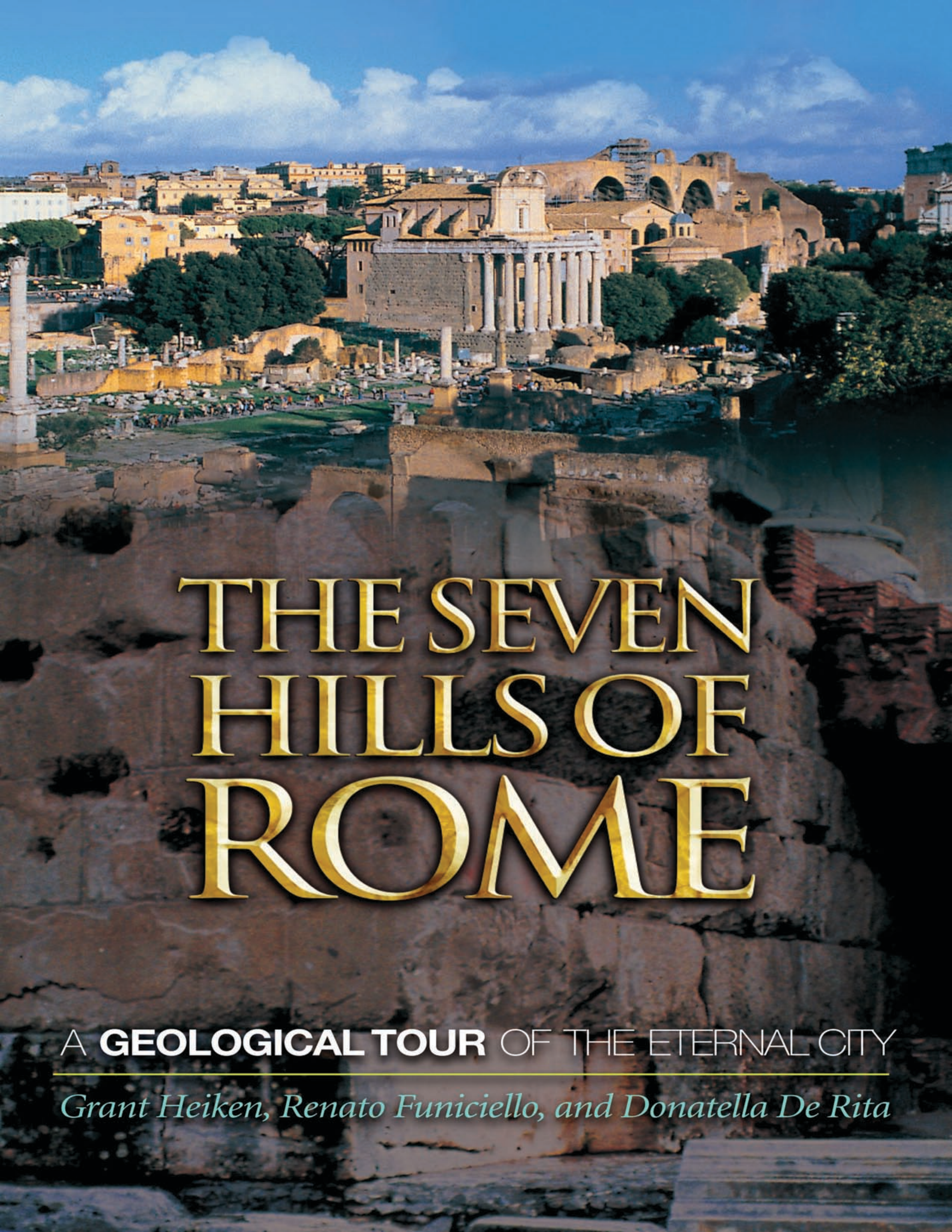

THE SEVEN HILLS OF ROME

A GEOLOGICAL TOUR OF THE ETERNAL CITY

Grant Heiken, Renato Funiciello, and Donatella De Rita

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Contents

Foreword

From its time as the historic center of the Roman world, Rome has been continuously a political, religious, and administrative capital. Geologic and terrain factors have assured its population growth and, above all, provided the conditions for survival of the most modern culture in the ancient world. From lessons of urban development and prosperity, the Roman people developed the capacity to recognize and to manage in a positive way the natural resources of the region. The volcanic terrain, the Tiber River and its complex watershed, the water resources of the central Apennines and surrounding countryside, and the abundant natural materials for construction, roads, and aqueducts have all contributed to the birth, growth, and success of Rome. If these natural riches were to be considered *res nullius* (a thing that has no owner), the city would experience progressive and eventually fatal decline. Worsening political and economic fortunes would be accompanied by inattention to the wonderful but fragile equilibrium of natural factors and their importance for urban development. Calamitous events, including the depletion of natural resources, would all contribute to a scenario of decline more profound than that of the ancient city in the 5th century A.D.

Modern Rome is a new city, born after the unification of Italy and developed in an impetuous manner because of the complex historical backdrop of Italy and Europe. Many aspects of the modern urban environment are leading to dissatisfaction and suffering for many, stimulating a strong awareness of the need to care for the city with great attention to its management and with appreciation of its environment. The long history of our city and links to its setting and environment are of increased interest to the international community. It is appropriate that the term *urban geology* has its origin in *Urbs*, which was the ancient name for the city of Rome. Justifiable interest in urban science is growing in the international community of scientists and in city administrations. City residents must understand the roots and factors both hidden and manifested by the environment in which they live.

The authors of this work have offered the citizens of Rome and its visitors a new understanding of the city and its environment, based on a synthesis of work by scholars and city officials. I hope that *The Seven Hills of Rome* will stimulate other cities to examine their environments in the same way.

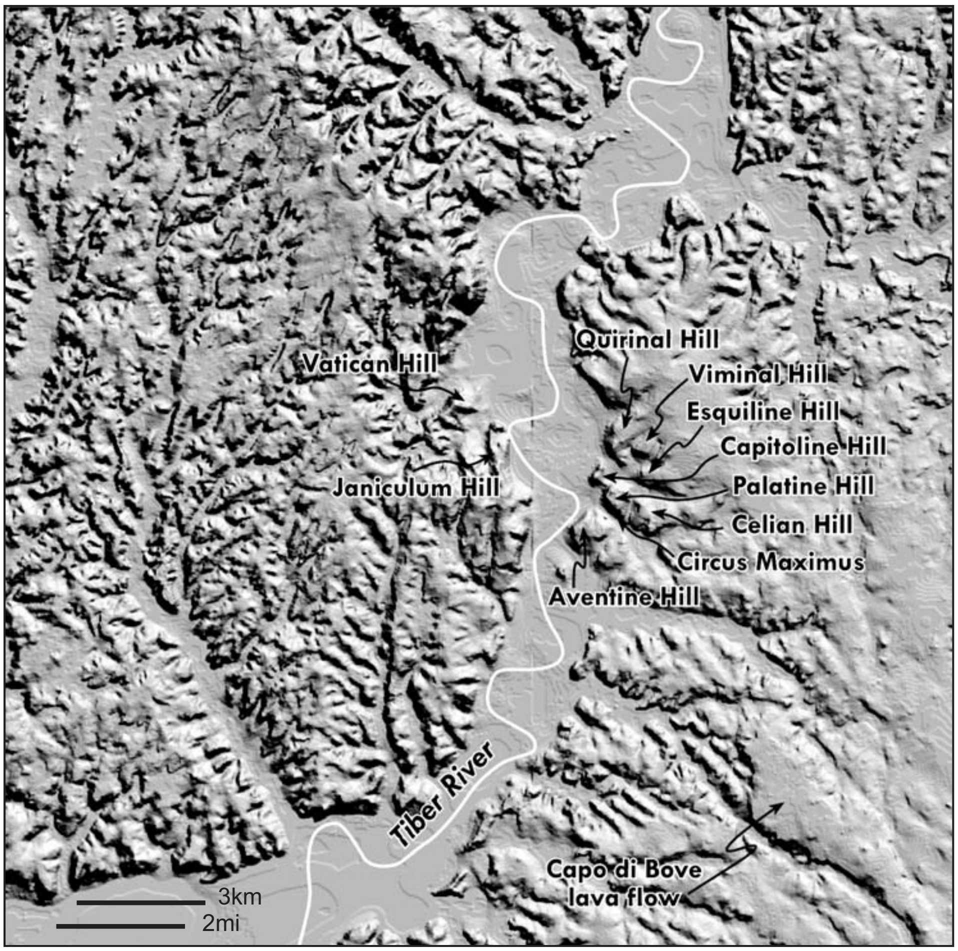
Walter Veltroni
Mayor of Rome

Preface

A SUNRISE over Rome, as seen from the Monteverde area above the right (west) bank of the Tiber, is a truly memorable experience, with the mixed clouds, a bit of mist above the river, and bells ringing everywhere. The distant Apennines and Alban Hills form a backdrop for center stage—the seven hills of Rome. Monteverde and the nearby Janiculum are wonderful viewpoints from which one can contemplate the history and cultural significance of this great city as well as its geologic foundation. Across the river, the seven hills are actually the eroded remnants of a plateau dissected over many centuries by streams. The stream valleys are less evident because man-made debris from more than three millennia has smoothed the original terrain.

Why was this site chosen for Rome of the Republic, Rome of Imperial times, and eventually Rome of the popes and Rome, the capital of unified Italy? For many reasons: proximity to a major river with access to the sea, plateaus affording protection, nearby sources of building materials, but, most significantly, clean drinking water from springs in the Apennines. Most of us recognize Rome as a source of inspiration for historians, architects, artists, musicians, and theologians. However, it's interesting to note that the success of Rome would not have been possible without the myriad benefits provided by its geologic setting. Even the resiliency of its architecture and the stability of life on its hills are supported by its geologic framework.

In addition to supplying an ideal setting, geologic processes have also threatened Roman life and property with floods, earthquakes, landslides, and (in the Bronze Age) volcanic eruptions. Understanding these threats allows planners to best situate homes and civic buildings and to lower the risk from the natural events so common on our dynamic planet. Rome is uniquely fortunate in that it has an excellent historical record that reaches back to Rome of the Republic—a record from the



The terrain with its underlying geologic framework has played an important role in the success of Rome as a city and an empire. The Tiber River, crucial to water transport into ancient Rome, was trapped on the west by the fault blocks of the Janiculum and Vatican hills. The Tiber's east banks are volcanic plateaus, composed of deposits from explosive eruptions in the Alban Hills. In addition to forcing the Tiber toward the west, these deposits make up the "seven hills of Rome."

past that, in turn, has helped geologists and geophysicists in their efforts to mitigate future disasters.

This journey began in 1995 with the publication of a technical monograph, *Geologia di Roma* (*The Geology of Rome*), by the National Geological Service of Italy. The work represented in the monograph should serve as a standard to be followed by every large city in the world. Understanding a city's geologic underpinnings and processes can save lives and property, guide development, and secure a sustainable future. The scientific coordinator of the monograph, Renato Funiciello, was also one of the thirty-seven contributors. At about that time, Grant Heiken was involved with the Urban Security Project at the Los Alamos National Laboratory, the purpose of which was to understand the interconnectivities of systems that make up a city. Funiciello and Donatella De Rita gave Heiken a copy of the Rome monograph at the "Volcanoes in Town" meeting in September 1995. The monograph, the meeting, and long discussions motivated the three of us to prepare a book, for the public, on the relationship between geology and the history of Rome, to demonstrate the importance of geologic setting in a city's past and future.

The book may be read by itself or as a supplement to histories of Rome or carried, along with a good city map, to expand a reader's understanding of the city as he or she explores its streets. Geologists love field trips, and we hope to infect the reader with an equal enthusiasm through the guides in the last chapter.

The book's chapters are arranged geographically and cover each of the seven hills, the Tiber floodplain, ancient creeks that dissected the plateau, and ridges that rise above the right bank. The chapters may be read sequentially or randomly.

Chapter 1 provides an overview of Rome, using views of the geologic setting at scales of a few tens of meters to thousands of kilometers and at timescales of hundreds of millions of years to a few hundred years. A basic description of the geologic history of the Mediterranean is included.

A visit to the Capitoline Hill in chapter 2 focuses on the eruption products of the two major volcanic fields that flank the city. Chapter 3 describes the Palatine Hill and introduces the reader to the consolidated volcanic ash deposits (tuffs) that form the seven hills and have provided most of Rome's building materials. The peaceful Aventine Hill is the venue in chapter 4 for discussing the city's defensive walls, as well as the hazards and opportunities provided by the quarries and catacombs that underlie the seven hills.

The importance of the Tiber to Rome and its commerce, in addition to the threat of floods it brings, is covered in chapter 5. This section also highlights the discovery of concrete by Roman engineers and the subsequent importance of that material to the city and the empire. Chapter 6 explains how the debris of millennia that underlies Rome is a bit of a curse to a modern city but a treasure trove for archeologists. Chapter 6 also covers the risk of earthquakes to the Eternal City and how ancient monuments help reveal damage caused by past earthquakes.

Ancient Roman roads enter the city from all directions; in chapter 7, the reader is introduced to the hills west of the Tiber (the Janiculum, the Vatican, and Monte Mario) and then approaches the city by the Via Aurelia, which crosses these ridges along the right bank of the Tiber. This chapter discusses both the risk of landslides and the rather mundane but critical resources of sand, gravel, and clay that were needed to build this great city.

Rome, one of the few cities in the world that has an excellent supply of drinkable water, has flourished on the basis of available water: history reveals that when the aqueducts were damaged, Rome's fortunes declined. A visit to the quiet Celian Hill in chapter 8 introduces the reader to water resources and to the travertine (formed by springwater deposition) commonly used in construction and sculptures. Chapter 9 takes the reader across the Esquiline Hill, one of the largest of the seven hills, where the topic is energy in ancient and modern Rome—the sources and use—and lessons we can learn from the past.

The importance of their geologic foundations in the survival of the commemorative columns of Trajan and Marcus Aurelius is described in chapter 10. The marble so prevalent in the architecture and artworks for which Rome is renowned, comes from many sources around the Mediterranean. The final chapter consists of three field trips around the center of Rome, which can be taken on foot or by public transportation. Any reader who completes all three trips deserves a good Roman meal and a bottle of wine!

We hope that after reading about the remarkable link between the geology and history of Rome, readers will take a hard look at their own urban communities. An understanding of every city's geologic framework is not only interesting but also important in planning for the future of that city.

THE SEVEN HILLS OF ROME

The Trevi Fountain was built on the north end of the Trevi Plaza between 1732 and 1762 by a large team led by Nicola Salvi. Attached to the facade of the Palazzo Poli, it is one of the most extravagant of Rome's many fountains (and one of the largest, at more than 30 meters wide). Water was transported into the city's public plazas through aqueducts originally built by ancient Romans and restored after medieval times. The water that flows so freely in the Trevi Fountain comes from springs near Salone outside Rome, via the Vergine aqueduct.

CHAPTER **1**

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.

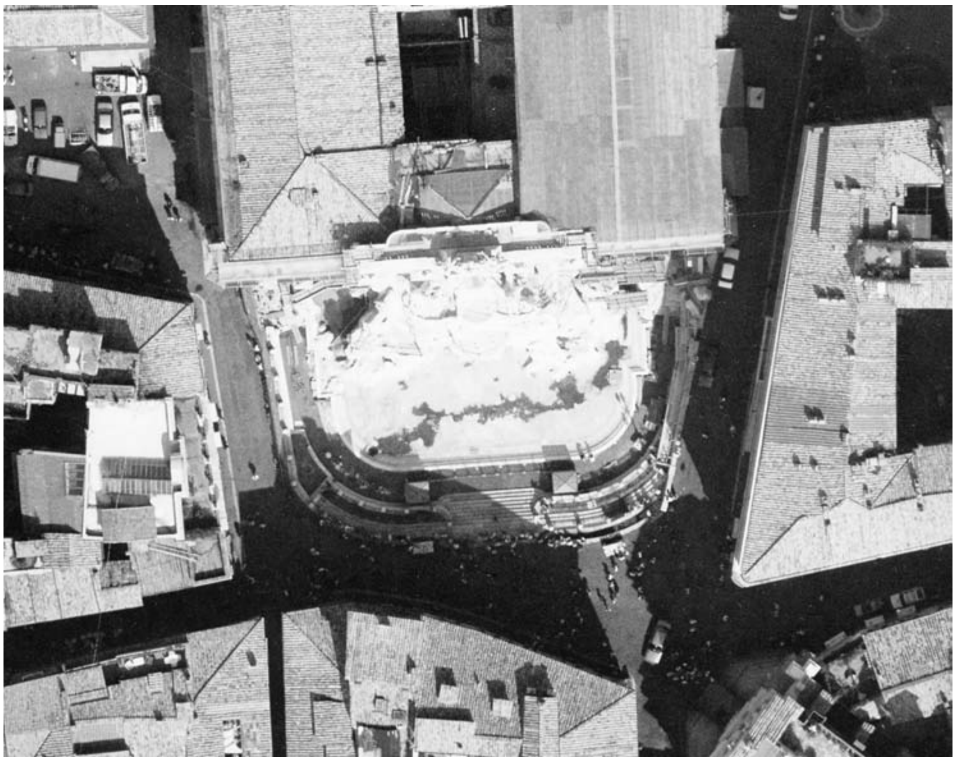
This is your first visit to the Eternal City of Rome and, with guidebook and map, you plunge into its historic center. The goal is the Trevi Fountain, one of Italy's most famous landmarks. The trek can be daunting. Myriad small piazzas are connected with narrow streets, twisting this way and that, cars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



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 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.

More about the Stone Used in the Trevi Fountain

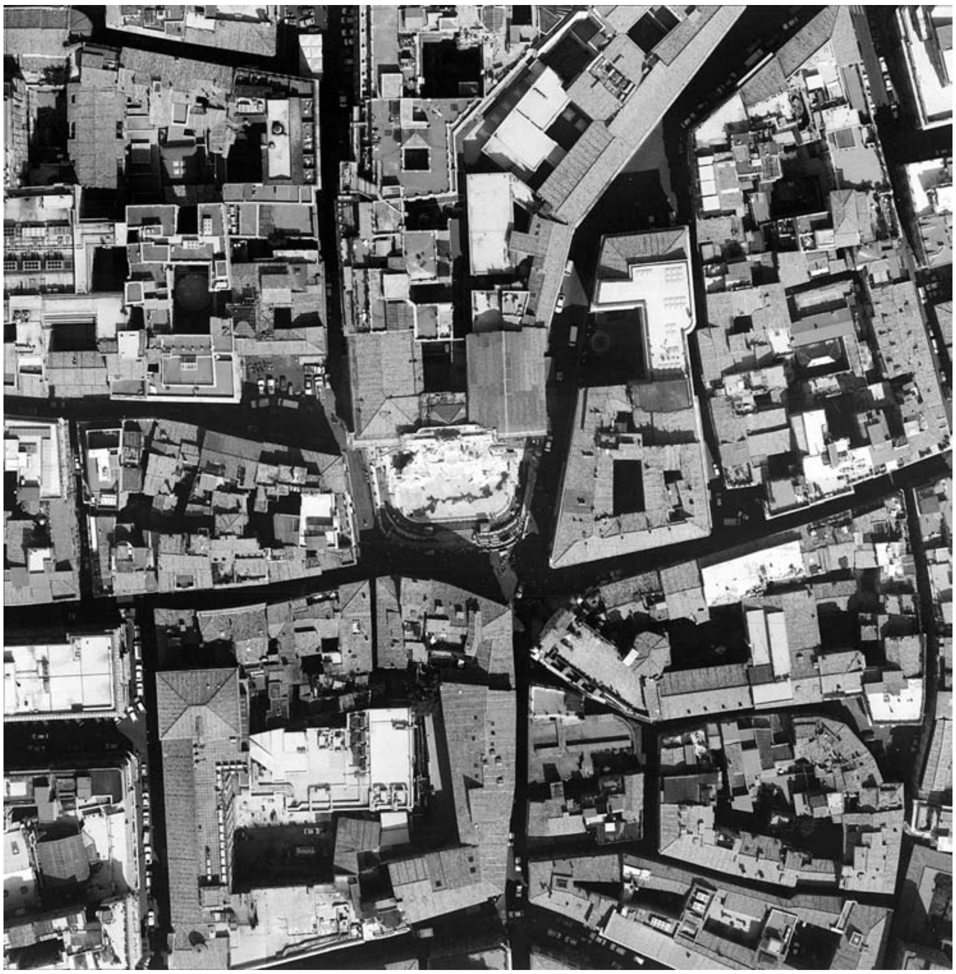
Peter Rockwell, an American sculptor living in Rome, is an expert on the history of stone carving. When he analyzed the features, sculpting techniques, and construction of the Trevi Fountain, he found that the fountain is 89.2 percent travertine, 7.2 percent marble, and 3.6 percent travertine breccia. 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



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.

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-

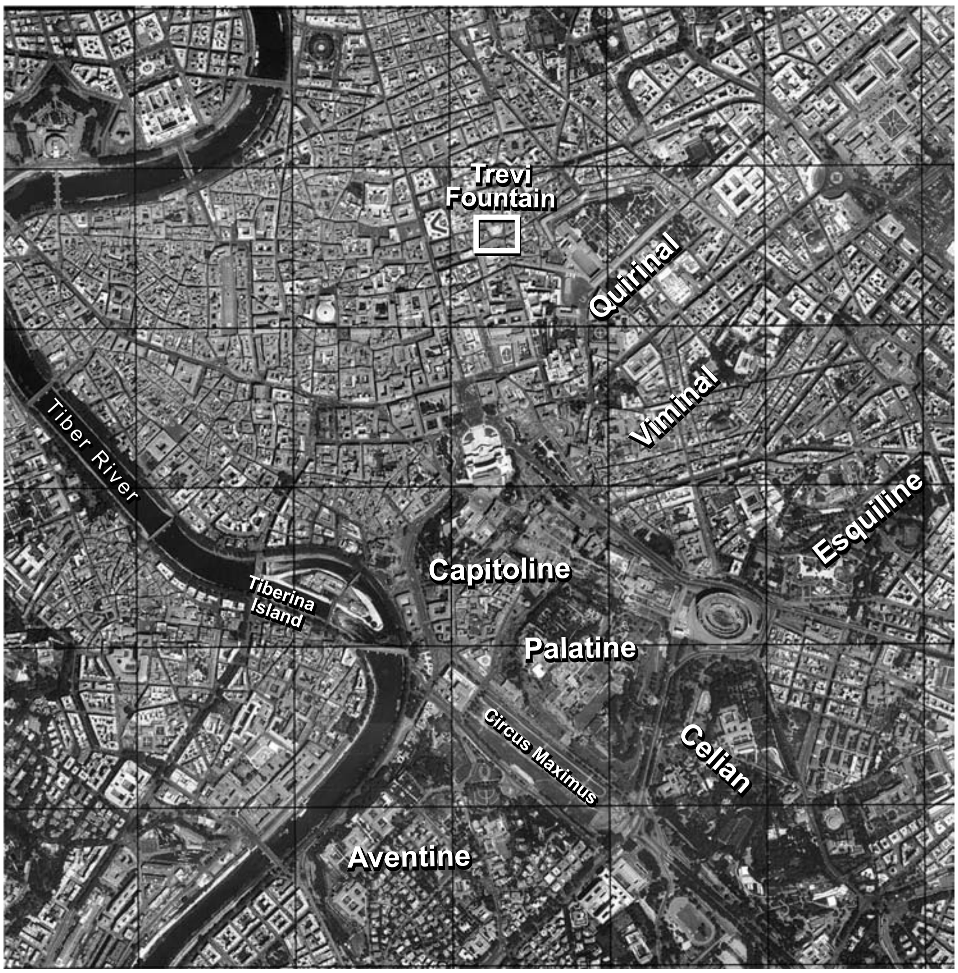
square-kilometer (3.5-square-mile), densely packed city center with its varied, complex history in a single week would challenge even the most dedicated tourist. From this vantage point, however, the geologic framework of the city becomes more understandable.

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, Celian, 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.

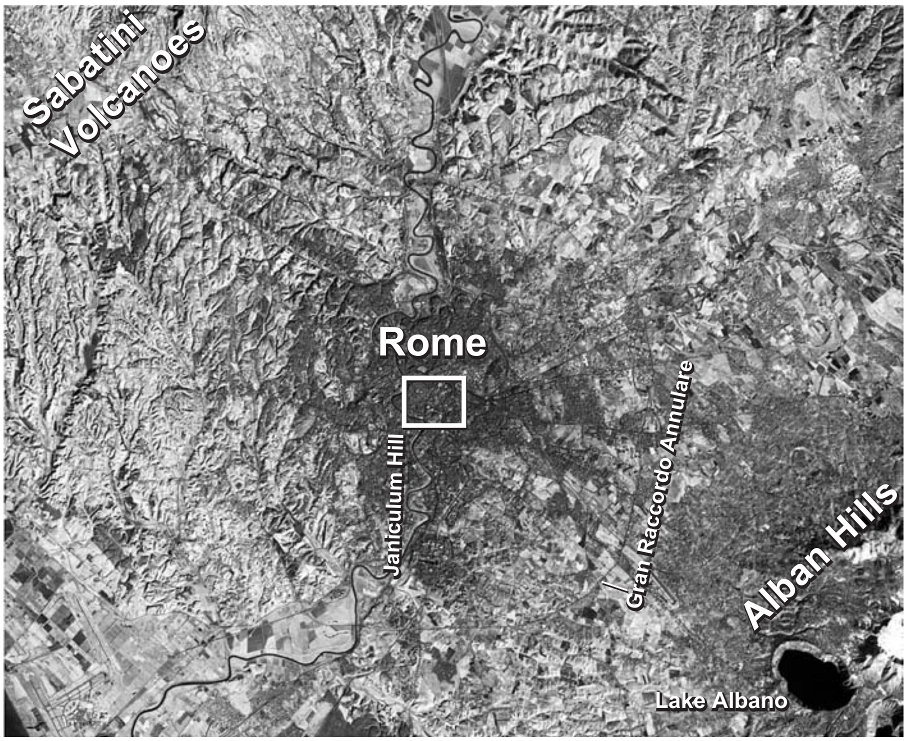
Development of a densely packed city on the Tiber floodplain began during medieval times. The plain, once occupied chiefly by Roman theaters, temples, and army training facilities—all easily cleaned (and repaired) after a flood—now began to accumulate homes and businesses as well. Floods submerged such 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



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 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.



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.