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93104



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TOP SCHOLAR



NEW ZEALAND QUALIFICATIONS AUTHORITY
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Scholarship 2021 Earth and Space Science

Time allowed: Three hours
Total score: 24

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should answer ALL the questions in this booklet.

Pull out Resource Booklet 93104R from the centre of this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Question	Score
ONE	
TWO	
THREE	
TOTAL	

ASSESSOR'S USE ONLY

QUESTION ONE: EL NIÑO–SOUTHERN OSCILLATION (ENSO) AND NEW ZEALAND

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Discuss and evaluate how the effect of the Southern Oscillation on the West Coast of the South Island can be used to further understanding of past climate.

Consider in your answer:

- how the sediment core can be dated
- the origin of the eroded rock and sediment, and how the deposition of the material varies between years
- what evidence is present in the sediment cores to show how often El Niño and La Niña have occurred in the past
- what other information is available from a core and how this could be useful.

The El Niño-Southern Oscillation causes variations in the weather patterns in New Zealand, particularly in the West Coast of Te Whaipounamu, where orographic rainfall leaves many accurate geological records. Sediment cores, such as the one taken from Lake Ōhau can be studied in order to deduce the patterns of past climate and how ENSO may affect it.

Lake Ōhau runs down from two valleys joined by a mountain whose annual orographic precipitation is approximately 2800 mm. This is a large amount of rainfall, which will cause significant erosion of the mountains and flow down the valley where the sediments will be deposited into the lake. These sediments settle year by year and produce a pattern between summer and winter which is seen in the core. The darker sediment was formed in the wetter winter, where the larger volume of rain was able to break free bigger, coarser sediments which pack together less finely and produce a darker layer. Summer, meanwhile, is lighter as there is less rain and so finer sediments only are eroded, forming a lighter layer. This variation allows the sediment to be dated from year to year so inferences can be made about each year. However, the sediment

core will be very deep, likely with hundreds and thousands of layers, so counting will be tedious, if not inaccurate. Nor can lengths be used to divide into the average year height, as there will be long term variation which will change the thickness. For this reason carbon-13 dating of the fossilised microorganisms within the sediments could be used to obtain the approximate ages of the core at various depths, with individual counting used to date it year to year. //

The sediments in the core will have been formed from the eroded metamorphic rocks of the Southern Alps, which were transformed deep underground and lifted up at the Australian-Pacific plate boundary which formed the Southern Alps. Metamorphic rock is more resistant to chemical weathering than other types of rock are, so the thickness of one year's sediment deposit is directly due to the volume of rain in that year which ~~eroded~~ physically eroded the rock. A thicker year would have been a wetter one, as more erosion caused a greater volume of sediments to be deposited in the lake, and a thinner year was therefore a drier one. The different thickness between summer and winter deposits can similarly be used to determine the rainfall variation between the seasons of one year. //

The thickness of the sediment deposits will vary between year to year, but will usually remain within a certain range, with the thicker deposits corresponding to wetter years. There will however be some unusually thick layers, which correspond to El Niño's wet conditions in the West Coast,

and some unusually thin layers which correspond to La Niña's dry conditions in the West Coast. From the thickness of these layers we can determine how many years between the occurrences of El Niño and La Niña. While individual years will tend towards some random variation in thickness, the oscillatory nature of ENSO would suggest that it is more likely that wet and dry periods occur over a larger time period and vary sinusoidally like the tides rather than randomly. From the sediment core we can determine the weather effects of ENSO over a long period of time, including whether there are different magnitudes of El Niño and La Niña, and even whether these too vary over time. We can also compare this with the current climate and make predictions about the present state, and whether the variation is likely to rise or fall in the future. //

Other information in the core can also be useful in determining geological and climate events of the past. Between summer and winter deposits, there will be variation both in thickness, ~~and~~ as was mentioned above, and in the color. While the thickness of the layers can be used to determine the amount of rainfall in a given time, the contrast between the light summer and dark winter layers can be used to investigate the intensity of the rainfall, and the resulting ~~the~~ coarseness of the erosion particulates, found in climates in the past. The composition of the sediments can too be investigated, such as a layer of ash which might suggest volcanic activity near the lake at

certain times, or a misalignment in the layers which was caused by an earthquake at some point in the past, which too can be dated by determining the ~~date~~ date of the most recent of its effects, before additional sediments were deposited on top. //

This sediment core from Lake Ohau provides much information of the climate variation in the past and how ENSO has affected it. Combined with other records in the surrounding area and beyond, ~~very~~ there is a lot of evidence that can be used to investigate the events both climate and geological, of the past. //

QUESTION TWO: VOLCANISM ON THE MOON AND THE EARTH

Compare and contrast the Moon's volcanic history with that of the Earth.

Consider in your answer:

- the effect of asteroids
- the characteristics of the crust
- the role played by gravity in the formation of the maria
- the presence or absence of water.

The moon has showed no volcanic activity for at least the last billion years, but before then it was more common, forming the large maria on its nearside. The volcanism exhibited by the moon, however, is very different to the familiar types shown on the Earth and in New Zealand, as well as the greater effects on its topology caused by asteroids. //

Having no atmosphere due to the moon's low gravity, asteroids are not broken down before they reach the moon's surface like they are on Earth. This results in the large white scars observed on the moon's surface, which remain in place for billions of years, as the moon has no tectonic activity, nor climate cycles, to cover these up. However, the nearside of the moon, where the crust is thinnest, is mostly protected by asteroids, because the Earth and its gravity field would get in the way of such asteroids' paths. This means that almost all the asteroids to strike the moon do so on its farside, where the crust is very thick, and so does not affect the mantle and kickstart and volcanic activity. If a sufficiently large asteroid were to strike the nearside, its shockwaves could travel through the thinner crust and cause ^{magma} volcanic activity, although this is unlikely due to the Earth's shielding effect. This could, however, have

occurred on the farside with an extremely sized asteroid, and lead to the volcanic events which created the Mare Moscovense, an irregular farside mare.

The moon's crust does not show any evidence of tectonic activity, and so subduction volcanoes cannot be the cause of the moon's features. Thus it can be deduced that all the mare on the moon were formed by hot-spots. This explanation is further supported by the plethora of nearside maria and the lack of them on the farside, as the thinner nearside crust means that mantle plumes which reach the mantle-crust boundary have a thinner distance to break through before erupting through the moon's surface. Hot-spots which do occur on the farside will have to be very strong in order to break through to the surface, which is another possible explanation for the Mare Moscovense, and will even then form very small maria, as little ~~lava~~ lava actually makes it to the surface. The elements analysed and found in the crust also provide evidence to suggest the composition of the ~~asteroid~~ ^{asteroid} which struck Earth to form the moon. //

The formation of the maria was influenced by gravity in two main ways. The first is the effect of the Earth's gravity on the moon. The moon is tidally locked to the Earth, meaning that the same face is always directed towards us. This is what caused the difference in crust thickness on the moon, and lead to maria formation. This formation was two-fold: the moon's heavy core was strongly attracted to

to the larger Earthly body, and so it crept towards it, displacing the crust and parts of the mantle to the far side. Additionally, the centrifugal effect as the moon orbited the Earth caused the lighter rock particles to move towards the far side, away from the gravity of the Earth. Together these effects caused the moon's near-side crust to become very thin, thus promoting the formation of maria. The second gravitational effect is the moon's own gravity, specifically its weak effect, which unlike the Earth does not support an atmosphere. This meant that in the event of a volcanic eruption, the ash cloud was simply ejected into space, leaving behind only the lava flows which formed the maria. If this ash had settled on the moon, it would have changed the composition of the basaltic magma and made it ~~cool~~ and shape differently, leading into a different geological record left behind.

The lack of water on the moon also had an important effect on its volcanic activity. The lack of oceans meant that all volcanic eruptions occurred on the moon's solid surface, and so the ~~molten~~ magma was able to flow for many hundreds of kilometers and form the large, circular maria as seen today. Another reason these maria are so large is that they were cooled only by radiation, and a small amount of conduction to the crust. This means they cooled much slower than volcanoes on Earth, which are able to cool by convection to the atmosphere, and conduction to water in oceans, which with its large heat capacity would cool magma much faster. This slow cooling process

lead to the large and non-viscous flow of lava which lead to the creation of the maria. The absence of water also means that there is no water cycle on the moon, and hence no erosion of the maria, meaning that magma flows are still visible billions of years later, and can still be analysed by scientists to gather information about its history. //

The moon's volcanism is vastly different to the Earth's, due to the lack of subduction occurring in its mantle leading to hot-spot volcanism only, and the moon's crust thickness causing volcanic activity to occur dominantly on the nearside. Additionally, the lack of water means these geological records are preserved, and even though the moon has shown no volcanism for a billion years, the effects of it are still visible. //

QUESTION THREE: GLOBAL SEA LEVEL RISE

Cyclic sea-level changes have affected our planet over hundreds of thousands of years.

Discuss the causes of global warming and its effect on sea level.

In your answer, you should also consider potential changes in:

- thermohaline circulation
- albedo effect
- solubility of carbon dioxide.

While the Earth naturally oscillates between hot and cold periods, it has always been a natural and gradual process. Never before has the global temperature been increasing so rapidly as it is today, and it is due to the effect of human development. If global warming continues to occur, sea levels will continue to rise, disrupting both human communities and global systems //

Global warming occurs due to the enhanced greenhouse effect. The greenhouse effect traps incoming ~~infrared~~ radiation from the sun on the planet. When shortwave solar radiation passes through the atmosphere, some is absorbed and retransmitted in all directions, but it ~~is~~ mostly passes through to the Earth's surface which absorbs it and retransmits it as longwave IR radiation. This infrared radiation passes through the atmosphere but is absorbed by some gases, such as CO_2 , CH_4 , and H_2O . These are called greenhouse gases, and they reflect and retransmit the IR light back towards the Earth's surface, trapping heat on the planet and raising its temperature over time. These gases are all produced by humans, particularly carbon dioxide which is produced by burning fossil fuels and is currently at higher concentration in the atmosphere than it has ever been (415 ppm, c.f. previous

natural height of 325 ppm). This shows that the current state of global warming is not a natural cause, but instead a human effect, as nature has never caused such high CO₂ levels on Earth in recent geological history. //

The effect of global warming heats up the planet and ~~causes~~ leads to the rising sea levels already being noticed today. In the recent past, trends suggest that periods of high CO₂ concentration and high global temperatures, which are being measured already, have associated high sea levels. This is because as the planet heats up, two things happen. The first is that land ice melts into water and makes its way into the ocean, increasing the amount of water contained within it and flooding coastal areas. Between the Antarctic and Greenland ice sheets, the sea could rise at least 66 metres, not to mention the glaciers in places such as New Zealand's mountains which also contain large volumes of ice. Fortunately, sea ice can not cause sea levels to rise, as water becomes more dense when it melts, so this ice is already contributing to the ocean's volume. The second way sea rise could be caused by global warming is that when water heats up, it expands so that a warmer ocean takes up more space than a cooler one. While this effect is minimal on the small scale, when generalised to the entire ocean and land ice, this represents a significant rise in sea level, which would lead to vast destruction of human communities in coastal areas, including most of New Zealand's main cities and farming plains. //

Sea level rise and global warming will also have vast effects on other parts of the Earth's global systems. The Thermohaline Current is one of these. As the oceans warm up, water will be less able to sink near the poles, as this requires it to be cold. Thus, the Antarctic Bottom Water and North Atlantic Deep Water currents will stop taking cold water to the equator, which will then heat up and transfer even more warmth to the poles, disrupting the entire current system and creating a feedback loop of ocean warming. The albedo system will also contain a feedback loop; as the high-albedo ice melts, more solar energy is absorbed by the water, causing further heating of the oceans and thus melting even more ice, once again furthering global warming and sea level rise. Finally, carbon dioxide solubility is also greatly affected by global warming and sea level rise. As the volume of the ocean increases, and more fresh water is added, more carbon dioxide is able to be absorbed into the ocean and its solubility is increased. While this does create a negative feedback loop and reduce the effects of global warming, it also increases ocean acidity, which speeds up the carbon cycle, as well as lessening the ability of microorganisms to live in the sea, ~~thereby~~ with knock-on effects to the rest of the world's ecosystems.

Cyclic sea level changes may be regular in the Earth's history, but they have never before occurred so rapidly, and at this time, they are indeed due to the effect of human industry on the environment. In

Order to preserve the planet for humanity is and all other species' future. Measures need to be taken to reverse the effects of global warming before they are too far gone to fix. Otherwise, systems worldwide will continue to be effected and create a massive positive feedback loop on the planet's vitality. //