower and raise material are still visible on the roof of the Bottini leading to the *smiragli*. Good geological sections are exposed along the chimney walls.

A small (15 cm wide, 25 cm deep), open channel (*gorello*) was cut in the floor of the Bottini to carry the water. The *gorello* was excavated usually at the center, occasionally on the side of the floor, but in other places, it was constructed higher or much deeper than the floor of the tunnels to maintain the proper slope gradient (Fig. 4C). To ensure constant water supply to the secondary tunnels and to client wells (*utenze*), the water flow in the main *gorello* was deepened either by partially damming it with a brick, or by forcing the *gorello* to meander, hence reducing its gradient, lowering water speed, and increasing water depth (Fig. 4D). To measure the amount of water provided to the clients, a plate with holes (*dadi*) of various diameters was placed at the start of the secondary tunnel. All clients, except some religious institutions, were charged according to the number and size of the *dadi* they were allowed; that is, for the amount of water delivered to their wells. The clients then retrieved water from their wells with buckets. Besides these authorized users, pilferage of water was common from early days on. Until the early 1900s, great care was taken to ensure a constant supply of good, clean, drinkable water to the town. Besides keeping the surface ground and the Bottini clean, several other things were done to this end. Large (~ 50 m long, ~ 4 m wide, and up to 2 m deep) decantation pools (*galazzoni*) were built along the Bottino Mestro di Fonte Gaia just before it entered the walled city. These pools allowed the settling of sediments introduced from the collector tunnels (*influenti*) after unusually heavy rainstorms, as well as reduction of the calcium content of the hard water through precipitation of $CaCO_3$. Similar but smaller pools were built, also near the center of town, before the water was distributed to parts of the city. Precipitation of $CaCO_3$ occurred also all along the *gorelli*, eventually impeding the regular flow of water. The calcite plaques that developed had to be removed regularly, usually every 50-60 years. This work is called *sgrumatura*, and it was, and still is, done with special iron tools. The removed plaques were stored in niches dug in the Bottini walls or transported outside. Furthermore, to ensure reasonable water supply even during dry periods, some Bottini were partially dammed to serve as reservoirs. It is along these Bottini that calcite precipitation has produced surreal, cave-like formations (Balestracci et al., 1993).

In the last two decades, the Bottini and other underground features of Siena have been refurbished. The Municipality of Siena has gated off the many entrances to the Bottini from private homes and, with the help of volunteers from the Diana Association, has started cleaning the various tunnels and removing dumped material from many *smiragli* and wells. This has allowed the re-utilization of water from the underground aqueduct for non-potable uses, and has permitted detailed geological studies to be made of the underground exposures by the University of Siena. These studies are important because, among other things, they provide an evaluation of urban risk associated with the presence of faults and potential slumping, hence an evaluation of the stability of foundations. Furthermore, many surface fountains that had fallen into disuse and/or had become partially buried have been refurbished. All this has also led to a re-evaluation of this complex water system for tourist purposes. A Water Museum (Museo dell'Acqua) is being set up in a building constructed over one of the ancient monumental fountains (Fonte di Pescaia). Shows have been done on the Bottini, and several books have been published, some with numerous pictures; in addition videos, CD-ROMS, and websites have been produced about them and the fountains. Although visits to the Bottini are limited to a few sites and to a few school groups per year to safeguard the fragile environment, part of the underground world can be glimpsed by participating in some special, short field trips to easy-to-reach, near-surface sites, usually organized by the Diana Association. Financial help for refurbishing the Bottini and the fountains and other activities has been provided by local institutions, such as the Town of Siena and the Monte dei Paschi Bank, as well as by international organizations such as the European Community. Much more financial assistance and volunteer work is needed to complete the full restoration of this important water system.

The objectives of this underground walking tour are: to analyze in some detail shoreface deposits of the Siena area, to observe the ancient construction techniques of underground aqueducts, and to establish the methods of distributing water to public fountains (*fonti*) and to private wells.

(The numbers (such as # 68) refer to secondary tunnels identified in descending order toward Fon-

te Gaia. The distance in meters (m) is from Fonte Gaia.)
- Access to the underground aqueduct (Bottino) is through the Fontegiusta entrance. After descending a steep staircase, a short tunnel leads to the Bottino Maestro di Fonte Gaia.
- Note a few pencil-like stalactites, small encrusting stalagmites, and some cave formations along walls.
 # 68 (~ 780 m) Via di Camollia 31– secondary tunnel to a private well (client, utenza).
#67 Small niches excavated on the walls for sacred images and for oil lamps. It was common practice for the miners to bring along such images and/or scratch crosses on the walls, as protection against underground evils. Observe the exposure of sandstone and thin, lensing conglomerate interlayers. Concretions (tightly cemented CaCO3 sandstone pods) occur consistently at the lower contact of the conglomerates. Conglomerates have round, sub-spherical pebbles, and are poorly sorted and not well structured.
 # 66 (~730 m) Note a cross scratched on the wall, and a niche in the wall filled with pieces of calcite that were routinely (about every 50-60 years) removed (sgrumatura) from the water channel (gorello) to free up water flow. The thickness of the CaCO3 pieces is about 4.5 cm, suggesting a rate of CaCO3 precipitation of about 7.5 mm per year. Exposure of sandstone with few isolated small pebbles and thin conglomeratic lensing layers; note dark gray algal growth on the lower parts of the sandy walls.
 # 65 (~713 m) Small dam along the main gorello to raise the water level to allow continuous supply to secondary, private gorello (utenza). Enlargement of the Bottino with a bench over a conglomeratic and concretionary layer (difficult to excavate). These enlargements usually occurred when two crews working in opposite directions met, and errors in alignment of the tunnels had occurred. The direction of advancement of the two crews can be surmised from the arcuate excavation marks (concave toward the miner). Note water dripping (stillicidio) from the roof of the tunnel. In the past it was wrongly believed that this would be a sizable source of water.
 # 64 Square-shaped smiraglio about 20 m deep.
 # 61 Three-dimensional view of conglomeratic layers.
 # 60 Niche filled with pieces of CaCO3 removed from the gorello. Small brick arches have been built to support the roof. Note roots from the roof and fresh air entering the Bottini. This tunnel is shallow here below the Lizza (square of La Lizza) where there are trees. Such a contamination would not have been permitted when the Bottini were used for drinking water.
 # 59 (600 m) Thin conglomeratic layer halfway up the sandy wall of the tunnel. Note that CaCO3 encrusts the surface of the sand below the conglomerate, indicating that water is percolating from the base of the conglomerate itself.
 # 59-58 Conglomerate with poorly-sorted clasts; among them there is a large angular clast of Macigno sandstone. This indicates that this material was derived from the NW, from the Chianti area, the nearest outcrop of the Macigno sandstone.
 # 56-55 Change in direction, width and height of Bottino. Secondary tunnels (utenze).
 # 55-54 Thin interlayers of small pebble conglomerate alternating with sandstone; cross-laminations.
 # 53 Coarse-pebble conglomerate interlayer in sandstone.
 # 52-53 Shell concentration exposed on the roof of the tunnel (Cardium).
 # 51 Secondary tunnel (utenza) apparently dug or enlarged with a slightly different technique or tool.
 # 49 Modern gate, and tubes possibly from the mid-1900s
 # 48-46 Smiraglio del Cavallerizzo (located between Piazza Gramsci and Piazza G. Matteotti). The tunnel here is at a depth of about 18 m. Note incisions on the roof of the Bottino made by ropes used to lift material to and from the tunnel. Conglomeratic layer well exposed. Ophiomorpha burrows.
 # 45 Horizontal- and cross-laminations in sandstone, some marked by granules and very small pebbles.
~ # 43 (~ 400 m) Narrow excavation on the right wall, and round hole on the left wall of the tunnel. These indicate that a door or wooden barrier was placed at this point, locked with a sliding piece of wood.
~ 382 m Normal fault striking N140o and dipping to the east at 60o. The fault face shows slickensides with striae and steps indicating direction of rock movement. Nearby there is a slight enlargement of the Bottino indicating a meeting of two crews working in opposite directions and a slight error in alignment of the tunnels.
#41 Cross-laminations in sandstone, and thin conglomerate layers. Nice nameplate (targa) of a client (utenza) designed in 1866 and refurbished recently (2002). Three-dimensional exposure of conglomeratic channel fill.
 # 41-40 Part of a large conglomeratic layer (channel). This conglomerate shows canalization at the base. Its top, however, is considered to be the original bedding surface (So), and therefore it indicates the dip of the strata. Reworked fossil shells are present in the conglomerate.
 # 39 Nameplate (targa) of a convent (Convento delle Cappuccine) indicating that some religious institutions were exempt from fees (senza tassa) for

the water used.
39-38 (~ 335 m) Conglomeratic layer reaches the roof of the tunnel.
38 (~324 m) Thick rock succession with few or no conglomeratic interlayers. Some small pebbles occur isolated within the sandstone.
36 Tight meandering of the gorello, built to slow down and thus deepen the water flow to raise the water level and ensure that there was aa constant supply to the side channels and the well (pozzi) of mansions (clients, utenze).
~ 280 m (near #36) A brick wall was built to avoid slumping. Some isolated concretions. A few targhe. # 33-31 Several meanders of the gorello. This is one of the most photogenic points for this feature (Fig. 6).
# 30 (~ 225 m) Via della Sapienza junction: continue straight on the main Bottino toward Fonte Gaia. (Watch for low ceilings!). In the secondary tunnel, note gorello covered by bricks to provide a flat, walking floor.
# 26 A few fossils in sandstone and some thin conglomeratic lenses.
# 25 Large oyster shell in sandy conglomeratic layer on left wall.
# 24 Utenza with well. This is located approximately below the palace and towers where the Feltrinelli Bookstore is located along Via Banchi di Sopra. Note large Ophiomorpha burrow on opposite side of the tunnel on the roof, marked by rusty weathered outline.
# 22 Dadi (flow regulators) at the utenza (Via dei Rossi). Notice on nearby walls the alternation of highly fossiliferous layers (the shells are for the most part dissolved) with highly bioturbated sandstones. The fossiliferous layers may be tempestites.
-(OPTIONAL): Deviation into the secondary tunnel of Via dei Rossi. The principal geological characteristic of this site is the development of thick conglomerates. The conglomerates are well structured; they vary in clast size from layer to layer, each with fairly well sorted clasts (all well rounded; the coarser ones sub-spherical, the smaller pebbles disk-shaped), some with a greater amount of sandy matrix than others. The layers lens out at the scale of the outcrop, with planar to slightly-eroded boundaries. Thin cut-and-fill structures occur throughout. No fossils have been observed on a cursory inspection. Similar conglomerates seen on surface outcrops have been interpreted as beachface deposits (Terzuoli, 1997).
21 Very narrow secondary tunnel. The secondary, private tunnels differ greatly from each other, from very narrow or very low, to high and relatively spacious. This depended in part on the wealth of the client that commissioned the digging.
20 Very low secondary tunnel. Thin, fossiliferous (note large Pecten) conglomeratic layer.
19 Enlargement in the Bottino, possibly due to error in alignment of the tunnels dug by two different crews advancing from opposite directions
15 Several plates (targhe), of two main types. Note that the gorello is not placed at the center the floor of the secondary tunnel, but it is built higher on one side to maintain the required slope to the wells of the clients.
~ 102 m Well-defined normal fault visible on both walls and roof of the Bottino. The fault has a throw of at least 2 m. Its orientation is N155o and it dips eastward 70o.
~ 95 Sandstone layers parallel- and cross-laminated; other layers have abundant Macharonicus bioturbation.
# 12 Isolated large lens of flat-pebble conglomerate.
# 10 Thin conglomeratic layers with well-rounded, sub-spherical clasts in coarse-grained sandstone.
# 9 Conglomerate layer in sandstone.
#8 Three-dimensional view of thin conglomerate layers in sandstone.
6 Well (Pozzo del fioraio): it corresponds to a well (grate on the floor of the courtyard) located in the bui-

Figure 6 - Meandering path of a gorello to locally slow down and deepen water flow to ensure constant water distribution to intersecting gorelli of utenze (clients).

lding in front of the Nannini Café in Via dei Banchi di Sopra, now occupied by a flower shop.
 # 2 Artificial pool (vasca di decantazione) constructed for settling of residual particulate matter before directing the water to clients in the Piazza Indipendenza area (Back-cover map).
#1 Old suspended Bottino and gorello leading the waters to the original site of Fonte Gaia (slightly displaced from the present fountain).
- Cross iron-gate and enter a man-made cavity dug into shoreface sandstone. This is one of about 500 cavities in underground Siena. Note conglomerate on the roof.
- Continue to the next room that contains instruments still used by the bottinieri for the sgrumatura of the Bottini.
- Climb a short staircase to exit onto Piazza del Campo.

Stop 4b:
(11.15hr) An alternative to stop 4 of the Bottini is to walk to the Piazza del Campo.
Besides admiring the palaces around this square, people can visit the Museum of the Palazzo Pubblico (Town Hall) and climb the Torre del Mangia for a magnificent view of the city and countryside (Fig. 7). The museum contains several famous art pieces, among them the *Maestá* by Simone Martini in the room of the Mappamondo, and the fresco (wall painting) of the *Effetti del Buon Governo* by Ambrogio Lorenzetti in the Sala dei Nove (room of the nine governing officials). The latter gives the opportunity to compare and contrast the Siena of the early 1300s with the one of today visible through the palace windows. It is also worth climbing to the back terrace of the palace where the elected officials during the Government of the Nine could spend their free time: these officials were not allowed to ever leave the Town Hall for the duration of their six-month tenure. From this terrace there is a splendid view of one of the valleys (Valdimonte) of Siena inside the town walls, and of the surrounding countryside. Note the resemblance between the present view and the one depicted in the *Effetti del Buon Governo* fresco.

Stop 5:
(12.45 hr) Piazza del Campo; Fonte Gaia.
Piazza del Campo is the center of life in Siena. It has a shell-like shape derived from its being the apex of one of the valleys of Siena - Valdimonte. Until the XI century, this area was located outside the old town walls. New town walls enclosed it during the first half of the XII century. To avoid erosion, a retaining wall was built in 1194 separating out the apex of the

Figure 7 - Palazzo Pubblico and Torre del Mangia.. Note stratification of different bricks used during construction.

valley. This wall is now located under the Town Hall. The ground was smoothed out and eventually covered by bricks disposed in a fishtail fashion. Piazza del Campo is one of the most famous town squares of Italy, because of its beauty and because a bareback horse race - the Palio - is run there twice a year in July and August.
Fonte Gaia is located at the apex of the square in front of the Town Hall. Jacopo della Quercia, one of Siena's most important sculptors, built the fountain from 1409 to 1419. The present-day fountain is a copy made by Tito Sarocchi in 1868. The original artwork is located in the museum of Santa Maria della Scala. When the new images were put in place, the fountain was also moved by 15 m to be exactly at the top-center of the square. This is a monumental fountain, but in medieval times it had practical uses as well. When the square was used as a market, entrails of killed animals were washed at the fountain, and the water was available for various other uses as well. Fonte Gaia never delivered as much water as wanted or needed. It nevertheless represented a great achievement of bringing water to the center of town, where no nearby spring was available.
Siena, the town without water, has constructed some of the most beautiful fountain complexes in Italy. There are various types of public fountains: monumental fountains, the fountains of the contrade

(neighbourhoods), and the public fountains of the newer 1900s aqueducts. The older, original ones were probably simple constructions around natural springs in valley bottoms, which later became monumental constructions, known in Siena as fonti not just fontane = fountains. The monumental fountains were complex systems used in various ways (see stop 11). The oldest fonti of Siena are those of Fontebranda, La Vetrice and Ovile, which are located in the lower part of the valleys near the major aquifer-aquifuge horizon, and Pescaia at a slightly higher elevation associated with a suspended water table. Another old fonte is that of Fonte Becci, which is located on the top of a hill, but close to a suspended water table. The disadvantage of the older fonti often was that their location was not only difficult to reach but also to defend, because some were outside the town walls. More recent fonti were instead built inside the town walls for the benefit of the citizens, not because of geological conditions. The latter fonti were, and still are, supplied by the Bottino Maestro di Fonte Gaia. Other fountains, called fontanine (= small fountains), have been built for each of the 17 contrade of the town. These fontanine are extremely important to life in Siena. They are where every newborn is baptized with a pagan ritual in the contrada, and from that day on the person becomes a life-long adherent of that neighbourhood. Simple public fountains were built for the new 1900s aqueduct. They all have the head of a wolf, in homage to the legend that Siena was founded by the fugitive sons of Remus (the mythical co-founder of Rome) who were raised by a she-wolf.

Figure 9 - Arches in Via della Galluzza built to protect old building against earthquakes

Figure 8 - Conglomerate exposed on a building wall in Piazza S. Giovanni. This conglomerate is interpreted as a beach deposit.

Stop 6:

(13.30 hr) Lunch.

Have lunch at a restaurant, possibly in the Market Square behind the Town Hall, from where magnificent views can be enjoyed of the back of the Palazzo Pubblico and of a valley (Valdimonte) inside the town walls.

- *After lunch cross Piazza del Campo upward to reach Via di Città through the Costarella (wide-road entrance to the square). The start of the Palio race is at the Costarella.*

- Turn left onto Via di Città and walk up toward the Duomo. Observe the various old towers built with Calcare cavernoso. Note various old palaces such as, to the left, the Chigi-Saracini (1300 AC) where the world-famous Academia Musicale Chigiana is located; and, to the right, note the Palazzo Piccolomini or, as it is called today, of the Papesse, where the Museum of Modern Art is located.

Stop 7:

(15.30 hr) (OPTIONAL) Palazzo Piccolomini.

This palace (1460-1495 AC) is so called because Caterina Piccolomini, sister of Pope Pio II, built it. Climb the tower for a 360° panoramic view of the city, and, in particular of the older quarters enclosed by the first city walls.

- Continue along Via di Città up to Piazza Postierla. In this square note the fontanina of the contrada of the Aquila (the Eagle neighborhood).
- Turn right into Via del Capitano and walk to Piazza del Duomo.

Stop 8:
(16.15 hr) Piazza del Duomo.

The Duomo of Siena is a magnificent Gothic monument built between 1229 and 1290. Only a brief, cursory visit can be made. Of particular importance are the walls with typical white (marble) and black (ophiolite) stripes, the vast, albeit dark, Gothic interior, and the main altar (pulpito) by Nicola Pisano. In front of the Duomo there is the museum of Santa Maria della Scala, one of the many medieval pilgrim-hospices along the Via Francigena. It was a hospital from medieval times until recently. It now contains a museum and, in its basement, good examples of dug cavities and a deep well, called il Rotone, from the big wooden wheel used to lift the buckets of water.

To build the Duomo, the top of the hill was leveled down to a conglomeratic layer that provided good foundations. A new, grandiose cathedral (Duomo Nuovo) was under construction between 1321-1339. The old cathedral (the present Duomo) would have been used as the transept of the new nave constructed at 90 degrees from it. The project was aborted because of the 1348 plague, as well as because of the instability of the ground - a fault runs along the area. This fault was responsible for earth movements during the 1798 Siena earthquake (intensity 7-8 on the Mercalli scale). A few columns, five arches and the incomplete facade (called facciatone = grande facciata = large facade) is all that remains standing of the Duomo Nuovo.

- Walk to the NE corner of the square and descend the steep marble staircase at the side of the Baptistery, to Piazza San Giovanni.

Stop 9:
(17.00 hr) Piazza San Giovanni - Baptistery and conglomeratic layer.

The Gothic Baptistery was built in 1317 in a quarry from where sand and gravel was mined for the construction of the Duomo. On the wall of a nearby house, to the east, note a conglomeratic deposit showing clasts of various sizes, well sorted, with slightly inclined layers. This conglomerate is interpreted as a beach deposit (Fig. 8; Terzuoli, 1997).

- From the NE corner of Piazza San Giovanni walk north into the narrow Via di Diacceto.

Stop 10:
(17.15 hr) Lookout (belvedere).

Brief photographic stop to view the church of S. Domenico and, at valley bottom, the house and church of S. Caterina and Fontebranda .

- Continue for ~ 40 m and then turn left (NW) down into Via della Galluzza. Notice arcs built to reduce damages by earthquakes (Fig. 9).

- Continue to the bottom of the slope and turn left (WSW) onto Via S. Caterina. On the right notice the house and church of S. Caterina.

Stop 11:
(17.30 hr) Fontebranda.

Fontebranda is one of the oldest and most famous monumental fountains of Siena, mentioned by Dante in the Divine Comedy:

"MA S'IO VEDESSI QUI L'ANIMA TRISTA
DI GUIDO O D'ALESSANDRO, O DI LOR FRATE
PER FONTE BRANDA NON DAREI LA VISTA."

(Inf. XXX 76-78) (If I saw here the sad souls of Guido or Alessandro, or of their brother, I wouldn't give up the sight of them even for Fonte Branda)

The location has a natural spring because of its ideal position near the contact between the main aquifer of the area and the underlying, thick, impermeable silty clays. This water has been used since antiquity, possibly since pre-historic times, certainly by Etruscans and later by Romans, as indicated by a 394 AC document. The early medieval fountain was located at a slightly higher elevation than the present one. The present fountain was built in 1193. It was a complex structure, much of which still exists, albeit somewhat changed through the ages. The original constructions and their uses can be found in old prints (Fig. 10). The water from the Bottini flowed into pools placed in a cascade fashion The first pool was for drinking water for people, the second for drinking water for animals, the third for washing clothes, and the fourth for washing and freshening-up animals, an important activity in ancient times. The water that drained from the pools was used for various artisan activities, such as washing wool and slaughtered animal remains, as well as tanning hides. Eventually the waters were canalized and used to drive mills, before being discarded. They were too polluted to pour onto the various gardens and fields (orti), as was done for other similar fountains. Indeed, the Fontebranda area was at those times the industrial part of town: a busy, foul-smelling place, as written complaints indicate. Although Fontebranda was one of the best fountains, it never provided enough water to satisfy the demand. Much work was done to improve its outflow. The 7500m-long Bottino Maestro di Fontebranda, eventually completed by 1460, was constructed by progressively digging farther away from the fountain, trying to open as much of the lower part of the aquifer as possible. This Bottino is entirely located deep under the northern part of the town of Siena.

Recently, since the late 1900s, the Fontebranda area has been renovated and turned into a tourist site. Shops, restaurants, coffee houses, and offices have

Figure 10 - Old print showing Fontebranda and the Church of the San Domenico convent at top of hill. Pools (I, H) at Fontebranda were for, from right to left, drinking water for humans (I), drinking water for animals (abbeveratoio), washing clothes, and, to the far left (H), washing and freshening-up work-animals (guazzatoio) (from Pecci, 1761, p. 154).

been built on the site of the old slaughterhouses, a large underground parking lot has been built just outside the ancient town walls, and elevators are being built to transport people from the higher part of town down to the valley bottom.

A good rock exposure is available at Fontebranda on the vertical slopes below S. Domenico. An ancient path provides easy access to the lower two rock sequences of the Siena area. These underlay the sequences that were examined inside the Bottino Maestro of Fonte Gaia (stop 4). The rocks exposed at Fontebranda show a lower, bioturbated (by *Ophiomorpha*) sandstone grading by alternation upward into a conglomeratic unit. The latter is sharply overlain by another bioturbated sandstone layer grading upward again into a second conglomerate. The sandstones are interpreted as shoreface deposits, overlain by conglomerates of gravelly beaches (Terzuoli, 1997). Farther up along the path it is possible to observe also the trace of the normal fault responsible for the ruinous 1798 earthquake.

Stop 12:

(18.30 hr) Fontebranda parking lot.

This underground parking lot was built at the base of Siena's main aquifer. Accordingly, much groundwater interfered with the construction. Such water is now being canalized around the foundations of the structure.

- Return to Florence

~ 160 (20.00 hr) Florence, Fortezza da Basso.

Acknowledgments

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Back Cover:
road map of the Siena area with stop locations

FIELD TRIP MAP

Edited by APAT