The STORY of EARTH

A PLACE LIKE NOWHERE ELSE IN THE UNIVERSE

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AUSTRALIAN TEACHERS OF MEDIA

A STUDY GUIDE BY
DAVE CREWE

Introduction

The Story of Earth is an Australian documentary for IMAX ® and other giant screen theaters directed by Russell Scott and written by Scott and Wain Fimeri.

The documentary, narrated by Rachel Ward, centres on how contemporary geology has potentially led to a new understanding of how life on Earth came to be. *The Story of Earth* centres on the discoveries of Professor Martin Van Kranendonk and his student Tara Djokic. Their studies in geology have produced findings in the Pilbara region of Western Australia that challenge our current understanding of how and where life originated, suggesting that life may have first sprung up in geothermal pools rather than on the ocean floor. Their investigation takes them to Iceland, where present conditions resemble the Earth billions of years ago. Along the way, the documentary showcases geology's ability to tell us deep truths about our Earth and our solar system through the study of rocks.

CONTENT HYPERLINKS

Curriculum Links

The Story of the Earth is suitable for students in Years 4-6 undertaking Science and Years 8-10 undertaking:

- Science
- English

As a curriculum resource in Science, *The Story of Earth* is primarily relevant to the Earth and Space Sciences strand of Science Understanding, though this Study Guide also incorporates strands from Science as a Human Endeavour and Science Inquiry Skills where appropriate. The program can be used to introduce and explore tectonic plates, the solar system and our charging Earth in upper primary Science. Addressing how geologists' study of rocks deepens our understanding of the past while linking these discoveries to phenomena such as tectonic plates, the origin of life and the solar system ensures that the documentary is equally well-positioned as stimulus material in Years 8, 9 and 10.

It is unlikely that teachers would use *The Story of Earth* purely as stimulus material in an English classroom. However, many of the activities in this study guide are well-suited to allow students to demonstrate many of the sub-strands within the Creating Texts Literacy strand of secondary school English while responding to the program.

Teachers are advised to consult the Australian Curriculum online at https://www.australiancurriculum.edu.au/ and curriculum outlines relevant to their state or territory for further information.

Relevant Content Descriptors for Year 4 Science:

Earth's surface changes over time as a result of natural processes and human activity (ACSSU075)

Represent and communicate observations, ideas and findings using formal and informal representations (ACSIS071)

Relevant Content Descriptors for Year 5 Science:

The Earth is part of a system of planets orbiting around a star (the sun) (ACSSU078)

Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS093)

Relevant Content Descriptors for Year 6 Science:

Sudden geological changes and extreme weather events can affect Earth's surface (ACSSU096)

Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multi-modal texts (ACSIS110)

Relevant Content Descriptors for Year 8 Science:

Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales (ACSSU153)

Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available (ACSHE134)

People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE136)

Reflect on scientific investigations including evaluating the quality of the data collected, and identifying improvements (ACSIS146)

Relevant Content Descriptors for Year 9 Science:

The theory of plate tectonics explains global patterns of geological activity and continental movement (ACSSU180)

Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157)

Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems (ACSIS172)

Relevant Content Descriptors for Year 10 Science:

The universe contains features including galaxies, stars and solar systems, and the Big Bang theory can be used to explain the origin of the universe (ACSSU188)

Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)

Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE191)

Relevant Content Descriptors for Year 8 English:

Create imaginative, informative and persuasive texts that raise issues, report events and advance opinions, using deliberate language and textual choices, and including digital elements as appropriate (ACELY1736)

Relevant Content Descriptors for Year 9 English:

Create imaginative, informative and persuasive texts that present a point of view and advance or illustrate arguments, including texts that integrate visual, print and/or audio features (ACELY1746)

Relevant Content Descriptors for Year 10 English:

Create sustained texts, including texts that combine specific digital or media content, for imaginative, informative, or persuasive purposes that reflect upon challenging and complex issues (ACELY1756)

Documentary Participants

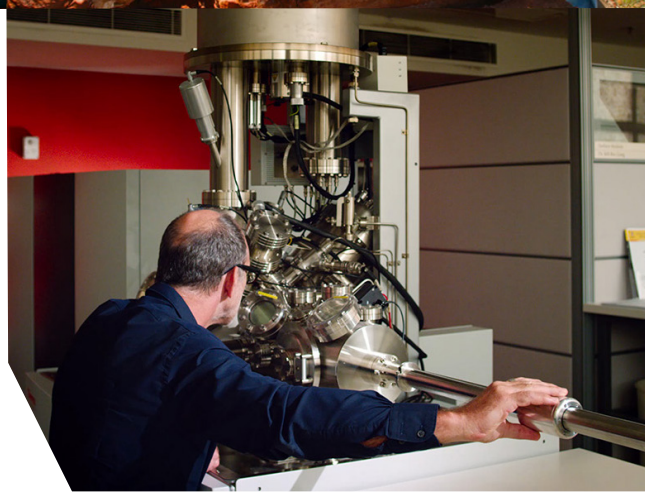
PROFESSOR MARTIN VAN KRANENDONK is the Head of the School of Biological, Earth and Environmental Sciences (BEES) at the University of New South Wales (UNSW) Sydney. He is a Professor of Geology with a particular interest in the early history of the Earth.
Professor Van Kranendonk is the Director of the Australian Centre for Astrobiology (ACA), Deputy Director of the Big Questions Institute and a member of the ARC Centre of Excellence for Core to Crust Fluid Systems. His research in the Pilbara and Yilgarn cratons has placed him at the forefront of Archean tectonic studies. He has published a book on the subject, *Earth's Oldest Rocks,* and has authored more than 110 publications in international journals.[1]

TARA DJOKIC is a PhD candidate at the Australian Centre for Astrobiology of UNSW, supervised by Professor Van Kranendonk. Her PhD work is focused on the geological setting and ecology of some of Earth's oldest evidence of life in Western Australia. Tara's work has led to the production of an online, virtual field trip based on observations from the Pilbara. The VFT has been used in an online Astrobiology course at UNSW since 2016 to teach multidisciplinary science students about early life on Earth, geology and scientific practice.[2]

Activities

The following activities are organised into five categories: Our Place in Space, Rocks, The Earth, Our Solar System and Origins of Life. The first category is primarily intended for Year 4-6 students, while the subsequent categories are primarily intended for Year 8-10 students.

Each category features activities ranging in complexity and difficulty. Given the brevity of the program – running under 40 minutes – it is recommended that teachers introduce a geology/earth science unit by screening the program, and then centre on one or more activities, returning to segments from *The Story of Earth* as required. While a particular Science classroom may not explore all the issues addressed in this documentary, it serves as a concise introduction to concepts that have been taught in previous years or will be expanded upon in future study.



OUR PLACE IN SPACE

These activities are intended for **Years 4-6 Science.** Using the ACARA standards as a reference point, the activities centring on geological concepts are best suited to Years 4 and 6, while the activities going beyond Earth into our solar system are best suited to Year 5.

* BENEATH OUR FEET

"The Earth's crust is not one solid piece. It is broken up into tectonic plates."

After watching the program, answer the following questions:

- What the Earth look like when it was first formed?
- Has the Earth changed since it first formed? How do you think it changed?
- What is the Earth made of? What does it look like underneath our feet?

- How did the continents form?
- What causes earthquakes and volcanoes?

Many of these questions are answered by an understanding of tectonic plates. After completing this discussion, the following ABC Education resources will help reinforce your understanding of tectonic plates' role in changing the shape of our Earth's surface over time:

Below Earth's Crust
(http://education.abc.net.au/home#!/media/30528/below-earth-s-crust)
This 14 minute clip – targeted at Years 6, 8 and 9 Science students – examines the "composition of planet Earth", delving beneath the Earth's crust into its mantle and core.

Earthquakes
(http://education.abc.net.au/home#!/digibook/617025/earthquakes-when-the-earth-shakes)
This interactive digi-book explains the importance of the Earth's tectonic plates to earthquakes and the formative of the continents we know of today.

After completing these two activities, return to the four questions discussed above. How would you answer these questions now? Reflect on what you have learnt from these resources, and write a short summary of the important information.

* FOSSIL RECORD

"These little bumps in the rock I'm measuring are fossils of structures called stromatolites. They are made by microbes that among the earliest forms of life on Earth."

One of the key pieces of evidence in Professor Van Kranendonk and Tara Djokic's re-evaluation of the origins of life is the discovery of fossils in the Pilbara region. Fossils provide scientists – particularly palaeontologists, who study fossils – critical information about life that existed and went extinct long before humans ever walked the Earth; but how are they formed?

Research how fossils are formed; there are many useful resources online and in libraries, but this BBC resource may be a good starting point for your research: http://www.bbc.co.uk/nature/fossils.

Try to answer the following questions:

- What are the differences between body fossils and trace fossils?
- What's the difference between preserved fossils and mineral replacement fossils?
- What was the first recorded fossil discovery, and who discovered it?

With your teacher's supervision, you may then be able to complete a hands-on activity simulating fossil formation. Plaster of Paris and leaves can be used to simulate impression fossils, while hot glue can be used to simulate a preserved fossil like those formed when an insect is preserved in amber.

* EXPLORING SPACE

"Revolving around the sun, new planets formed from gathering debris."

The Story of Earth is, as its title suggests, primarily a story of our Earth. But the program also includes references to the formation of our solar system, and how we differ from our neighbours Mars and Venus.

To develop a better understanding of our place in the universe, work in small groups with the guidance of your teacher to produce a multi-modal presentation on our solar system. This presentation should include a timeline of the life of our solar system – how and when did it form, and how has it changed over time? – and a representation of the planets in our solar system and their distinctive properties.

When completed, each group should share their presentations with their class.

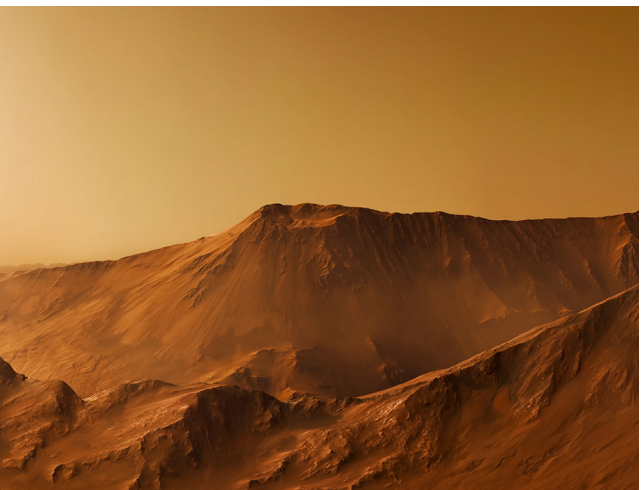
ROCKS

These activities are intended for **Year 8 Science**, but could easily be addressed in Year 9 or 10 Science. Students will explore what the study of rocks can tell us about our past, while contemplating the career of a geologist. Using online resources including a 'virtual field trip', students will examine the Dresser Formation region as shown in *The Story of Earth*.

* ROCK AROUND THE CLOCK

"Being a geologist is a little bit like being a detective. The clues to the story are in the rocks. Their structure and composition tells us what the world was like when they were formed."

In voiceover, Professor Van Kranendonk explains that the study of rocks allows geologists to understand the past. In the short sequence set in the green valley of the Blue Mountains' Eden, Claustral Canyon, what do the rocks tell the professor and his students about what the region would have been like in the past? Identify two specific examples.



Professor Van Kranendonk observes to a student that a rock wall might not be "sedimentary, particularly."

- Using a diagram and accompanying definitions, create a simple explanation for the three main categories of rock: sedimentary, igneous and metamorphic.
- Based solely on the professor's description of the observed rock as appearing "like fluids that have come into a crack", how would you categorise the rock in question?

Meanwhile, in the Pilbara region, Tara Djokic is exploring a gorge in the Pilbara region, as the narrator notes that the rocks are "red because they are rusty".

- What is the significance of the rocks' red colour, as explained by the narrator?
- The rocks in the gorge are layered. What is the relevance of such layers to geologists – what can they determine about each layer?

We then see Tara Djokic examining stromatolites, which she describes as "fossils of structures … made by microbes". By researching in stromatolites in more detail, write an explanation – supplemented by diagrams as necessary – describing the appearance and importance of stromatolites. The Western Australian Government has a usual resource on stromatolites and their importance to research, found here: http://www.dmp.wa.gov.au/Stromatolites-and-other-evidence-1666.aspx

✱ GEOLOGY AS A JOB

"Days in the field can be long and physically demanding, but it sure beats working for a living."

The picture *The Story of Earth* paints of geology as a career is one of exploration, discovery – and *fun.* Immediately after the line quoted above, the program launches into a fast-paced montage of geology students jumping and abseiling down waterfalls.

How does the footage shown present the career of a geologist? Research geology as a career (*teachers may wish to assign different students to investigate the career's opportunities, the required training, the associated challenges, etc*) and share and discuss your findings with your class.

Tara Djokic is a PhD candidate under the supervision of Professor Van Kranendonk. What does it mean to be a PhD candidate? What would be Tara's specific role and responsibilities as a geology PhD candidate?

✱ THE DRESSER FORMATION

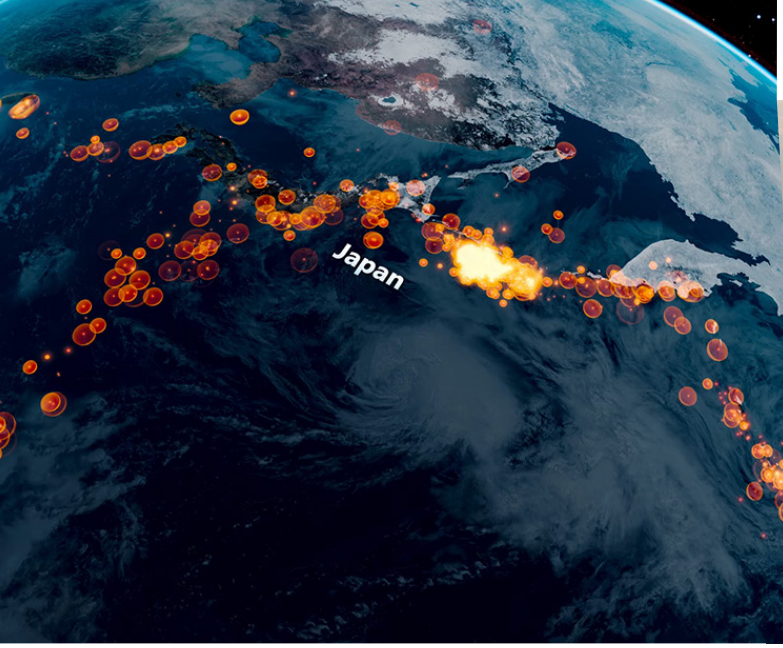
"The Pilbara is about as far away from civilisation as it gets."

While the Pilbara region is only the setting of small section of the program (**[07:32 to 16:12]**), Tara's discovery of geyserite adjacent to stromatolites proves crucial to *The Story of Earth*'s central question.

To get a sense of the landscape, one could begin by examining Tara's 3D models of the Dresser Formation, an important area in East Pilbara where the geyserite was found. They can be found here – https://sketchfab.com/taradjokic - and are compatible with VR if your school has the technology available.[3] (*Teachers, you may wish to assign the 15 different models to your students, and ask each to note down specific or general observations of the rocks seen in their model.*)

While the Pilbara region is certainly too remote to plan a field trip for most schools, through the power of modern technology you can attend a 'Virtual Field Trip'. The Dresser Formation VFT – found at http://vft.asu.edu/VFTDresser/panos/Dresser/Dresser.html – developed in collaboration between Arizona State University and ACA allows you to explore the area, watching videos and viewing detailed pictures of the landscape and rocks.

The full list of VFTs can be found at http://vft.asu.edu/, including a VFT on the Karijini Gorge (also from the Pilbara, as seen in *The Story of Earth*). An extensive compilation of useful resources related to the region can also be found at the NASA Macquarie University Pilbara Education Project (http://pilbara.mq.edu.au/wiki/Main_Page); a page on the Dresser Formation (http://pilbara.mq.edu.au/wiki/Dresser_Formation) has links to many videos of Professor Van Kranendonk examining and describing the phenomena found in the area.



THE EARTH

These activities are intended for **Year 9 Science**, but could also be addressed in Year 8 or 10 Science. Students will investigate the geological significance of volcanoes and tectonic plates, and explore the origins and importance of the Earth's atmosphere and magnetic field.

THE HEART OF FIRE

"This is why we've come to Iceland - the geothermal hot springs! To see the earth as it once was!"

The exciting implication of Tara's discovery – explored in more detail in later activities – is that life may have begun in geothermal hot springs rather than on the ocean floor as originally believed.

After watching *The Story of Earth* (or during the Iceland segment), answer the following questions based on the information presented in the program:

- Why are Professor Van Kranendonk and his students visiting Iceland to investigate a discovery from the Pilbara region?
- What are the "huge tears in the crust of the Earth" that Professor Van Kranendonk discusses in voiceover?
- How are tectonic plates "forces for good" for our planet?

- How does the Earth's molten core help protect the planet from solar radiation?
- What visible evidence does the program provide of the magnetosphere?

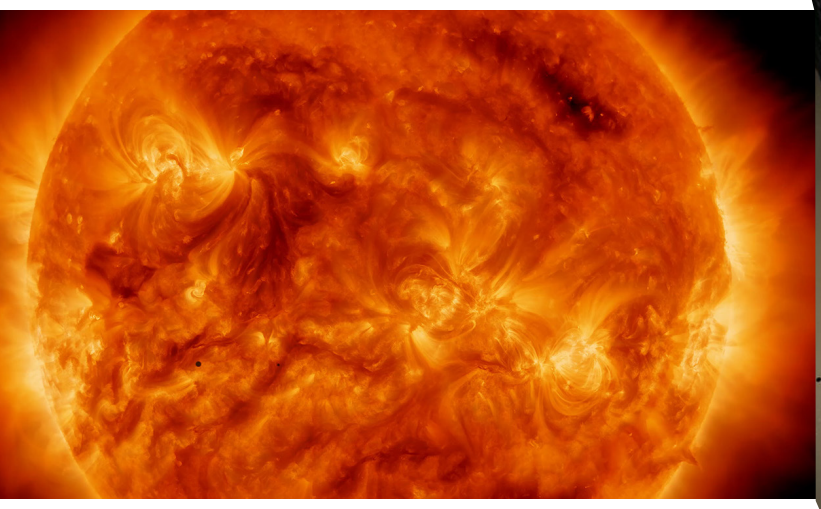
By researching geothermal pools, identify how they are formed and the geological phenomena observed within and around such 'hot springs'.

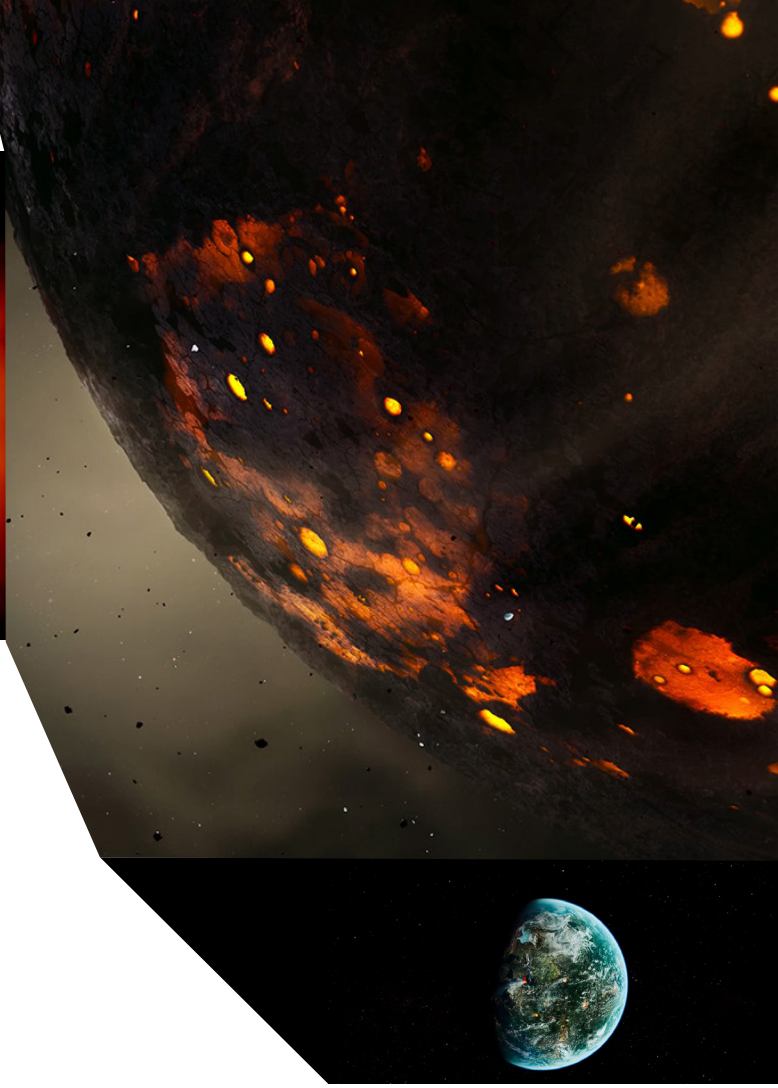
THE AIR THAT WE BREATHE

"We have many reasons to be grateful that the earth has a molten core."

The Story of Earth regularly links the Earth's atmosphere to geothermal activity. In a small group, research the relationship between volcanic activity and our atmosphere, and produce a presentation or poster demonstrating how the Earth's atmosphere was produced and is maintained by volcanic activity. Include in your poster or presentation an identification of the **positive** and the **negative** effects of volcanic activity on our atmosphere.

Study the aurora phenomenon observed in *The Story of Earth.* What causes this phenomenon – often called the 'Northern Lights' – and how is the influenced by the Earth's molten core?





OUR SOLAR SYSTEM

These activities are intended for **Year 10 Science**, but could also be addressed in Year 9 Science. Students will consider their own prior understanding of the origin of the Earth, and consider research the geological conditions when the Earth and the Moon first formed, and compare our planet with nearby neighbours.

* FORMATION OF THE EARTH

"The third planet from the sun was an inferno. Impossibly hostile to life. Over billions of years this uninhabitable ball of molten rock transformed into a paradise covered with oceans of water and shrouded in life giving atmosphere.
This is our home. Earth."

The opening minutes of *The Story of Earth* are a short story of the Earth's beginning. Your task is to research and produce a poster representing the Earth's early years. This should focus on the Precambrian Era – from the beginning up to about 600 million years ago – including the Hadean, Archean and Proterozoic Eons (note that the Archean Eon is the focus of much of Professor Van Kranendonk's research).

* OTHER PLANETS

"This is a world without tectonic plates. Venus. With no greenhouse gas recycling system, the atmosphere thickened, causing temperatures to skyrocket, until all that's left is a scorched, barren planet."

The documentary makes mention of both Venus and Mars over its runtime, noting that Mars differs from Earth in its lack of active volcanoes (linked to its lack of an atmosphere), while Venus has no tectonic plates (and therefore a toxic atmosphere and high temperatures). Use the following table to examine the similarities and differences between these three planets in more detail. Fill in each cell with brief descriptions of the geological/environmental features.

Planet	Venus	Earth	Mars
TECTONIC PLATES			
VOLCANOES			
IMPACT CRATERS			
PRESENCE OF LIQUID WATER			
ATMOSPHERE			
MAGNETIC FIELD			

ORIGINS OF LIFE

These activities are intended for **Year 10 Science**, but could also be addressed in Year 8 and 9 Science. Students will reflect upon their own understanding of the origins of life on Earth, and the possibility of life on other planets. Finally, students will look into the research underpinning the documentary's assertions in the context of the scientific method and the scientific community.

* HOW IT ALL BEGAN

(Note: this activity can be completed before or after watching The Story of Earth. If completed beforehand, it will allow students to evaluate their own prior understanding – or lack thereof – as to origins of life on Earth. If completed after watching the program, it will allow the teacher to assess how much information they've retained on the subject.)

"Is it possible that life may not have begun in the ocean?"

Write a short story about the origins of life on Earth. This is intended to be a creative piece of writing and not purely factual; you are encourage to speculate rather than rely on research. Consider what conditions must have been like – where would life have first appeared, and what the geological state of the Earth have been at that time?

Share your stories with your classmates and discuss the similarities and differences in both the content of your writing and the writing techniques applied.

* SCIENTIFIC DISCOVERY

"A single rock I found in the Pilbara opened up a new chapter in the story of Earth – life might not have started in shallow oceans but very likely in geothermal pools like these." ***[32:10]***

As is to be expected from a brief documentary, *The Story of Earth* somewhat simplifies the specifics of the scientific method. Professor Van Kranendonk's research into stromatolites in the Pilbara region and the possibility that life originated many millions of years[4] before the "previous most convincing and generally accepted multidisciplinary evidence for oldest life remains"[5] was published in August 2016, authored by Allen P. Nutman, Vickie C. Bennett,

Clark R.L. Friend, Allan R. Chivas and Professor Van Kranendonk. That report can be found at https://www.nature.com/articles/nature19355, though you'll need a subscription to the Nature database to read the complete report.

Nutman *et al*'s report was a precursor to the specific findings addressed in *The Story of Earth,* which were published in May 2017. Where the earlier report focused on stromatolites in a marine environment, the follow-up article (by Djokic and Van Kranendonk along with Kathleen A. Campbell, Malcolm R. Walter & Colin R. Ward) has specific links to the possibility of the origin of life in hot springs, rather than in the ocean. This report can be found online at https://www.nature.com/articles/ncomms15263 and does not require a subscription. Djokic and Van Kranendonk summarise their findings in this (paywalled) Scientific American article: https://www.scientificamerican.com/article/life-on-earth-came-from-a-hot-volcanic-pool-not-the-sea-new-evidence-suggests/

Nor is the discovery uncontentious, as suggested by the documentary's frequent use of "might" and similar language as a qualifier. A Nature article[6] on Nutman *et al*'s findings has a distinctly sceptical tone: ""If we found something like this on Mars would we stick a flag in it and call it life?" [asks astrobiologist Abigail Allwood]. "I don't think we would.""

By researching the debate around the aforementioned articles, write a short persuasive arguing either that their findings *do* prove that life must have originated in geothermal pools, or that they *don't.* The following resources may prove helpful in preparing your essay:

- http://www.nature.com/news/2008/080125/full/news.2008.529.html
- https://www.nature.com/news/claims-of-earth-s-oldest-fossils-tantalize-researchers-1.20506
- https://www.nature.com/articles/nature19429
- https://theconversation.com/evidence-of-ancient-life-in-hot-springs-on-earth-could-point-to-fossil-life-on-mars-77388 (note that this is written by Djokic)
- https://www.smithsonianmag.com/science-nature/evidence-early-life-ancient-hot-springs-suggest-life-may-have-evolved-land-180963268/

After completing your essay, reflect upon the following question:

- Is an argumentative essay the best way to come to a conclusion in a scientific context? Why or why not?

* LIFE ON MARS?

The quote above from Abigail Allwood brings up the topic of life on Mars. This isn't an entirely hypothetical point; what precisely counts of evidence of life is crucial to forming a scientific consensus around life on other planets – including Mars.

Students interested in this topic may wish to watch a video recording of a UNSW Science conference on Mars, featuring contributions from both Djokic and Allwood. The video – found at https://www.youtube.com/watch?v=md52txoEbus – runs for an intimidating four-and-a-half hours, but the video's description should allow viewers to navigate to the section that they are interested in.

Endnotes

1 https://research.unsw.edu.au/people/professor-martin-julian-van-kranendonk and http://www.bees.unsw.edu.au/martin-van-kranendonk

2 http://www.bees.unsw.edu.au/tara-djokic

3 The Claustral Canyon seen in the opening minutes of the program has also been 3D-mapped and coded into VR; however, as far as I can tell the only way to access this at the time of writing is to visit the NSW National Parks' Heritage Centre in Blackheath in person.

4 220 million years, to be precise.

5 Abstract of https://www.nature.com/articles/nature19355

6 https://www.nature.com/news/claims-of-earth-s-oldest-fossils-tantalize-researchers-1.20506

Other relevant resources online

earth and Environmental Science
http://www.earthsciencewa.com.au/course/view.php?id=21

Earth and Space Science
http://www.earthsciencewa.com.au/course/view.php?id=16

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