TEACHER NOTES – ASTRONOMY IN THE NEWS #03
FUTURE MISSIONS TO VENUS

Slide 2 – Background Science: Venus – Earth's Twin?

Venus is the second planet in our Solar System, and is very similar to Earth. It has a similar radius (0.95 the size), mass (0.82 as massive), and composition to that of Earth. However, that is where the similarities end. Venus is a harsh environment, with a thick atmosphere of 96.5% carbon dioxide and 3.5% nitrogen. It has extremely high pressures, 9.3 MPa, and high surface temperatures of 737K. These conditions make the atmosphere a supercritical fluid at the surface. This means that liquid and gas phases do not exist, but the pressure is not high enough to allow them to remain solid. The pressure at the surface is equivalent to that of a depth of 1km under water.

Venus appears to be volcanic, with a lot of large volcanoes present, including multiple systems 100km wide, with only the Big Island of Hawaii that size on Earth. There are hints of active volcanic activity. Firstly, the abundance of sulphur dioxide in the atmosphere has increased and decreased over time, implicating large volcanic eruptions. Secondly, there were observed localised infrared hot spots on the surface, thought to be from volcanic eruptions and fresh lava. The surface, and impact craters, are also pristine, implicating that the surface is fairly fresh, with a resurfacing event between 300 and 600 million years ago.

There is currently no evidence of tectonic activity, which may be because the surface is too strong to subduct, especially without water. However, there is no knowledge of the internal structure, just a suggestion that it is similar to Earth due to its similar mass and size.

IMAGES:

1. Side-by-side comparison, to scale, of Venus and Earth. This demonstrates the similarity in size.
2. Radar images of impact craters on the surface of Venus. The radar images were combined with radar altimetry to produce a 3D simulated image of the surface. This shows how pristine the impact craters are, implying that the entire surface of the planet was refreshed fairly recently (300-600 million years).

Slide 3: VERITAS and DAVINCI+

The two future missions to Venus, with expected launches in 2028-2030, VERITAS (Venus, emissivity, radio science, InSAR, topography and spectroscopy) and DAVINCI+ (Deep atmosphere Venus investigation of noble gases, chemistry and imaging).

VERITAS will make a 3D topographical map of Venus, determine if it has current tectonic and volcanic activity, and map the surface to determine why it developed so differently to Earth. DAVINCI+ will test the composition of the atmosphere, along with its formation and

evolution. It will determine if there was ever an ocean, and determine the nature of geographical features called tesserae.

The two missions have very similar science goals, and as a result, I will focus more on the VERITAS mission. However, I will indicate where both missions have complementary aims.

The majority of the goals for VERITAS are geological in nature. There will be two instruments onboard VERITAS, a spectral instrument and a radar imager and they will work in combination to determine the nature of the surface and determine if Earth and Venus are fundamentally different or are they just “cosmetic”.

As part of the 3D topological map, deformations will be mapped, such as strike-slip faults similar to the San Andreas fault. The presence of features like this would indicate tectonic activity, with imaging also detecting active surface faulting, determining if there is tectonic movement.

Active tectonic activity could also be indicated by active volcanic activity, assuming some volcanoes are driven as on Earth. If there is current volcanic activity, the chemical composition of recently formed rocks from magma can be spectrally analysed, revealing the chemical nature before interactions with the atmosphere. Any active volcanoes could be impacting the climate, and also indicate if the planet’s interior contains large quantities of water, like Earth does. (Also DAVINCI+)

Subduction and volcanism balance the atmospheres on Earth, so if Earth and Venus are twins, why did Venus become inhabitable, whilst Earth hosts life. This may have implications for determining what makes rocky planets habitable, linking it to exoplanet studies that are ongoing.

Tessera (plural: tesserae) are plateau-like features which may be analogous to Earth’s continents. One theory of continental formation is that iron-rich oceanic crust melted and subducted in the presence of water. This produced vast amounts of new, less iron-rich continental crust which were now above the ocean. By measuring the spectral composition of the surface, the composition can be compared to that of continental crust on Earth, whilst giving insight into any previous water on Venus. (DAVINCI+)

The original articles that this resource is built on can be found here:

https://www.bbc.co.uk/news/science-environment-57339355

https://www.theguardian.com/science/2021/jun/02/nasa-venus-return-two-missions

More details about the two missions can be found here:

https://www.jpl.nasa.gov/news/veritas-exploring-the-deep-truths-of-venus

https://www.hou.usra.edu/meetings/lpsc2020/pdf/2599.pdf

IMAGES:

1. (Top left) This is a visualisation of the VERITAS satellite. This image indicates that it is an orbiting mission.
2. (Top middle) This is a radar images from the Magellan satellite that orbited Venus and was launched in 1989. This was the last NASA mission to Venus, although other space agencies have sent probes since, and NASA have done flyby observations on the way to other planets. This image displays the "pancake domes" on Venus. They are thought to be from volcanoes similar to shield volcanoes, such as Mauna Loa on Earth. They are called pancake domes as they are approximately 10 miles wide, and only one mile deep. They are also much larger than the equivalent features on Earth.
3. (Top right) Visualisation of the DAVINCI+ mission. This shows the probe as it descends to the surface, which will take 63 minutes. There will also be an instrument that remains in orbit.
4. (Bottom left) Survey of volcanoes on Venus, with the different symbols indicating the different types. The underlying image is the topological data from the Magellan mission. This plot is illustrative of the number of major volcanoes, or volcanic sites, that there are on Venus, with over 1600 counted. It is thought that over 100,000 may be on the surface when smaller features are accounted for. This compared to the approximately 1500 that are on Earth.
5. (Bottom right) Topological map of Venus from the Magellan mission. This shows the height above the average planetary radius. You will see that the majority of the planet is a flat plane at roughly 0km elevation, but there are plateaus of higher elevation. These plateaus are the tesserae, and could be comparable to continental shelves.

Slide 4 – Activity: Balancing Venus' Chemical Reactions

There are several chemical reactions that occur on the surface and in the atmosphere of Venus involving the volcanic eruptions. A few of them are listed on this slide, but need balancing. The answers are given here:

$S_2 + \mathbf{4}CO_2 \longrightarrow \mathbf{2}SO_2 + \mathbf{4}CO$

$SO_2 + CO_2 \longrightarrow SO_3 + CO$

$S_2 + \mathbf{2}CO_2 \longrightarrow COS + SO_2 + CO$

The middle equation does not need balancing, as it is already balanced, but the other two do require input.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	11.6, 11.26
Pearson Edexcel Chemistry	0.3, 8.18, 8.19, 8.26

Pearson Edexcel Combined Sciences	Chemistry: 0.3, 8.18, 8.19, 8.26
OCR Chemistry B	1.1, 2.4
OCR Combined Science B	C1.1, C2.4
AQA Chemistry	4.1.1.1, 4.3.1.1, 4.9.1.2
AQA Combined Science: Trilogy	5.1.1.1, 5.3.1.1, 5.9.1.2