Assessment Schedule – 2014

Scholarship Earth and Space Science (93104)

Evidence Statement

Q	Evidence	1–2	3–4	5–6 Scholarship	7–8 Outstanding scholarship
1	Io's and Europa's elliptical / eccentric orbits mean that these moons will have widely varying distances from Jupiter during the course of their orbits. This is because Io and Europa are subjected to gravitational forces not only from Jupiter but also from Ganymede and Callisto / the other 2 Galilean moons. These gravitational forces cause tidal flexing of Io and Europa, which is amplified when the moons line up in their orbits. The tidal flexing causes stretching and squeezing / deformation (and the moons to change shape), which causes **friction** in the mantle and crust of these moons, which generates a lot of heat On Io, the tidal heating is enough to melt rock, forming magma. The magma is less dense than the surrounding rock and rises until it erupts from the surface. The proximity of Io to Jupiter and the constant flexing and heating causes the volcanoes to be violent (NOT the amount of silica in the magma). Europa is further away from Jupiter, so the tides it feels from Jupiter's enormous gravity are less, although it is still affected by Ganymede and Callisto. Europa has enough tidal flexing to generate friction, and therefore heat which will cause some water to be liquid. The cracks in the icy crust are fractures in the ice as a result of tidal flexing. When the cracks form, liquid water is squeezed up through them and the cracks quickly freeze over. There are a lot of cracks despite less tidal flexing as compared with Io, because ice is able to deform and melt at lower temperatures than the silicate rocks of Io. Europa's ocean would move as this moon orbited and rotated – this could	• Very little understanding of tidal heating and the effect on these moons, with very little development of ideas.	• Shows some understanding of tidal heating and the effect on these moons, with only some development of ideas. • Some synthesis and integration of the processes.	• Good understanding of tidal heating and the effect on these moons, with good development of ideas. • Good analysis, synthesis and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of tidal heating and the effect on these moons, 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.

	also put strain on the crust. A thicker icy crust is stiffer and will not bulge with the changing tides as much as a thin ice shell. A liquid ocean suggests heat from the mantle, which would be caused by friction from tidal heating. Europa may have volcanic activity at the bottom of the ocean as a result of the tidal flexing. This could result in a hot mantle with seafloor volcanoes and geothermal vents. This heat would result in a thick ocean and a relatively thin layer of ice on top. No heating from volcanic activity would result in a thicker ice sheet and less ocean underneath. Any heat generated by tidal flexing will be trapped because ice is a good insulator. The thickness of the icy crust may depend on the viscosity of the silicate mantle. The lower the viscosity, the softer and hotter the mantle, and the greater the ocean relative to the ice sheet.				

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2	The (cold, dense katabatic) winds cause evaporation, which causes heat (latent heat) to be lost from the sea. Therefore ice is formed. Because the wind pushes the ice to the edge of the polynya, the ice-free water can produce more ice in a continuous process. Sea ice only contains fresh water, so the left over salt stays in the ocean / is expelled from the ice when seawater freezes to form sea ice. The left over salt AND the cold temperature result in dense brine that sinks and flows down the continental shelf to the bottom of the deep ocean (to form Antarctic Bottom Water (AABW) – the densest water in the open ocean). The downwelling / sinking of this very dense brine drives the density driven global thermohaline current (THC), which distributes heat, nutrients and gases (not just water) through the other ocean basins. Note – there is downwelling in this area but not upwelling The cold, dense waters transport oxygen from the atmosphere into the deep ocean, so as to supply oxygen to deep ocean ecosystems. CO_2 is more soluble in cold water so the sinking brine lowers atmospheric concentrations of CO_2 by carrying it from the surface to the deep ocean, storing it for thousands of years. The ice-free waters of a polynya mean that the ocean can receive relatively high levels of sunlight from early spring onwards. Access to sunlight results in vigorous blooms of phytoplankton, which take up large amounts of CO_2 and produce O_2. The phytoplankton also incorporate carbon from the ocean into their carbonate skeletons / platelets. When the phytoplankton die they sink and the breakdown of their organic tissue releases CO_2 and nutrients in the deeper ocean. The carbonate skeletons / platelets become part of the sediment at the bottom of the ocean, sequestering carbon / forming long term storage of	• 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 understanding of the question with good development of key points. • Good analysis, synthesis and integration of the processes exhibiting well developed understanding 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.

	carbon. A reduction in polynya size means that phytoplankton production is reduced, which means that less carbon will be sequestered. Any reduction in sea ice production also reduces brine production and the sinking of dense water to form the AABW. This will result in the THC slowing down, and it will not be as efficient at distributing nutrients, gases and heat around the planet.				

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3	The Louisville Seamount Chain (LSC) was formed when the Pacific Plate (PP) moved over the hotspot, which is a plume of basaltic magma from the mantle. The plume / magma rose until it broke through the crust, forming a volcano / seamount. Each volcano was once active, but as the PP moved, each volcano was also moved away from the magma source and became extinct. There possibly there wasn't time for large amounts of massive sulfides to be made before the volcano / seamount was moved away from the hot spot, when all black smoker activity would have stopped because of the lack of heat source. Part of this chain plus any massive sulfides produced is lost when the oldest part of the chain is subducted under the Australian Plate (AP) / into the Kermadec trench. The Kermadec volcanoes have formed because of subduction of the PP under the AP, with magma forming when the PP has subducted to a certain depth. At this depth water (from subducted sediment / oceanic crust) becomes superheated, and helps to lower the melting point of rock so that magma forms, rises, breaks through the ocean floor and forms volcanoes. Subduction is continuous and many of these volcanoes are still active, with geothermal vents and black smokers that are also still active. It is more likely that massive sulfides will be found around the Kermadec volcanoes because the volcanoes and the hydrothermal vents are still active. The massive sulfides formed by the Kermadec volcanoes could be considered renewable because they are continuing to form within human time-scales. Also, ongoing geothermic activity results in more being produced. No massive sulfides will be being made by the LSC volcanoes because they are extinct. Any massive sulfides formed when any LSC volcanoes were active	• Very little understanding of the relevant tectonic processes, with very little development of ideas about renewable resources and implications.	• Shows some understanding of the relevant tectonic processes, with only some development of ideas about renewable resources and implications. • Some synthesis and integration of the processes.	• Good understanding of the relevant tectonic processes, with good development of ideas about renewable resources and implications. • Good analysis, synthesis and integration of the processes, exhibiting well developed understanding of the context.	• Thorough understanding of the relevant tectonic processes, with excellent development of insightful ideas about renewable resources and implications. • 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.

	would now be covered in a thick layer of sediment which would make them harder to detect and to extract. Kermadec massive sulfides would be easier to extract although depth of water would be a problem in both areas. Whether the sulfides are renewable or not, mining would have to be done very carefully so as not to disturb delicate and unique ecosystems. There may have to be designated mining areas and designated protected areas. If the resources are renewable, it may be possible to mine in just one or a few places. This would cause a lot less environmental degradation.				