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93104



931040

SUPERVISOR'S USE ONLY

OUTSTANDING SCHOLARSHIP EXEMPLAR



NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

Tick this box if you
have NOT written
in this booklet

☐

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	

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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 sediment core can be dated using a number of principles. These include making use of the law of superposition (older layers at the bottom with younger layers on top) for relative dating, and C-12 dating, biological dating, etc. for absolute dating. Essentially, interactions between the geosphere, biosphere, hydrosphere, cryosphere, & atmosphere can help us ~~determine~~^{gain} an understanding of past climates. The sediment core ~~is~~^{can be} expected to have pollen or other ^{organic} remains, which can be C-12 dated or cross-correlated with certain species known from data banks, etc. to help us determine what conditions were present at the time, as different climates have different species. However, as climate is a long-term variation, with El Niño/La Niña being less than a year in length, only thin layers in sediment cores can be analysed for changes in species & climates.

The pollen, DNA, etc. of certain species could be analysed ~~in~~^{under} a microscope to see if there are any discrepancies which perhaps indicate pollutants or changes in temperature.

The sediments ^{we are} concerned with in this investigation are

- x- as the greater erosive rate means more ~~sediments~~ ^{material} is deposited in a certain timeframe, due to more erosion
- y- as a lower erosive rate leads less erosion leading to less ~~sediments~~ ^{sediments} being deposited

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terrestrial sediments. These come from the Southern Alps, which consist of mostly white-colored igneous rocks, before being eroded by rivers into places ^{in the} ~~the~~ western South Island. ~~Lake Ohau~~. The rate of erosion in a year can be ~~estimated~~ ^{interpreted} based on the thickness of a layer in the sediment core. For example, a thicker ^{layer} ~~core~~ indicates ^a higher erosive rate ^{Ex} while a thinner layer probably indicates ^a lower erosive rate. ^{Ex} The layers representing years, as shown on Fig 2 of the resource booklet, are defined by large & thin layers, with darker layers representing winter.

In El Niño conditions, due to the increase of westerlies, the west coast of New Zealand receives greater precipitation while the eastern side, from the Southern Alps eastwards, experiences less precipitation due to the cool, dry air above the eastern Pacific ^{near NZ} being cooler during El Niño (due to the weakened or reversed trade winds for unknown reasons) and the rain shadow given by the Southern Alps which prevents westerlies from moving eastward. Due to the lack of much precipitation in ~~the~~ ^{eastern} NZ during the El Niño episodes the erosive rates on the Southern Alps ~~decreases~~ ^{drop} drastically due to the decreased physical weathering (from water) acting on its rocks ~~there~~ ^{near}. The calmer weather ^{may} also mean less winds ^{along the} ~~boundary~~ ^{boundary} Ferrel-polar cell ~~area~~ ^{area} and hence air temperatures and hence a lesser amount of rainfall. Thus, we expect El Niño ^{layers in} sediment cores to be thinner than ^{most} layers, which signify either "normal" years with little to no variation

in Pacific Ocean winds & surface temperatures of La Niña years. Thin layers in sediment cores may also signify a change in ocean currents, causing cool ~~water~~ ^{and in turn air} land. Hence lesser evaporation & in turn precipitation ^{to form on} the coasts of New Zealand. This causes a lesser erosion rate & hence the sediments deposited during an El Niño year decrease.

Winter

In El Niño conditions, due to the increase in westerlies, ^{which pick up Tasman Sea moisture} the west coast of New Zealand receives

greater precipitation ~~than the west~~ than in normal conditions.

La Niña

El Niño

Despite the rain shadow provided by the Southern Alps, the increased ^{orographic} precipitation

El Niño

means that the annual precipitation on the South Island east of the Southern Alps ^{also increases in the western South Island}

Normal

Because of the increased precipitation overall,

more physical weathering of the Southern Alps occurs, and at a greater rate—the erosion rates increase. ~~Furthermore,~~

Hence, the amount of sediments deposited on a labelled like those of ^{the western South Island} ~~them~~ to later be used in sediment

cores increases in an El Niño year, and hence

we expect El Niño years to have ~~greater~~ thicker layers in sediment cores than regular layers, like in the

above examples. In a La Niña year, ~~it is quite~~

~~possible that~~ due to the greater northeasterly winds,

the South Island receives less rainfall, and hence

the hydrological weathering ^{on the western side} of the South Island's

Southern Alps decreases and so does the rate. Hence,

less terrigenous sediments can be expected to be

- deposited in lakebeds, and so the resultant layer of a La Niña year in a sediment core may be thinner or indicated on the pg4 examples.
- If we use a variety of indicators to help us relatively date each layer in a sediment core we can be able to work out a range of dates for the El Niño & ~~La~~^{western} Niña years & ~~to~~ determine how they affected the South Islands perhaps for the last ~~century~~ ^{thousands or even millions of years}. Through this we can learn lots about past climate & the atmosphere.
- The present & the past are the so-called windows to the future. Perhaps similar events can occur in the future. Studying past climate can help us realize what might happen in the future.
 - The erosion rates can be powerful enough for landslides to occur, especially in El Niño years. Because of this, people in the western South Islands should be on alert for possible landslides, especially during El Niño.
 - By studying El Niño & La Niña patterns in the past we might be able to determine if there is really a trend in the oscillation.
 - By studying previous climates perhaps through the ~~usage~~^{analysis} of pollen in sediment cores allowing us to determine what species dominated during long-term climates we might be able to determine what the western South Islands climate was like in the past & how the southern oscillation had in connection to it.
 - Considering our current climate crisis, we might see if there is any variation between the Southern Oscillation & climate.

Extra space if required.

Write the question number(s) if applicable.

QUESTION
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1 & climate in the past compared to what it is today. Could anthropocene global warming have had any effects on the climate & oscillations? - Pacific nations like Chile[^] ^{which lies in the same latitude} ~~may well have had~~ as NZ^{South Islands} may well benefit from research made here on the nature of the oscillation //

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 lacks water and hence plate tectonics, or water, or another appropriate liquids is needed to lubricate plate tectonics. This could very well contribute to the lack of evidence of plate tectonics on the Moon compared to the various observations of plate tectonic theory we see on Earth, which has numerous amounts of water available to lubricate plate tectonic motion. As volcanism bears two possible sources, subduction (convergent boundaries) & hotspot volcanoes, this means that the Moon's past volcanism would have been more hotspot-based. The hotspots on the Moon would have possibly been "fueled" by the Earth's gravity. Because the Moon is tidally locked, we expect its Earth-facing side to experience tidal flexing. This is evident in that most of the lunar ~~maria~~ maria are present on the Earth-facing side. The Earth's gravity would have caused the ~~Earth's gravity~~ Moon's interior to be slightly skewed towards the Earth, and hence the closer core would mean the interior of the Earth-facing side would be heated more. This is evident in that the Moon's core & mantle are closer to the surface of the Earth-facing side than they are to the far side.

i.e. the far side crust is thicker than the crust on the near side

^ implying that tidal flexing from Earth's gravity brought them towards Earth and in turn heating up magma near the near side, which would have been brought up to ~~the~~ ^{surface of the} Moon's Earth-facing side in a hot-spot like fashion due to tidal flexing. Tidal flexing on the Moon's Earth-facing side is also evident by deep moonquakes (release of ~~energy~~ ^{energy} stored in rocks) being on the Earth-facing side of the core. Hence Earth's volcanism is more evenly distributed around its surface, due to most of its volcanoes being subduction-based & its mantle being unevenly heated (forming hotspots), while the Moon's volcanism was concentrated on one side due to its volcanism being dependent on the Earth's gravity. Due to the low viscosity of the magma, it is possible that the volcanism would have occurred for 1-2 billion years. A number of factors are evidence for this — the large age of the more samples & the possible age for the youngest more flows. The volcanism ^{period} could also be an indicator of the Moon's geological cooling. When the Moon was formed, most likely according to the giant-impact hypothesis shortly after the Earth's formation, it would have gained much radioactive elements from the Earth, ^{as it formed from mixed materials from the interior of the planet & the impactor.} These radioactive elements would be more numerous as Earth's internal heat is partially sourced from the decay of heavy & unstable elements & radioisotopes. Therefore the Moon would also have a great share of radioactive elements, which would have heated

its core (per radioactive decay) to produce hotspots (via uneven heating) and form the maria through volcanism. The Moon, when having formed from accretion would have some heat energy generated from friction in its core (Kelvin energy). However, due to the low mass of the Moon compared to Earth, the ~~amount~~ amount of heavy elements the Moon would have initially formed with would have been less than Earth's. Because of its low mass & quantity of radioactive elements, the Moon would have lost all of its heat energy (from Kelvin energy & radioactive decay) so quickly, leaving it with a cool core, and hence not enough heat in the core for mantle convection currents or hotspots able to form volcanism. Hence, ~~despite~~ due to the Moon's small mass & despite the fact that it formed at the same time as the Earth, its volcanism could only occur in a smaller, limited timeframe compared to Earth, which still bears a hot interior & hence tectonic activity due to its larger mass ~~allowing~~ ~~maintaining~~ some heat energy to be retained. This fits in with our theories and observations of the Moon's volcanism happening only as recent as 1 billion years ago. Furthermore, our theory of radioactive decay of heavy & unstable isotopes being responsible for the Moon's initial internal heat & volcanism is supported by the occurrence of K, P, O, Si, etc. along with U & Th. These would have been brought by the lunar magma to the surface by the tidal flexing & internal

Heating-induced volcanism. Another potential reason for the Moon's volcanism having stopped is that it is receding from Earth at a rate of 3-4 cm per year indicating it must have been much closer billions of years ago—close enough for Earth's tidal forcing to have a significant effect on the heating of the lunar interior. Currently, the distance between them is too great for Earth's gravity/tidal forcing to show any significant effect on the ~~Earth's~~ Moon's interior (and) heating. When the Moon was much closer to Earth, and when its core was still hot and molten, volcanism would have been present for billions of years, as the large size of the ~~magmas~~ ^{molten} implies that the ^{low viscosity magma} would have been spreading over the lunar surface for a prolonged period. While flood basalts (like those in Deccan, India) are known on Earth, the maria—the lunar flood basalts—are similar in size. The Moon's original volcanism may have been caused by hotspots & tidal forcing from Earth, although it is quite possible the Moon also bore plate tectonics during the years it was geologically active & had a hot interior. The heat from the lunar core, ^{sourced from Kelvin energy & radioactive decay} when it was hot, would have likely heated the lunar mantle allowing ~~the~~ convection currents to be set up in the mantle, and giving the early Moon potential for plate tectonics. A new study, based on molybdenum isotopes, suggested that the Moon-forming impactor ("Theia"), ^{in the giant impact} ~~which formed~~ theory, may well be the source of the Earth's water. In this

Extra space if required.

Write the question number(s) if applicable.

QUESTION
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2 cases we expect that the early Moon may have also had water and perhaps even an atmosphere; hence plate tectonics would have also been possible in an early Moon. However, the Moon's small ^{and hence gravity} massⁿ meant it could no longer support an atmosphere and that it lost its heat energy relatively quickly. Because of this most of the water would have been lost to space due to the lack of an atmosphere to provide atmospheric pressure, ~~and hence by magma~~ ^{or heated up by lava} to become a gas (steam/water vapour) which would have ^{then} been lost to space due to the Moon's smaller gravitational attraction. Asteroid impacts ~~may~~ also have little correlation with the ~~eruption~~ formation of maria while the Tycho crater (an impact crater) is relatively close to the mare Oceanus Procellarum, ~~implying that magma from Tycho~~ ^{basaltic lava} More Mesosene B further away from other impact craters. Furthermore, these impact craters are believed to be significantly younger than the maria. //

It is study of the Moon's origins which allows us to determine how it formed. The Moon's volcanism differs from the Earth in that it was concentrated on one side & also caused by tidal flexing, while Earth's volcanism is mainly caused by its interior heating. //

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.

Global warming is primarily the result of increased concentrations of CO_2 & other greenhouse gases in the Earth's atmosphere, primarily in the troposphere. It has been primarily caused by anthropogenic (man-made) greenhouse gas emissions. As the concentration of greenhouse gases in the atmosphere increases, they cause ^{total} internal reflection of long wavelength radiation emitted from the ground to increase and this causes the atmosphere (particularly the troposphere's) temperature to increase. As the extra heat energy is conducted to the seawater below, thermal expansion causes it to expand, causing sea levels to increase //

While equatorial, tropic and sub-tropic regions increase in temperature due to the increase of GHGs in the atmosphere causing heating, they also cause cooling in the polar regions. ~~They~~ This is because they heat up ~~the increasing~~ the equatorial troposphere by trapping re-radiated heat energy from the ground, causing it to expand (as air ~~heats up~~ ^{expands} when it is heated up). This causes the boundaries of the ~~Hadley~~ ^{Hadley} & Ferrel cells to move southward. The expanding troposphere near the poles means that the

However, the ^{polar} ~~cooling effect~~ ~~increasing effect~~ caused by the GHGs is much less than more than cancelled out by the warming effect they have on the Earth's climate. As shown in Fig 2, the ice on the Arctic Ocean has decreased drastically due to melting in ^{higher} temperatures.

The thermohaline circulation would be drastically devastated by ~~the~~ global warming. For instance, a rising temperature may mean that the heat transfer patterns between ~~the ocean & land~~ ^{the ocean & land} may be altered; for example, Europe might experience warmer summers & cooler winters. Storm cycles will also be heavily altered. ^(x) In the long term, if climate change is not tamed,

the THC may stop. This may see ~~a~~ a lack of warming in Europe due to a lack of any mechanism by which warm Caribbean water is brought to Europe by means of ocean currents, which heat up ^{land} ~~land~~ cool down by absorbing heat energy from the ^{atmosphere} ~~surrounding area~~ by conduction. The warmer Arctic water may

Lack of the THC will cause changes in global temperatures, and perhaps a heating climate might lead to a hotter USA & Europe.

The heating Arctic Ocean ^{& above atmosphere} means there is more heat energy available for the ice to absorb & melt. As the latent heat required for ice to melt stays constantly ~~the~~ an increase in the Earth's temperature in the Arctic (and hence heat energy) means that ^{a greater mass} ~~more~~ of ice melts. As ^{water} ice has a high albedo of 0.9, this means that ~~the~~ if Earth's ice caps melt, the albedo of the Earth decreases as the Earth's

surface ~~decreases~~ due to with less high-albedo ~~light~~ ice absorber more solar EMR than it emits. The ocean has a much lower albedo of 0.06 & is hence a heat sink. The melting ice exposes more low-albedo ocean which ~~absorbs~~ ^{absorbs} more EMR than it reflects, decreasing Earth's albedo. This means the Earth now absorbs more heat than it did previously. This means more IR is re-emitted by the ~~surface~~ heat sinks like the land & sea and therefore due to the increase in GHGs which contribute to global warming, more IR is totally internally reflected and hence the Earth's temperature increases globally. This means that land ~~ice~~ ice sheets are melting due to the increased global temperatures. // (The ice melting ^{high-albedo} due to increased temperature mean that less ice exists to reflect away EMR, and so the Earth's temperature increases in a positive feedback loop as more EMR is absorbed.) While melting sea ice does not affect sea levels, melting land ice does as a greater volume ~~ice~~ of ~~ice~~ ^{melting ice} is added to the seas from the land. Hence an increase in ~~temperatures~~ ^{sea levels} means that sea levels may well increase due to land ice melting which may cause damage to towns & potential floods & avalanches. The leading effect caused by the Earth's decreasing albedo in a positive feedback loop means that, due to thermal expansion, the oceans will continue to rise & perhaps flood many low-altitude cities like Miami, Nassau, Amsterdam, and Copenhagen.

With the sea reclaiming low-lying places like Florida, the Netherlands, and Denmark, its surface area increases & hence more low-albedo sea is available to ~~reflect away~~ absorb EMR, leading to further heating & another positive feedback loop as temperatures increase, leading to more thermal expansion & increasing sea levels, etc. As CO_2 dissolves more in stony, cold water due to the less energetic H_2O molecules being able to form attractive bonds to the CO_2 molecules, CO_2 dissolves less in warm waters. Therefore if the oceans increase in temperature due to global warming, less CO_2 will be absorbed. This leads to more CO_2 accumulating in the atmosphere & causing heat energy (IR) to be returned, causing a positive feedback loop with more heating.

Unfortunately, anthropogenic global warming cannot be found easily, and the greenhouse gas we have added to the atmosphere means that more ~~heat~~ heat is retained & so ^{mean} temperatures increase. This could lead to the Milankovitch cycles being altered on the long run - peak temperatures for interglacial periods could well increase and ^{so will} the sea levels. CO_2 concentration