Past time, future places?

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I'm tempted to offer the excuse for including this piece, if you think after reading it that an excuse must be necessary, that it's just for fun. I could say that there is a serious motive in exploring how environment necessarily changes with time and place. I could say that a good scientist needs imagination. In the dense curriculum of a science degree packed with learning facts and techniques it's easy to overlook that imagination is a really important part of creativity, and creativity is a very important part of science. Imagine what isn't there but perhaps could be; then see where logic and knowledge take you. In scientific imagination, the key words you've just read are 'perhaps could be'. Imagining pigs that fly, reindeer pulling sledges through the sky or power-crazed immortals in their palaces in the clouds isn't going to count. Nevertheless, there's a lot left to put in your own essay in praise of scientific imagination. The following, though, is not an essay, just a short story.

Episode 1

Close your eyes and transport yourself to a rocky foreshore where the lava has cascaded from the low hinterland into the ocean. The foreshore is almost the only place where there is some mobility. Inland, jagged rocks piled crazily upon each other stretch to the horizon, the residue of a prolonged oozing of basalt onto the lava plains from the volcanic cones rising in the distance. The sky is hazy. The sky is always hazy, for somewhere very distant volcanoes are active. In this era volcanoes are always active. In our mind's eye we are on Earth 3.5 billion years ago. It's hard to imagine that this place will one day be fertile, will one day be a cradle of life, will one day be a centre of intelligent life in this part of the Universe.

You and I are on the edge of a small bay with a beach where black, roughly rounded, large vessicled boulders sit on coarse black lapilli. We are looking out to sea from our rocky vantage above some low, crumbling, partially smoothed terraces. No barnacles threaten to cut our feet, no seaweed will cause us to loose our grip, no fish will detain us in the rock-pools, no mew of gulls catch our ears. All these are more than three billion years into the future. Waves roll in silently from afar, rising to breaking height as they reach the outlying rocks beyond us. They break their silence, splintering on the rock ledges in a sunlit dazzle of whiteness, in a complex of spray and hiss and low roar as they froth and bubble shorewards. Seeming to loose the battle between water and stone they end up surging against the impenetrable shoreline just below us. Spent of its energy and its bubbles, water runs in glassy transparency back over the rocky ledges to meet the heave of the next on-coming wave. A philosopher of the future asks: '*Was this incessant noise, this constantly changing scene of swirling turquoise and white surf over the black rocks present when there was no-one to hear it, no-one to see it?*'. Of course it was. Silly question, really.

Not everything is familiar, though. Our watches from the future record that a day is only nineteen hours long. The sea lapping beneath us soon recedes, leaving the outlying rocks that were breaking the waves when we first arrived now high and dry; the waves a distant line of white foam. The cause is soon obvious. The full moon rises out of the haze above the sea conspicuously larger than the silvery disk we are familiar with, a sight to make any poet wax lyrical. As the Sun shortly sets in the West, no torch is necessary to pick our way over the rocks. At least I thought it set in the West. We are in what I'd have called the southern hemisphere but our compasses pointed to the local pole. The Earth's magnetism must have changed. If the South is now North is the West now East? If I thought the stars would tell us

I was wrong, as we'd discover when night wore on. Few stars can be seen when the full Moon is high. In six hours the Moon set into the haze but the stars that came out were a disappointing sight.

The night sky drawn by our ancestors more than two millennia before we were born is scarcely distinguishable from the night sky we grew up with. Earth this may be in our minds' eyes but the night sky here is unrecognisable. Not a single constellation looks familiar. Perhaps we can make up our own names: *the earpiece*, *the monitor*, *the bezel*, *the cryochamber*……. Actually it's not that easy, for although there appear to be more bright stars above us, less than a hundred cut through the haze across the whole sky. Also, we are distracted by the roar of the sea, which is now coming in apace. We'd better retreat up the cliff by our torchlight to the jagged plain above the rounded boulders. In the near darkness, the roar of an incoming tide that could lift the waters over 10 m is not a sound one wants to argue with. *Never turn your back on an advancing tide* is an adage that crosses the ages. Safely out of harm's way, fatigue from the experience of the only half familiar sets in and the mind's eyes close.

Episode 2

It is another day in another place, on New World 4, a mere 10,000 years in the future that the mind's eye opens again. Yet, I'd seen it almost all before; almost but not quite. The Moon above was half a hand wide and more than bright enough to shine down conspicuously in daytime. Not only had there been men on the moon but women and children too. From their lunar base the colonisation party had observed New World 4 spinning beneath them before finally selecting where to begin in earnest on the planet. Besides, the Moon had given everyone a chance to experience real gravity rather than artificial gravity, and distances much longer than the one kilometre of the spacecraft on which they had all been born.

New World 4 is barely one-and-a-half billion years old. The era of sustained bombardment has passed but in truth it is pretty barren world inspite of the seeding pods that were sent a millennium ago. In favourable places they had done their job but it is optimistic to expect to do in a thousand years what took three billion on Earth, even though there was no need to struggle to invent life or overcome catastrophe. The atmosphere is dense and breathable, after acclimatisation on the journey here, and a little genetic tinkering for the travellers, but weathering, though, takes time, more than it had been given. The highest mountains rise to 20 km, rivers cascade fearsomely across the land almost carving it as you watch, the shorelines are tidal battle zones between rock and sea, the storms fearsome. Mankind never had to cope with nature so raw on Earth. Colonising New World 4 will test the ingenuity of 12,000 years of civilisation, or 24,000 if you start counting from the dawn of farming society on Earth.

Colonising such a young planet is an experiment that humanity has never attempted before. There are advantages, big advantages, in terms of the availability of all the untapped resources of minerals and materials; the hope, at least of the founders, of establishing a biosphere with no poisons or disease. The lack of alien microbes, viruses and potential parasites against which the colonisers may have no natural protection is not just a bonus but a fundamental requirement. They came with eyes and minds wide open, fully aware of all the laws of nature and with an encyclopaedia of mistakes not to be repeated. Never before has mankind been able to take to a virgin planet the genetic recipes for a world of life, life not only as it has developed on Earth but life that in all probability has not been brought into existence anywhere in the Universe. There are indeed an astronomical number of planets in the Universe but this number is microscopic in comparison with the number of genetic

combinations that are theoretically possible. The founders can at least control the start of life on New World 4 but some think its evolution will ultimately be beyond their control. The pessimists think the first signs will come in a century; the optimists put the figure at a million years and by then surely their descendants will be able to solve the problem. All agree, though, that they have the undoubted advantage of being untroubled by moral questions over the rights of indigenous life. There is none. That was clearly established a long time before the venture was started.

It's all very well for you and I to sit on the rocky coast and wistfully watch the waves washing against the grey granitic shore while the founders expand their first colony. We aren't the ones doing the hard work, taking the risks and betting the lives of ourselves and our children on making a success of it. Whether they will succeed or not I don't know. Contemplating what might happen, the mind's eye closes again.

Episode 3

I see you are beside me once more as the mind's eye opens, on Earth's dusty shore-side rocks one billion years into our future. The Earth around us is not the Earth I recognise. I'm in a reflective mood and wondering why there are any shore-side rocks at all. Plate tectonics has come to a halt, for the energy that powered it from the isotopic decay of elements is no longer enough to maintain it. Plate tectonics isn't an obvious phenomenon in the timescale of a life-time but without its mountain building and volcanism, the weather wins the battle to shape the landscape. About 20 million years is all it takes to erode high mountains into rolling plains. That may be an over estimate. If a 5000 m high mountain loses height by just 1 mm a year on average, then it will last only 5 million years. 5000 m is exceptionally high. In the world of the present day there are less than 300 mountains that height or more. Put another way, the average depth of the oceans is over 3.5 km and the average height of land above sea level is well under 1 km. There's more than enough room under the sea to wash all the land away and cover it to a good depth. Why have we any land at all? All hail plate tectonics.

1 billion years into the future is not an inconceivable time. It's less than 30% of the time that life has existed on Earth until the present day. It's not just that the mountains have gone. So too has most life as we know it. Future mankind, or the sentient creatures that run the Earth's ecosystem in future, really have only two choices: shield the Earth from the ever increasing heat from the Sun or clear out to another planet. The issue isn't 'global warming' as we recognise it but the inevitability that on a timescale of hundreds of millions of years the Sun will get hotter. We know enough for sure about how stars work to realise that this is inevitable. Plenty of visible stars in the sky have already evolved the way our Sun will go in the future. The average global temperature on Earth in 1 billion AD is now near 50°C. There is still land because a lot of the old oceans have been lost to space. The increased UV from the Sun has greatly increased the top of the atmosphere creation of hydrogen from water, hydrogen that Earth's gravity isn't strong enough to retain. Rocks exposed around us are too hot to touch. There is no sign of the life we might have expected, at least nothing that walks or flies or plants its roots firmly in the soil. What's left are dense, hot, saline lakes in the trenches, encrusted with bacteria. Waves as we used to watch them are a rarity, the layered crust is too thick. Wind swirls dust into miniature whirlpools in the air, spreading the crustal debris over the rocky landscape.

It used to be said that cockroaches would outlast most life on Earth but even the cockroaches have gone. No moving life can be seen in the searing daytime heat. During the nights that seem long, for the Earth has slowed its rotation, large, white worm-like creatures, armoured

against both heat and corrosion emerge from the crevices under the jumble of shoreline rocks and browse on the saline bacteria. Maybe they are an evolution of the extraordinary environmentally tolerant tardigrades. Small scuttling ant-like scavengers mop up detritus. Perhaps they are the cockroaches' descendants. The Earth has seen life cradled, developed, evolved and diversified in ways unique to this planet, each million years building on the heritage of its predecessors. The millions counter has clicked over to a billion, or a bit over 4.5 billion if you count from 'first life'. In the Universe, though, forevermore does not exist. On Earth, the very finite span of ten billion years will not even exist. The pageant here is coming to an end.

A billion years of evolution, though, is a very long time and life that could trace its genetic history to mankind is still alive and well in the solar system, and beyond. As the Sun gets ever more energetic, the outer solar system is becoming the new inner solar system. Mercury, Venus and Earth may be heading for oblivion, perhaps Mars too in the future, but you can't get rid of mankind's descendants that easily.

Episode 4

I'm sure both you and I want to see what happens to the Earth in the end. It's not a pretty sight. 3.5 billion years into the future, the Andromeda galaxy is already disrupting the orbits of stars in the Milky Way, though it hasn't reached the edge of our galactic disk yet. The Earth has bigger troubles. By now the Sun above is an orange-red, a thousand degrees cooler than the familiar Sun, though some three times wider. Our old friend the Stefan-Boltzmann law tells us that it will be bathing the Earth in four times the energy we get now – not that Stefan or Boltzmann's names will survive until then but the law seems to work for stars we see five billion years in the past so it's likely to still work in the future. We'd better not stay long. One finger at arm's length barely covers the fiery disk.

It's academic that the Moon is too far away to create noticeable tides, for there are no seas and oceans. Microbes were among the first life on Earth and will have been among the last. Even they are unlikely to survive this long in the baking dry heat, though 'never say never'. As the Sun goes into the first of its red giant phases life on Earth will be extinguished, not by the blinds being drawn as the light fades and our heat ebbs into space but in the blistering, incinerating inferno of our Sun's final consumption of what nuclear fuel it can transform. Not even future civilisations can prevent this happening. On Earth, there is no 'happily ever after'. The Sun will expand to beyond the orbit of the Earth, if not now then in the second red-giant phase. Life uses every trick in the book to survive, as the history of the last 3.5 billion years has proved. The Earth has been good while it lasted, very good indeed, but the roving mind's eye will need to look beyond the Earth for the continuation of this story.

JSR

Footnote

It seems to be generally agreed that the Moon likely formed at about 1.3 times the Roche limit from the centre of the Earth (i.e. about 3.8 Earth radii) and it did not take long for it to loose its spin so that one face always pointed towards the Earth. It also likely moved away from the Earth quite quickly, perhaps reaching some 40 Earth radii by 4 billion years before the present (4 Ga BP). The details are hard to calculate theoretically because they require a knowledge of the effects of tidal friction and this in turn depends on the distribution of land and ocean in the early Earth. Moreover, no geological evidence in rocks younger than 3.5 Ga BP has yet been found that enables the Earth-Moon distance (and hence the length of a lunar month) to be deduced. Tidal friction also slows up the spin of the Earth, lengthening the day. Again there is no geological evidence yet that enables the length of the day to be deduced for the very early Earth but 18 hours is, within experimental error, a reasonable estimate for 4 billion years ago.