Assessment Schedule – 2020

Scholarship Earth and Space Science (93104)

Evidence Statement

ONE

Evidence	1 – 2	3 – 4	5 – 6	7 - 8
Well labelled, accurate diagrams are considered as evidence. **Tectonics** • The Kermadec arc volcanoes have formed because of subduction of the Pacific Plate under the Indo-Australian Plate. • As the Pacific Plate is subducted, the water in the sediments / oceanic crust is superheated, which lowers the melting point of the rock creating magma that rises to the surface and creates a volcano. • The Havre volcano is a caldera volcano, which means that it has formed from very viscous, silica-rich, potentially rhyolitic magma. **Eruption** • Consider the relation of the Kermadec volcanoes in relation to the subduction zone in lava type (cf White Island). • Pumice is formed by the expansion of gas in the molten-phase rock. The arrangement of the pumice boulders on the seafloor, sometimes precariously stacked four blocks high, suggested that these pieces were also at first buoyant, but then gently sank as their pores became saturated with water. • In New Zealand, rhyolitic magma is formed from the melting of the continental Indo-Australian Plate. • However, at the Kermadec arc, the sheer mass of water sitting above submarine volcanoes, for example, exerts an enormous pressure that doesn't exist for volcanoes on land. • The assumption has always been that this would make a deep underwater eruption quite passive, with lava flows rather than explosions. • The eruption of magma in deep submarine settings is poorly understood – many of the world's submarine volcanic arcs remain largely unexplored. • Not only does pressure change how lava forms; the interaction between the water and the cooling magma is completely different than when magma interacts with air. When water hits hot magma at 800 °C, it vaporises in an instant. Its rapid expansion into steam can be strong enough to break the lava apart. However, when magma comes in contact with water, the temperature change is so dramatic that the magma instantly solidifies in a	• Very little understanding of question with very little development of ideas. • Resource booklet copied only.	• Shows some understanding of question with only some development of ideas. • Some synthesis and integration of the processes.	• Good understanding of question with good development of ideas. • Good analysis, synthesis, and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of question with excellent development of ideas. • Sophisticated analysis, synthesis and integration of the processes, showing perception and insight applied to the context. • Reflection on the answer resulting in extrapolation. • All aspects of answer expressed with convincing communication. • Must show integration of ideas.

process called quenching.

- Submarine silicic eruptions are rare events and the precise role of hydrostatic pressure (because of the weight of the overlying water column) in modulating eruptive dynamics is unknown.
- In fact, had this explosive eruption not occurred, it would likely not have been predicted because of the prevailing idea that hydrostatic pressure at the eruption depth (which exceeds 9 megapascals) can significantly suppress explosivity. The Havre volcano, stretching between 900 and 1200 metres below sea level, experiences a pressure between 92 and 122 times that of sea level, which scientists suspect dampened its explosiveness and shaped the various types of lava formations.

Impacts

- Understanding how volcanic eruptions interact with water is especially important in places like Auckland, where a future eruption might interact with ground water or occur in shallow sea, as well as create a tsunami risk.
- Knowledge gained from studying a recent eruption, like Havre, will help geologists study previous volcanic cases, and recreate what might have happened during ancient eruptions and see the historic effects.
- Owing to the duration and succession of different stages of volcanic activity, tsunamis during volcanic events can be numerous and related to different source mechanisms.
- However, volcanic tsunamis are difficult to predict and monitor, and the time available for issuing an alarm is often very short, typically a few minutes.
- Apart from increasing human knowledge, the research could have impacts for human safety. When lava contacts sea water, there can be an explosive effect which could lead to a collapse or landslide, which could trigger a tsunami.
- Different mechanisms might be implied in the generation of volcanic tsunamis underwater explosion, caldera collapse (resulting in rapid subsidence of the sea floor), volcanic earthquake and shock waves produced by the large explosion.
- Opportunities to cover the potential modes of tsunami generation, wall collapse, phreatic (unlikely), caldera floor collapse.
- Need to consider locality of population centres on the N / E coast. Proximity to coast of almost half of NZ population, distance to tsunami source in terms of energy dissipation and warning time but also that the indistinct nature of the geophysical remote sensing will not currently be able to provide specific warnings.
- The best way to predict this is through intensive monitoring of earthquake

activity (changes in heat flow and distribution), the build-up of stresses in overlying rocks, including deformation like the bulge in the side of the caldera. • The characteristics of tsunamis generated by landslides depend upon their volume, origin (subaerial or submerged) and dynamics (e.g. initial acceleration etc.), and some areas, when mapped, can be designated as high or low risk which could then be monitored closer than others with perhaps seismometers closer to high risk areas. • Volcano-tectonic earthquakes result from the accumulation of stress induced by magma ascent. They are characterised by seismic swarms at shallow depth (less than 10 km), with magnitudes typically less than Ms = 6, and thus generate small-magnitude tsunamis. This was observed in the Havre eruption. • Monitoring these quake swarms could be a good way of monitoring with current technology, as well as looking for pumice rafts, which could indicate size of event by size of raft. This is important due to tsunami risk. • Poring over comprehensive, high-resolution satellite images, scientists can use the presence of gigantic rafts of silicic pumice (in this case covering an area spanning roughly 400 square kilometres). By tracing the rafts back in time to their source, when there was also evidence of an atmospheric plume emitted from a point source, and a thermal hotspot, they could be able to find new areas of activity previously not known about. This would be an 'ambulance at the bottom of the cliff' system, however. • Due to the majority of volcanism occurring underwater, it would make any research applicable to many countries and possibly successful monitoring could be used globally. Countries that NZ works closely with like Tonga, which have less scientific budget, could benefit from any research done in NZ. • Depending on heat released, as well as quantities of green-house gases, global climate change models may have to be adjusted if research shows that they are different to current data. Heat would also change the amount of carbon dioxide that the water was able to hold.				

https://ocean.si.edu/holding-tank/vents-volcanoes/mystery-underwater-volcano

TWO

Evidence	1 – 2	3 – 4	5 – 6	7 - 8
Well labelled, accurate diagrams are considered as evidence. • Evaporation and condensation are the two processes that most influence the ratio of ^{18}O to ^{16}O in the oceans. • Water molecules containing light oxygen are easier to evaporate than water molecules containing a heavy oxygen atom because the molecule is lighter. • At the same time, water vapour molecules containing the ^{18}O condenses more readily because the heavier water is easier to condense. • As air cools by rising into the atmosphere or moving toward the poles, moisture begins to condense and fall as precipitation. • At first, the rain contains a higher ratio of water made of ^{18}O, since those molecules condense more easily than water vapour containing light oxygen. • The remaining moisture in the air becomes depleted of heavy oxygen, as the air continues to move poleward into colder regions. • As the moisture reaches the upper latitudes, the falling rain or snow is made up of more and more water molecules containing light oxygen. **Glacial periods** • Cooler temperatures extend toward the Equator, so the water vapour containing heavy oxygen 18 rains out of the atmosphere at even lower latitudes (closer to the Equator) than it does under milder conditions. • The water vapour containing light oxygen moves toward the poles, eventually condenses, and falls onto the ice sheets where it stays. • The water remaining in the ocean develops increasingly higher concentration of heavy oxygen compared to the universal standard, and the ice develops a higher concentration of light oxygen. • Thus, high concentrations of heavy oxygen in the ocean tell scientists that light oxygen was trapped in the ice sheets. The exact oxygen ratios can show how much ice covered the Earth. **Interglacial periods** • As temperatures rise, ice sheets melt, and freshwater runs into the ocean. • Melting returns light oxygen to the water and reduces the salinity of the oceans worldwide. This also removes data as ice melts possible ice cores. • Higher concentrations of light oxygen in ocean water indicate that global temperatures have warmed, resulting in less global ice cover and less saline waters. • Shells of marine organisms can also reflect ^{18}O:^{16}O ratio and can act as a	• Very little understanding of question with very little development of ideas. • Resource booklet copied only.	• Shows some understanding of question with only some development of ideas. • Some synthesis and integration of the processes.	• Good understanding of question with good development of ideas. • Good analysis, synthesis, and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of question with excellent development of ideas. • Sophisticated analysis, synthesis and integration of the processes, showing perception and insight applied to the context. • Reflection on the answer resulting in extrapolation. • All aspects of answer expressed with convincing communication. • Must show integration of ideas.

secondary climate record. They can be found in global sediment, not just polar regions. • During glacial periods, organisms possess shells made of $CaCO_3$ containing more heavy oxygen. • The opposite is true for interglacial periods where the organisms will have $CaCO_3$ shells that contain more ^{16}O than ^{18}O, reflecting the oceanic conditions that they are living in. • Currently, the world is experiencing an interglacial period. The ice caps are melting, which means that more ^{16}O is present in the ocean. Look at historical warmings and use this to predict our future. • The carbon dioxide provides two of the oxygen atoms in the calcite. The calcite must get the third from the water. The isotope ratio in the calcite is therefore the same, after compensation, as the ratio in the water from which the microorganisms of a given layer extracted the material of the shell. A higher abundance of ^{18}O in calcite is indicative of colder water temperatures, since the lighter isotopes are all stored in the glacial ice. The microorganisms most frequently referenced is foraminifera. • Accurate estimates of ocean temperatures can be deduced from the distribution on foraminifera where morphology and species distribution is a function of ocean temperature. • Because the Milankovitch cycles and the ice core records allow us to predict what the climate should be continuously into the near future, we are able to accurately predict the variation from the prediction. This allows an accurate measurement of the departure from the predicted path.				

THREE

Evidence	1 – 2	3 – 4	5 – 6	7 - 8
• Large atmosphere of H and He due to mass, despite red dwarf instability. • Closer to its own star but within the habitable zone for a red dwarf star. • Temperature could still be quite high if atmospheric pressure raises boiling point. **Tidal locking is unlikely because:** • Heat transfer is going to make the hot side heat and form convection cells, transporting water vapour away from the hot side to the cold, where it would then form ice and be stored. • This would remove the water vapour from the atmosphere, which as it seems to be present, is an unlikely situation. • Temperature range is less extreme than Mercury, which could mean liquid water being present, oceans regulating its temperature. **Tidal locking is likely because:** • Length of orbit around its star is shorter than Mercury. • Closer to its star than Mercury. • Need more info such as length of day. • If tidally locked, the thermal gradient would be in the order of 6 degrees Kelvin for every 10 degrees longitude from the dark side. This means that there would be strong constant winds at high altitudes from the "hot pole" to the "cold pole". This means any water vapour would be moved from the hot side to the cold side. The lower level (surface) winds would blow from the cold side to the hot side depositing dust / ice on the warm side. These would initially form katabatic winds, depositing water vapour as ice at the poles. With energetic atmospheric mixing much like the troposphere. • Water cycles – this implies the cold pole would be cold and icy much like Antarctica. The cold winds blowing around from the dark side to the light side. This would tend to move any surface liquid water and dust towards the warmer regions. There is a possibility that there may be water circulation, but as the cold surface air is blowing across the surface (cold to hot) and there no potential for Coriolis force (no rotation), this unlikely to be	• Very little understanding of question with very little development of ideas. • Resource booklet copied only.	• Shows some understanding of question with only some development of ideas. • Some synthesis and integration of the processes.	• Good understanding of question with good development of ideas. • Good analysis, synthesis, and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of question with excellent development of ideas. • Sophisticated analysis, synthesis and integration of the processes, showing perception and insight applied to the context. • Reflection on the answer resulting in extrapolation. • All aspects of answer expressed with convincing communication. • Must show integration of ideas.

on a large scale (no Ekman spiral and limited upwelling). • Atmosphere density / hydrosphere depth could be considerable as density suggests a rocky planet but significantly less dense than solar rocky planets (Earth or Mercury). Atmosphere will be very thick, so potentially much hotter at surface, much like Venus. Surface pressures could be significantly higher than Earth's. This would tend to provide additional protection to harmful radiation but would also raise the boiling point of water, allowing liquid water to exist at higher temperatures. • If a habitable zone exists, assuming uniform thermal gradient, it would form a ring at between about 10 to 30ish degrees around the hot pole; this is the zone where the temperature is such that shallow surface water would not evaporate and / or could be replaced from ice blown over from the frozen dark side. (Ice movement not water.) • Tectonic activity: there may be potential for tectonic activity, and this could provide geothermal energy for life under the ice and water sheets if they exist. The motion of plates may result in mass transport of ice and rocks along with sediments and possible subduction / mountain-building. **Red dwarf implications:** • A very long life span for those, trillions of years. • Cooler. • Less stable surface, more solar flares, which can cause planets to lose atmosphere. • K2-18b is closer. • More intense UV rays due to being so close to the active red dwarf star. • Planet is very large and would receive a lot of energy on the facing side. Due to its proximity to the star there would be large incident fluxes of UV and IR radiation, and charged particles, particularly since intensity is dependent on an inverse *r*-squared relationship. This would expose any life to constant streams of damaging radiation. Because the planet is slow or non-rotating, there would be a minimal magnetic field to protect the surface from charged particle flux. However due to the close orbit around its star, tidal locking could be a possibility, and this would affect liveability and would make sure that the only temperate zone would be between the facing side and the cold side.				

Aspects that would make the planet a **good** prospect for life are: • Water cycle looks to be present. With water vapour, clouds and rain would enable erosion, tectonics (lubrication of plates). • Life cycle of the red dwarf star. • Gravity is slightly stronger than Earth but not extremely. • Clouds could form a negative feedback loop to affect climate stability. Aspects that would make the planet a **poor** prospect for life are: • No information if other cycles are present. • Could be more of a mini Neptune rather than a super Earth. • A thicker atmosphere may shield life from damaging radiation, as well as extremes of temperature. Other aspects to consider: • Tidal locking does not require a non-uniform distribution of mass, but the formation of ice shields on the cold side could lead to this. • Mercury is considered to be tidally locked in a 3:2 orbital resonance, which is potentially likely for a planet at this radius. This means there is potential for K2-18b to have a day length of several orbital periods. This would have a massive effect on the potential planetary systems.				

Cut Scores

Scholarship	Outstanding Scholarship
13 – 18	19 – 24