31. Philip Light was listening to the conversation and immediately suggested that there must be at least one other rock outcropping in the region of the second cutting. Orson confirmed he was correct, adding that in a zone 100 metres from the eastern edge of the second cutting there were also some rocks exposed that were not what he pointed out previously.

Q: Which rocks did Orson confirm were exposed and/or outcropping in the most easterly section of the second cutting?

a. Rhyolite exposed, Basalt exposed and outcropping.
b. Hornfels, marble, quartzite and slate exposed, basalt exposed and outcropping.
c. Hornfels, marble, quartzite and slate exposed, dolerite exposed and outcropping.
d. Limestone, shale and sandstone exposed, basalt, exposed and outcropping.
e. Limestone, shale and sandstone exposed, dolerite, exposed and outcropping.
f. Rhyolite exposed, dolerite exposed and outcropping.

32. Rose was keen to learn more about Orson's fossils but thought he might have his labels a bit mixed up. She confirmed he had the fossil names correct but suggested he had them out of chronological order. Based on her knowledge if the distribution of fossils through time she wrote down the order they should be in for Orson.

Q: What order did she place the following fossils in? Write the correct period next to the fossil using: Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Pliocene

A kangaroo femur	
Dunkleosteus – a placoderm fish	
Monograptus sp. a graptolite	
Redlichiina – a Redlichiida family trilobite	
Tetragraptus sp. – a graptolite	
a Lepidodendron early plant fossil	

33. Orson was impressed with Rose's help and asked her for feedback on three radiometric ages his geological consultant sent him during the excavation. Unfortunately, he had misplaced the details about which rock returned which date. The three dates are:

- Rock 1 - 420.3 ± 0.5 million years
- Rock 2 - 259.1 ± 0.4 million years
- Rock 3 - 3.60 ± 0.1 million years

Q: What did Rose have to say about these dates?

a. Rock 1 = Rhyolite, Rock 2 = Dolerite, Rock 3 = Basalt
b. Rock 1 = Dolerite, Rock 2 = Rhyolite, Rock 3 = Basalt
c. Rock 1 = Rhyolite, Rock 2 = Basalt, Rock 3 = Dolerite
d. Rock 1 = Basalt, Rock 2 = Dolerite, Rock 3 = Rhyolite
e. Rock 1 = Basalt, Rock 2 = Rhyolite, Rock 3 = Dolerite
f. Rock 1 = Shale, Rock 2 = Sandstone, Rock 3 = Limestone

34. Amber was also interested in the folding that can be seen in the layers of sandstone and shales (figure 8). She asked when it happened.

Q: What did Philip accurately say in reply?

a. The folding took place at the very end of Silurian or in the very early Devonian.
b. The folding took place at the end of the Mesozoic, 66 million years ago.
c. The folding took place before the dolerite intrusion but after the rhyolite intrusion.
d. The folding took place during the metamorphism that formed the hornfels, marble, quartzite and slate.
e. The folding took place after the Permian but before the Pliocene.
f. The rocks are not folded, they were deposited that way on the floor of a deep-sea basin that had very large waves.

35. Amber also asked when the limestone was folded (figure 8) but was surprised when Philip said it wasn't.

Q: What else did Philip say when explaining this to Amber?

a. The base of the limestone is an angular unconformity. The top of the limestone in contact with the river gravels is an erosional scour.
b. The base of the limestone is a disconformity. The top of the limestone in contact with the river gravels is an angular unconformity.
c. The base of the limestone is an angular unconformity. The top of the limestone in contact with the river gravels is a lava tube filled with sediments.
d. The limestone is the result of a rhyolitic lava flow fed by a vertical dyke that post-dates the folding.
e. The base of the limestone is an angular unconformity. The top of the limestone in contact with the basalt is conformable.
f. The base of the limestone is a disconformity. The top of the limestone in contact with the basalt is conformable.

36. Orson was much keener on collecting minerals than fossils. He showed his friends a really nice set of white wollastonite crystals. The label said it's a metamorphic mineral, a calc-silicate, with the formula $CaSiO_3$. He was particularly pleased with these crystals as he personally found them in the first excavation cutting they were just talking about. They all agreed it was a superb specimen. Amber was intrigued to know where wollastonite could come from in the cutting. Orson pointed to the formula of wollastonite saying:

> *... all you need to form wollastonite in a metamorphic setting like this is some quartz and some calcite mixed together so they can chemically react to form the calc-silicate.*

Q: Where on the image of the first cutting did Orson indicate he found wollastonite?

a. At the base of the limestone, immediately above the contact with the rhyolite.
b. In the very upper layer of the limestone, in contact with the basalt.
c. At the base of the marble, immediately above the contact with the slate.
d. On all the contacts between the dolerite and other rocks.
e. At the base of each quartzite, immediately above the contact with a slate.
f. On all the contacts between the rhyolite and other rocks.

37. Amber was even more intrigued by the chemistry of this mineral and its formation even though she was usually more interested in living things. She asked:

> *... surely there was more than just wollastonite formed by this reaction and if so what was it and where did it go?*

Q: Orson was less certain of this answer but Philip stepped in and helped him out by saying …

a. Calcite plus quartz only makes wollastonite.
b. Calcite plus quartz makes wollastonite plus water which mixes with other fluids in the rock
c. Calcite plus quartz makes wollastonite plus aragonite.
d. Calcite plus quartz makes wollastonite plus marble.
e. Calcite plus quartz makes wollastonite plus carbon dioxide which mixes with other fluids in the rock.
f. Calcite plus quartz makes wollastonite plus sulphur dioxide which mixes with other fluids in the rock.

38. Meanwhile, everyone else moved back out onto the deck to admire the clear night sky. Gemma excitedly pointed out Saturn and Jupiter because she just received news that she would be joining the team exploring Titan on the first mission to the Saturnian system. Roxanne was on the first mission to Europa, so was familiar with the trials and tribulations of interplanetary trips, even with the all-new +10 boosted version of the Epstein Drive. Her friend Andy Syght had good news too, he was chosen for a mission to explore Venus. Andy asked Gemma …

> *... You're just back from the Moon and now you're going to another moon? How long will it take you to get there?*

Gemma did some quick-calculations using data she had already downloaded (see below) …

Even with the new +10 Epstein Drive it will take a long time to get to Saturn. Gemma knew that when Saturn is in opposition – the position where Earth is directly between the Sun and Saturn – it is 1277.42×10^6 km from Earth.

Assuming the +10 boosted Epstein Drive generates an average speed of 100,000 m/s, and the actual flight path was about 20% more than the opposition distance (due to the fact that both planets are constantly moving) she came up with an approximation.

Q: How many days did she decide it should take her craft to travel from Earth orbit to an orbit around Saturn?

a. Close to 100 days
b. Close to 1000 days
c. Close to 200 days
d. Close to 2000 days
e. Close to 10 days
f. Close to 20 days

39. Andy was new to space travel and was having trouble wrapping his head around the distances involved. He noted that Saturn is, on average, 1,316 x 10^6 km from Venus but commented that if Gemma was at Saturn during opposition and he sent her a radio message **she might not get it because …**

a. Earth was between Venus and Saturn
b. The Sun was between Venus and Saturn
c. Jupiter was between Venus and Saturn
d. Only either of a or b
e. Only either of b or c
f. Any of a, b or c

40. Gemma acknowledged they would be a long way apart and asked …

If nothing blocks your radio message, how long would it take to reach me (using the average distance apart as a guide)?

Q: What did Andy's quick calculation yield?

a. Approximately 7.5 minutes
b. Approximately 75 minutes
c. Approximately 750 minutes
d. Approximately 15 minutes
e. Approximately 150 minutes
f. Approximately 1500 minutes

41. Andy showed Gemma a picture of the surface of Venus (figure 9 below). His work program while in orbit around Venus includes documenting all the volcanic landforms on Venus and determining the extent of current volcanic activity on the planet. He said that landforms A, B and E were volcanic in origin with B the centre of a big dome complex called the Aine Corona. Liner features C and F are also very clear in this radar image as are branching linear features D. He challenged Gemma to place them in order of oldest to youngest, hinting that there may not be a perfect solution.

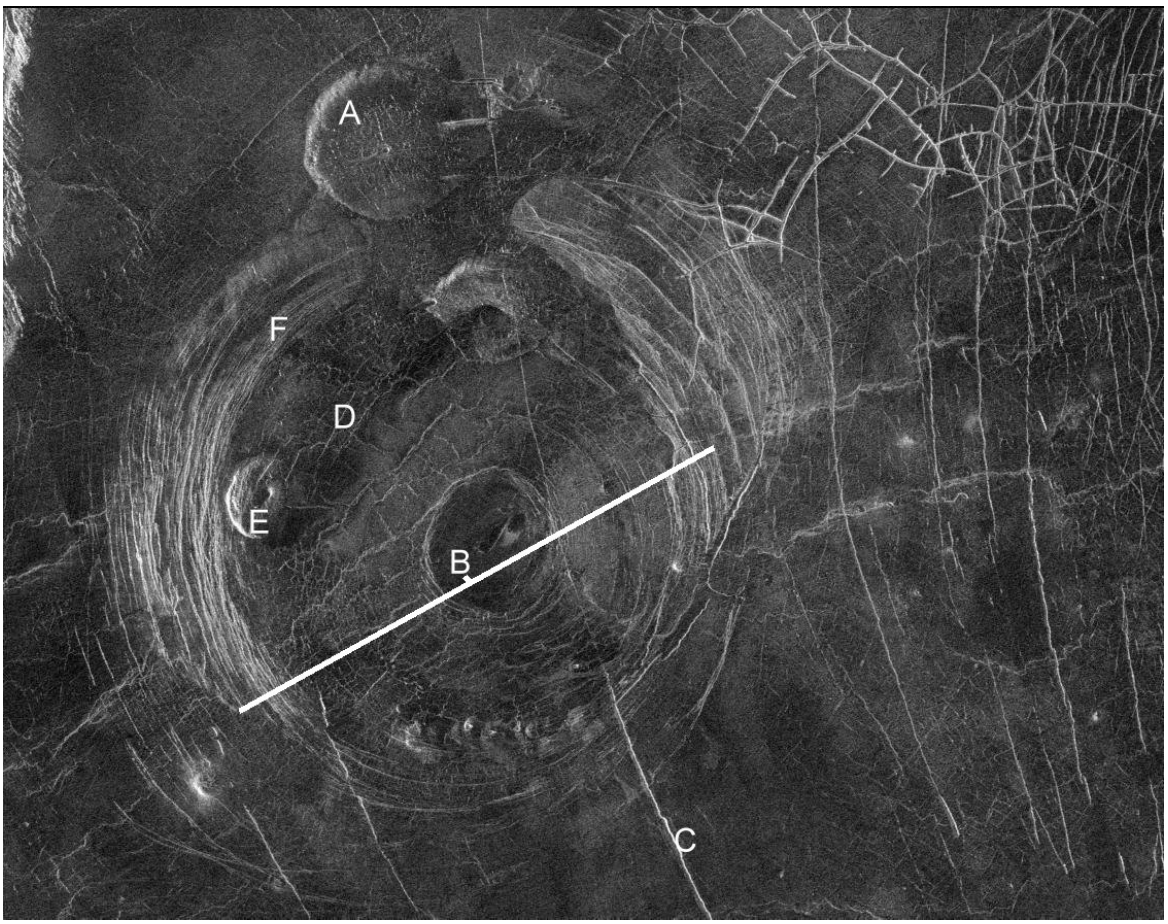

Figure 9: This image shows a region approximately 300 kilometres across, centred on 59 degrees south latitude, 164 degrees east longitude and located in a vast plain to the south of Aphrodite Terra. This region is known as Fotla Corona.

Q: What do you think Gemma said as she put them in the correct order (oldest to youngest) and explained why she put each of A, B, C, D, E and F in the order (or lack of order) that she did (5 marks):

42. Andy showed Gemma another picture of the surface of Venus (figure 10 below) and explained that even now, with such great tech available to them, the surface of Venus is too hostile for any contact science, although plans are in place for a surface base by the end of the century. He added that the atmospheric surface pressure was at least 75 times Earth's atmospheric pressure at sea level and, at ~470°C, it is far too hot for most life as we know it. The fact that the carbon dioxide atmosphere is charged with clouds of sulfuric acid just adds to the difficulties that surface explorers might face. Gemma studied the image, taken from an orbital station, and asked …

What on Earth … oops, I mean on Venus … caused that long dark sinuous feature in the landscape?

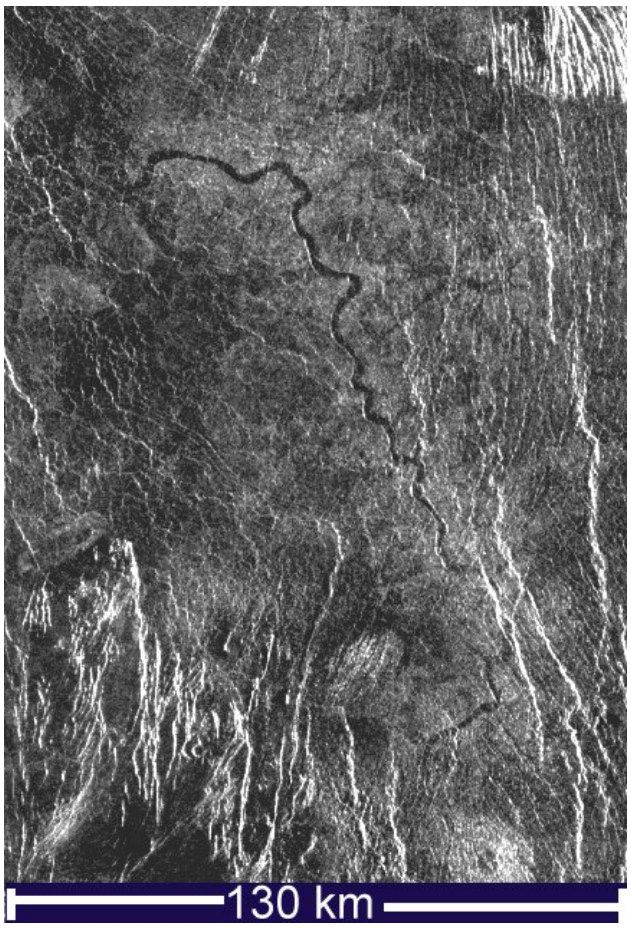

Figure 10: This full resolution radar mosaic from Magellan at 49 degrees south latitude, 273 degrees east longitude of an area with dimensions of 130 by 190 kilometres shows a 200-kilometre segment of a sinuous channel on Venus. It is approximately 2 kilometres wide.

Q: What was Andy's reply?

a. It is a river channel, caused by flowing water, just like channels formed in rocky country here on Earth.
b. It is a river channel, caused by a flowing liquid. Just like on Titan, that liquid is not water but methane.
c. It is a river channel, caused by a flowing liquid. Just like on Mars, that liquid is not water but carbon dioxide.
d. It is a river channel, caused by a flowing liquid. That liquid is not water but nitrogen from cryovolcanoes.
e. It is a river channel, caused by a flowing liquid. That liquid is not water but fast flowing lava from a very hot volcano.
f. It is a river channel cut into the rock by flowing sulfuric acid.

43. Gemma was intrigued by volcano A in the first image Andy showed her (figure 9).
She wondered why it was such an odd pancake shape with a flat top and steep sided edges.

Q: What did Andy say is the most likely explanation?

a. It is formed from very high viscosity lava that is thick and cannot flow far from its source.
b. It is formed from very low viscosity lava that is thin and runny, spreading out in all directions like water.
c. It formed in an impact crater that has since eroded away.
d. It formed from lava that has since been eroded flat by the actions of sulfuric acid rain
e. It formed from a low viscosity lava trapped by a ring dyke.
f. It formed from a high viscosity lava that exploded violently, removing the top of the volcano in the process.

44. Later in the evening at Orson's house, Vincent Knight, Gemma's astronomer friend, was waxing lyrical about the objects visible in the night sky from the deck. Daytona Light was listening too and commented that Carl Sagan once famously said of planet Earth and all that it embodies:

> *These are some of the things that hydrogen atoms do given fifteen billion years of cosmic evolution.*

Sedimentologist, Sandra Shore, asked:

> *From a scientific perspective, is this statement accurate, given what we know of stellar and biological evolution?*

Q: How should Vincent answer? Write your answer with reference to our solar system's formation and Earth's carbon-based inhabitants. Limit your answer to no more than 10 dot points, no more than 2 sentences each. [5 marks].

45. As the evening dragged on the friends teased each other with True or False questions while sky gazing for satellites and meteors during what was a very clear but dark night, especially after midnight when the Moon set.

Q: What phase of the Moon was it that evening?

a. New Moon
b. Full Moon
c. First Quarter
d. Last Quarter
e. Blue Moon
f. Impossible to tell

Each person on the deck took it in turns to come up with a TRUE OR FALSE question or missing-word question. How will you go on their impromptu quiz? CIRCLE the correct answer.

46. What is a sedimentary rock made up mostly of angular pebbles called?

a. Breccia
b. Conglomerate
c. Slickensides
d. Agglomerate
e. Cataclastite
f. Coarse sandstone

47. On Earth, clouds are composed of .....

a. ice crystals and/or tiny droplets of liquid water
b. water vapour
c. only ice crystals
d. only water droplets
e. droplets of liquid methane
f. droplets of liquid carbon dioxide

48. The Australian Plate is moving which direction at about 7 cm/year?

    a. West
    b. East
    c. North
    d. South
    e. Up vertically
    f. Down vertically

49. How many perfect cleavages does muscovite have?

    a. 0
    b. 1
    c. 2
    d. 3
    e. 4
    f. 5

50. Quartz is the most common mineral in the Earth's crust. TRUE or FALSE

51. Xenoliths are only found in Gneiss. TRUE or FALSE

52. Some clays are the weathering products of feldspars. TRUE or FALSE

53. Some clays are the weathering products of pyroxenes. TRUE or FALSE

54. The Red Sea is a flooded rift-valley. TRUE or FALSE

55. Subducting oceanic lithosphere melts to form magma. TRUE or FALSE

56. The Benioff Zone is the zone of subduction-related earthquakes generated within the descending oceanic lithospheric slab. TRUE or FALSE

57. Most volcanic rocks contain a mixture of tiny crystals and glass. TRUE or FALSE

58. Diamonds are formed inside exploding volcanoes over subduction zones. TRUE or FALSE

59. Quartzite is a sedimentary rock. TRUE or FALSE

60. Carbon dioxide, Methane and Nitrous oxide are all greenhouse gases. TRUE or FALSE

61. Calcite is harder than Quartz. TRUE or FALSE

62. Fossilised faeces (poo) are a thing. They are called coprolites. TRUE or FALSE

63. Birds are dinosaurs (well, they are direct descendants of some dinosaurs anyway).
TRUE or FALSE

64. Mercury, Venus, Earth, Mars and Uranus are all rocky planets. TRUE or FALSE

65. Part of New Zealand is on the Australian Plate. TRUE or FALSE

66. Quartz has 1 perfect cleavage. TRUE or FALSE

As the Sun rose, they all said good bye and headed off on their new adventures across planet Earth and throughout the solar system.