IESO 2026 TURIN

WRITTEN TEST 2 — THE LAND THAT RISES

Risk and surveillance in an active caldera

Time: 80 minutes • Questions: 35 • Score: 35 points • Read all the data before answering. Only one correct answer for all questions.

SECTION A: VOLCANIC SYSTEM AND BRADYSEISM — Questions 1–9

The Campi Flegrei (CF) are an active volcanic area west of Naples, comprising the municipalities of Bacoli, Monte di Procida, Pozzuoli, Quarto, Giugliano in Campania and part of the city of Naples. The name, from the Greek for "burning fields", reflects the volcanic nature of the area and the presence of numerous fumaroles and thermal springs, known and exploited since antiquity.

Unlike Vesuvius, the CF do not form a single volcanic edifice but a volcanic field with several eruptive centres within and around a depression called a caldera. The caldera resulted from the repeated collapse of the roof of the shallow magma chamber following its emptying during at least two large eruptions: the Campanian Ignimbrite eruption (Ignimbrite Campana, IC event 40,000 years ago) and the Neapolitan Yellow Tuff (Tufo Giallo Napoletano, TGN event 15,000 years ago). The IC event is the most energetic known in the Mediterranean: an enormous quantity of ash was dispersed into the atmosphere, affecting climate at a regional and probably global scale.

The post-TGN eruptive history includes at least 70 eruptions that occurred in three epochs of activity (15,000–10,600 / 9,600–9,200 / 5,500–3,800 years ago) separated by long periods of quiescence and deflation. The last eruption, in 1538, produced the Monte Nuovo cinder cone.

The Campi Flegrei area undergoes slow ground deformation called bradyseism ("slow movement of the ground"). The historical record has been reconstructed thanks to the Serapeo of Pozzuoli, a Roman market of the 1st–2nd century AD: the borings of marine molluscs (lithodomes) at different heights on the three surviving columns record the ground oscillations relative to sea level over the centuries. Some more recent events (all with no eruption) are:

- the 1969–1972 crisis, with a maximum uplift of ~170 cm;
- the 1982–1984 crisis, with an uplift of ~185 cm in 2.5 years (~40,000 people evacuated);
- current period (2005-ongoing), uplift ~110 cm measured until 2024.

[Figure 1: Serapeo of Pozzuoli — on the right: boring of lithodomes]

Table 1 — Bradyseism parameters 2020–2024

Year	Uplift (cm/yr)	Quakes (events/yr)	Hypocentre depth, average (km)	Fumarole T (°C)	Cumulative uplift from 2005 (cm)
2020	~8	~850	2.8	~95	~65
2021	~10	~1,200	2.9	~98	~75
2022	~11	~1,800	3.1	~102	~86
2023	~12	~2,400	3.3	~106	~98
2024	~12	~2,680	3.5	~110	~110

Question 1
Analyzing the 2020–2024 data in Table 1, which relationship is best supported between ground uplift and seismicity?

A. Ground uplift increased while seismicity showed no consistent long-term trend.
B. Ground uplift increased while seismicity remained approximately constant.
C. Ground uplift and seismicity both showed an overall increasing trend.
D. Seismicity increased more rapidly than ground uplift.

Question 2
During the 1982–84 crisis, uplift reached ~90 cm/yr without an eruption, whereas the current uplift rate is ~12 cm/yr. Which conclusion is best supported by these observations?

A. Higher uplift rates indicate an imminent eruption.
B. Lower uplift rates indicate a declining volcanic system.
C. Ground deformation is not sufficient for eruption forecasting.
D. Ground deformation is sufficient for eruption forecasting.

Question 3
Bradyseism at Campi Flegrei results from interactions among Earth systems. Which interpretation best explains these interactions?

A. Geosphere processes drive hydrothermal fluid circulation, which influences surface degassing and atmospheric emissions.
B. Geosphere processes are controlled mainly by regional tectonics, with only limited influence from hydrothermal fluids.
C. Atmospheric processes drive hydrothermal circulation, which in turn controls ground deformation.
D. Hydrothermal fluid circulation controls magma generation, which drives deformation of the volcanic system.

Question 4
GPS measurements show the ground moving simultaneously upward and outward in all directions, with the maximum displacement at the center (Rione Terra). This deformation pattern is most consistent with:

A. A pressure source at depth expanding in all directions.
B. Progressive collapse of the caldera floor toward its center.
C. Regional compression producing uniform uplift across the caldera.
D. Regional tectonic displacement affecting the entire Campania region.

Question 5
Post-TGN activity produced intense eruptions in different epochs, separated by long quiescences. A volcanologist must assess the current state of the system. Which interpretation is best supported by the geological evidence?

A. Current bradyseism at CF allows a defined timing of the next eruption to be predicted.
B. Past epochs indicate that future reactivation follows a predictable cycle.
C. The current lack of eruptions demonstrates progressive exhaustion of the magma reservoir.
D. The current lack of eruptions does not indicate that CF is extinct.

Question 6
Before the Monte Nuovo eruption (1538), strong ground uplift was observed, followed by subsidence during the eruption. Which process best explains this sequence?

A. Accumulation of erupted material created the new mount, which then isostatically sank deeper.
B. Pressure from intrusive material before the eruption was released as magma erupted.
C. Progressive recharge of the magma chamber caused uplift followed by contraction as magma moved deeper.
D. Regional tectonic movement first uplifted and then lowered the caldera floor.

Question 7
Based on the information provided about recent bradyseismic crises at Campi Flegrei, which scenario represents the greatest socio-geological risk even without an eruption?

A. Damage to buildings and infrastructure from repeated earthquakes.
B. Flooding of coastal infrastructure, such as of the Pozzuoli harbour nearby.
C. Local accumulation of volcanic toxic gases (CO_2, H_2S).
D. Local slope instability after heavy rainfall.

Question 8
Based on the monitoring data presented, which combination of observations would indicate a transition toward a higher volcanic crisis state?

A. Slower ground deformation, increasing seismicity with lower hypocentre depths.
B. Stable ground deformation, constant seismicity, with formation of new surface faults.
C. Accelerating ground deformation, increasing seismicity, changes in fumarolic gas composition.
D. Reduced deformation, increasing shallow seismicity and increase in the amount of fumarolic gases.

Question 9
Based on the eruptive history described above, what might be the pattern of the whole Campi Flegrei caldera?

A. A superficial localization of a magma basin which moves vertically thanks to plasticity of the overlying layers.
B. A new independent magmatic reservoir that is slowly increasing its energetic content.
C. A hot spot that periodically receives influence from deep within the mantle.
D. A deep primary source of magma that periodically transfers material into shallower reservoirs.

SECTION B: MULTIPARAMETRIC MONITORING — Questions 10–18

The following table reports some of the most relevant parameters which are continuously monitored by the National Institute of Geophysics and Volcanology (Istituto Nazionale di Geofisica e Vulcanologia - INGV) networks.

Table 2 - Reference table (essential data).

(INGV) sites	Seismology stations: 27 sites; Geodesy system network: GPS/tiltmeters/tide gauges/InSAR*; Geochemistry stations: 6 sites; MEDUSA marine network (Monitoring Enel Ultramarine Data for Archaeological/Volcanic Sites); Pisciarelli (seismic+acoustic station)

*The GPS (Global Positioning System): Fixed antennas on the ground that measure horizontal and vertical movements of the ground to the nearest millimeter.
*Tiltmeters: Sensors inserted into small wells that measure the inclination of the ground. They function like highly sensitive levels: they detect whether the ground is "swelling" or "deflating."
*Tide gauges: Sensors positioned along the coast that measure sea level. As Pozzuoli rises and falls, the relative sea level on the coast changes; historic and modern tide gauges track this movement.
*InSAR (Satellite Interferometry Radar): Use of space-based satellites that "scan" the Campi Flegrei from above. By comparing radar passes over time, they create millimeter-level visual maps of the entire caldera deformation

Parameter	Value / Data	Field
Typical magnitude	M 0.5–2.5 (historical max M 4,7: 31/07/2026)	Seismicity
Hypocentral depth	0.5–4.0 km (tectonic > 5 km)	Seismicity
Dominant frequency	1–5 Hz, long-period (tectonic > 10 Hz)	Seismicity
Hydrothermal system	up to ~3 km; 350–400 °C at 2.5–3 km	Fluids
Main seismic zone	3–4 km	Seismicity
Alert levels	GREEN / YELLOW / ORANGE / RED - current: YELLOW	Civil Protection
Degassing	fumarole T 95→110 °C; H_2O 78.5→74.8%; CO_2 and SO_2 increasing; Solubility Sequence CO_2→SO_2→H_2O	Geochemistry

Question 10
Recent monitoring shows that periods of increased low-frequency seismicity coincide with intensified hydrothermal fluid circulation and increased fumarolic activity. Volcanic earthquakes at Campi Flegrei typically have frequencies of 1–5 Hz, whereas tectonic earthquakes usually exceed 10 Hz. Which interpretation best explains these observations in terms of Earth System interactions?

A. Regional tectonics are dominant compared to volcanic earthquakes.
B. Seawater infiltration in fractures reduces friction and generates lower magnitude earthquakes.
C. Atmospheric processes interacting with fumarolic activity increase magma fluidity.
D. Interactions between geosphere and hydrothermal fluids generate longer seismic waves.

Question 11
The brittle-ductile transition (BDT) in the Campi Flegrei caldera occurs at an unusually shallow depth, between 2.5 and 3.5 km, where the rock temperature reaches about 350°C - 400°C, at the lower level of the hydrothermal system (see Table 1 and 2 for details). Most earthquakes at CF typically occur at a 3–4 km hypocentre. Which interpretation best explains these observations?

A. The rocks below the hydrothermal system are more ductile, so they fracture less often.
B. Steam explosions produced by the hydrothermal system generate the deepest earthquakes.
C. Rock temperature has little influence on earthquake generation.
D. Surface monitoring cannot detect earthquakes within the hydrothermal system because of its buffering effect on waves.

Question 12
Recently, after hundreds of microearthquakes (M<2) in a few hours, an M 3.2 event occurred. What is the most plausible interpretation in the Campi Flegrei situation?

A. Possible fluid migration which accumulates stress with progressive fracturing.
B. A typical aftershock sequence preceding a previous main event.
C. Instrumental detection of deep magma movement preceding the main fracture.
D. An ordinary background activity for a volcanic area.

Question 13
Monitoring at Campi Flegrei indicates relations between ground uplift, hydrothermal fluid circulation, degassing, and earthquake swarms. Which feedback best explains these observations?

A. Degassing progressively reduces hydrothermal fluid circulation and seismic deformation.
B. Progressive loop enhancement of degassing, fluid circulation and deformation.
C. Degassing progressively suppresses ground uplift, which positively decreases internal pressure.
D. Surface processes such as degassing of the magma progressively reduce deep pressure and limit earthquakes.

Question 14
The options below correspond to the description of the four alert levels. Based on the monitoring information presented for Campi Flegrei, which description best matches the current alert level?

A. Parameters at background conditions: routine monitoring is maintained.
B. Significant acceleration of several parameters: potential pre-eruption conditions.
C. Persistent anomalies in different parameters: intensified monitoring and civil pre-alarm.
D. Parameters above background conditions: intensified monitoring but no measures activated.

Question 15
In the monitoring of Campi Flegrei, which parameter=information pairing is most appropriate?

A. Seismology=ground deformation; geodesy=fluid circulation; geochemistry=rock fracturing.
B. Seismology=ground uplift; geodesy=rock fracturing; geochemistry=fumarole temperature.
C. Seismology=rock fracturing; geodesy=ground deformation; geochemistry=fluid composition.
D. Seismology=magma movement; geodesy=seismic activity; geochemistry=fumarole gas composition.

Question 16
During the 1982–84 Campi Flegrei crisis, the average hypocenter depth increased from ~1.5 to ~2.8 km. Which interpretation is best supported by these observations?

A. The hydrothermal system migrated into colder, deeper rocks.
B. The brittle fracturing zone expanded to greater depths as pressure increased.
C. Improved seismic monitoring detected earthquakes that had previously gone unnoticed.
D. Regional subsidence progressively lowered the earthquake hypocenters.

Question 17
The MEDUSA marine infrastructure in the Gulf of Pozzuoli records seafloor deformation in the submerged part of the caldera. What additional information does it provide beyond the land monitoring network?

A. It distinguishes vertical from horizontal ground movement.
B. It determines the direction of deep marine currents influencing phreatic infiltration.
C. It improves reconstruction of the geometry and location of the pressure source.
D. It directly measures changes in magma temperature beneath the caldera.

Question 18
At the Pisciarelli seismic and acoustic station, detection of phases of ground uplift is accompanied by modified fluid circulation and gas release. Which description best explains the observed feedback?

A. Gas release progressively reduces pressure and suppresses further deformation.
B. Surface heating reduces deep pressure, limiting magma ascent.
C. Ground uplift boosts fluid circulation and degassing.
D. Surface degassing and deep pressure are independent processes.

SECTION C: GEOCHEMISTRY AND DEGASSING — Questions 19–25

Table 3 — Composition of fumarolic gases (Solfatara di Pozzuoli)

Year	H_2O (%)	CO_2 (%)	SO_2 (%)	CO_2/SO_2
2020	78.5	17.8	2.1	8.5
2021	77.2	19.1	2.3	8.3
2022	76.0	20.5	2.6	7.9
2023	75.2	21.8	3.1	7.0
2024	74.8	22.4	3.9	5.8

Question 19
Fumarole temperatures increased from 95 °C to 110 °C between 2020 and 2024 (See also Table 2). Which mechanism best explains this trend?

A. Regional climate warming increased ground temperatures throughout the area.
B. Superheated steam and hot gases coming from below pierce the shallow aquifer.
C. Oxidation of near-surface sulphide minerals generated additional heat.
D. Reduced rainfall caused by global warming reduced dilution by meteoric water.

Question 20
CO_2 is the least soluble of the main volcanic gases. If fumaroles show a sudden increase in CO_2 without corresponding changes in SO_2 and H_2O, which interpretation is most consistent with these observations?

A. Deep magma has begun releasing CO_2 before the more soluble gases.
B. Magmatic activity is declining and the CO_2 is being released by cooling rocks.
C. Magma is rapidly approaching the surface and volcanic gases such as CO_2 increase.
D. SO_2 and H_2O gases have been previously eliminated by volcanic processes.

Question 21
During a volcanic escalation, which sequence of geochemical changes in fumarolic gases is most likely?

A. Initial increase in CO_2, then in SO_2, then H_2O.
B. Rapid simultaneous decrease in the concentration of all volcanic gases.
C. Increase of atmospheric gases (O_2, N_2) drawn into the fractures.
D. Increase in H_2O as the first signal, followed by CO_2 and finally SO_2 in order of increasing solubility.

Question 22

Considering a large explosive eruption of Campi Flegrei (on the scale of the Campanian Ignimbrite, IC event), which Earth systems do the main volcanic gases (CO_2, SO_2 and H_2O) and aerosols directly affect?

A. Hydrosphere (water acidification) and Biosphere (toxicity of air and waters) on a local scale; Atmosphere (volcanic gas dispersion) on a possibly extensive scale; Geosphere (rock alteration) on a more global scale.

B. Atmosphere (volcanic gas dispersion), Geosphere (rock alteration), Hydrosphere (water acidification) and Biosphere (effects on living organisms) only on a local scale.

C. Atmosphere (climatic effects) worldwide; Geosphere (rock alteration), Hydrosphere (water acidification) and Biosphere (toxicity of air and waters) only on a local scale.

D. Atmosphere (climatic effects), Hydrosphere (water acidification), Biosphere (effects on living organisms) and Geosphere (rock alteration) on a possibly extensive scale.

Question 23

Based on the trends shown in Table 2, what does the observed decrease in H_2O and increase in CO_2 and SO_2 indicate?

A. The fumaroles are becoming exhausted.

B. The contribution of meteoric water is increasing.

C. The contribution of magmatic gases is increasing.

D. The hydrothermal system is cooling.

Question 24

In the geochemical cycle of volcanic carbon, which source of fumarole CO_2 is UNLIKELY?

A. Deep magmatic degassing.

B. Hydrothermal circulation.

C. Decarbonation of carbonate rocks.

D. Decomposition of organic matter.

Question 25

Gas trends shown in Table 3 register a progressive increase in both CO_2 and SO_2, but a progressive reduction in CO_2/SO_2 ratio. This could be explained by the interaction between these gases and the shallow aquifer water. Which interaction explains the pattern in CO_2/SO_2 ratio?

A. SO_2 is increasingly dissolved in the water at a rate higher than CO_2.

B. SO_2 reacts with the water acidifying the shallow aquifer and producing sulfur.

C. Precipitated minerals such as sulphates and carbonates are produced by alteration of surrounding rocks and cation extraction.

D. SO_2 flow becomes more powerful and fast, and interaction with the thermal waters is reduced.

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SECTION D: MAGMATIC PROCESSES, ERUPTIVE PRODUCTS AND RISK MANAGEMENT—Questions 26–31

The Campanian volcanic district (see Figure 2) lies at the margin of the Tyrrhenian arc, in a context of subduction of the Adriatic plate beneath the Apennines. Partial melting of the mantle generates magmas that rise, differentiate in crustal chambers and feed the explosive volcanism of CF and Vesuvius. This geodynamic setting produces volcanic processes and materials summarized in Table 4.

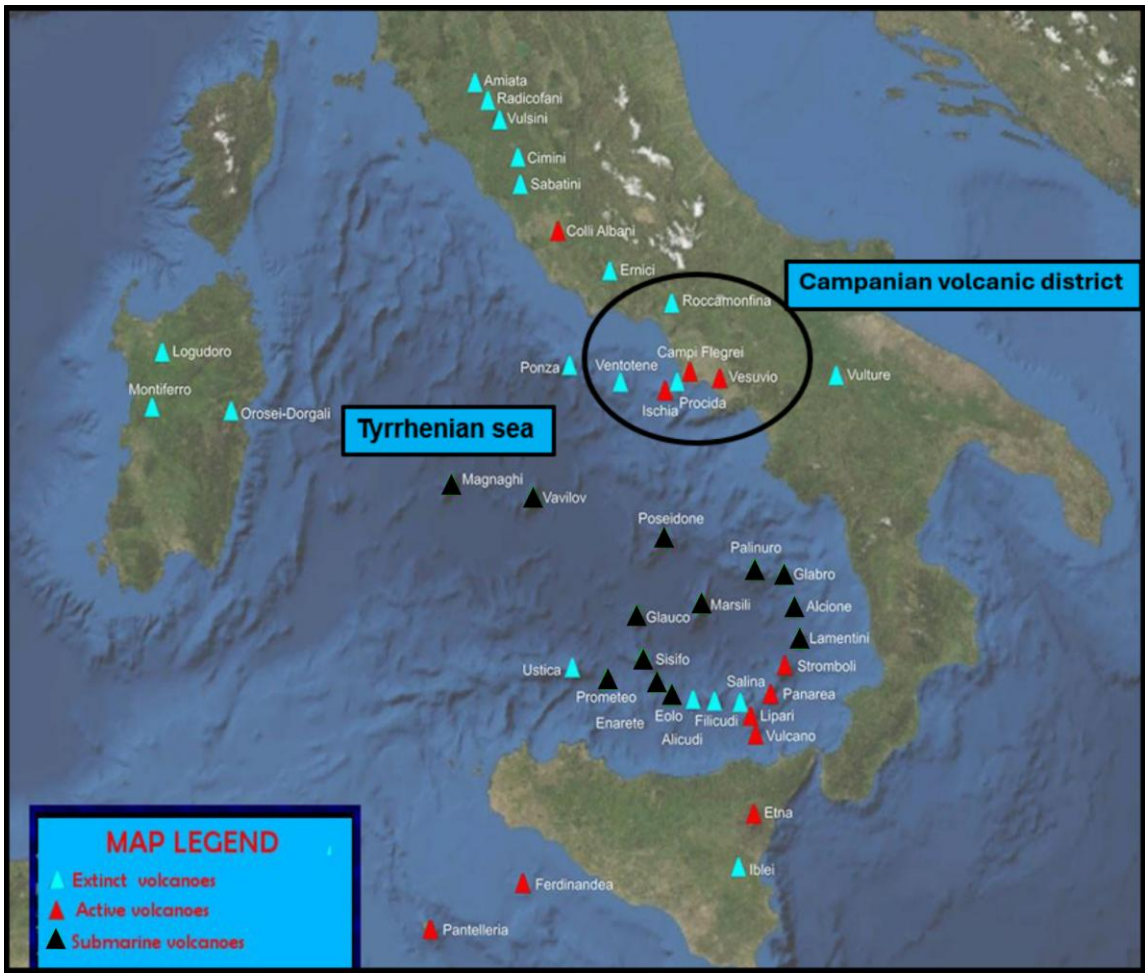

Figure 2: Volcanoes of Italy

Table 4 volcanic processes and materials of the Campanian area

Eruptive products	
Type	**Description**
tephra	volcanic ash (<2 mm)
lapilli	volcanic scoria (2–64 mm)
bombs and blocks	plastic and solid chunks (>64 mm)
pumice	vesiculated rock (porosity >70%)
ignimbrite	pyroclastic-flow deposit, a mixture of gas and fragments produced at 300–800 °C, velocity 100–700 km/h.

Eruptive styles	Description	Examples
Explosive	viscous silicic magma (~60–65% SiO_2) and trapped gas;	Campi Flegrei (CF), Vesuvius
Effusive	fluid basaltic magma (~50% SiO_2) and continuous degassing;	Etna
Phreatomagmatic	magma–water interaction and volumetric expansion (~1000×).	Campanian Ignimbrite

Question 26
The Campanian Ignimbrite (IC event 40,000 years ago) deposited ~300 km³ of material. Using the given information, which geodynamic process fed the magma chamber?

A. An extensional setting similar to what occurs at mid-ocean ridges.
B. Partial melting of the mantle in a subduction context.
C. Local crustal radioactive heating, sufficient to produce partial melting in 40,000 years.
D. Pleistocene glacial compression that generated heat by friction in the deep crust.

Question 27
A pyroclastic flow (ignimbrite) can be very destructive because:

A. It combines temperature, velocity, asphyxiating gas and particulate.
B. It generates shock waves at low temperature that destroy everything.
C. It is composed mainly of toxic gases and moves slowly but unstoppably.
D. It can modify the atmosphere for a very long time.

Question 28
Comparing the CF magma with Etna's one, which property/ies change and govern the eruptive style?

A. Viscosity and the ability to trap gas influence eruption.
B. The content of gases in the two types causes high pressures in both cases.
C. The higher temperatures, that favours more explosive eruptions.
D. Density prevents the rise of magma and limits eruptions.

Question 29
Unlike Vesuvius, Campi Flegrei contains many potential eruptive vents distributed across the caldera. What is the main implication for volcanic risk management?

A. Future eruptions are likely to be smaller because the volcanic activity is distributed over a wider area, therefore emergency planning is fragmented in smaller alert zones.
B. Vent location has little influence on emergency planning because in case of risk the entire alert zone must be evacuated.
C. Emergency planning is more complex because it must consider uncertainty in the location of future eruptive vents and a more extended alert zone.
D. Emergency planning is not possible on a global scale because vent location cannot be predicted.

Table 5 — Comparison of Italian volcanoes

Volcano	Type	Composition	Style	Last eruption	Population exposed
Campi Flegrei	Caldera	Trachytic/phonolitic	Explosive	1538	~500,000
Vesuvius	Stratovolcano	Tephrite/phonolite	Explosive/Plinian	1944	~700,000
Etna	Shield	Basaltic	Effusive	2026	limited
Stromboli	Stratovolcano	Basaltic	Persistent Strombolian	permanent	~500

Question 30
Stromboli (see also Figure 2) has maintained a persistent minor explosive activity (every 10–20 minutes) for millennia. This dynamic equilibrium derives from:

A. Weather conditions on the island that favour condensation of the surface magma.
B. A deep hot spot with a continuous supply of fluid lava.
C. A continuous equilibrium between deep supply of gas and degassing.
D. A deep fracture that connects all the deep magma reservoirs of the Italian volcanoes.

Question 31
Based on the information in Table 5, where is the greatest overall volcanic risk?

A. More information is needed to assess the greater risk between Campi Flegrei and Vesuvius.
B. Near Stromboli, because its persistent explosive activity makes it the least predictable volcano.
C. Near Vesuvius because it combines a relatively low hazard with a large exposed population.
D. Near Etna, because it’s the biggest European volcano and its frequent eruptions produce the greatest volcanic hazard.

SECTION E: MEDICAL GEOLOGY AND THE EARTH SYSTEMS — Questions 32–35

Medical geology studies how geological processes and materials affect atmosphere and hydrosphere, and consequently the human health. In volcanic areas that contain fumaroles and thermal waters, gases and aerosols (SO_2, CO_2, H_2S, fine particulate matter PM2.5) can affect respiratory health; another important example is dissolved fluoride, which has a high affinity for calcium and can alter the biological availability of this element.

Table 6 — Exposure zones around an active degassing area

Zone	Distance (km)	SO_2 in air (ppm)	PM2.5 in air (µg/m³)	Fluoride in water (mg/L)	Dominant setting
A	0.5	2.8	42	4.5	Near fumaroles, downwind
B	2.0	1.4	36	2.5	Urban margin, downwind
C	4.0	0.9	18	0.8	Plateau, cross-wind
D	6.0	1.2	28	1.8	Depressed basin, air stagnation

Question 32
Based on the information in Table 6, why does Zone D show higher SO_2 concentrations and PM2.5 values than Zone C despite being farther from the fumaroles?

A. The difference results from measurement adjustments, because distance must be relativized.
B. Greater distance from the fumaroles increases length of gas exposure.
C. Volcanic gases become more hazardous as they are concentrated by cross-winds farther from the source.
D. The topographic setting of Zone D favours accumulation of volcanic gases.

Question 33
The recommended threshold of fluoride in drinking water is ~1.5 mg/L. Which health outcome is most consistent with the observation of fluoride contents in Zone A?

A. Acute respiratory illness caused by inhalation of fluoride particles.
B. Possible dental and skeletal damage (fluorosis) through drinking water.
C. Corrosive effects on the digestive trait of humans and fauna, especially if acidifying air gases (such as SO_2) are also involved.
D. Temporary health effects on mineral bioaccumulation, that reduces as distance from the fumaroles decreases.

Question 34
Based on the given information, which interpretation explains the relationship between volcanic degassing and human health in the studied areas?

A. Downwind areas suffer mostly atmospheric and hydrospheric exposure, regardless of distance.
B. The various types of volcanic degassing products might have different pathways and timescales in impacting human health.
C. Urban exposure to gas-contaminated hydrosphere and atmosphere together determine the worst human health impacts.
D. Orography of the area and wind direction from the fumaroles limit the effects of volcanic degassing on human health.

Question 35
According to the above, how are the earth systems linked when considering medical geology?

A. Human activities have an impact on geosphere, hydrosphere and atmosphere, which ultimately rebound on human environment.
B. The geosphere influences atmosphere and hydrosphere, which then impact biosphere and human environment.
C. Water from the hydrosphere produces geothermal effects, exploited by the human environment that influences atmosphere and biosphere
D. Atmosphere erosion influences geological and hydrological events, which have an ultimate effect on biosphere and human environment.