Potential for microbe colonisation of Mars by rocks launched into space by the Chicxulub impact

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Abstract. 65 million years ago the Chixculub impact in present-day Mexico threw millions of tonnes of Earth rock into outer space. Some escaped Earth's gravity and it is estimated that about half a tonne of Chixculub rock reaches the Martian surface each year. Of this about 15% is estimated to be unsterilized - meaning that some microbes could be expected to survive the journey in about 75kg of rock reaching Mars each year. But what are the conditions like at touch down? Are there habitable pockets on the surface of Mars where earthly microbes might survive? An estimate is made of the possibility of rocks landing on Martian ice fields and sinking into a warm patch where there is liquid water. The answer is 11 grams per year. This does not sound like much but the cumulative amount since the Chicxulub impact is estimated to be more than 700 tonnes. If so then billions of microbes have reached liquid water on Mars.

Keywords: Mars, transpermia, lithopanspermia, microbes, meteoroid, impact

1 Introduction

A possible mechanism for transfer of life between planets is via rocks ejected by major asteroid or comet impacts. The term "transpermia" was coined by Oliver Morton to describe the transfer of lifeforms by this method and to distinguish it from the more general concept of panspermia. Davies [1] discusses several possibilities for transpermia including hypothetical Mars-life reaching Earth and Earth-life reaching Mars via meteoroids. Melosh [2] outlines the mechanisms by which such transfers can take place. Mileikowsky and others [3] build on Melosh's work and provide estimates of transfer rates between Mars and Earth over the past 500 million years.

In the following analysis the consequences of the most recent major impact are considered. 65 million years ago the Chixculub impact in present-day Mexico caused notable extinctions on Earth but it also threw millions of tonnes of Earth rock into outer space. A small proportion of ejected rocks from near the surface would have reached escape velocity under conditions that would not have killed some of the hardy bacteria and archaea deep within the rocks. They became outer space travellers.

This paper presents a first-pass attempt to estimate the probability that these space travellers have reached pockets of liquid water near the surface of Mars. The probability is based on a sequence of fortunate and somewhat unlikely events:

1. The microbes survive the trip between Earth and Mars aboard a meteoroid
2. The microbes survive the entry through the Martian atmosphere and the hard landing on the surface of Mars
3. Portions of the meteoroid bearing dormant microbes land on water ice and sink to where there is sub-surface liquid water
4. Some of the microbes colonise the habitat

It should be noted that many of the values in this analysis are speculative. The resulting probabilities are subject to large uncertainty - perhaps several orders of magnitude. However, the main point from the analysis is that it is likely that some Earth microbes have reached liquid water on Mars.

2 Surviving the trip

2.1 Estimates of Earth-rocks reaching Mars from the Chicxulub impact

Wallis [4] estimates that, averaged over millions of years, about half a tonne of unsterilized Earth rocks from Chicxulub have collided with Mars each year. That is, any hitchhiking microbes would not be killed by the launch from Earth or the hazardous, lengthy journey between Earth and Mars. Applying Mileikowsky's methodology [3], it is conservatively estimated that, each year, 75kg (15%) of these rocks would reach the surface of Mars with surviving microbes.

The flux would have been much higher in the first few million years after the impact.

2.2 Survival on the surface of Mars

Colonisation of present day Mars by these microbes would be formidable [5]. The microbes would tend to be trapped in fragments of the original boulder scattered over the dry, cold surface of Mars. Under these conditions they would probably remain dormant after a freezing journey through space.

To live and grow the microbes would need liquid water. Recent research, including observations at the Phoenix landing site, suggest that on rare occasions, liquid water is present near the surface of Mars. In particular Möhlmann [6 & 7] describes several circumstances where liquid water might exist. One is where solar radiation heats subsurface ice which melts and the pocket of melt-water retains sufficient pressure to avoid sublimation. This could be quite common where ice is present and is exposed to partial sunlight.

3 Finding liquid water on Mars

3.1 Ice on Mars

In addition to the Martian polar regions, water ice is know known to be present in glacier-like formations in some mid-latitude Martian craters [8]. Every 5 million years or so it is thought that Mars undergoes major climate change and polar water is distributed to the mid-latitude to form these ice deposits in craters. They have only been detected relatively recently because the ice is covered by a thin layer of dust that obscured the ice from remote sensing equipment.

It has been estimated that there are about 43,000 craters on mars with a diameter of 5km or more. Assuming that 5% of these contain water ice (speculative) then the total surface area of ice in craters is estimated to be 170,000 square kilometres. Adding the approximate area of polar ice caps (estimated 880,000 sq km) gives a total of 1 million sq km of ice on the surface of Mars. This covers just 0.73% of the total surface area of Mars.

Using Antarctica as an analogy, it is estimated that 12% of the ice on Mars would be exposed to sufficient sunlight to melt sub-surface ice in summer each year (speculative). Assuming three months of sufficient sunlight per year then, on average, 2% of all of the surface ice could be expected to have liquid water near the surface. This means that, on average, 0.015% (2% x 0.73%) of the Mars surface has liquid water near the surface.

3.2 Probability of Earth microbes landing in liquid water

Of the estimated 75kg of unsterilized, microbe-bearing Earth rocks reaching the surface of Mars each year only 0.015% might, by extreme good fortune, land on ice and reach sub-surface liquid water. Although this amounts to just 11 grams per year the cumulative amount over 65 millions years is 711 tonnes. Under this scenario there appears to be ample opportunity for Earth-life to colonise Mars.

The quantity of rocks reaching Mars would have been much higher in the first few millions years after the Chicxulub impact. This tends to compensate for the demise of microbes that spend millions of years in space. Therefore the above calculations should be regarded as a long-term average. There is very little chance of viable microbes reaching Mars today within rocks that were ejected in the Chicxulub impact and have spent 65 million years in space.

4 Types of microbes that might survive on Mars

Several researchers have reported on experiments where Earth microbes have survived and colonised simulated conditions on Mars [10-12]. *Bacillus subtilis* is often cited as an example of a species that might survive a journey through space (as spores) and be revived on reaching suitable conditions on Mars. Nicholson found that the species is not particularly suited to even the most hospitable Mars conditions but enough survive to facilitate evolution to better cope with those conditions. Methanogens and other extremophiles are other candidates [13-17].

Cockell examined the possibility of photosynthesizing microbes surviving the trip and colonising Mars [18]. Because photosynthetic organisms must grow near to the surface of a rock they are much less likely to survive ejection from Earth, interplanetary transfer and atmospheric entry at Mars.

However for other bacteria and archaea that typically colonise the interior of earth rocks it likely that a large proportion would be able to colonise Mars.

5 Conclusion

Based on the broad assumptions set out in this paper it is estimated that, averaged over many millions of years, the equivalent of 11g rocks of microbe-bearing Earth rocks reach sub-surface liquid water on Martian surface ice deposits each year. This applies to current conditions on Mars, which were similar to the time of the Chicxulub impact.

The unsterilized surface rocks from the Chicxlub impact likely contained between one million and 500 million micro-organisms per gram of rock [19]. Even if just a small proportion survive the journey, there is the potential for billions of micro-organisms to colonise small niches on Mars during the first few millions years after the Chicxlub impact.

11gram piece of sandstone

Similar transfers are likely to have taken place during subsequent large impact events (Eltanin 2Mya, Kara Kul 5Mya, Popigai & Chesapeake 35Mya) [20].

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Links are at: http://users.tpg.com.au/horsts/swaprock.html

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