Assessment Schedule – 2015

Scholarship Earth and Space Science (93104)

Evidence Statement

Q	Evidence	1–2	3–4	5–6	7–8
ONE	*The response must focus on what the cores tell, and why. Reference must be made to the time scale of thousands of years (rather than millions of years).* *A well labelled relevant diagram contributes towards evidence.* The oldest sediments are at the bottom of the core and the youngest at the top – this sequential order gives a relative date for each layer. More accurate dating of different layers can be gained from distinctive layers such as volcanic ash from a known eruption or dust particles from a specific known event or C-14 dating of organic material. When these are compared with relative dating and C-14 dating, a chronological sequence for thousands of years can be determined. Phyto- and zooplankton have unique skeletons / platelets that are found in sediment layers. Different plankton are highly sensitive to changing environmental conditions, such as temperature, and can be identified using microscopes. They can also be chemically analysed to show changes in oceanic conditions. E.g. the C-12:13 ratio in the skeletons of phyto- and zooplankton, especially those using calcium carbonate, could give an indication of the temperature of the environment at the time. A higher temperature would mean more photosynthesis, resulting in a lower C-12:13 in the atmosphere because plants selectively take up carbon dioxide containing C-12 during photosynthesis. Seawater absorbs carbon in the C12:13 ratio of the atmosphere at the time and plankton form their skeletons / platelets using the same ratio. Identification, chemical analysis and examination (for irregularities or deformities) of plankton skeletons in different layers in a core would indicate changes in ocean chemistry, ocean currents, and temperature over the relevant time period. A comparison of, e.g. the same layer in different cores, could give an indication of, e.g. ocean current flow in one time period and may indicate changes in current flow such as a reversal or slowing down. Deformed or fewer than expected plankton skeletons could indicate environmental pollution or ocean acidification, especially if cross-correlated with 'normal'	• Very little understanding of question with very little development of ideas.	• 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.

	skeletons from other cores or from data bases. Rock sediment that has originated from the erosion and weathering of land would need to be analysed for size, mineral content, geographical origin of rock, and age. Any deviation from the norm of larger particles deposited closer to the coast and finer particles further off-shore could indicate a major event like a tsunami, turbidity flow, or change in an ocean current. An analysis of plankton may also indicate, e.g. turbidity, if the plankton were found to be well away from their place of origin. A comparison of rock sediment over time and between cores could enable the rate of erosion and weathering of certain rocks, such as those that make up the Southern Alps, to be worked out. This would indicate changes in weather patterns, resulting in more or less rain (water being a primary cause of weathering) and the rate of uplift of the Southern Alps. As the height of the Southern Alps increased, they would act as a barrier to prevailing westerly winds. Rainfall would increase on the windward side, causing an increase in the rate of erosion. If erosion patterns appeared to have changed, as indicated by a different type of rock being eroded, this could indicate a change in prevailing winds. Deep-sea sediment layers may contain volcanic ash from large eruptions occurring in New Zealand. The chemical composition of volcanic ash is unique for each eruption, so core records can be cross-correlated with land records. Records of volcanic eruptions found in cores are not affected by erosion, and so would give an uninterrupted record of, e.g. eruptions in the Taupo Volcanic Zone. The ash can also be dated (by K / Ar dating). Deep-sea sediment is also a record of climate change on earth. Biological production in the world's oceans and its chemical composition changes as the oceans heat up or cool down over thousands of years. Analysis of plankton skeletons, e.g. isotope ratios plus species distribution, will provide evidence of such changes. Pollen grains can also give an indication of the distribution of plant species, plus an indication of the climate at the time. Information on major geological events, such as the uplift of the Southern Alps, can be gained from deep-sea cores. When the Southern Alps are eroded, the material is carried down rivers and out to sea. The material is deposited on the ocean floor according to size, unless deposited on the continental rise or the sides of under-sea canyons. Then an earthquake may dislodge the material, resulting in				

	a turbidity current and coarser material swept much further away. The record of a turbidity current in the core can be dated and used to confirm the date of major tsunamis and / or earthquakes. The relative thickness of rock sediment layers may indicate the rate of weathering – a thicker layer indicating more erosion because of more rain and / or more rapid uplift of the Southern Alps. Analysis of any organic material among the rock sediment could give a C-14 date, and if there is pollen identification of the pollen grains, could indicate the plants growing at that time, which would also give an indication of possible climate and temperature.				

Q	Evidence	1–2	3–4	5–6	7–8
TWO	**Key Points** *A well labelled relevant diagram contributes towards evidence.* If there is less ozone in the stratosphere, less UV can be absorbed and less heat retained, resulting in the stratosphere being cooler. This, combined with a huge cold landmass and a cold troposphere (because very little heat is radiating from the land to warm the troposphere), results in a greater temperature and pressure difference between the mid- and polar latitudes. Cold air is dense too, which increases the already high pressure at the poles. This results in the polar jet stream and the band of westerlies moving southwards and strengthening. The westerlies bring a lot of precipitation because they pick up moisture from the Southern Ocean. Heat is lost during evaporation of the seawater, making the current and winds colder, which also prevent heat from the Equator moving southward. The cooler stratosphere means that more polar stratospheric clouds (PSCs) form in the winter, and therefore more ozone is destroyed, enhancing and prolonging the ozone hole. Greenhouse gases (GHG), which accumulate in the troposphere, trap radiated heat / infra-red from the surface of Earth and re-emit it, heating the troposphere. The extra heat has caused expansion of the troposphere, causing the boundaries of the three convection cells to move southwards. This also cools the stratosphere. The cooler stratosphere, combined with the stronger westerlies and polar jet stream, whether caused by the ozone hole, GHGs, or both, means that more PSCs form in the winter, and therefore more ozone is destroyed, enhancing and prolonging the ozone hole. GHG also increase pressure differences between mid- and polar latitudes, strengthening the westerly winds and the polar jet stream and causing the climate belts to shift even further south. The combined effect on the depletion of the ozone layer of the ozone hole and GHGs may mean that the closing of the ozone hole may be delayed by years or decades. This will have the effect of cooling the southern-most latitudes while the rest of the world is warming. When the ozone hole finally does close over, or stop forming each winter / spring, the effect on the Southern Hemisphere atmospheric circulation will be the opposite to that of the GHGs. The GHGs will keep on causing the southerly boundaries of the convection cells to	• Very little understanding of the question with poor coverage of key points.	• Shows some understanding of the question with some development key points • Some synthesis and integration of the processes.	• Good understand-ing of the question with good development of key points. • Good analysis, synthesis and integration of the processes exhibiting well developed understand-ing of the context.	• Thorough understanding of the question with excellent development of key points. • 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.

	move polewards and the pressure gradient between the mid- and polar latitudes to be large, whereas the renewed ozone layer will cause the pressure gradient to be less, and the wind and climate bands to move towards the Equator.				

Q	Evidence	1–2	3–4	5–6	7–8
THREE	*A well labelled relevant diagram could contribute towards evidence.* Because of the different boiling and melting points (bp and mp) of water and methane, the "liquid water" habitable zone (HZ) around red dwarfs (RD) would be inside the "liquid methane" one. Red dwarfs are relatively cool, so the zone for liquid water would be close to the star because water has a relatively high mp. Methane has a much lower mp and so would be much further out. The position of both the zones would depend on the size of the red dwarf. The size of the proto-red dwarf is larger than a main sequence red dwarf, so as the red dwarf forms and ages and gets smaller, the two zones would get closer to the star, but would proportionally have the same or similar distance between them. Life, if present, is likely to be microbial / prokaryotic cells / like Archaea / extremophiles that may only reproduce infrequently and very slowly. Even very primitive life needs a long time to evolve, so a planet would have to be in the habitable zone for millions of years at least. Red dwarfs do have very long life cycles, but seeing that the habitable zone can change in a star's lifetime, means that life would need to develop within the time that a planet was in either zone. A liquid, either water or methane, is needed to transport materials / nutrients / minerals around a life form. Water stays liquid over a hundred degrees Celsius whereas methane stays liquid only over twenty-two degrees Celsius. This would result in a wider "liquid water" zone and a narrower "methane" one. Therefore a zone with liquid water is the most likely zone for life to evolve in, because the planet can experience a wider range of temperatures, and still have life compared with a planet in the methane zone. However, life developing on a planet in the methane zone could have more time, because the planet is not affected by tidal locking or severe space weather. As the red dwarf forms and ages, the star becomes smaller, although hotter. The habitable zones will also change, becoming closer to the star, although how close will depend	• Very little understanding of the question with very little development of ideas.	• Shows some understanding of the question with only some development of ideas. • Some synthesis and integration of the processes.	• Good understanding of the question with good development of ideas. • Good analysis, synthesis and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of the 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.

	on the temperature of the star. Note that, when fusion of hydrogen to helium begins the habitable zones would become further away from the star but then carry on becoming relatively closer to the star as it ages. The implication of this is that a planet that was not in either of the habitable zones may enter one as the star ages, or if already in one, may leave it. So this will affect the time the planet is in the habitable zone, and therefore the time available for life to evolve. If a planet leaves a zone, life may continue evolving underground, where the water or methane may stay liquid for longer. A planet that is very close to a red dwarf (and possibly in the water zone) would probably be tidally locked, with one side always facing the star. If only one side is facing the star, that side is going to be heated vastly more than the side facing away from the star. The side facing away from the star will experience very low temperatures, and water probably wouldn't be liquid. The side facing the star may become too hot for water to stay liquid so that it would evaporate away. There may be a narrow band between the hot side facing the star and the cold side not facing that may have liquid water. Planets close to the red dwarf would also experience severe space weather, especially when the star was young. This could result in any atmosphere being stripped away, which would also mean no retention of heat on the far side of the planet. Radiation from young stars could also result in photochemical damage to molecules or mutations to developing life. A planet in the methane zone would not experience tidal locking or intense radiation and so life may have a chance to develop despite the narrower zone. Life processes are slower in colder regions such as the methane zone – this may slow down evolution of life but not affect life that is already there because extremophiles can have very slow reproduction rates and some can even go into hibernation by forming spores. Planets in the methane zone may also not be rocky but gaseous because they formed past the frost line for that particular star. Life is less likely to evolve on gaseous planets but there may be rocky moons on which life mat evolve.				