

## CHAPTER 1

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### A Tourist's Introduction to the Geology of Rome

At early midnight, the piazza was a solitude;  
and it was a delight to behold this  
untamable water, sporting by itself  
in the moonshine.

—NATHANIEL HAWTHORNE, *The Marble Faun*

THE MONUMENTAL Trevi Fountain in central Rome symbolizes the relationship between the city and its geologic underpinnings. The stone from which sculptors created this work of art, the clean water from springs in the Apennines and volcanic fields near the city—transported by the famous Roman aqueducts—and the stones underfoot are all products of Rome's geologic heritage.

Construction of the fountain began in 1732, following a design by Nicola Salvi and using stone from the region. Travertine, a sedimentary spring deposit from quarries near Tivoli, and marble, a metamorphic rock from Carrara, in northern Italy, were used for the figures. The plaza is paved with small blocks of lava from flows along the Appian Way. For more than two millennia, Rome's fountains have provided neighborhoods with clear, refreshing water from springs in the Apennines, the Alban Hills, and the Sabatini region: a precious resource transported through aqueducts that were built during the Roman era and restored by the popes beginning in the 16th century.

This is your first visit to the Eternal City of Rome and, with guidebook and map, you plunge into its historic center. The goal is the Trevi Fountain, one of Italy's most famous landmarks. The trek can be daunting. Myriad small piazzas are connected with narrow streets, twisting this way and that, cars and scooters crowd the pavement, and the modern Roman phalanx—a tour group—impedes your progress. Buildings

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of all shapes and vintages block your horizon, scaffolding masks the architectural lines of famous landmarks, and resurfacing hides the ancient streets, making it impossible to view the city's past, hidden under its many debris layers.

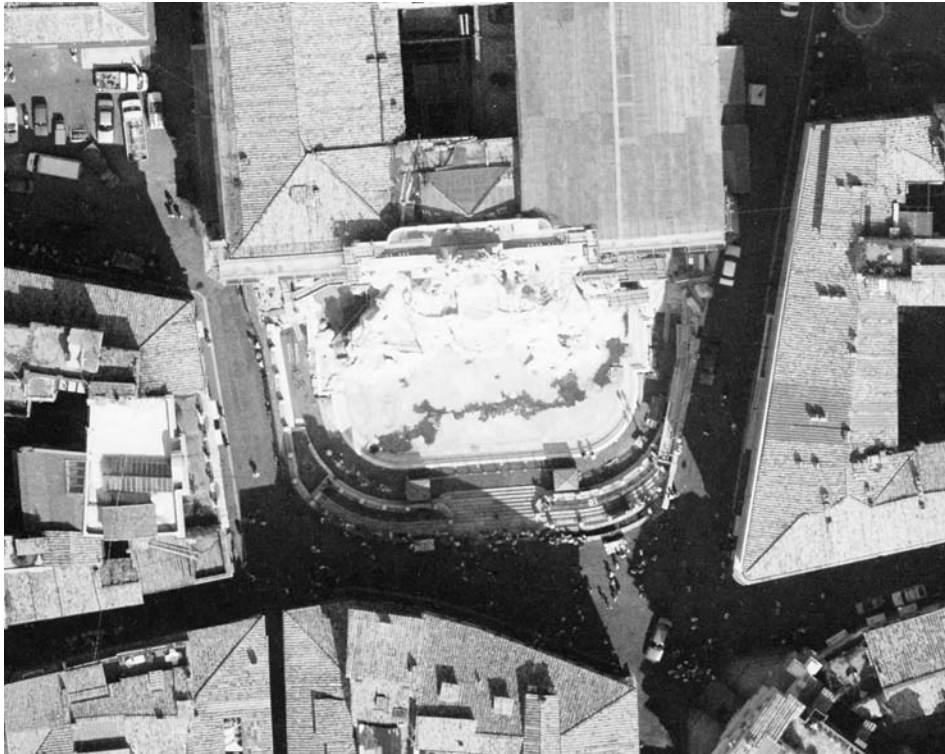
During a brief visit, how do you get a grip on the geographic and temporal components of Rome, where a remarkable combination of geologic setting, environment, and history has produced a city that attracts millions of visitors every year? One fascinating approach is to imagine that you are able to rise above the Trevi Fountain, pausing at different elevations above the city so you can see Rome through a series of windows: first, just 30 meters, then 300 meters, then 3, 30, 300, and 3,000 kilometers on a side. Examining the setting of Rome from these six perspectives allows us to view the interactions between geologic setting, urban development, natural disasters, and humans' continuing struggle to modify and control the environment

### THE 30-METER WINDOW

Approximately 30 meters (98 feet) wide, the Trevi Fountain dominates its small piazza and is one of Rome's most easily recognized landmarks. Most movies filmed in Rome include the requisite scene at (or in) the fountain. Tour leaders and books remark on its ornate sculptures and the way that both the figures and the water emerge from the rock. The piazza actually is a small area, but even at this 30-meter scale, we can learn quite a bit about the importance of geologic setting in the history of Rome and its Empire.

To begin with, why is such a large fountain located in such a claustrophobic space? Seeing it for the first time, visitors are frequently amazed that such an astounding monument is seemingly tucked into a corner of a crowded city. It's important to remember that, despite their sometime glorious appearances, Roman fountains for 2,400 years served the practical purpose of providing water for the populace. A neighborhood fountain supplied this precious fluid for drinking, cooking, cleaning, and flushing public toilets. During the Republican period and the Imperial dynasties, Rome had an abundant supply of clean water from several sources, thanks to its geologic setting and extraordinary engineering. The water infrastructure was later rebuilt and restored under the popes.

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The Trevi Fountain occupies most of this small plaza. The Trevi was as much a display of art as a source of water for the neighborhood, and its light color reflects the use of travertine and marble in its construction. Although not easily seen here, the streets and plaza are paved with *sanpietrini*, small blocks of lava quarried from lava flows in the Alban Hills, a volcanic field southwest of Rome.

The Trevi Fountain, among others, was and still is supplied by the Vergine aqueduct (Aqua Virgo), which brought water from springs at Salone, 16 kilometers (10 miles) east of central Rome, via a circuitous route that enters the city from the north. Inaugurated in 19 B.C., the aqueduct was damaged during the siege of Rome by the Ostrogoths in A.D. 537–38 and was reconstructed near the end of the 15th century. Most of the Vergine aqueduct is underground and passes immediately under the Piazza Trevi. Three streets converge at this fountain, so it is possible that its name may have derived from *tre vie* (three streets).

The first fountain at Trevi was a utilitarian model, built for Pope Nicholas V in 1453 and derided as the “village well.” Bernini had this

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fountain destroyed in anticipation of erecting one of his own design. In fact, his design was not used, but his influence resulted in the fountain being moved from the south to the north side of the piazza, its present location. After an intense competition between sculptors in 1730, the design of Nicola Salvi was selected. Construction of the new fountain took thirty years, between 1732 and 1762, using two architects, ten sculptors, and many assistants. The fountain's travertine base emulates nature, with rough stones, cascades, crevices, grottoes, and carved representations of thirty plant species. The figures, including Oceanus (Neptune) and the Tritons, are carved in Carrara marble, one of the finest natural materials used by the greatest sculptors.

Although the fountain once supplied fresh water to the neighborhood, the flowing cascades are now recirculated and are no longer potable. If you're thirsty, however, *fontanelle* (small water fountains) along the shallow steps leading down to the fountain provide clear, cool, drinkable water.

Tired? The Trevi's steps are an excellent place to sit for a while and look around. The rounded paving stones below your feet are *sanpietrini*, blocks cut from lava that flowed from one of the volcanoes of the Alban Hills to the edge of what are now Rome's city limits. These stones are the same type Imperial Rome laid down for heavily traveled roads throughout its empire.

Although you can't see it, beneath the *sanpietrini* there is plentiful evidence of both anthropogenic (human-related) and geologic events. Immediately below is a 5- to 10-meter-thick (16- to 30-foot) layer of debris left by man's activities; it is mostly within these debris layers that archeologists find clues to the city's complex history. Below the debris is a 60-meter-deep (197-foot) channel cut by the Tiber River as it flowed into a sea much lower than today's Tyrrhenian Sea. Sea level has since risen during the latest warm cycle of the Earth's atmosphere, and the Tiber valley has been subsequently filled in with river sands, gravel, and mud. Beneath this alluvium is a thick sequence of fossiliferous sandstone and mudstone layers that were deposited in an ancient seabed 2 to 3 million years ago.

We could go still deeper, but we'll stop here, let you catch your breath, then return to street level and begin our rise above the Trevi Fountain's neighborhood.

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### ***More about the Stone Used in the Trevi Fountain***

Peter Rockwell, an American sculptor living in Rome, is an expert on the history of stone carving. When he analyzed the features, sculpting techniques, and construction of the Trevi Fountain, he found that the fountain is 89.2 percent travertine, 7.2 percent marble, and 3.6 percent travertine breccia. The principal stone used for the base of the fountain (the scogliera da sola) is travertine, a porous calcium carbonate spring deposit. Roman travertine was (and continues to be) quarried near Tivoli, east of Rome, where bicarbonate mineral warm water issues from springs found along faults at the base of the Apennines and flows into a sedimentary basin.

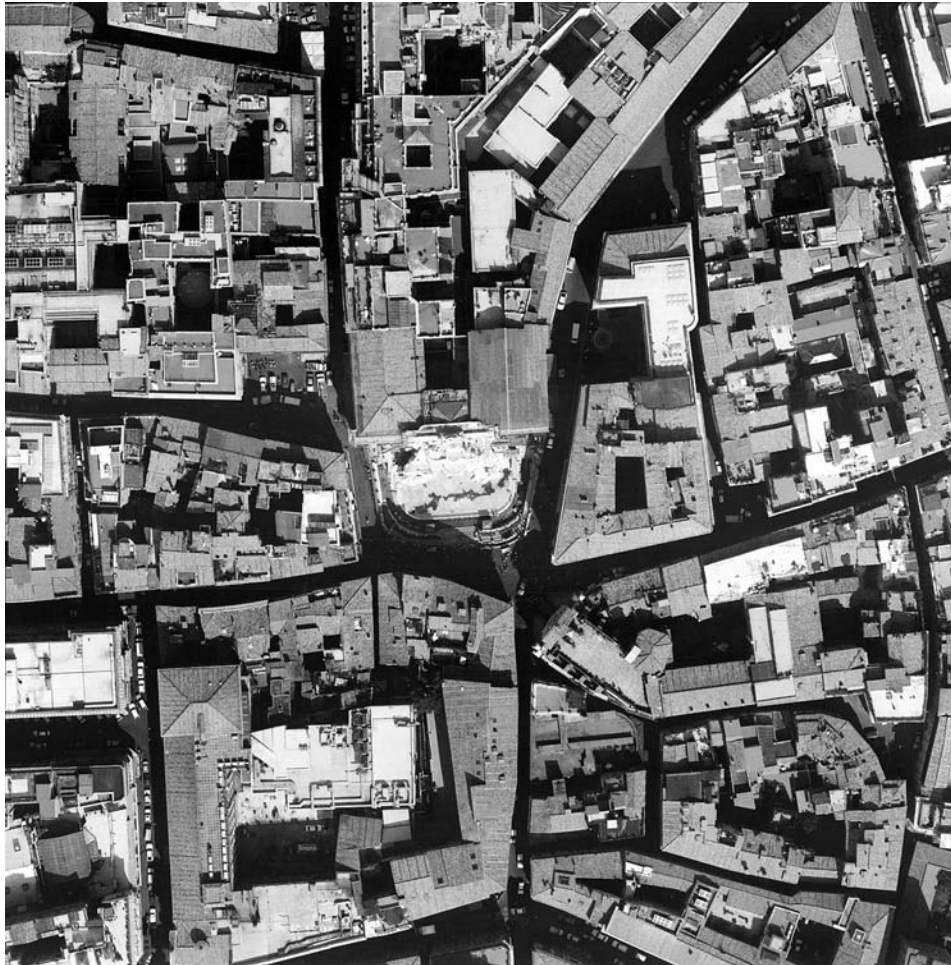
Travertine is a particularly useful rock type: for the geologist, it provides clues to the dynamic history of the Apennines and adjacent sedimentary basins; for the hydrologist, it reveals information about the evolution of the springwaters; and for the archeologist or art historian, it contributes to the provenance of many sculptural pieces.

Travertine breccia was at one time a uniform, thin-layered, brittle spring deposit that was broken by faults. The angular pieces of rock were then cemented by younger travertine as water flowed through the rubble—the final product is a “breccia.” The famous Carrara marble is a metamorphic rock (limestone that has been altered by high temperatures and pressures) from northwestern Italy.

### THE 300-METER WINDOW

Centered on the Trevi Fountain, a 300-meter-square (984-foot) window offers a view that includes parts of the Trevi and Colonna neighborhoods. Immediately east of the fountain, the natural terrain rises 40 meters (134 feet) until it meets the lower walls of the Quirinal Palace. The Quirinal Hill, one of those famous “seven hills of Rome,” was a residential area in Imperial Roman times, was the site of the pope’s

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In this aerial photograph of the neighborhood around the Trevi Fountain, the edges of the image are 230 meters (750 feet) by 260 meters (850 feet). To the west (left) of the fountain, the north-south streets overlie sediments of the Tiber River. The curving street to the east may follow a drainage at the base of the Esquiline Hill, located at the right edge of this photo, which consists of deposits of volcanic rock (tuff). All the original geologic features have been masked by accumulations of debris over the millennia.

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summer palace, then the home of the Italian royal family, and, most recently, the official residence of Italy's president.

Much of this area is underlain by the sands and muds of an alluvial plain deposited when the Tiber overflowed its banks. Until the 1950s, the Tiber regularly ravaged central Rome with floodwaters that reached as far as the lower Via del Tritone—just beyond the northwestern edge of this view.

The Quirinal Palace was constructed on the edge of a plateau; the flat area was built up from the alluvium and marsh deposits of an early Tiber River, which in turn were overlain by deposits of consolidated volcanic ash from the Alban Hills and Sabatini volcanic fields. These volcanic ash deposits were deposited by fast-moving flows of hot gas and ash from eruptions between 600,000 and 300,000 years ago. Blocks from consolidated ash deposits (tuffs) have been used throughout the history of Rome (and, indeed, throughout the world) as a common building stone. There is ample proof that tuff deposits also offer a stable foundation for construction; overlying buildings have been minimally affected by Rome's earthquakes.

In this view we can see that the Tiber's tributaries have cut ravines and small valleys through the Quirinal Hill. These erosion channels, as well as the Tiber's ancient channel, were most likely carved when sea level was lower and are now partly filled with alluvium. The Via del Tritone, mentioned previously, follows what was an alluvium-filled ravine that has also been partly filled in with man-made debris.

Our geologic information about Roman sites is based on extremely rare outcrops, underground quarries, and engineering drill holes. Geologic mapping within a city is always a challenge because so much terrain is covered with the debris from several millennia of human activities. Fortunately for us, many Roman and Italian organizations have spent decades producing an interdisciplinary study of the geology of Rome.

## THE 3-KILOMETER WINDOW

Pulling back farther gives us a 3-kilometer-wide (1.86-mile) window through which we can view a large piece of Rome's historic center, including all of the famous "seven hills." To thoroughly explore this 9-

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square-kilometer (3.5-square-mile), densely packed city center with its varied, complex history in a single week would challenge even the most dedicated tourist. From this vantage point, however, the geologic framework of the city becomes more understandable.

The tuff plateau, with its seven hills, is easy to identify on a relief map; it consists of a sequence of ancient sedimentary rocks left by the Tiber and volcanic rocks (tuffs) from the Alban Hills and Sabatini volcanic fields. Here are the Quirinal, Viminal, Esquiline, Capitoline, Caelian, Aventine, and Palatine hills, as well as the Pincian, which is part of the same plateau that now hosts the vast Villa Borghese Park. Many ancient Roman ruins occupy these hills, the most famous of which are visible near the Roman fora and the Colosseum. Massive tuff deposits from volcanoes changed the course of the Tiber and narrowed its valley floor to create what became a strategically located city that could be strongly defended but had easy access to water transportation. The floors of small tributaries were convenient, open sites for markets, theaters such as the Theater of Marcellus, and larger public structures like the Colosseum and the Pantheon. The plateau's tuff deposits were also the source of stone used for early city walls and the foundations of the great buildings of Imperial Rome.

Development of a densely packed city on the Tiber floodplain began during medieval times. The plain, once occupied chiefly by Roman theaters, temples, and army training facilities—all easily cleaned (and repaired) after a flood—now began to accumulate homes and businesses as well. Floods submerged such built-up areas as the now-well-known Piazza Navona and the Trastevere neighborhoods. If these later generations had followed the urban planning strategies of their ancestors, there would have been far less damage and loss of life during post-Imperial city growth. Planning ways to mitigate the effects of flooding was a standard process for early Romans—one that should be adopted even today in the world's cities.

### THE 30-KILOMETER WINDOW

Looking down at Rome through a window 30 kilometers (18.6 miles) square, we can see most of the modern city, its suburbs, and the ring road (Gran Raccordo Annulare). This view extends well beyond the

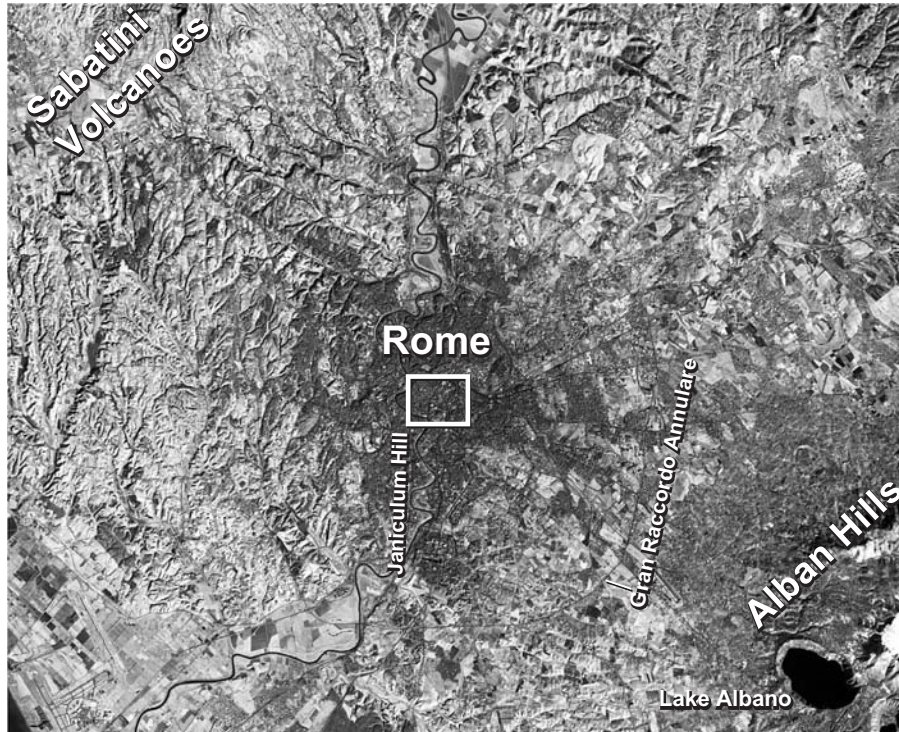


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You can pick out several familiar features in this aerial photograph of central Rome (3 kilometers on a side), which is centered on the Trevi Fountain (white rectangle). Most of the more important elements of Rome's geology also can be seen here. The "seven hills" are visible, including the Quirinal, Viminal, Aventine, Esquiline, Celian, Palatine, and the Capitoline (the last four of these surround the Roman fora and the Colosseum). All the hills are erosional segments of a plateau that consisted of mostly volcanic tuffs that were erupted in the Alban Hills to the southeast of Rome. The flat floodplain of the Tiber and several of its meanders are visible on the left, as is the elongate Tiber Island. Tributaries of the Tiber drained the plateau and left ravines and small valleys that are now partly filled with debris.

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To rise higher above the immediate area around Rome, we needed a satellite image; this one is approximately 30 kilometers on a side. Much of 20th-century Rome is included within the Gran Raccordo Annulare (GRA), the faintly visible ring road that circumnavigates the city and passes over many of the geologic components of Rome. A north-south-trending block of 2 million- to 700,000-year-old marine sedimentary rocks defines the eastern edge of the Tiber floodplain as it passes through Rome. From the southeast and northwest, volcanic plateaus slope toward the Tiber from their sources in the Alban Hills and Sabatini volcanic fields. The floodplain of the Tiber is narrow here, having been confined by a north-south-trending basin and volcanic rocks before it turns west below the Janiculum and flows into the Tyrrhenian Sea. The area in this image encompasses much of what was Rome before the numerous conquests that created the Empire.

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original walls of the Imperial city, nearly reaching an area under control of the Etruscans in what was the city of Veii, 16 kilometers (10 miles) north of Rome.

The Tiber River follows a structural depression created late in the geologic history of the region, when the land was being pulled apart by movements of the Earth's crust. At this scale, we see the Tiber crossing Rome from the north, then turning southwest toward the Tyrrhenian Sea. The hills west of the river (Monte Mario and the Janiculum [Gianicolo]) are composed of million-year-old marine mudstones and sandstones, evidence of a time when the region was beneath the sea.

Eruptions in volcanic fields located southeast and northwest of Rome created two plateaus that descend toward the Tiber. Rapidly moving flows of ash and gas from explosive volcanic eruptions dammed the river with deposits of ash (tuffs) and changed its course. Both of the volcanic fields, the Sabatini to the northwest and the Alban Hills southeast of Rome, have played an important role in creating the terrain that we see today: gentle plateaus pinching the Tiber floodplain and creating high ground for the city. In geologic terms, the volcanic fields are young—the most recent eruptions occurred in the Alban Hills about 3,500 years ago. Roman writers such as Livy and Pliny the Younger recount tales of explosions and “rains of fire” in the Alban Hills, but none of these events have been verified. A recent study by two of the coauthors supports the hypothesis that large bursts of gas in Lake Albano in historic times buried sections of the volcanic slopes with mud.

As the Tiber River leaves central Rome and the narrow valley that was created between upfaulted sedimentary rocks and volcanic ash plateaus, the slope of the riverbed decreases and the flow is placid as the river approaches the sea. This is the head of the Tiber delta, which has been expanding into the sea since the river first reached the coastline. The major Imperial Roman seaport of Ostia (now Ostia Antica), near the window's southwest corner, is now 4 kilometers (2.5 miles) from the sea, landlocked by the silts and sands of the growing river delta. The Tiber and its delta were key factors in the mercantile and military successes of the Roman Empire, making it possible to establish ports near Rome and thus ship materials and goods upriver into the city.

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### THE 300-KILOMETER WINDOW

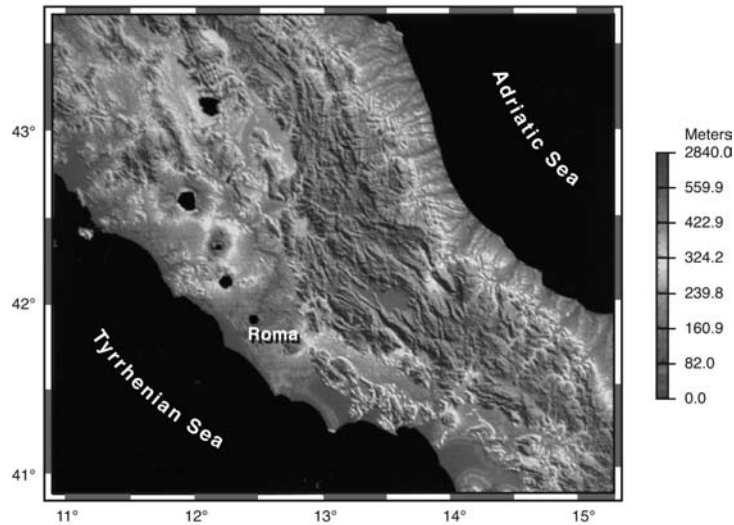
At the 300-kilometer (186-mile) scale, which encompasses all of the Italian Peninsula, we can see many geologic components that have affected the history of Rome and its interactions with other peoples. Terrain had a great impact on the early growth of the Roman Empire and still influences Italy's natural resources and transportation systems. We'll look at several of these features more closely.

#### *The Apennines*

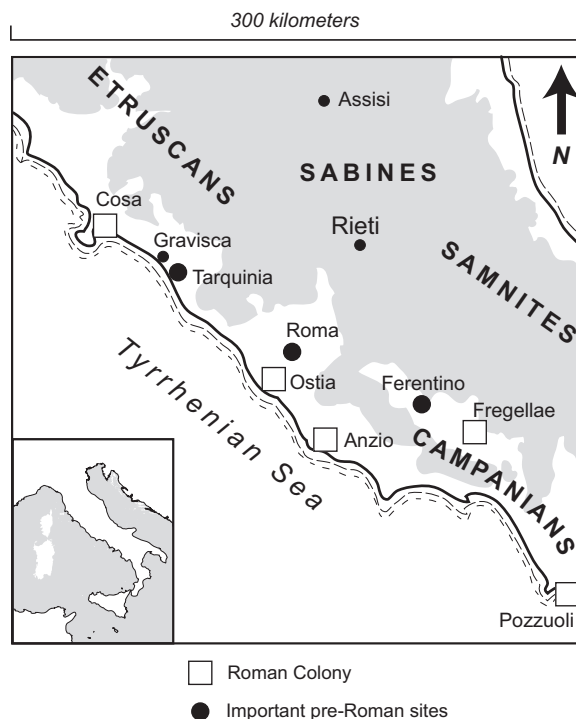
The Apennines, the backbone of the Italian Peninsula, have had both historic and geologic importance. These rugged limestone peaks and ridges run from Genoa and Turin down to the instep of Italy's "boot" south of Taranto. Above the timberline, the rugged snowcapped peaks provide rocky platforms for everything from ski areas to radio and television transmission antennas. The highest of these peaks is the Gran Sasso, with an elevation of 2,912 meters (9,554 feet). Because the foothills of the Apennines are so close to sea level, the chain is truly impressive as it rises abruptly above the Tyrrhenian coastal plain to dominate Rome's eastern and northern horizons. High mountain valleys host small farms and many villages. Today only a few large highways are visible in aerial photographs; many of the main routes follow deep tunnels cut through the mountains.

The ridges of the high Apennines, with their harsh alpine terrain, separated the cultures and languages of pre-Roman Italy. The high ground was held by the Sabines, Etruscans, Lucanians, and Peucetians; the Adriatic coastal plain by the Daunians and Picenes; and the Campanian Plain by Campanians and Greeks. Strongly independent, these peoples were isolated by terrain and language. To defend itself and expand its empire, Rome had to conquer the rugged natural barriers and then establish colonies of military veterans whose presence helped pacify the indigenous population of those distant valleys.

Roman consular roads connected the colonies by following creases in the natural terrain that were created by folds and thrust faults (slices of rock pushed over one another to create what looks like a slanting



At this elevation, our 300-kilometer window looks down on the entire central Italian Peninsula, from the Adriatic to the Tyrrhenian Sea. The northwest-southeast-trending Apennine Mountains, which form the backbone of the Italian Peninsula, are easily seen in this digital elevation map. The high mountain chain is the product of tens of millions of years of geologic compression and the stacking up of slices of the Earth's crust. In contrast, lowlands on the western side of the Apennines were formed during extension, or pulling apart, of the crust over the last several million years. The oval or circular mountains near Rome (with large crater lakes) are volcanic fields.



The rugged, high peaks of the Apennines were occupied by many different cultures with multiple languages. Both the mountains and their peoples had to be controlled before Rome could develop its empire. (Adapted from Potter 1987)

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deck of cards). For example, both the Via Flaminia and the Via Appia follow routes along valleys formed by erosion along major faults. When following the structural grain was impossible, well-built mountain roads traversed passes between valleys.

Limestones deposited in ancient shallow seas as long ago as 300 million years have become a very important component in the Eternal City's sustainability: they formed the major rock reservoirs that hold Rome's water supply. The limestones are also quarried for building stone and provide the lime used in concrete.

You might ask, "How could all these marine sediments end up being exposed in a chain of high mountains?" The Apennines are the product of a collision between the continental plates of Africa and Eurasia. Instead of forming a continuous, more or less east-west boundary between the two continents, as one might expect, however, the merging developed on a trend from the northwest to the southeast, along the shoreline of the present-day Adriatic Sea and the eastern slopes of the Apennines.

The complex collisions and extension (pulling apart) of the Earth's crust in this region lasted from about 20 million to 2 million years ago. The compression (or "thrusting") occurred along two major lines that run along the Italian Peninsula; these are separated by a north-south-trending fault, along which the motion is absorbed by strike-slip movement (two blocks moving laterally along a nearly vertical fault). At the same time, the Italian Peninsula began to rotate counterclockwise, opening basins to form what is now the Tyrrhenian Sea.

### *The Tyrrhenian Sea and Coastal Plain*

These cycles of extension and compression not only thinned (or stretched) the oceanic crust below the Tyrrhenian Sea but also produced high heat flow and volcanic activity beneath the sea and along the Tyrrhenian shore. The coastal plain we see today follows the transition between the thrust faults of the Apennine chain and the subsiding Tyrrhenian basin, which has been opening slowly over the last 20 million years. Formation of this coastal margin was irregular, beginning in the south and migrating toward the north.

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Today, these complex processes of compression and extension continue to produce irregular movement along faults of all types on the Italian Peninsula, generating frequent earthquakes, some of them catastrophic. A further and even more dramatic activity—volcanism—has contributed to the Roman area's complex geologic history.

### *The Volcanoes of Rome*

Volcanism is a natural phenomenon not often associated with Rome itself, but it has played a very important role in the formation of the Tyrrhenian coastal plain. From this viewpoint, we can see a line of volcanic fields along the edge of the Italian Peninsula from Naples through Rome and on to Tuscany. Much of this volcanism was explosive, producing plateaus that radiate from large craters, which are visible on this image as a number of circular or semicircular basins scattered from the Alban Hills to Bolsena Lake. Many of the large craters contain lakes that are reservoirs for some of the Roman water supply. The largest around Rome is Bracciano, which provides potable water and in the future may generate electricity from geothermal systems.

These are young volcanic systems (the last eruption was about 3,500 years ago). The largest of the eruptions left collapse craters (or *calderas*), which were formed when eruptions evacuated underlying magma chambers. Looking closely, we can see that superimposed on the *calderas* are smaller volcanic craters and some lava domes.

### *The Tiber and the Paleo-Tiber*

If you approach Rome from the north, the major river you see is the Tiber. Upstream from the city, the river has a fairly wide floodplain and empties a drainage area that extends into north-central Italy. The Tiber follows the geologic structure that we discussed earlier and does not turn toward the sea until it reaches Rome. Before volcanic eruptions built up the fields flanking Rome, the ancient Tiber meandered along a structural basin, the western margin of which is formed by the hills behind the Vatican and Trastevere. The ancient river flowed to the south-southeast, below what is now Cinecittà—large, blocky buildings that house film studios at the southeastern edge of the city. Today's

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Tiber flows through Rome along a narrow valley; its path was shifted to the west by rapid deposition of volcanic ash from eruptions in the Alban Hills.

### THE 3,000-KILOMETER WINDOW

At 3,000 kilometers (1,863 miles), our panorama frames most of the Mediterranean—one of the most geologically complex areas of the Earth. Now we see the consequence of movements between the African and Eurasian plates of the Earth's mobile crust. Slowly, slowly, the African plate is sliding under the Eurasian plate. Geologic events created today's Mediterranean Sea, as well as the landmasses that make up southern Europe, the Middle East, and North Africa. The shoving together (compression) created many of the Mediterranean mountain ranges, including the Apennines, the Dinaro-Hellenic chain of the Balkan States, the Alps, and the Pyrenees. The sections being pulled apart (extension) have become ocean basins, including the Tyrrhenian Sea, part of the Aegean Sea, and the large Liguro-Provençal Basin between Sardinia and Spain.

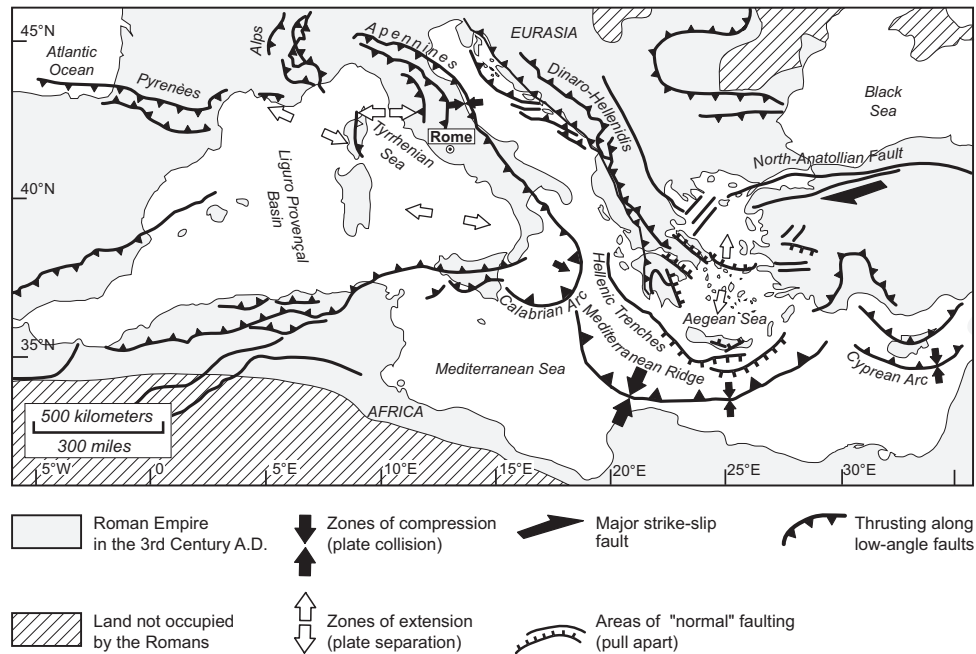
The most visible product of all this pushing and pulling of the Earth's crust—the Mediterranean Sea—became the core of the Roman Empire. In addition to being an obvious source of food, the Mediterranean was (and continues to be) the main thoroughfare for merchant and military ships. It provided the access needed to develop an extensive empire and the protection needed to defend that empire from other powers.

When we examine stones used by the Romans for both art and building materials, we can see both the geographic extent and the geologic scope of the Empire. Marble came from Italy, the Balkan Peninsula, Turkey, Egypt, France, Asia Minor, and Spain; granite, gabbro, serpentine, and porphyry were brought back from Egypt; and alabaster was returned from Egypt, Tunisia, and Algeria. Roman artwork used precious metals and gemstones from all corners of the Empire.

This preview of Rome's geologic and geographic setting, taken in seven steps, also is a preview of this book, revealing the constant interaction between geologic setting, humans, urban development, and people's response to the natural phenomena that have affected the city.



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In the last window, we can see the extent of the later Roman Empire (at the time of Diocletian in the 3rd century A.D.) on a simplified geologic map that depicts the Mediterranean Sea and the landmasses around its margins. Our window is a bit distorted here, with the 3,600-kilometer measurement in an east-west direction to encompass the Mediterranean. Complex plate tectonic processes formed the seas that Rome found so crucial for military and merchant transportation. This geologic setting offered up a rich variety of metals, gemstones, and building stone used by the Romans, as well as a variety of soils required for growing wheat, grapes, and olives for oil.

The area's complex geologic pattern was shaped by movements of the African and Eurasian crustal plates. Compressive and extensional forces in this zone are overwhelmingly complicated, even to geologists. Compression (shoving) has produced the thrust faults (marked with "teeth" and dark arrows), and extension (pulling apart) has opened up basins in the sea and on land, such as the deep Liguro-Provençal basin, located between the Spanish coast and Sardinia. Volcanic activity occurs throughout and includes the many Italian volcanoes on Sicily, in the Tyrrhenian Sea, and along the western coast of the Italian Peninsula. (From a diagram by Claudio Faccena, University of Roma Tre)

## TIMELINES

There are many events in the womb of time which will be delivered.

—WILLIAM SHAKESPEARE, *Othello*



Archeological excavations in the Roman fora unravel the last 3,000 years of Rome's history one layer at a time, as shown in this photograph of a dig in the Forum. It is slow, meticulous work that requires patience, experience, and a good eye. To understand the geologic history of Rome, we must go backward 300 million years, as summarized in the timelines presented here.

**T**HE LINKS between the history of Rome and its geologic foundation are strong, yet they are rarely considered, in part because of philosophical differences between historians and geologists. Both professions deal with history, but in very different ways. Historians focus on the interactions between people, primarily within a culture but also between cultures; their approach is usually linear: events are located on timelines that span years, decades, and centuries; and their work is based chiefly on the written word, but occasionally on oral traditions as well. Geologists are concerned with interactions between

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natural elements and, increasingly, between nature and humans. They must rely on the mute witness of rock and soil. Finally, given the vastness of geologic time, geologists tend to think in “powers of ten.” We begin this book by examining the Trevi Fountain and then rise above it in steps of ten, initially looking down on a piazza about 30 meters on each side and finally viewing a vast region 3,000 kilometers on a side. In the timelines presented here, we begin our journey 300 million years ago and move toward the present in similar steps—but in time rather than distance. The geologic processes that have shaped the Rome and surrounding region we see today are part of a continuum, but to evaluate them in a linear fashion would require more time and paper than we could envision for any book!

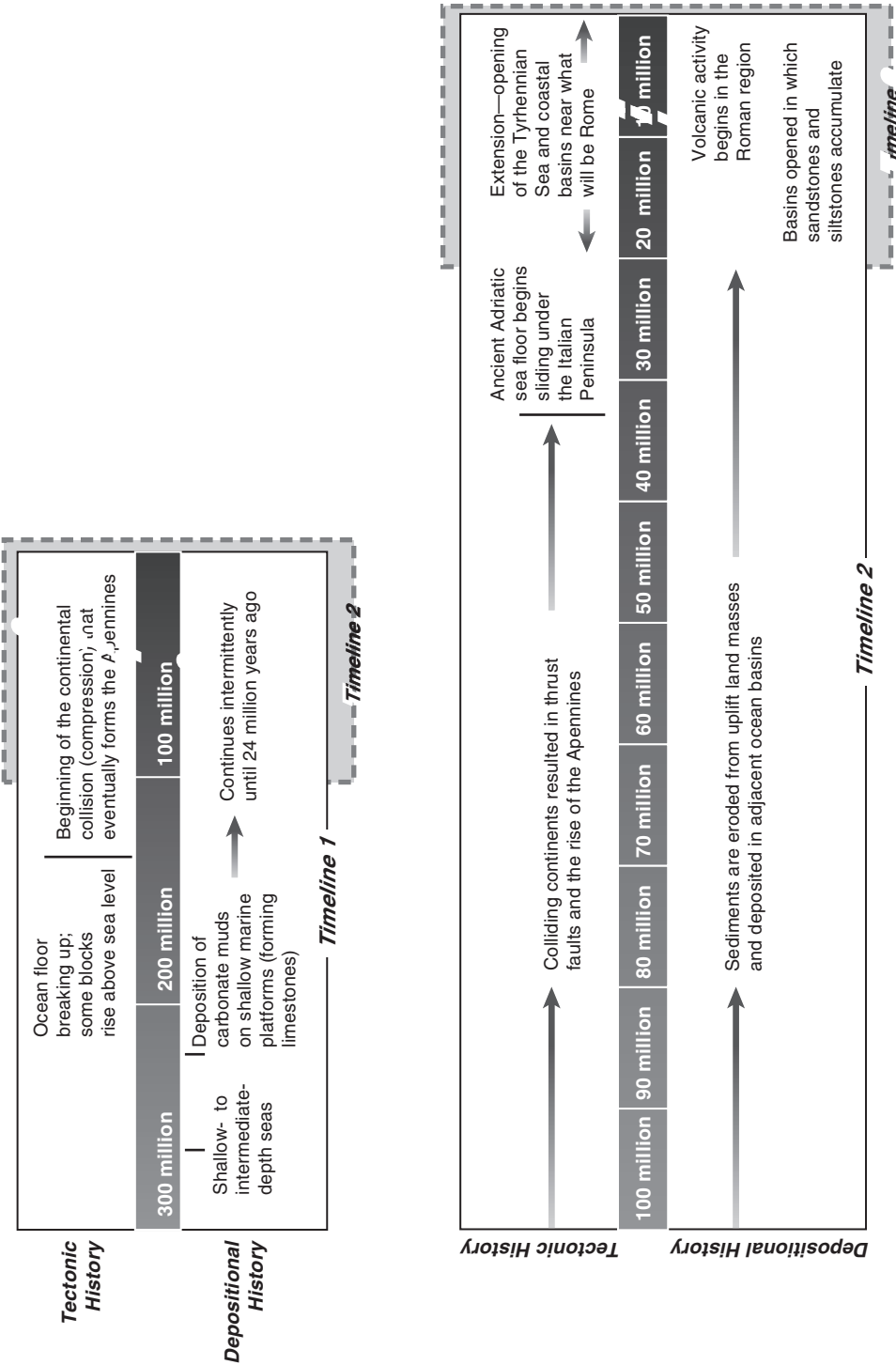
Italy in general and the Apennines in particular have some of the most complex geology in the world. The effort to understand how the Italian Peninsula and the Apennine chain were formed has required detailed fieldwork by hundreds of geologists over the last hundred years. Scientific concepts and technologies have changed, but the rocks are the same, as are the locations in which they were described by pioneering geologists—so even the most rapid of plate tectonic movements haven’t changed the shape that much. In the late 1970s and early 1980s, the Italian government began the Geodynamics Project to integrate all that was known about the geology of Italy to better understand the nation’s natural hazards and geologic resources. To assemble the geologic map of Italy in five years required the efforts of nearly 100 geologists (not counting students), coordinated by Maurizio Parotto of the University of Rome. Geologists often disagree, usually in a friendly, competitive way, about the structure, rock types, and ages of units; thus, compiling a single geologic map of Italy also required considerable strength and diplomacy. Field, laboratory, and numerical studies of geologic problems of the Apennines continue to constantly refine and update what is known, especially in the light of new ideas concerning the dynamic Earth.

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### 300 MILLION TO 20 MILLION YEARS BEFORE THE PRESENT

Most of the rocks in the Apennines in central Italy are varieties of limestone (calcium carbonate) or dolomite (calcium magnesian carbonate), with some sandstones and claystones. Nearly all these rocks were deposited as sediments in shallow to intermediate-depth seas that covered the region from about 300 million to 10 million years ago (timelines 1 and 2). Until about 15 million years ago, they were part of a broad seaway (the Tethys Sea), which spanned much of what is now Europe and connected the Indian and Atlantic oceans. These ocean basins were not just static areas where carbonate mud accumulated for hundreds of millions of years; they were dynamic, shifting at rates of a few centimeters (about an inch) per year as the Earth's crust moved. To understand these marine environments of the past, we need to pull apart all the crumpled and stacked layers of rock—at least on paper. Building on their lifetimes of work in the Apennines, Antonio Pratlurion and Maurizio Parotto of the University of Roma Tre have done just that and have given us glimpses of the early seas, islands, and basins that occupied the region.

A number of tectonic, volcanic, and sedimentary events were occurring at the same time. For example, from about 220 to about 70 million years ago, there was a large oceanic carbonate platform across what now is Lazio and Umbria. (To envision this environment, think of the present-day Bahamas and the shallow seas that surround them, all of which are actually situated on a platform that rises above the floor of the Atlantic Ocean.) The ancient carbonate platform of Lazio and Umbria rose above a sea floor that was in motion. The water depth and depositional environment changed with time: about 220 to 190 million years ago, the ocean floor began to break up; some blocks rose above sea level, and others were submerged along down-dropped sections. The resulting environments then included areas from above sea level and from adjacent oceanic basins that had slowly filled with limy muds and sands, as well as some reefs that may have been present in the shallower seas. Small ocean basins inset into the platform were also filled with lime mud and sands that eventually became laminated limestones. These geologic conditions existed until about 19 million years



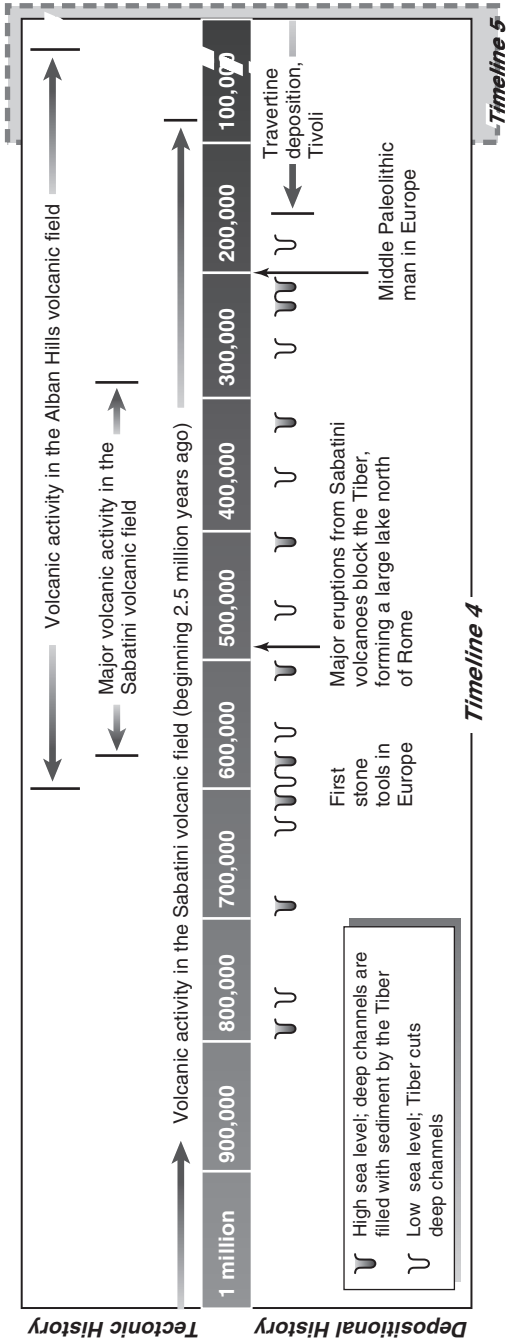
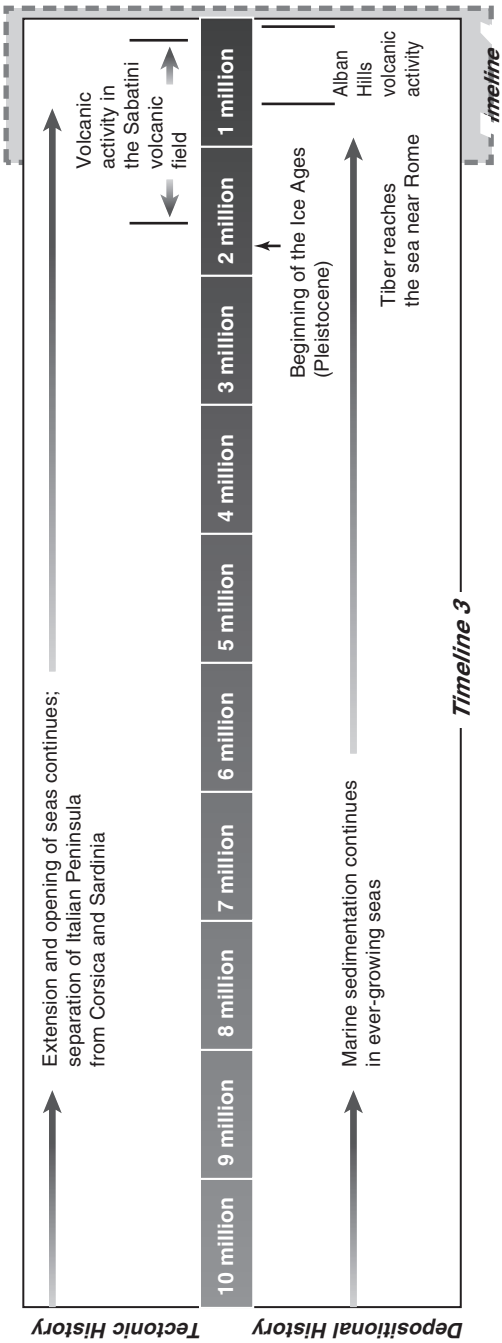
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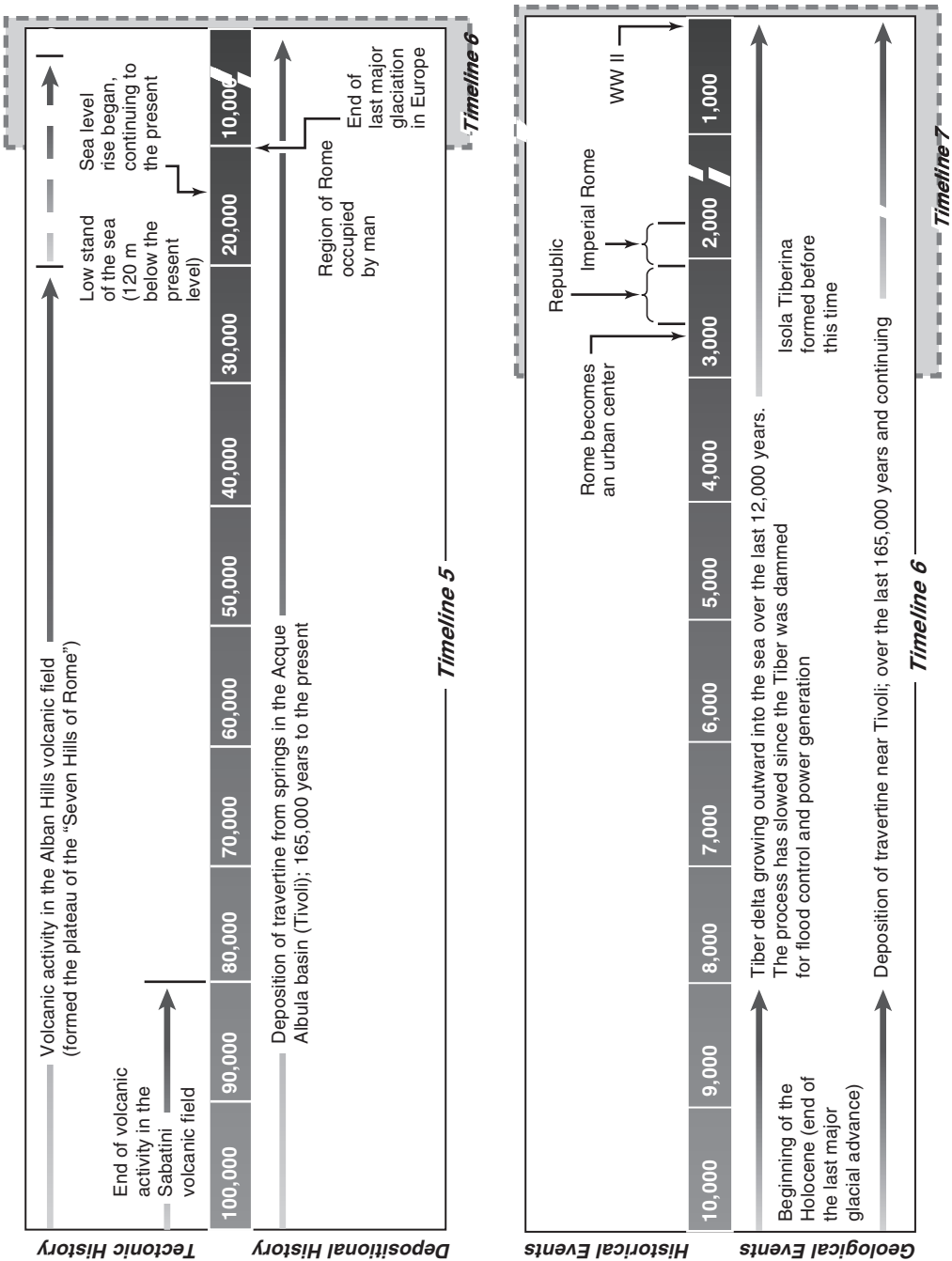
ago. The sediments, eventually turned into marls (a carbonate-rich claystone) and mudstones, are now exposed in the Apennines of Umbria and Marche to the north and Sicily to the south. Evidence that could reveal the extent of the ocean basins adjacent to the Lazio-Umbria carbonate platform has been more or less obliterated by later continental collisions.

About 130 to 33 million years ago, plate collisions compressed marine sedimentary rocks along a north-south line (see timeline 2). Instead of bending like a rug, the layers that made up the upper part of the Earth's crust, including the sedimentary rocks, broke along myriad north-south-trending, low-angle faults that slid one over the other along very low, westward slopes. Imagine a sheet of thick cardboard lying on a table. You cut completely through it along a number of parallel lines, which we'll use as an analog to faults. Now, while you hold the right side motionless, you push the left side toward the right, which compresses the cut sections and stacks them up so they slant downward toward your left hand. This stack of cardboard sheets is the equivalent of the early Apennine mountain chain. As you can see if you visit the high Apennines around Gran Sasso, northeast of Rome, the reality is much more complex, but this simulation gives you a general idea of what has happened over the last hundred million years.

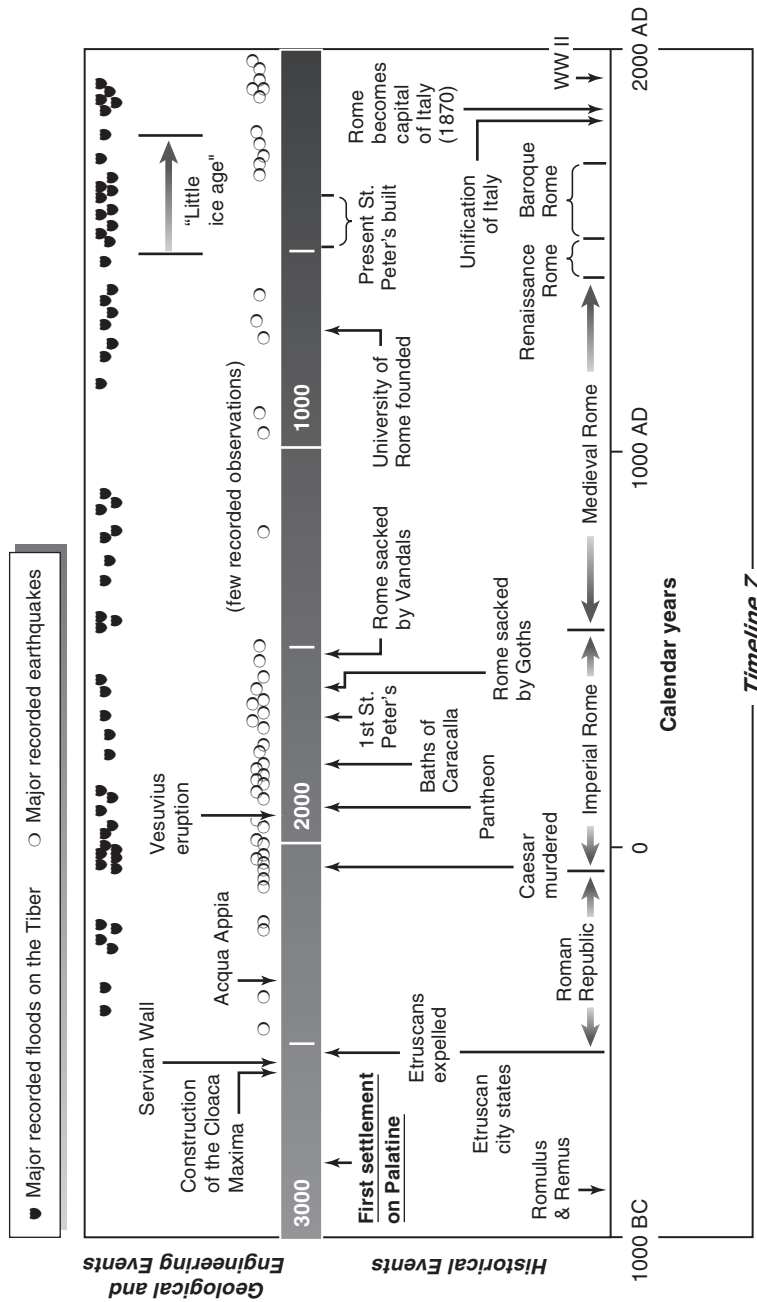
### 20 MILLION YEARS AGO TO THE PRESENT

In contrast to the compression that for hundreds of millions of years had stacked up sedimentary rocks to form mountains, the Earth's crust in this part of the world now began to pull apart and stretch (timelines 3–7). About 25 to 20 million years ago, the thinned crust below what is now the Adriatic Sea began sliding under the Italian Peninsula to form what is called a *subduction zone*. At the same time, the upper portions of the western Mediterranean, the Ligurian Sea, began to open as the crustal blocks we now know as Sardinia and Corsica drifted to the east with a counterclockwise motion. Collapse of the crumpled wedge that was the Alps pushed deeply buried rocks to the surface (one of the best examples of these rocks is the Carrara marble so frequently used in the great sculptures of Italy). Stretching and thinning of the









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crust also produced a setting for the beginnings of volcanism, an activity that continued intermittently from about 600,000 to 3,500 years ago in volcanic fields that flank Rome to the north and south.

The pulling apart of the Tyrrhenian coastal plain over the last 20 million years had formed elongate basins up to 10 kilometers (6 miles) wide and 2,500 meters (8,200 feet) deep, bounded by “normal” faults (in which one side moves down relative to the other) that are more or less parallel to the coast. The subsiding basins were rapidly filled with debris washed down from the Apennines or from the volcanoes that were erupting during the same period. Because they were close to the coast, sediments were deposited both above and below sea level, thus getting a sequence of interbedded marine and “continental” sedimentary rocks in the area of Rome. Regardless of the type of motion (pushing or pulling), the structural trends of features such as the Apennine mountain chain or coastal basins have stayed more or less the same over the last several hundred million years.

The depth of the Tiber River valley has changed a great deal over the last 13,000 years. The river quickly eroded its valley and tributaries to develop equilibrium relative to the sea, which was once nearly 70 meters (230 feet) below its present level. As sea level rose, the Tiber stopped eroding and began depositing sediment, which is now quite thick below the Tiber as it passes through Rome.

Each of the major events that occurred during this timeline of 300 million years took tens of millions to millions of years—with two exceptions: the arrival of humans 600,000 years ago (just 0.2 percent of the timescale) and the founding of Rome 2,800 years ago (a mere 0.0006 percent of the timescale). Despite the ways we have changed the face of the planet, *Homo sapiens* hasn’t been around for long.