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Outback Search for Life on Mars

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Abstract (summary)

The ocean may have covered most of the Earth and there was probably no polar ice - the water temperature could have been as high as 800C due to planetary heat rather than from the Sun, which was 20% less luminous than it is today. [...] the technique used which measures a planet's gravitational pull on a star - can only detect massive planets like Jupiter and Saturn.

Full Text

Headnote

What can we learn about life on Mars from ancient rocks in Western Australia and recent discoveries made by a string of Mars obiter spacecraft, a polar lander and two rovers?

In a remote corner of Australia you will find the world's earliest convincing evidence of life on Earth. The evidence, in the Pilbara area of Western Australia, tells us that life got going on Earth early in its history, before 3.5 biilion years ago - and on a planet that would look like an alien world to us compared with Earth today. It is a link to our place in the cosmos, and may provide clues to the possibility of past or present life on Mars. It is an important key in recognising ancient life forms on Mars, and to determine - even without the presence of organic material - that the evidence is as convincing on the red planet as it is on Earth.

The squiggles, lumps and mounds left 3.42 billion years ago in the Pilbara by microbial mats - known as stromatolites - have been hotly debated as to whether or not they are evidence of early life on Earth. But the work of one of our former students at the Australian Centre for Astrobiology, Abigail Allwood, and others has largely changed that view.

Abby's paper in Nature (June 2006) demonstrated that a collection of some of the shapes in the ancient rocks of the Pilbara have the form of a microbial reef extending tens of kilometres and across at least seven separate forms of stromatolites. It would be extraordinary if geological processes had expertly copied the biology of such a reef - the only other explanation and the basis for the debate on whether the shapes in the rock were made by geological processes or life.

There are also somewhat less wellpreserved stromatolites 3.5 billion years old in the same region that have been studied in detail by Martin Van Kranendonk of the Geological Survey of WA.

It is difficult to imagine the great age of these fossils - or even grasp that the only inhabitants on Earth were microbes for most of its 4.6 billion year history, with animal life not rising until around 600 million years ago and terrestrial plants even more recently.

But within die ancient remnants of die microbial mats, and among the related cyanobacteria of today, lies a biological story of die cosmos. We fit into the bigger picture - and perhaps one where there might be examples of other multicellular organisms and even intelligence on worlds beyond the solar system.

We do not know how life got started on early Earth. We do know that once the right conditions were there - even though those conditions were quite hostile - life began to thrive. There was no oxygen to speak of; no grass to clothe the plains; no lichen to cling to the rocks. The ocean may have covered most of the Earth and there was probably no polar ice - the water temperature could have been as high as 800C due to planetary heat rather than from the Sun, which was 20% less luminous than it is today.

The details are debatable, but what is probable is that there was no ozone layer. Earth was being flooded by UV solar radiation that is now largely absorbed by the ozone layer.

Nevertheless, the microbial mats that formed the stromatolites were flourishing in a shallow sea or lagoon in the ancient past of the Pilbara area. They formed in relatively quiet periods between very active volcanic episodes. There was enough of a respite for life to have gained a toehold in the shallow waters where fine sediment accumulated .

The first microbes were extremophiles - single-celled forms that enjoy life at the extreme. Extremophiles are still evident on Earth today, and in many types of extreme environments. Examples include extreme heat and cold, high salt concentration and high pressure. Some microbes live kilometres below the surface of the crust where it is hot, the pressure is high and there is no sunlight. Others make a living in cold, high deserts where rain comes rarely.

The extremes of life were first recognised in the 1970s, right around the time that the first two landers went to Mars in search of evidence of life on its cold, rusty and irradiated surface. Viking 1 and Viking 2 landed in what was thought to be safe plains, but both settled in boulder-strewn fields. They sent back pictures of morning frost and soils that appeared to be much like those found in the deserts of Australia. One almost hoped for a critter to pass the stereoscopic lenses.

The three soil experiments sent back contradictory results. After years of study, the conclusion was that the experiments had detected unusual soil chemistry rather than life.

While this puzzle was being picked apart, other scientists were busy in Yellowstone National Park uncovering the first evidence that would radically change our view of the potential for life on Mars and beyond: that life can survive and thrive in extreme environments outside of the bounds we once imagined.

Another piece of evidence that allows us ro go back even further is the ratio between the different forms of an element such as carbon. For every carbon- 1 3 atom there are on average 89 carbon- 12 atoms. In living things that ratio changes because of biology's preference for carbon- 1 2. That carbon isotopie signal can be traced back 3.5 billion years, and some contend 3.8 billion years.

Zircons found in the Jack Hills of Western Australia show that liquid water was present 4.2 billion years ago, and that the building blocks for life were possibly there too. It suggests that if life got going so early on Earth it is possible that Mars and several moons of both Jupiter and Saturn also played - or still play - host to at least microbial life.

In spite of all of this, not a single extraterrestrial microbe has been found beyond the Earth's biosphere. The exception was Earth bacteria surviving for a number of years on a camera retrieved from an unmanned lunar lander (Surveyor) by Apollo astronauts. The bacteria "woke up" when offered ambient temperatures and growth medium back on Earth.

Nevertheless, the appropriate cliché is that the absence of evidence is not evidence of absence. So we press on with questions that pose more questions leading to the biggest questions of all. Where did we come from? Are we alone in the universe? What is our future in the cosmos? These are the big questions of astrobiology.

We are now confident that Mars had a wet and warmer past. Whether this period lasted long enough for life to have emerged is still unknown, but the clues have been mounting for not only that possibility but the chance that life still exists on Mars today.

All life as we know it needs the presence of liquid water to some extent. It seems that pure liquid water cannot exist on the surface of Mars because of the very low pressure there. When the temperature rises (up to 20°C at the equator) any ice "sublimes" to vapour; there is apparently no temperature at which the ice becomes liquid.

There are hints of recent changes on the surface of Mars that persuade us to move forward with more research. For example, spacecraft orbiting Mars have captured images of areas where gullies have formed in recent times, suggesting outflows of a liquid.

Even more intriguing, in August 2008 the Phoenix team announced the discovery of some unusual soil chemistry - the presence of a chemical called Perchlorate. Although toxic to most life, it is thought these perchlorates have die ability to act as a kind of super anti-freeze, allowing water to be liquid at low temperature and pressure. Droplets seen on the legs of the Phoenix lander changed over time and disappeared altogether with the onset of winter and falling temperatures.

Several stories appeared in the media in February 2009 suggesting that if liquid water could be present on the surface of Mars it increased the possibility of life there. The jury is still out on the Perchlorate anti-freeze proposition, but what Phoenix showed directly was die presence of significant amounts of water-ice (as opposed to carbon dioxide-ice), confirming what had been seen remotely by orbiting instruments - that Mars has a lot of water, albeit frozen at the poles.

A more likely place for extant life, though, is not at the surface but below it. The internal heat of Mars is great enough for water to be liquid at depth in the crust. In such environments on Earth there are microbes in the porous spaces in the rock.

Another intriguing clue also came recently - that significant amounts of methane are present on Mars. Mike Mumma and his team at the Goddard Spaceflight Center point out that mediane can only be present on Mars if it is being constantly replenished. There are only two known activities that would cause this ongoing release of methane on Mars geological processes or life.

Could it be geology? Perhaps, but Mars currently does not have tectonic activity and may never have had this. However, past volcanic activity is evident. Olympus Mons on Mars is the highest volcano in the solar system at 27 km high, or three times the height of Everest. Close by are three "shield" volcanoes on an area known as the Tharsis Bulge.

Recent observations indicate that this volcanic activity has extended to relatively recent geological times - in the past two to several hundred million years. The Tharsis Bulge stands at one head of the massive Valles Marineris - a Grand Canyon on steroids whose length is greater than the distance between Sydney and Perth. Features reminiscent of vast flowing rivers of the past are carved into the floor at many points in the Martian Grand Canyon as well as elsewhere on the surface of Mars.

Both the Mars exploration rovers - Spirit at the Gusev Crater and Opportunity at Meridiani Planum - have found evidence of past surface water. For example, Opportunity has found fields of small iron-rich hematite spheres that have features suggesting they formed in water. If liquid water did exist on the surface of Mars, the question is whether it was there long enough for life to have evolved.

Why is water so important? Why not liquid methane or liquid ammonia? Both methane and ammonia have to be very cold to be liquid. This means that chemical reactions - the stuff needed to make and maintain life - happen at a very slow rate because of the low temperature. While this does not mean life cannot exist at these low temperatures, pure water has a wide temperature range (0-100°C) at which it is liquid at the atmospheric pressures of Earth. It also has other properties important to life that the others do not have:

* water-ice is less dense than the liquid form, so ice floats; and

* water has polarity, enabling the creation of chemical bonds that other liquids cannot make.

Yet another factor is that water is found everywhere in the universe.

If microbial life exists on Mars today, the critical question will be: "Is it related to us?" If it is then we may be Martians. Life could have travelled inside rocks blasted off the surface ofMars by asteroid impacts. Such an example is the Mars meteorite ALH 8400 1 , which was presented by NASA in 1 996 as possibly containing evidence of past life on the red planet. While this was later seriously disputed, it does not discredit the possible methodology of "seeding" life on Earth.

If the putative life had no relationship to us then we are faced with something very profound. If life evolved independently in two separate places in the same solar system, then the universe will be full of life.

Finding intelligence elsewhere in the universe would change our way of thinking. Very quickly it would be understood that the vast distances in space make a trip there or by them to us very unlikely. But we would know that we are not alone in the unimaginable vastness of the cosmos. We would also know that at least on one other world intelligence has survived its childhood, not by a few thousand years but perhaps millions or billions ofyears.

The Australian Centre for Astrobiology spans geology, paleobiology, microbiology and astrophysics. In the latter area we have an active program in the search for extrasolar planets, of which more than 350 are now known. However, the technique used which measures a planet's gravitational pull on a star - can only detect massive planets like Jupiter and Saturn.

No current telescope, either Earth-based or space-based, can directly photograph planets around other stars. The light from the star is far too bright, and the planets far too dim. The hunt for Earth-size planets is therefore dependent on other techniques.

Early in March this year Kepler was successfully launched by NASA to undertake the search for Earth-like planets. It will observe 100,000 stars over a number ofyears to watch for the distinctive, but very tiny, drop in a star's brightness when a planet moves into the line of sight between the remote star and Kepler's light detection equipment. Scientists are hoping the results will uncover other worlds like ours, thus giving the Search for Extra Terrestrial Intelligence program specific targets to listen to.

Back home in our own solar system we continue to probe other worlds for water and for life. Europa, a moon of Jupiter, has a thick ice crust that may overlie a deep ocean. Titan, a moon of Saturn, is particularly alluring with a thick atmosphere that may be reminiscent of the early Earth, only much colder. Other moons contain evidence of water-ice, including possible hidden reserves of water deep in craters of our own moon where sunlight never travels.

And on Earth mysteries abound, linked inextricably to the puzzle of life elsewhere in the solar system and beyond. The big questions about our planetary and biological evolution may be answered while looking for life elsewhere in the universe. To discover who we are, where we came from and what our future will be we may have to look to other worlds and to the stars so we can extend our sample set of life from one to many.

Sidebar
Dr Martin Van Kranendonk of the Geological Survey | of Western Australia explains the locations of ancient stromatolites in the Pilbara to international researchers

Sidebar
In 1976 the Vfkfng landers provided the first view of frost on Mars, credit: nasa/jpl

Sidebar
An ancient Pilbara stromatolite that was probably constructed by mats of anaerobic microbes around 3.45 billion years ago. Inset: Modern stromatolites In Shark Bay, Western Australia constructed by mats Of aerobic cyanobacterla. Credit: Australian Centre for Astrobtology

Sidebar
A false-colour image of gullies several hundred metres long in a crater in the southern highlands of Mars, taken by the High Resolution Imaging Science Experiment (HiRISE) camera on the Mars Reconnaissance Orbiter. The gullies emanating from the rocky cliffs near the crater's rim (upper left) show meandering and braided patterns typical of water-carved channels. North is approximately up and illumination is from the left. Resolution is 26 Cm/pixel. Credit: NASA/JPl/UnIverslty of Arizona

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