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HOW LONG WOULD EVIDENCE OF AN EXTRATERRESTRIAL VISIT SURVIVE: AN EDUCATIONAL EXERCISE

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With the discovery of objects entering the solar system from interstellar environments, the discussion of the possibility of extraterrestrial visitors to Earth has resumed. We examine the question of how long the evidence for such visits could be expected to last on Earth and on the Moon. Using geological estimates and our current knowledge of the lunar regolith, we conclude that evidence for visits to Earth more than 100,000 years ago would not survive to the present. Radiocarbon dating of some organic material (assuming large C-14 abundance) is of the same order of magnitude. Similarly, evidence of visits to the lunar surface would not survive for more than 100 million years.

Keywords: radiometric dating; C-14 dating; extraterrestrial lunar regolith; weathering

КОЛКУ ДОЛГО БИ ТРАЕЛЕ ИНДИЦИИТЕ ЗА ПОСЕТА ОД ВОНЗЕМЈАНИ: ЕДУКАТИВНА ВЕЖБА

Откритието на објект што навлезе во Сончевиот систем од меѓуѕвездените пространства ја разгоре дискусијата за можни посетители-вонземјани. Разгледано е прашањето за времетраењето на индициите (доказите) за ваков настан на Земјата и на Месечината. Врз база на геолошки проценки и на нашите денешни сознанија за лунарниот реголит, може да се заклучи дека докази за посети на Земјата што се постари од околу 100 000 години не би „преживеале“ до денес. Датирањето, пак, на органски материјал (при претпоставка за многу повисок количински удел на ^{14}C во примероците, е од ист ред на големина. Слично, индициите за вонземни посети на Месечината не би траеле повеќе од 100 милиони години.

Клучни зборови: радиометриско датирање; C-14 датирање; вонземен лунарен реголит; атмосферска ерозија

The entry of the first object from outside the solar system in 2017 [1] has triggered renewed interest in the question of extraterrestrial visits to Earth. The foundational scientific paper on this subject was written by American physicist Michael Hart,[2] who proposed a statement he called ‘Fact A’.

There are no intelligent beings from outer space on Earth now

Like most scientists, I accept Fact A and reject the notion that extraterrestrials are visiting the Earth right now. I have to point out, however, that this rejection does not extend to evidence for visits by extraterrestrials in the past. Given the relatively young age of the solar system, there has been ample time for many advanced civilizations to have visited Earth. It is legitimate, therefore, to ask how long ago a hypothetical extraterrestrial visit could have occurred without leaving evidence that could be detected today. Could we have been visited, in other words, without our knowing it?

One advantage to asking the question this way is that it uses student interest in extraterrestrials to get them to think about the basic structure of the Earth and (as we shall see) the Moon. We can begin with a simple fact about plates: the fact of the matter is that on geological time scales, nothing on the surface of our planet is permanent. Mountain ranges are thrown up and worn away, oceans form and disappear, glaciers advance and retreat. On a time scale of hundreds of millions of years, the action of plate tectonics changes everything on the Earth's surface. This picture of the planet is an integral part of the scientific world view.

It is reasonable to argue, therefore, that had we been visited by extraterrestrials more than a couple of hundred million years ago we could not expect any evidence of that visit to have survived into the present. But can we find a tighter limit than a few hundred million years?

Tectonic activity is a relatively slow process — with the exception of earthquakes and volcanic eruptions, it takes hundreds of millions of years to have an effect. Weathering connected to the Earth's climate, on the other hand, is much faster. A heavy rainstorm can change the bank of a stream overnight, and freezing and thawing during the winter can create potholes in concrete roads, as motorists discover each spring. This sort of weathering would obliterate evidence of an extraterrestrial visit faster than the long term changes due to plate tectonics.

Confronted with a problem like this, a problem that involves determining the age of old materials, a chemist's first thought is likely to turn to radiometric dating. Unfortunately, there are assumptions that have to be made to apply this technique to the problem of dating extraterrestrials — assumptions that need not apply away from the Earth. Take carbon-14 dating as an example. To use this technique, we need to know something about the relative abundance of carbon-14 in the past — data we get from things like tree ring studies. Needless to say, those studies would tell us nothing about the relative abundance of carbon-14 in the atmosphere of an exoplanet.

As a working exercise, one could hypothesize that the abundance of C-14 in the exoplanet's atmosphere was a million times higher (i.e. 1 atom in a million, instead of one atom in a trillion) than is her on the Earth. We will also assume (unreasonably) that the extraterrestrials can move instantaneously through space from a point to another point. This means that, they left the exoplanet with a 1 ppm of C-14 in their carbon and entered our world. After a period of approximately 20 half-lives of C-14 [$t_{½}(^{14}C) = 5570$ y] its abundance will be close to the present one on Earth, as $2^{20} \approx 1\ 000\ 000$ (actually it is $1.048 \cdot 10^6$). In Earth conditions the dating based on C-14 is possible for objects not older than 55 000 years.[3] In this exercise it is now extended to ~ 160 000 years, due to the much higher C-14 abundance. Being conservative and allowing still higher abundance of C-14 in the atmosphere of the exoplanet one may approach the value of some 200 ky. By the way note that 1 ppm of C-14 means huge radioactivity of the samples and the bodies of the extraterrestrials, thus under such extreme conditions their very existence might be questioned… but let us leave aside these subtleties. Anyway, have the extraterrestrials visited us before a period longer than 200 ky, this approach becomes useless.

Thus, we have to look for other ways of dating suspected extraterrestrial remains.

One way to approach this problem is to pick some structure created by humans and ask how long that structure will survive given the existence of the weathering process. If we then assume that evidence of extraterrestrial visits will last as long as that structure, this should give us a pretty good estimate of the time the record of that visit will remain visible to us before the Earth's inevitable weathering processes destroy it.

The most striking example of a long lasting artifact from the past is the Great Pyramid of Giza in Egypt. The pyramid is familiar to our students, and this familiarity will draw them into our next question:

How long will the great pyramid last?

Anyone who has actually visited the site of the pyramids in what is now suburban Cairo will be shocked by this question. After all, the pyramid is a pile of stone over 400 feet (120 m) high. Surely it will last forever!

No, it won't — nothing on the surface of the Earth lasts forever.

We know that the Great Pyramid was built around 2560 BC to serve as the tomb of the pharaoh Khufu (the pharaoh's name is often given by its Hellenic counterpart, Cheops). It originally had a closely fitted white limestone covering — it must have looked dazzling under the Egyptian sun. In 1303, however, an earthquake loosened the covering stones, and they were eventually carted away to be used in nearby buildings. What we see today, then, is a massive pile of stones (mainly various types of limestone) that once formed the interior of the monument. When it was built, the great pyramid was 481 feet (146.6 m) high. Since then, the removal of the outer coating and the subsequent erosion has reduced the height to about 455 (138.7 m) feet.

And that gives us a clue as to how to go about estimating how long the pyramid will last, for the fact is that rain and wind blown sand are slowly eating away the stone building blocks. In 1960, geologist Kenneth Emery,[4] then at the University of Southern California, visited Giza to study the pyramid. He noted that the removal of the smooth outer coating left the newly exposed stones arranged in a kind of step pattern When stones from the upper parts of the pyramid weather, the resulting debris is trapped on the lower steps. By measuring the accumulated detritus, Emery was able to estimate the rate of erosion. His conclusion: the lifetime of the pyramid will be on the order of 100,000 years.

If we assume that the evidence for an extraterrestrial visit is unlikely to last longer than the pyramids, then Emery's rough estimate of the future of the Pyramid of Khufu points to one crucial conclusion: evidence of an extraterrestrial visit to Earth that occurred more than 100,000 years ago is unlikely to have survived to the present.

Having said this, we have to emphasize that this does *not* mean that there were, in fact, visits before this time. It just says that if there were such visits, we could not expect to find evidence for them. It is also important to note that this conclusion applies only to evidence of visits to Earth, where standard weathering processes operate. Nevertheless, borrowing from Michael Hart we can state something we'll call 'Fact A*'

If there was an extraterrestrial visit to the Earth more than 100,000 years ago, it is unlikely evidence would have survived to the present

The lunar regolith

A common argument in the UFO debate is that extraterrestrials have landed on the Moon rather than on Earth. The Moon has no atmosphere, so the kinds of processes eating away at the Great Pyramid simply do not occur there. This means that we can ask whether evidence of past extraterrestrial visits would survive longer on the Moon than they do on Earth

Despite the fact that terrestrial style weathering does not exist on the Moon, there are other processes that operate to produce similar results. Because the Moon has no atmosphere, solar wind particles and micrometeorites – materials that routinely burn up or are absorbed in the Earth's atmosphere – constantly bombard the lunar surface. This sort of 'space weathering' has, over time, broken up the surface rocks on the Moon and churned the resulting mixture into a covering known as the lunar regolith.[5] Most of this material consists of smallish pieces of rock, less than ½" across, interspersed with larger boulders. The heat associated with small impacts produces what is known as *breccia* — a material composed of small pieces of rock that have been welded together. I find it easiest to picture the lunar regolith as something like a pile of Rice Crispies that have been exposed to damp air for a long time, so that the individual grains stick together.

In addition to collisions with smaller bits of material from space, the Moon has been hit by larger meteorites — the sorts of impacts that have produced craters on Earth (think of the Barringer crater in Arizona as an example). Unlike their terrestrial counterparts, however, large lunar craters do not disappear over time. The dark regions on the Moon ('mare') are a reminder of massive impacts that occurred early in the life of our satellite. The impacting body had enough energy to break through the Moon's crust, releasing the still molten magma underneath. And while a large impact like that is unlikely today, it is estimated that there are roughly three impacts a year that produce craters 100 square meters in size.

In discussing the lunar environment, then, we have to take two processes into account: the constant impacts of cosmic rays and micrometeorites and the occasional large, crater producing, impact.

Recent human activities like the Apollo space program have given us what scientists call a 'natural experiment' to deal with the question of how long materials will last on the lunar surface; The fact of the matter is that human beings have left an enormous amount of material on the lunar surface – 40,000 pounds, by some estimates. We can ask, therefore, how long evidence for the Moon landings will survive on the Moon, with the understanding that this is a good estimate of the time evidence for an extraterrestrial visit might survive as well.

If you think about the logistics of a Moon mission, you can easily understand why there is so much junk on the Moon. There is a great energy cost associated with the process of taking material from the Moon's surface into orbit. Since a major scientific payoff of the lunar landings was the return of Moon rocks to Earth, anything not needed for the ascent would be left behind. That geologist's hammer that was so useful during the surface excursions, for example, was of no further use on ascent. By leaving it behind the astronauts were, in essence, making room for another pound of lunar material to be returned to Earth. The powerful rockets that slowed the descent aren't really needed for takeoff either, so they are left behind as well.

So we have all sorts of debris and a simple picture of how the lunar surface was formed. There is a constant rain of particles and micrometeorites punctuated by the occasional impact of larger bodies. The question, then, is how long the evidence of an extraterrestrial visit would survive in this sort of environment. One way of approaching this question is to ask how long the detritus of the Apollo missions would survive on the lunar surface if there were no further human landings.

Let's start with the large craters. As we said above, recent observations suggest that about 300 square meters of the Moon's surface are churned up by these events each year. Presumably, this number was significantly higher during the Moon's early existence, but we will assume that it has been approximately at this level since then.

The surface area of the Moon is about 40 million square kilometers, so it would take about 10 billion years for the impact of large meteorites to churn up are area comparable to the total lunar surface area. Like the Earth, the Moon is about 4.5 billion years old, so we can conclude that as far as large impacts are concerned, it is likely that evidence of a past extraterrestrial visit to the Moon more than a billion years ago would still be up there today.

How about the micrometeorites and cosmic rays?

This effect is a little harder to calculate, but we can proceed this way: the general consensus is that the lunar regolith is about 5 meters thick in the (younger) mare regions and up to 15 meters thick in the (older) highland regions. We can make a couple of simplifying (but unrealistic) assumptions to get a sense of the time it would take for these microimpacts to wipe out evidence of the Apollo landings. First, let's assume that the formation of the lunar regolith was uniform in time. Then let's pick an arbitrary depth of the regolith — a foot (30.5 cm) or an inch (2.5 cm), for example — and say that any surface object would be obliterated in the time it took that much regolith to form. We could, for example, say that the number of micrometeorite impacts needed to create an inch or a foot of regolith would be sufficient to destroy evidence left on the lunar surface by the Apollo astronauts.

If we take 12 meters as a typical depth of the regolith and 4 billion years as the time it has been forming, then the average rate of formation is about 3 meters per billion years. If we take 3 cm (about an inch) as our standard 'destruction depth', then we would conclude that the evidence of the Apollo landing would last about 10 million years on the lunar surface — considerably longer than the pyramids but less than the time associated with tectonic activity of Earth. Increase the 'destruction depth' to 30 cm (about a foot) and the time becomes 100 million years. We can therefore extend Fact A* to read:

If there was an extraterrestrial landing on the Moon more than 10–100 million years ago, it is unlikely evidence of the event would have survived to the present.

Obviously no evidence for such a landing has been found, but we have examined such a small portion of the lunar surface that we cannot, with confidence, say that no such evidence exists.

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