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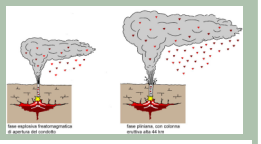


Eruption styles in order of increasing explosivity. Source: INGV. See p. 9.

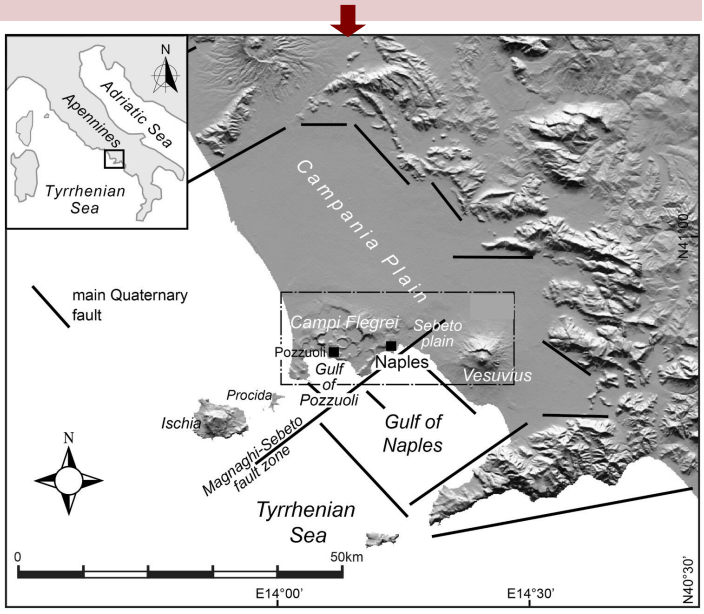
In our newsletter you can read about topics relatde to geography, geology and our natural environment. Comments are welcome!

An unknown volcanic complex in Italy

In 2023, significant concern emerged in Italy regarding increased seismic activity in the Campi Flegrei volcanic complex, located near Naples. This situation brought attention to the potential hazards and complex tectonics associated with this relatively unknown supervolcano. In this issue an update through 2024...

Sketch map, presenting essential details of the volcanic area of Campi Flegrei and Vesuvius with indication of the main fault zones (black lines). Location on the inset map: Campania Plain coastal 'graben', a depressed crustal block, bordered by parallel normal faults. The frame indicates the location of the satellite view on page 2. Source: A. Ascione et al. 2020.

Yellow tuff, Campi Flegrei. Source: Yiftah-s via Wiki Commons CC BY-SA 3.0.



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Campi Flegrei: active volcanic complex near Naples

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The Campi Flegrei ('burning fields') or Phlegrean Fields made Neapolitans restless since the summer of 2023. They live *in* the largests active caldera in Europe, comprising numerous craters, fumaroles and lakes.

There´s a continuous stream of information about the volcano. Some aspects are still under debate within the scientific community. On these pages both will be adressed.
Campi Flegrei, a nested collapse structure, covers an area of about 15 miles across in the Campanian region. It extends west from the outskirts of Naples to the Tyrrhenian Sea. About a third is submerged beneath the Bay of Pozzuoli.
In 2023 earthquakes started to be felt. Since then, over 1,100 quakes have been recorded. In May 2024 a 4.4 magnitude tremor shook the region, the strongest in 40 years, according to the National Institute of Geophysics and Volcanology (INGV). Will the Campi Flegrei come back to life after almost 400 years of dormancy?

Densely populated area

The peculiar landscape attracted human settlements since Neolithic times and hosted the first Greek colony Cuma and the Roman town Puteoli (Pozzuoli). Different geomorphical units, such as coastal plains, with volcanic cones, are still detectable (see map, previous page). Geoarchaeological records and historical chronicles attest to man's coexistence with eruptions, ground movements, shoreline changes, floods and landslides. Today more than 360,000 people live *in* a caldera. Guidelines for the safety of residents and visitors, monitoring for earthquake resistance of buildings, and protocols for dealing with potential pyroclastic flows and other volcanic hazards have been renewed.

Two major eruptions

The Campi Flegrei caldera formed through a collapse related to the major Campanian Ignimbrite eruption (about 39,000 years ago). Magma was emplaced as pyroclastic currents and flow deposits, in Italy and beyond, as far away as in Athens and Kiev.
A second major eruption, the Neapolitan Yellow Tuff eruption (about 15,000 years ago), deposits thick outcrops, forming a smaller caldera, the currently active portion, inside the main caldera.

Satellite view (location, see map on p. 1) of the Campi Flegrei area, with the indication of locations of the quarters of the Naples urban area, main towns of the metropolitan area (yellow characters) and main toponyms (white characters). The white line delimitates Naples municipality. A. Ascione et al. 2020.

Eruptions and quakes

In the past 12,000 years volcanism and deformation of the caldera floor has been very intense. Many explosive mini-volcanoes have erupted. The Solfatara (near Pozzuoli) still emits gases.
The Monte Nuovo cone was generated during the most recent major eruption (1538). Over the past 70 years tens of thousands of smaller earthquakes have occurred.

Ground movements

The volcanic activity is concentrated in and around the town of Pozzuoli, with several craters in the area. Experts say that the new unrest is related to periodically slow ground movements, so-called bradyseism, which they first demonstrated in the supervolcano.
Since pre-Roman times, the caldera has shown a background trend of slow subsidence (1–2 cm per year), interrupted by episodes of faster ground uplift, and volcano-tectonic seismicity.
As a result, over the centuries, Pozzuoli's position above sea level has risen and fallen several meters.

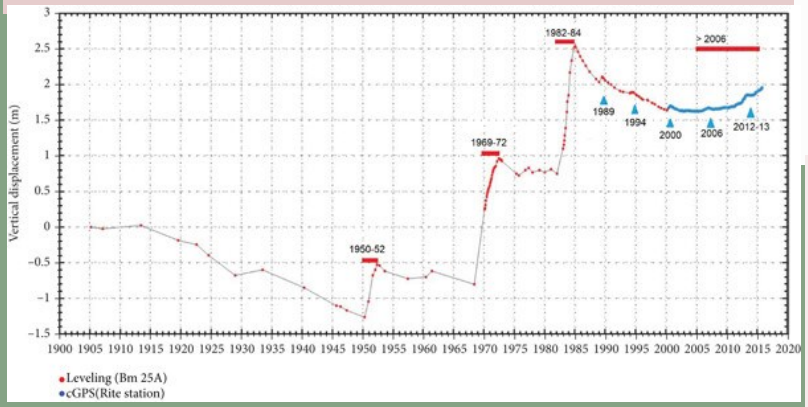
Bradyseism

Between 1538 and 1950 a long period of subsidence ensued. A phase of rapid uplift of about 0.8 m started, followed by about twenty years of subsidence, that lasted until 1969 (see table).
Two other dramatic bradyseism phases occurred: in 1969–1972 and 1982–1984. Both starting with uplift followed by an amount of subsidence that did not balance the preceding uplift. More than 10,000 light earthquakes and damage to buildings led to the temporary evacuation of 40,000 residents.
A new phase of slow uplift began in 2005 and continues to the present time. . Pozzuoli has raised up to 4 meters. Volcanologists need to understand this, to make better predictions.

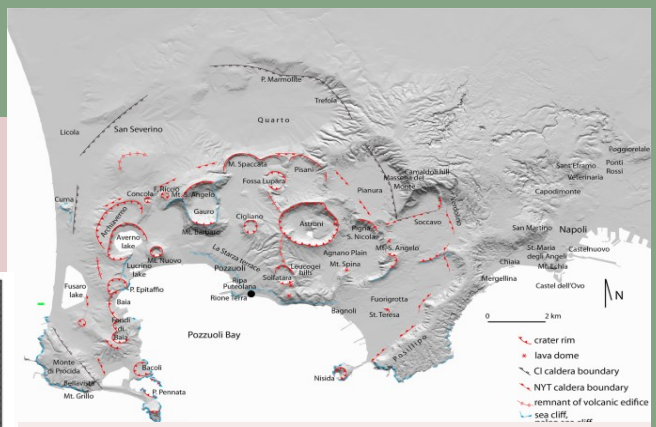
Now and in the future

If the current trend continues, an eruption could follow, with devastating consequences for Italy and beyond. But this is a worst-case scenario. Slightly explosive eruptions are possible, however.

Fumaroles, Solfatera. Source: Norbert Nagel via Wikimedia Commons CC BY-SA 3.0.



Ground displacement of Pozzuoli Porto since 1905 measured by precision levelling (until the year 2000 in red) and the close GPS benchmark of Rione Terra (since 2000, blue dots). Lima, A. 2021.



Map of the Campi Flegrei caldera and the Campanian area with collapse structures that formed during the first (outer, black scarps) and second major eruption (inner, red scarps). Costa, A. 2022.

Magma dynamics

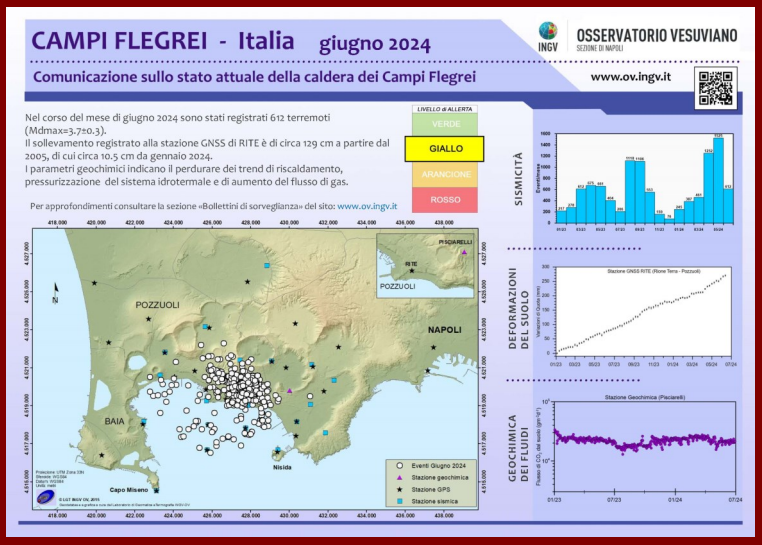
Scientific opinions differ about the cause of the unrest and its outcome. Large volcanic calderas can take decades or more to return to activity after centuries in repose. Their reawakening frequently triggers several, intermittent episodes of seismic activity and associated ground deformations, before magma erupts. Several theories have been proposed for the origin of the past volcanism and bradyseism.

Fracture model

The driving mechanism for the accelerated ground uplift can be attributed to an emplacement of magma at shallow depth. A study by the University of London and INGV has revealed that parts of the volcano have been stretched to almost breaking point, confirming scientists' prediction that the structure of its crust is changing and may make the volcano more prone to eruption. The most recent rupture developed between 2013 and 2023. The rate of local volcano-seismic earthquakes evolved from an exponential to a hyperbolic increase with time.

Researchers used a model of volcano fracturing to interpret earthquakes and ground uplift. Although a few times fractures were almost there due to ground lifting, nothing indicates that an eruption is near, say most volcanologists. The uplift, currently at 1.5 cm per month, does raise concerns about the impact on buildings. Besides, ground movements led to only mild eruptions in the near past. Other volcanologists suggest a hydrothermal model is more consistent with the bradyseism phenomenon. The post-1985 ground deformation can be described as a response to changes in fluid content and pressure in a shallow hydrothermal reservoir, a new study found.

In an active volcanic system hosting a wide hydrothermal circulation, both magmatic and hydrothermal fluids could be responsible for the observed ground displacement.



ALERT LEVEL YELLOW: The Vesuvian Observatory's monitoring system reveals some variations in the state of activity of the Campi Flegrei.

June 2024 monthly record: 612 light earthquakes were recorded. Since mid-April 2024, the average value of the lifting speed in the area of maximum deformation is about 20.3 mm/month at the Rione Terra GNSS station (RITE). The uplift recorded is about 129 cm since November 2005, of which about 10.5 cm since January 2024. Source: INGV.it.

Monitoring

The INGV closely monitors earthquake waves, ground deformations, gases and liquids in the fumaroles. If necessary, the population is alerted (see information above).

The INGV regularly reports on the state of Campi Flegrei on the website of the Vesuvian Observatory, part of the INGV (Vesuvius Observatory - Campi Flegrei - Current Status; ingv.it). Currently code yellow is in effect: *activity of the volcano slightly higher than normal.*

Plate tectonics and major plate boundaries. Red: divergence. Blue/purple: convergence, resp.subduction/ collision. Green:transform. Source: M.Bitton via Wiki Commons CC BY-SA 3.0.

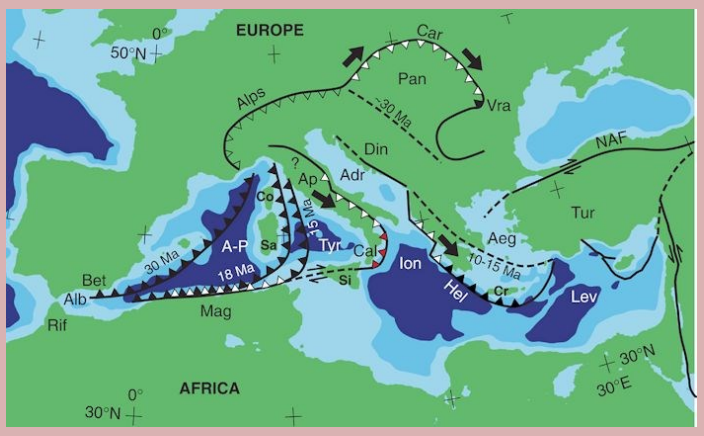
Double Trouble

Italy's position on plate margins

As a result of the long-standing position along plate margins, Italy is a full-featured complex and active volcanic–tectonic region: highly earthquake prone as well as facing multiple large, dangerous, currently active volcanic systems. Complete with an active supervolcano.

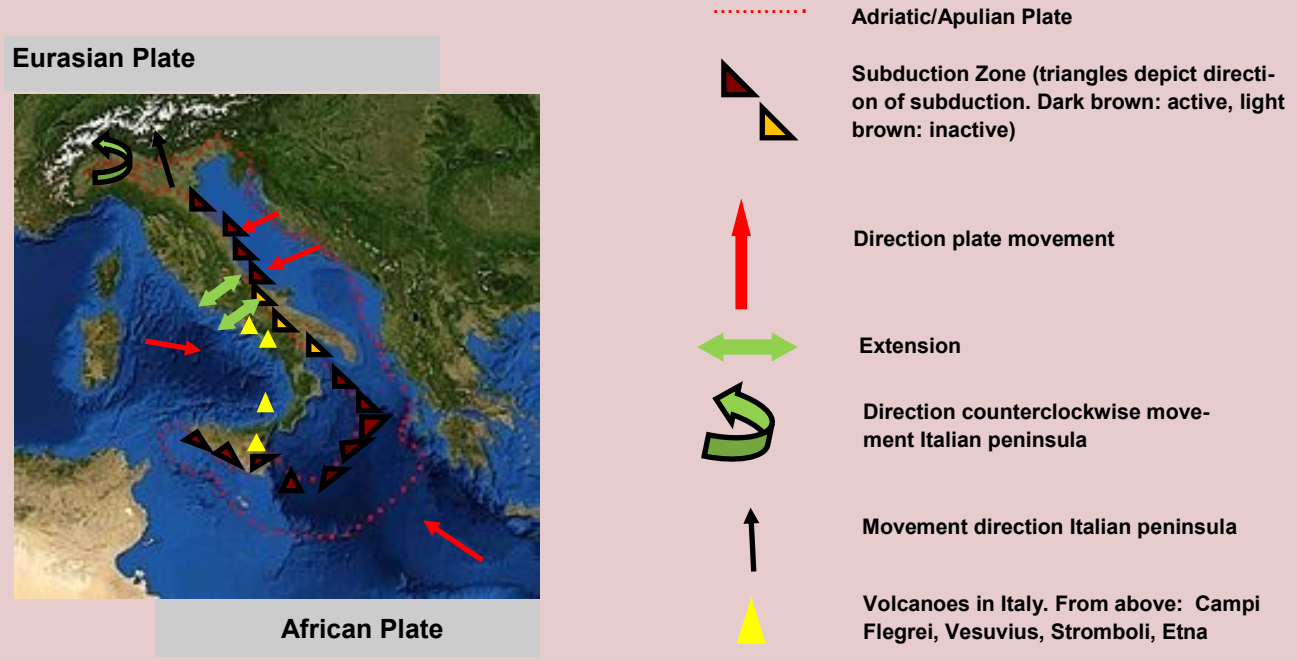
The margin of the African and Eurasian tectonic plates runs through the centre of Italy. Tectonics are driven by the ongoing collision with oceanic crust subducting under continental crust just to the east of Italy, since the early Cretaceous.
In the eastern Mediterranean Sea multiple microplates were jostling. The plates started rotating as one bumped against each other. The Adriatic/Apulian Plate may have originally be-longed to Africa but is now viewed as an independent microplate in the collision zone.

Subduction
During tens of millions of years the Adriatic/Apulian Plate runs the length of the Adriatic Sea, curving down and around Italy and Sicily. This platelet is subducting under the main portion of the Eurasian Plate.
The Adriatic/Apulian Plate ('Adriatic' is usually used when referring to the northern part, 'Apulian' refers to the southern part, added during the Permian) was deformed during the Alpine Orogeny, when the plate collided with the Eurasian Plate.
In the Eocene the rate of convergence almost stopped, and the direction changed from NE to NNW. The Alps were formed as the Adriatic/Apulian Plate overrode the Eurasian Plate and created a vast fold and thrust belt of mountains.
The Adriatic/Apulian Plate is thought to still move independently of the Eurasian Plate in a NNE direction, with a small component of counter-clockwise rotation.



Microplate rotation in the Eastern Mediterranean Sea from the west to the east and relative motion along boundaries. Three lines left of Italy: relative locations of slab rollback of the Adriatic Plate, 30 Ma (farthest west), 18 and 15 Ma. Current location is to the east coast and bends south around Italy and Siciily. Triangles depict direction of subduction. Wortel/Spakman, 2000.

The Adriatic/Apulian Plate (currently covering the Adriatic Sea, Istria, the eastern Italian Peninsula, Malta, and the coastal part of Slovenia) and movement underneath Italy with location of volcanoes. Source: Wikipedia/ Geopress.



Extension

The Adriatic/Apulian Plate plunges westward below the Apennines. The Apennines were built by subduction of the microplate under Italy. The mountains are described as an accretionary wedge (forms from sediments accreted onto the non-subducting tectonic plate) along the subduction hinge of the Adriatic/Apulian and Ionian microplates.
The hinge has moved some 700 km to the east over the last 23 million years. The subduction was so steep that slab rollback beneath Italy is thought to be taking place. The plate thus moved ever more eastward.
The scraped sediment from the African Plate was piled up into a mountain range.

The rotation of the peninsula created horizontal pressure, allowing the Apennines to grow, against the forces of gravity. This created extension and a 'bac arc basin', the Tyrrhenian Sea. Crustal thickness in the middle of the sea basin is less than 10 km. The stretching brings up deeper magma.

Double Trouble

Double trouble for Italy: Situated on the margins of the Tyrrhenian and Adriatic/Apulian Plate, microplates between the African and Eurasian Plate. One is moving eastward and the other in a southwesterly direction. Due to the subduction zone according to the 'slab roll back' principle, for million of years from now many volcanoes occur in the southwestern part of Italy. Stretching of the Thyrrhenian Plate allowed the Campi Flegrei to erupt.
During subduction and metamorphic dewatering of the oceanic crust, fluid-induced melting of the mantle wedge occurs at a depth of 100 km, and magma is formed.
Magma formed above a subducting plate, slowly rises into the overriding crust and finally to the surface.
Some remains in the earth's crust, but the deep fractures at the site offered the magma a way up, as in the eruptions of the Campi Flegrei, located west of the subduction zone.

Aemilia de Koningh/Geopress

Noordelijke Apennijnen. Bron: Geopress.

Cradle of volcanology

Modern volcanology has most of its origins in Italy .

The eruption of Mount Vesuvius in 79 A.D. provided the earliest detailed eyewitness account of a volcanic eruption in recorded history, as described by Pliny the Younger to the Roman historian Tacitus. This account has been instrumental in shaping the understanding of volcanic phenomena and terminology. The descriptions of the eruption (iconic pine tree-shaped cloud) have become the basis for classifying certain types of explosive volcanic eruptions ("Plinian eruption"). The Strombolian eruption refers to mild blasts.

Living close to volcans and research for centuries, made the Italian language an important source for worldwide used volcanic terms:

Lapilli: Small rock fragments ejected during an eruption
-Fumarole: An opening in the earth's crust emitting hot gases and vapors
Solfatara: A type of fumarole that emits sulfurous gases
Volcano: Derived from Vulcano (one of the Aeolian Islands).

A. de Koningh

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Greater Adria

Recently geologists from various countries have reconstructed the evolutionary history of the mountain ranges and seas in the Mediterranean region. The research reveals how a piece of continental crust, that once separated from North Africa, plunged into the earth's mantle under Southern Europe. “Most mountain chains that we investigated originated from a single continent that separated from Africa about 240 million years ago,” according to principal researcher Van Hinsbergen, professor of Global Tectonics and Paleogeography at Utrecht University's Department of Earth Sciences in a press release.

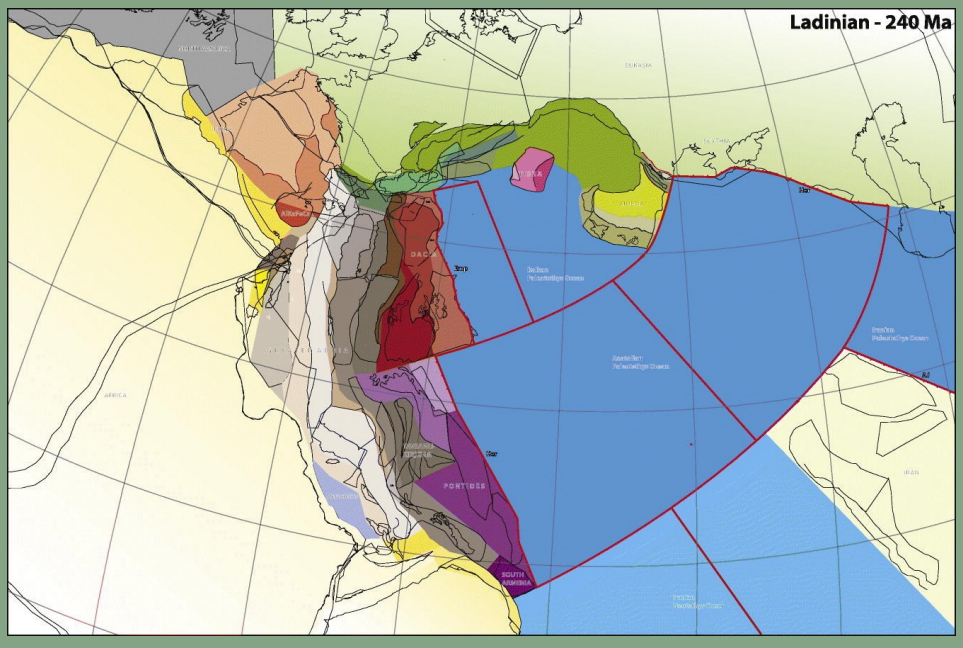
Scientists believe the landmass started to move northward, and what they gave the name ´Greater Adria´, shoved beneath the continent into several subduction zones. Most of this continent was situated underwater and formed shallow, tropical seas in which sediment deposited, for example in large coral reefs. Van Hinsbergen: “The sedimentary rocks were scraped off when the rest of the continent subducted into the mantle. These scrapings are now the mountain belts of the Apennines, parts of the Alps, the Balkans, Greece, and Turkey. The only remaining part of this continent is a strip that runs from Turin via the Adriatic Sea to the heel of the boot that forms Italy.” The small tectonic Adriatic or Apulian Plate, carrying primarily continental crust, is considered a still-existing remnant or part of the historical, largely vanished continent.

The reconstruction, based upon GPlates software, started with entering thousands of pieces of information from the literature about movement in the earth, such as fault lines and magnetism stored in the rocks.

Animation of the Mediterranean region, from today until about 240 million years ago:
Greater Adria formation and destruction: Mediterranean Plate Tectonics. - YouTube

Source: Mountain range formation and plate tectonics in the Mediterranean region integrally studied for the first time, Douwe van Hinsbergen et al. Utrecht University, News, 2-9-2019.

Aemilia de Koningh/Geopress



Reconstruction of the Mediterranean region, about 240 million years ago. Shades of dark brown indicate parts of what would become the North African coast, which would break up to form the microplate continent Greater Adria. Yellow: Africa. Green: Eurasia. Blue: Tethys Ocean. Source: D. van Hinsbergen, et al. via Wiki Commons. CC BY-SA 4.0.

Roadtrip from Puglia to Campi Flegrei

Road trip from Bari to Napels, across the inactive subduction zone and Apennines to Campi Flegrei and Vesuvius. Source: Wikipedia/Geopress.

The micro-continent Greater Adria existed for about 100 million years before being mostly subducted under southern Europe. The subduction process scraped off the top layers of the plate, creating mountain ranges and leaving behind geological features that are still visible today in a region like Apulia and in he Apennines.

Drive by car from Bari to Naples on the A16 Autostrada, also known as 'The Two Seas Highway' across Southern Italy, from the Adriatic coast in the east (Bari) to the Tyrrhenian coast in the west (Naples).

This journey not only offers a scenic drive but also a unique opportunity to witness the relative intact remains of the geological history of a vanished continent, from the limestone landscapes of Apulia to the volcanic terrains near Naples (2.5 hours).

Bradanian trough (retreated fault plane = red dotted line) and the highlands of the subregion Murgia, Puglia. Source: M. Tropeano, et al. The Murge and Premurge areas are planned to be a UNESCO Global Geopark.

Start: where the A16 begins, near Canosa di Puglia, where it branches off from the A14 autostrada. The route traverses the southern Apennine mountains, offering scenic views of the Italian countryside. The A16 terminates in Naples, specifically at the "Napoli est" (Naples east) exit.

Start: Bari, A16

The route starts in the hilly limestone region of Apulia, formed from ancient coral reefs uplifted above sea level. This area was once an archipelago of islets created by the subduction of Greater Adria under the Apennines.

Flatter Area: Bradanic Trough

Continue over the flatter terrain of the Bradanic Trough, a former deep-sea trough that silted up during the Pleistocene, around 500,000 years ago. This area, now part of the Apulian landscape, features fields of grain and windmills, marking where the Adriatic/Apulian Plate plunged into the depths.

Crossing the Bradanic Trough

The Bradanic Trough, once a deep sea trench, has risen above sea level and is now part of the southeastern tip of Italy. This region offers a unique view of the geological transition from sea to land.

Irpinia and the Apennines

Drive through Irpinia, a region characterized by the high mountains of the Apennines. This area showcases the dramatic uplift of the terrain due to the subduction of the Adriatic/Apulian Plate, which contributed to the formation of these mountains.

Descent to Naples

Finally, descend towards Naples, where the landscape is dominated by volcanic activity. Mount Vesuvius lies southeast of the city, and the Campi Flegrei volcanic area is located to the northwest.

Aemilia de Koningh

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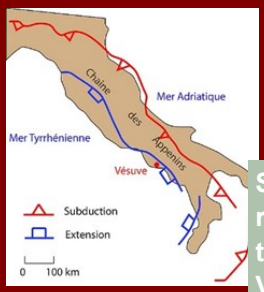
Italy's Big Three

The magma erupted by Italy's volcanoes is thought to result from the upward forcing of rocks melted by the subduction of one plate below another.

Eruption of Mt. Vesuvius on a drawing from 1822. Source: Wikipedia.

Famous Italian volcanoes and their relation to tectonic plates:

Mount Vesuvius



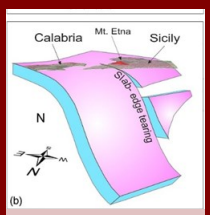
Schematic representation of the Vesuvius. Source: S. lenard via Wikimedia Commons CC BY-SA 4.0 .

Nowadays Mount Vesuvius is a stratovolcano reaching a height of 1,281 m in the caldera of the ancient Somma volcano, whose summit collapsed (likely during the 79 AD eruption). The younger volcano has regrown inside and formed a new cone. In 79 A.D. after a century-long slumber, Vesuvius woke up with a Plinian eruption, that buried several Roman towns, like Pompeii, under several meters of ash. Excavated parts of these cities allow us to have an excellent view on Roman life and culture, frozen in a moment.

The explosive volcano, created by subduction, is situated on the overshifting European Plate. The subducting Adriatic/Apulian Plate is melting at depth. Volcanologists do not consider it likely that the volcano will 'awaken' this century.

Mount Etna

Mount Etna is a shield volcano, rising to a height of over 3 km above sea level in the Mediterranean, formed at least 300.000 years ago. A stratovolcano formed on top of it.



Schematic of suspected slab tear powering Etna Bron: G. Barecca et al. (2020)

The volcan lies atop a slab-edge tear faulting at the margin of a subduction system *on* the plunging African Plate. It's origin is currently best explained through the deep and vertical tearing in the lithosphere caused by the dynamics of slab retreat at the southern edge of the Ionian subduction zone. The volcano is situated above a slab window, created by differential rollback of the subducted oceanic plate, essentially creating the tear in the slab. Extension due to rollback subduction occurs.

In 2023 the Etna blew strikingly beautiful rings into the sky. A new crater and calm weather conditions were the cause. August 2024 the volcano has begun erupting, spewing ash above Sicily and temporarily halting flights.

Stromboli

Stromboli one of the Aeolian Islands, is a stratovolcano. The explosive volcanic arc originated behind the subduction zone, south of the Tyrrhenian Sea. A part of the oceanic crust and the sediment lying on it plunges under the continental plate there. Stromboli 's almost continuous eruption for the past 2,000–5,000 is famous. Only mild blasts, a pattern of Strombolian eruption.

Amilia de Koningh

Aeolian Islands. Source: Wikipedia.

The Apennines: seismically active

The Alps and Apennines are the two belts that shaped Italy since the Cretaceous (Alps) and Ecocene-Oligocene (Apennines).
The mountains of Italy are of paradoxical provenience, having to derive from both compression and extension.

The Apennines are a mountain range of parallel smaller chains, extending 1200 km along the length of peninsular Italy. The range is divided into the northern, central, and southern Apennines.
Before the year 2000, the approach was that the Apennines had the same origin as the Alps. Even today, some authors use the term 'Alpine-Apennine system'. However, the Alps were millions of years old before the Apennines rose from the sea. The mountain belts are associated to two opposite subductions.
In essence the east side of Italy features a fold and thrust belt raised by compressional forces acting under the Adriatic Sea.
In the western part of Italy fault-block mountains prevail, created by spreading or extension of the crust under the Tyrrhenian Sea. The paradox of how contraction and extension can occur simultaneously in convergent mountain belts, remains a fundamental and largely unresolved problem in continental dynamics.
Compressional forces have been acting from north to south in the Alps and from south to north in the Apennines. But instead of being squeezed into mountains the Po valley in Northern Italy has been subsidizing since about
25 million years ago, before the Apennines existed. It is a filled portion of the Adriatic Trench, called the Adriatic foredeep after its function as a subduction zone was discovered.
While the Alps sandwiched the whole crust of both Eurasian and African Plates, the Apennines rather developed by the accretion of the upper crust of the lower plate alone.The dipping Adriatic/Apulian Plate below the Thyrrhenian Plate pushes up and folds the Italian part of the Thyrrhenian Plate

Central Apennines

The present-day geological setting of the Central Apennines region is the result of the complex oblique collision between the Eurasian and African Plates related to the closure of the Thetys Ocean during the Permian - Cenozoic, where the plates meet and constantly grate against each other creating seismic and volcanic tension. Etna, Stromboli, Vesuvius and Campi Flegrei lie close to this fault.
In addition, Italy has a series of smaller fault lines, particularly along the Appenine Mountains.
Relatively shallow earthquakes are fairly common along the entire length of these mountains due to the number of faults which run along the range, which can rupture and cause earthquakes. Movement on one of the many faults *can* lead to a bigger one.
Because Italy now barely rotates, horizontal pressure has decreased. Gravity and stretch on the contrary are dominating. The suspicion rose that the mountain range is collapsing under its own weight.
Since 1950, more than 6,700 people died by the direct consequences of earthquakes in Messina (1908), Irpinia (1930, 1980) and L'Aquila (2009). The last major one in 2016 was in and around Norcia and Amatrice (respectively 6.3 and 6.2 on the Richter scale).

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Apennines, divided mountain range. Source: Wikipedia.

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The editors have a broad journalistic and editorial background related to these themes.

Coming up soon:

Roman Fountain on Crete - Bad chestnut harvest - The middle - class city - Bicycles in Levanto/Italy - Serpentinite

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