THE THREAT OF MT AKINGBADE: A problem solving activity for upper GCSE and A level geology / geography students.

INSTRUCTIONS

This activity is primarily designed to test students' teamwork under pressure, whilst demonstrating the complex applications of real world physical geography and geology. They should not need extensive prior knowledge of the subject matter; information is given to them to use in the task, and instead they are assessed on how well they apply this information.

The full time needed to run the activity is approx. 2.5 hours. It can be shortened or adapted to suit one lesson's run time. There are 3 main parts:

1. Introduction – delivered by the teachers
2. Problem solving – students work in teams to come up with a solution to the posed scenario
3. Presentation – students give five minute summaries of their proposals to the teacher.

The presentation can be cut to save time, as students also submit their proposals on a hand-in sheet.

Set up:

Print off and assemble as many problem solving packs as you need for the class. Teams should have maximum 6 students for the activity to work best.
The pack should contain:

- A copy of the explanatory presentation
- A base map of the region

- A geological map of the region. Note that the geological map does not show drift deposit (e.g. sand, silt, soil)
- A combination map (base and geology) of the region
- Pictures of the rocks referenced in the geological map
- A sheet to help you calculate the budget, which students will hand in
- An A3 summary sheet to write your conclusions on, which students will hand in

You should also print off enough borehole data sheets to have one per team. Keep to one side in case the students wish to buy one.

Place rock samples or pictures at the front of the class, labelled A, B, C etc. If you have appropriate specimens, use those; if not, use pictures. The rocks are as follows:

- Rock A – Basalt (pahoehoe)
- Rock B – Pyroclastic rock (e.g. welded ignimbrite)
- Rock C – Basalt (a'a)
- Rock D - Pyroclastic rock (e.g. welded ignimbrite)
- Rock E - Basalt (a'a)
- Rock F – Basalt (pahoehoe)

Running the activity:

- Split students into teams, maximum 6 per team.
- Show the students the introduction presentation. This should take around 15 minutes.
  Timings are included in the presentation – you can edit these as appropriate
- While the students work on their solutions, set yourself up in a space (e.g. desk) where the they can ask for consultations or paid data.
- When time is up, collect in the summary sheets, budgets and maps. Choose teams in a random order to present their findings.
  Teams can present in front of the class, or invite them to another area to give their presentations
- If you are running as a competition, choose a winner based on the marking criteria: scientific application, innovation, teamwork, and presentation. There is not one right answer, but there is guidance for markers indicating where students may make errors, and what they should notice to help them form a decision.

Guidance for markers:

The aim of this challenge is to balance the social, financial and environmental costs of volcanic hazard management. The student's plans should reflect the depth of information they have managed to gather from the map and data available.

They are required to:

- Assess the geology of Mt Akingbade and the surrounding area
- Assess the hazards posed to New Barnes by Mt Akingbade.
- Propose an exclusion zone around Mt Akingbade. The exclusion zone prohibits any new building in, or commercial use of, the land within the zone. Anyone wishing to enter the exclusion zone will require a permit.
- Propose a management plan for New Barnes, to mitigate the risks of the hazards posed by Mt Akingbade

They should conclude from the geology that the eruptions from Mt Akingbade are effusive, with some limited pyroclastic surges arising at the beginning of eruptive episodes.

The teams should identify that New Barnes is vulnerable to the following hazards:

Hazard	Evidence	Areas at risk	Mitigation
Lava flows	Previous flows; concluded from map and examining rock types	Western edge of town, including slum housing v vulnerable. More lava during basaltic eruptions than in eruptions with higher silica content. Also travels further when basaltic.	Evacuation or monitoring and diversion with barriers and water. Localised evacuation.
Pyroclastic flow / surges	Previous flows; concluded from map and examining rock types	All areas of town vulnerable due to ability to travel over water. The pyroclastic surges are localised and resulting from lava dome collapse, rather than as the result of an explosive Plinian eruption, requiring evacuation across 10s or hundreds of km.	Evacuation of all vulnerable areas. Seismic data and monitoring not yet sophisticated enough to accurately predict path of flow.
Ash fall	Borehole data (optional purchase)	Build up on roofs potentially causing them to collapse. Areas to N, NW and W more vulnerable due to prevailing winds	Reinforced buildings
Lahars	Borehole data (optional purchase)	Town has grown around mouth of river; rainy season for New Barnes may lead to heightened risk of lahars. No glaciers or glacial lakes, risk is relatively low.	Flood mapping Lahar warning system

How does your exclusion zone address the risks posed by these hazards?

- Should cover the areas on the southwestern half of the volcano AT LEAST
- Should prioritise areas to west of river.

If any areas of New Barnes lie within your exclusion zone, what is your plan to manage these areas to prevent risks during a future eruption? Include any measures you might take, to prepare both for and during an eruption. This may include monitoring, analysis, evacuation, infrastructure, etc.

- There should definitely be areas of New Barnes included in the exclusion zone! If not, there has been a misunderstanding on the student's part.
    - They have been informed that NB is growing westwards, i.e. towards the volcano – this should be prevented by the exclusion zone.
    - If they haven't included any part of the town in the exclusion zone, ask why

- Whatever their plan, students should install monitoring systems to help predicts eruptions.
- Teams that choose to relocate areas of NB will need to consider the following
    - Cost
    - Where to move to. Requires either deforestation, loss of agricultural land. If they choose this, how will they compensate?

- Teams that don't relocate will need to account for
    - Temporary relocation during an eruption
    - Keeping residents safe from hazards, by (e.g.) diverting lava flows, monitoring for lahars, evacuation in case of pyroclastic flows

Some teams may choose a combination of permanent and temporary relocation.

If they are relocating because of pyroclastic risk – have they clocked that the island will need evacuating too?

Are there any measures you suggest are necessary outside of your exclusion zone, to mitigate the hazards posed by Mt Akingbade? If yes, please list below

- Lahars – monitoring, flood mapping, possibly moving urban areas away from high risk areas
- Ash fall – mostly to NE of Mt Akingbade, due to prevailing winds
- Possibly lava flows too – same measures as within exclusion zone

Budget

- The students are asked to prepare a budget. In previous years, they have has strict guidelines on how much they can spend. This challenge requires an estimate, as some aspects are very difficult to know from data available.
- Items highlighted in red are unnecessary for this volcano, given the data available.

Mitigation costs ***note that you may need to estimate some of these costs. You may be asked to explain your estimates.** **You should choose the costs that you think are necessary for the hazards you identified, and for your mitigation plan.**			
Seismic monitoring station for Mt Akingbade	£172,000,000		
Ground swelling monitoring system	£16,000,000		
Summit lava dome monitoring system	£210,000,000		
Hydrological survey of drainage system around Mt Akingbade and New Barnes	£3,500,000		
Volcanic lake gas concentration monitoring station	£215,000,000		
Lahar warning system	£70,000,000		
Jökulhlaups warning system	£70,000,000		
Landslide warning system	£70,000,000		
Lava flow warning system	£70,000,000		
Building reinforcement for fallen ash load	£18,000,000 per km2		
Construction of barriers for lava diversion	£500,000 per km		
Lava diversion using water	£80,000,000 per km, per day		

ROCK A

ROCK B

Rock C

ROCK D

ROCK E

ROCK F

BUDGET TEAM NAME: _____

Below are costs you need to consider. This will help you estimate the cost of your management plan. The government has offered a budget of £1.1 billion.

Costs of relocation of for urban areas				
Evacuation				
Map area		**Cost per unit (£)**	**Qty**	**Total (£)**
Residential		35,000,000 per km2		
Residential (slum housing)		18,000,000 per km2		
Commercial area		44,000,000 per km2		
Industrial estate		53,000,000 per km2		
Costs of land purchase for relocated urban areas. Note, you MUST account for all relocated areas				
Primary forest / native shrubland		£12,000,000 per km2		
Deforested area		£2,700,000 per km2		
Agricultural land		£38,000,000 per km2		
Costs for temporary evacuation of urban areas (note that these costs are per day) You should estimate the cost of evacuating residents per day in the event of an eruption, if this is your chosen mitigation method.				
Map area	**Population density, people per km2**	**Cost per unit (£)**	**Qty**	**Total (£)**
Residential	19 500	£58 per person per day		
Residential (slum)	127 000			
Commercial centre	3750			
Industrial estate	100			
Mitigation costs *note that you may need to estimate some of these costs. You may be asked to explain your estimates. You should choose the costs that you think are necessary for the hazards you identified, and for your mitigation plan.				
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Construction of barriers for lava diversion		£500,000 per km		
Lava diversion using water		£80,000 per km, per day		
Public information campaign		£2,000,000		
Data available to purchase				
Borehole data		£3,400,000		
◐ consultation				

SUMMARY SHEET

TEAM NAME: _____

What VOLCANIC HAZARDS have you identified around Mt Akingbade? Use as many rows in the table below as you need.

Hazard	Evidence	Areas at risk

CONTINUES OVERLEAF

How does your exclusion zone address the risks posed by these hazards?

If any areas of New Barnes lie within your exclusion zone, what is your plan to manage these areas to prevent risks during a future eruption? Include any measures you might take, to prepare both for and during an eruption. This may include monitoring, analysis, evacuation, infrastructure, etc.

Are there any measures you suggest are necessary outside of your exclusion zone, to mitigate the hazards posed by Mt Akingbade? If yes, please list below

CONTINUES OVERLEAF

What are the advantages and disadvantages of your plan?

Advantages	Disadvantages

CONTINUES OVERLEAF

CONTINUES OVERLEAF

Problem solving

The Threat of Mt Akingbade

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What is a volcanic hazard?

"A volcanic hazard refers to any potentially dangerous volcanic process that puts human lives, livelihoods or infrastructure at risk of harm" – **British Geological Survey**

Types of volcano

Shield Volcano

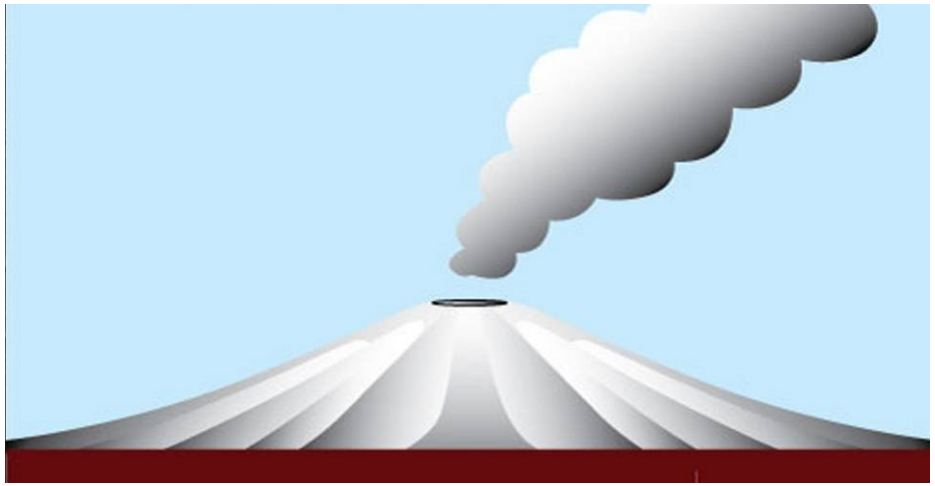
Very runny lava, gently sloping sides

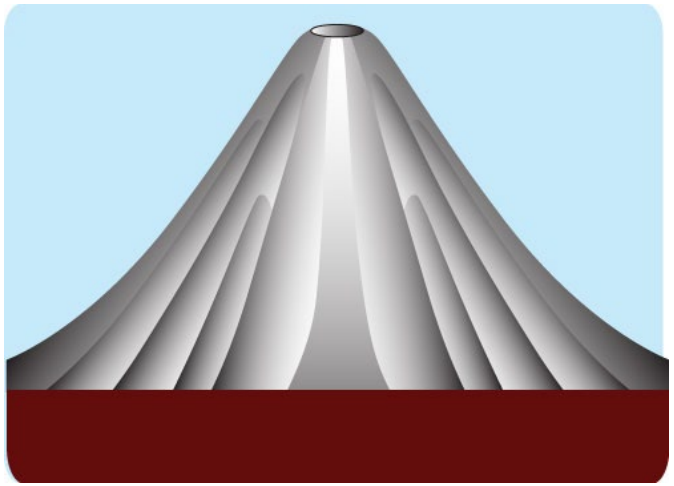
Gentle, effusive eruptions, large volumes of lava

Stratovolcano

No lava or extremely viscous lava. Very steep sides

Explosive eruptions





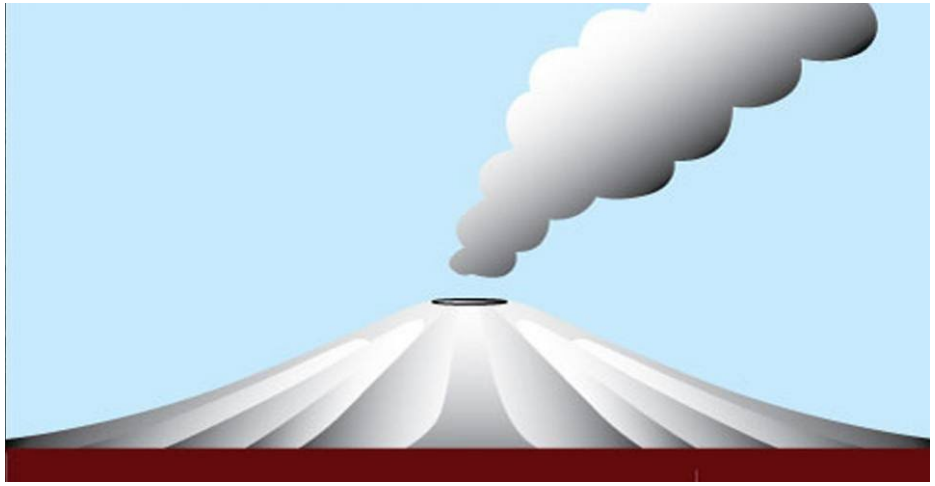
Types of volcano

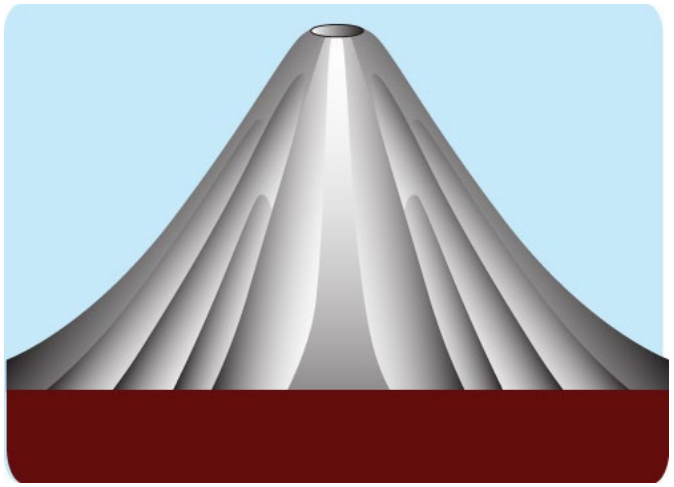
Shield Volcano

Slopes tend to be made of successive layers of lava, with some ash or pyroclastic material

Stratovolcano

Slopes are made of successive layers of ash and pyroclastic material. Little or no lava.





Hazards - Lava

Whilst it is extremely destructive, lava does not always pose a threat to human life, as it does not move very quickly and so people can be evacuated in time.

The rate of flow of lava depends on its silica content. Runny lava contains less silica. As it flows, it forms a distinctive pattern on its surface like the skin of custard. This type of lava is called pahoehoe.

Hazards - Lava

With higher silica content, lava flows are unable to move as far, or as quickly. They acquire a blocky, rubbly surface. This type of lava is known as A'a.

Some volcanoes extrude a mixture of runny and viscous lava, during different eruptive episodes, depending on magma feeds deep under the volcano

Hazards - Lava dome

Sticky lava can also lead to the formation of a lava dome. Because of the high viscosity of the lava, it cannot travel far from the vent and a dome of lava builds up.

These domes can be hazardous, as they are usually unstable and prone to collapse, leading to pyroclastic flows, surges, or density currents.

Hazards – Pyroclastic flows

Pyroclastic flows are exceptionally hot clouds of material, containing a mixture of rock debris and gas, that flow along the ground at high speed.

They tend to flow down hillsides, along valleys and towards lower ground, travelling at hundreds of kilometres per hour.

There are multiple ways that pyroclastic flows form, although they are most commonly associated with volcanoes that have some level of explosivity

Hazards – Pyroclastic flows

As well as lava dome collapse, pyroclastic flows can occur at a huge scale during explosive eruptions, when the ejected material is too dense to rise into the atmosphere. It then collapses and flows down the side of the volcano.

The flows leave distinctive rock deposits around the side of the volcano, often instantly welded together by the heat of the flow

Hazards – Landslips

Occasionally, explosive eruptions can be so powerful as to trigger collapse of a volcano completely, causing devastating landslides and large scale pyroclastic flows. These types of blow out only occur in volcanoes with extremely viscous lava. Landslips can also be associated with tsunamis if the debris displaces seawater

Lahars and Jökulhlaups

Both of these hazards arise from the rapid interaction of water and volcanoes.

Lahars are fast-flowing rivers of mud, formed when recently erupted ash reacts with rainwater or melted glacial water around the summit of a volcano. The likelihood of a lahar is extremely high in areas that experience short, intense bursts of rainfall.

Lahars and Jökulhlaups

A jökulhlaup is a sudden release of water from a lake that lies under or close to a glacier. They can be triggered by the eruption of a volcano situated beneath a glacier that melts overlying ice, or weakens a dam made of glacial moraine sediments. The sudden removal of the lake dam releases a huge volume of water to produce a ‘megaflood’ that can wash away roads and bridges.

Volcanic gases and lakes

Many volcanoes emit toxic gases from their summit or vents, which can be extremely harmful to humans and wildlife.

If a crater lake forms in the summit of a dormant volcano, gasses can seep out of the crater and dissolve into the lake water, creating a secondary hazard.

Ashfall

Ash from a volcanic eruption can reach many kilometres height in the atmosphere, causing disruption to air traffic and even altering global climate.

In areas of closest proximity to a volcano, many metres of ash can accumulate on building roofs, leading to collapse and major disruption to infrastructure.

How to mitigate?

Almost all volcanic hazards can be accurately managed with careful monitoring and prediction of the volcano. Seismic monitoring, tiltmetres to measure ground swelling, and GPS stations to measure surface change can all help to track magma movement underground and predict a volcanic eruption.

Fieldwork can also be carried out at a volcano’s summit to measure gas output and lava composition, which help to predict what hazards may arise during an imminent eruption.

How to mitigate?

Sometimes, the dangers posed by a volcano necessitate large scale evacuation, either permanently or temporarily. This may be due to high risk or high frequency eruptive events, or where hazards like a large pyroclastic flow or volcano collapse are anticipated.

Both permanent and temporary evacuation is costly; citizens may also be reluctant to leave their homes and livelihoods, particularly where their work may be facilitated by the presence of the volcano. Temporary evacuation also asks for precise eruption prediction, which is not always possible, and can lead to public distrust if a “false alarm” is raised.

How to mitigate?

Some hazards, like lava flows, can be managed with more localised interventions. For example, predicting the most likely path of lava and installing barriers to divert it from key buildings or homes. The front of an advancing lava flow can even be sprayed with water to cool it and form a natural barrier. Where lava cannot be stopped, localised evacuations can then occur.

Lahars and jökulhlaup can be predicted by accurate mapping of the drainage system in the area around the volcano.

Buildings can also be reinforced to withstand the weight of significant ash fall, although in some cases towns and cities can become buried completely.

What is an exclusion zone?

Exclusion zones are areas drawn up around volcanoes where there is considered to be greatest risk.

These zones may include areas that already have established settlements on them; in this case, the government should decide how to manage the risks faced by those communities. Some may choose to relocate those communities; others may wish to only temporarily evacuate citizens in the event of an eruption.

Welcome to New Barnes!

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Welcome to New Barnes!

- New Barnes is the capital of Cambria, a country with an emerging economy
- The total population of Cambria is 8.73 million and growing, with a fertility rate of 3.2
- 15 years ago they overthrew a 40-year dictatorship and the current government is the country's first democracy. They joined trade and economic union with 17 other countries in 2011
- The population of New Barnes is 5.2 million

Welcome to New Barnes!

- New Barnes is seeing rapid development. As a major port city, it is now able to export far more widely due to customs union
- Major exports are plastic manufacturing (37% of exports), maize (16%), and olive oil (6%)
- The population has grown by 11% since 2011
- Rapid expansion has led to slum housing for workers who fish along the coast and/or work in the docks and manufacturing areas

Environmental profile

- The city skyline is dominated by Mt Akingbade, a volcano with a poorly understood eruptive history
- The slopes of Mt Akingbade are mostly undeveloped and densely vegetated
- State wide, deforestation is increasing due to rapid development
- New Barnes has a tropical climate, with heavy rains during monsoon season between July and October
- Prevailing winds are south-westerly

Environmental profile

- Volcanically rich soils around Mt Akingbade and across Cambria have led to a thriving agriculture industry, which also drives deforestation.
- Native forest around New Barnes and Mt Akingbade is home to a number of vulnerable species, including a population of the critically endangered O’Donnells Tree Toad. The Population are concentrated to the west and northeast of the town.

Mt Akingbade

- The volcano's eruptive history is poorly understood. Historical records detail 4 eruptions in last c. 1000, where religious scholars documented ash and lavas erupting from the summit
- Each episode lasted for several years, with periodic eruptions
- New Barnes' government is investing in disaster resilience, and it's your job to survey the volcano

Mt Akingbade

- The slopes of Mt Akingbade are densely vegetated. LiDAR has been used to survey the area and has helped to identify the most recent deposits issued by the volcano
- A team of field geologists have collected samples from these deposits. You will have access to these samples.

Your task

Assess the volcanic hazards posed to the town of New Barnes by Mt Akingbade. Create a management plan for these hazards, using a $1billion fund created by the City council of New Barnes.

Your plan may include measures to keep citizens safe during an imminent eruption, and/or to build resilience for future eruptions.

1. Assess the geology of Mt Akingbade and the surrounding area
2. Assess the hazards posed to New Barnes by Mt Akingbade.
3. Propose an exclusion zone around Mt Akingbade. The exclusion zone prohibits any new building in, or commercial use of, the land within the zone.
4. Propose a management plan for New Barnes, to mitigate the risks of the hazards posed by Mt Akingbade

Materials to help you

- A copy of the explanatory presentation
- A base map of the region
- A geological map of the region
- A combination map (base and geology) of the region, onto which you will draw your exclusion zone
- Samples of the rocks referenced in the geological map
- A sheet to help you calculate a budget, which you will hand in
- A summary sheet to write your conclusions on, which you will hand in

How will this be marked?

You have a total of 1 hour and 45 minutes to complete the task. It is recommended you stick to the following timings:

- 15 mins: Read brief and intro presentation
- 15 mins: Assess the geological data to determine the hazards posed by Mt Akingbade.
- 30 mins: Consider how each hazard will be mitigated.
- 45 minutes: Prepare and write up budget, write up summary sheet. Prepare key points for your presentation to the judges.

When time is up, you will hand in

- Your budget
- Your summary sheet
- Your combination map

You will then be called in a random order to present to the judges. You have 3 minutes to communicate your key points, and 2 minutes for questions!

Budget

Part of the assessment is the budget you produce for your project, and how wisely you spend money. The budget for this project is an estimate of the costs incurred when managing the hazards associated with Mt Akingbade.

The government has suggested a budget of £1.1 billion; marks are not gained for saving money!

You have the opportunity to “buy” information from an external contractors. If you would like to use this, talk to your teacher

Questions

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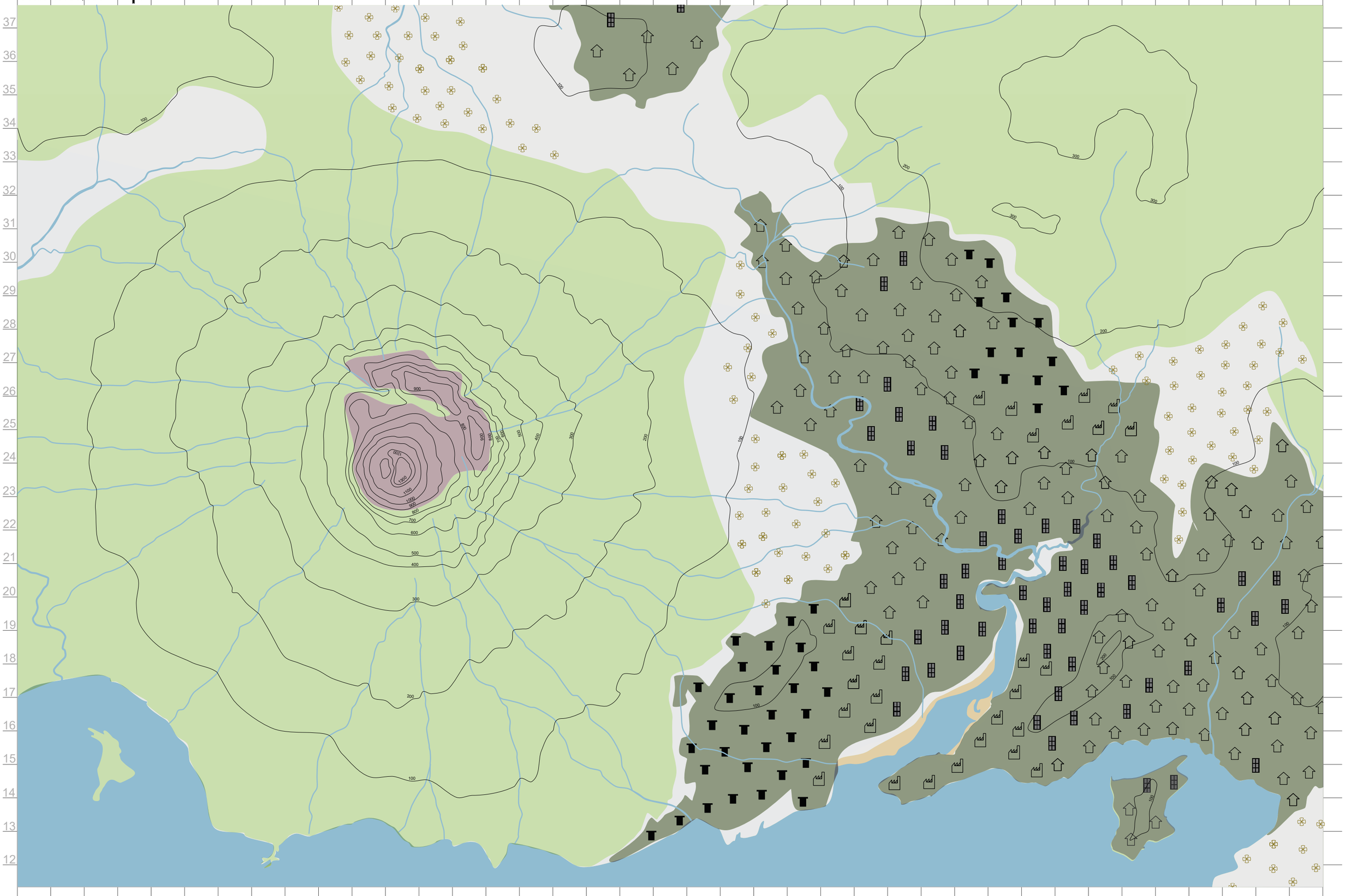

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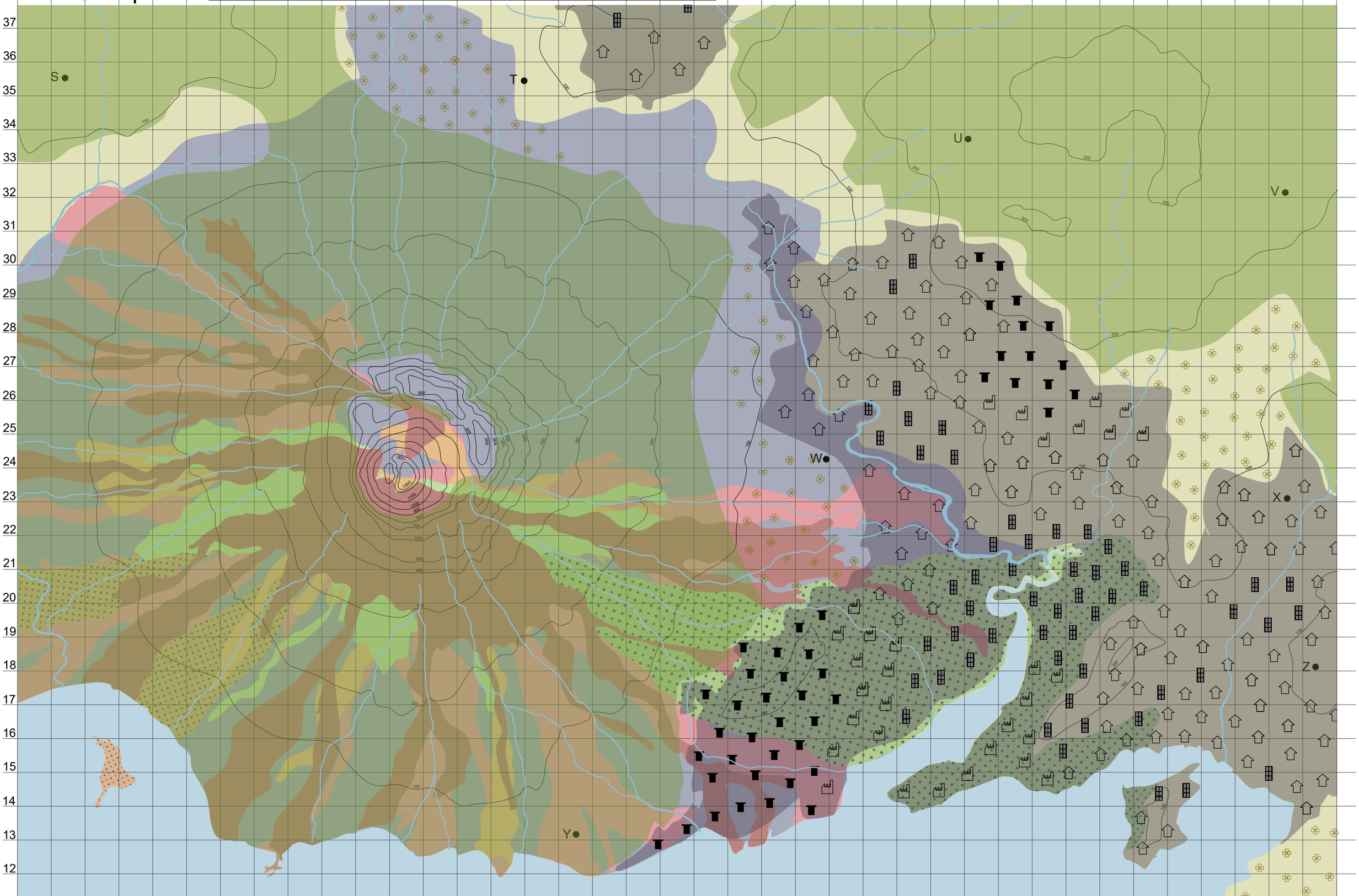
TEAM NAME:



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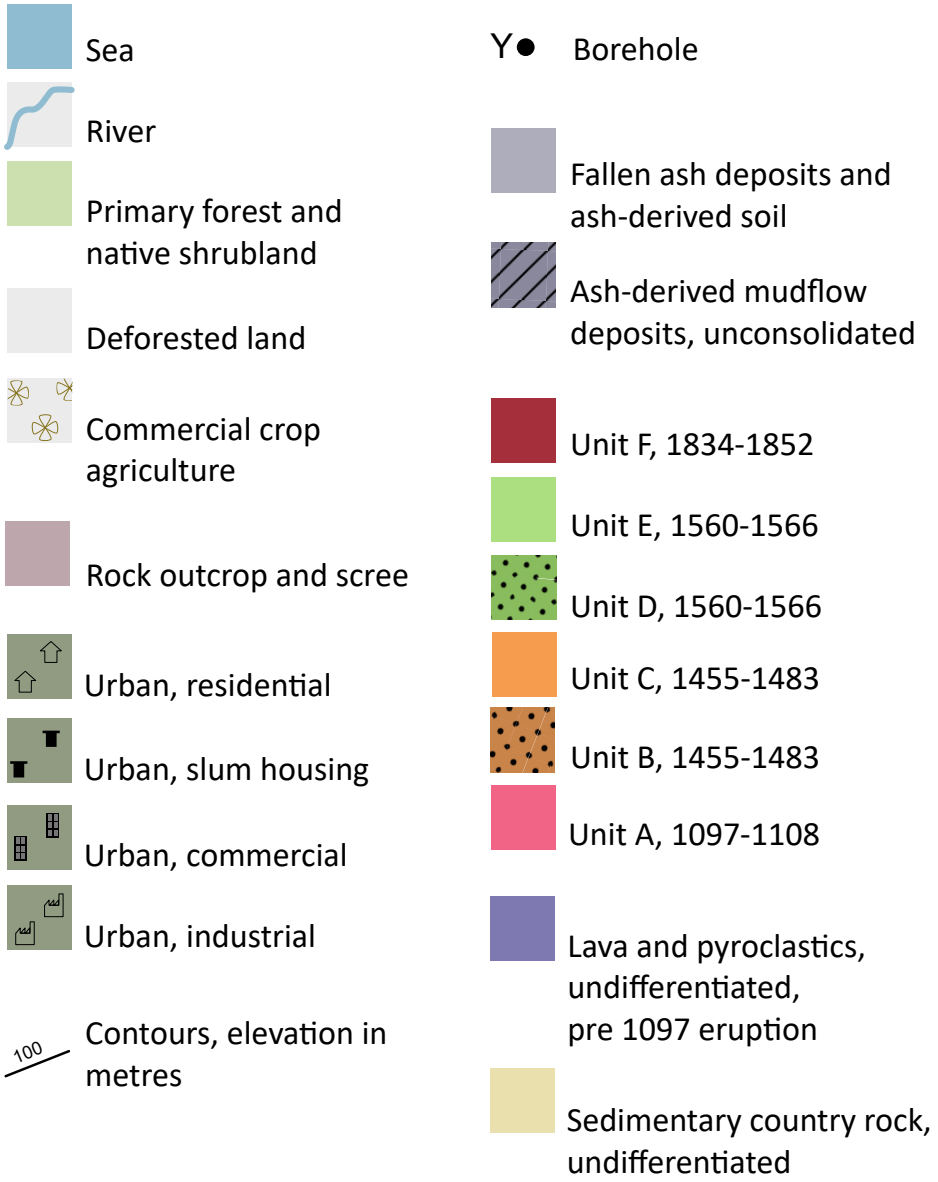
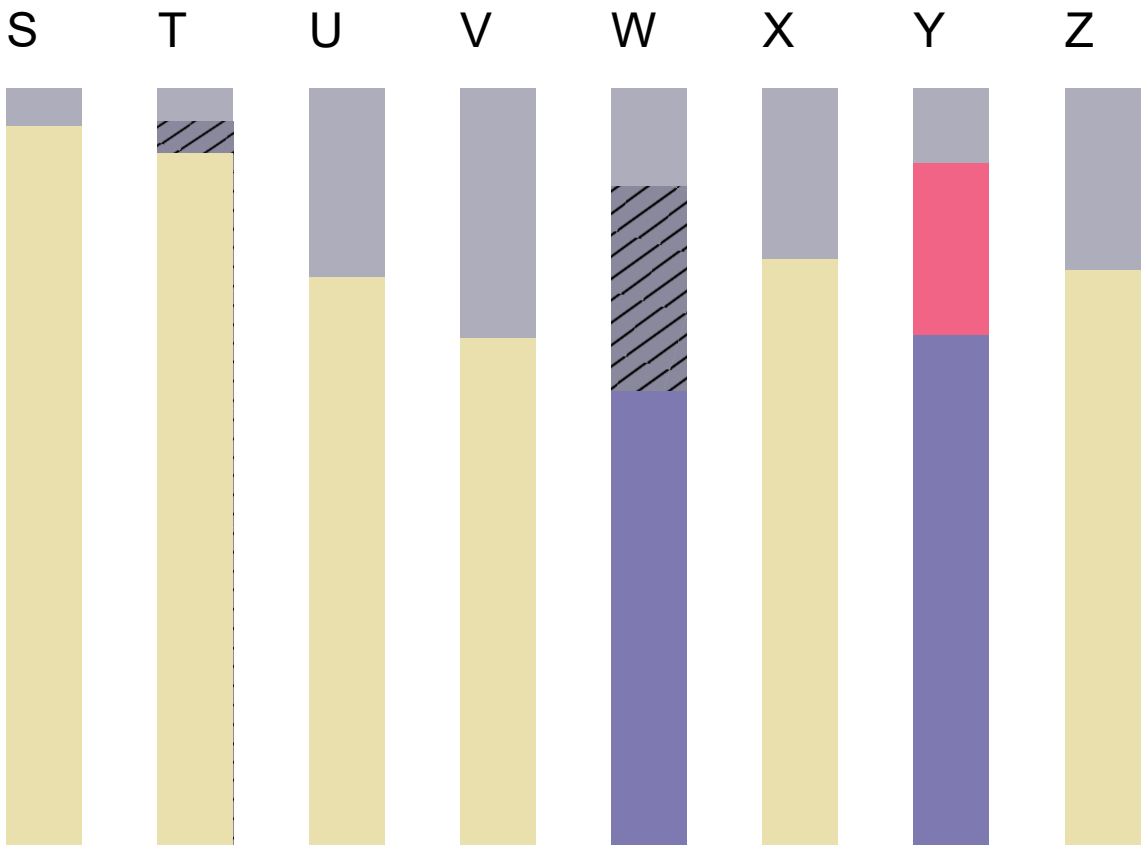


Key

Sea
River
Primary forest and native shrubland
Deforested land
Commercial crop agriculture
Rock outcrop and scree
Urban, residential
Urban, slum housing
Urban, commercial
Urban, industrial
100
Contours, elevation in metres
Y
Borehole
Fallen ash deposits and ash-derived soil
Ash-derived mudflow deposits, unconsolidated
Unit F, 1834-1852
Unit E, 1560-1566
Unit D, 1560-1566
Unit C, 1455-1483
Unit B, 1455-1483
Unit A, 1097-1108
Lava and pyroclastics, undifferentiated, pre 1097 eruption
Sedimentary country rock, undifferentiated

Borehole data Scale: 1cm = 10m



Borehole data Scale: 1cm = 10m