

The Earth

An Intimate History

R. Fortey

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The Earth is hard to avoid. It is all around us, and what it is made up of, makes for the most massive and tangible objects there are. The bodies of astronomy are of course much larger, on the other hand so much more distant that they in general present to the human eyes such tiny speckles that they have to be viewed under the microscope so to speak. Their specimen are of second order, tiny specks on photographic plates, rather than the real thing. With rocks it is different, they are too big to carry, and can be left in the field. The field itself cannot be brought into human custody but remains at large.

The scientific story of the earth started in the 17th century, and some simple principles of the position of layers were put down. The layered earth became a clock and indicated a passage of time, exactly how much, was not clear. Concomitant with the dating of rocks came the identification of fossils. Nowadays, fossils are used as fingerprints to date rocks, while fossils originally were dated by the rocks in which they were embedded. The immutability of species was for a long time considered beyond doubt, the dogma against which Darwin was fighting well into the 19th century, yet the connection with rocks made the idea of evolution obvious to many naturalists well ahead of Darwin. In fact the geological record, as well as anything else testified against the creation stories of the Bible.

The vast vista of geological chain, mirroring the vast vistas of space, we succinctly expressed by the Scottish geologist James Hutton, who famously and poetically expressed it: No vestige of a beginning, no prospect of an end. He saw an endless cycle of orogenesis, i.e. mountain building, followed by erosion and sedimentation. His compatriot and successor Charles Lyell popularized and developed Hutton's notion of uniformitarianism, i.e. that the processes that changed the earth are themselves constant, and can be seen working today. In particular he opposed the idea of rapid and catastrophic changes, and emphasized that changes are gradual and very slow, their rates observable at the present. In particular it shows that the earth must be very old, otherwise there would not have been time to wear down tall mountains. Lyell's three volume work *Principles of Geology* of 1830 was a pioneering and fundamental work, the essence of which is still considered valid, even if the dogma of unitarianism must occasionally be softened.

The author refers to three generations of influential text-books, the first being Lyell's, and the second being that of the Austrian Eduard Suess another three volume compilation - 'Das Anlitz der Erde' from the 1880's, and finally the British Arthur Holmes whose 'Principles of Physical Geology' came out in its first editions in the 1940's. The story they tell is more or less the same as to details, the great revolution in geology occurring with the theory of Plate Tectonics which was established as late as in the 1960's. Holmes was a pioneer in this respect and referred to it in his single volume text-book while it was still considered irresponsibly speculative. Holmes started his career by dating rocks

using radioactive decay already back in 1911, a technical invention that permeates much of modern geology. With plate tectonics most of the pieces fell into place. Before the origin of uplift and mountain building was something of a mystery, the standard explanation being that the Earth while cooling actually shrunk in size, and the crinkled surface of an apple cooked in fire was used as an illustration, which I remember from my childhood. This turns out to be false, the size of the Earth is unchanged¹. Instead the earth is covered with pieces of crust that float upon the mantle like ice-flows on a lake, but driven not by wind but by heat convection. The movement is very slow, at the rate of the growth of finger-nails. Plates either bump into each other, and when they collide, their edges buckle and there is uplift when one plate subducts under the other. The process is slow but not continuous but proceeding by small jerks, which are of very short duration (in geological terms) and felt as earthquakes. Or they split apart along a rift and ocean floor is created by magma welling up from cracks in the crust and expanding on either side until being subducted under continental plates. So while continental plates may preserve parts of them for a very long time, ocean floor is ground down and obliterated in the innards of the world, within a comparatively short time. The telltale signs of past movements are left in the landscape, but in complicated ways that are very hard to entangle, the preliminary work having been done during a century or so of field work and geological map-making. There is erosion that leads to sedimentations on the ocean floor, there is collision that lifts up ocean floor, or spew forward magma from the interior through volcanic eruptions, associated with the process and then cooling down as so called igneous rock. Layers are folded upon each other and then partially eroded away, only to undergo further sedimentations or being covered with magma, and then undergoing further buckling and folding. Repeat the whole process a couple of times, and the result is confusing to a high degree. To read the history of a landscape, you need to form three-dimensional pictures from which to infer the dynamics. Thus even if the principles are easy it is a case of inversion, seeing the end result and come up with a logical scenario that explains it all².

The geologist is a world traveller. The profession is an out-door one, with the practitioner taking field trips with a hammer, taking samples of rocks and trying to get the big picture. This makes the writing of a popular book on the subject very attractive. The reader is taken on an educational tour of the world. He or she is also presented with puzzles, which are easy to state and motivate, although quite hard to solve and disentangle. The subject is earthy.

But even geology suffers from a lack of mathematics. The shyness of mathematics and the anathema of mathematical formulas no matter how elementary is the bane of all popular science writing, and condemns it always to be short of their goal. There is

¹ As a child I was very puzzled by the past being dug up from under ground, did that not mean that the Earth was actually expanding that earth was raining down on it, maybe from meteoric impacts? This shows the danger of popular simplified explanations that do not logically fit together and puzzles the inquisitive mind.

² One is reminded of proofs in mathematics, but the difference being, that a proof in mathematics is constructed to justify a conclusion, a so called theorem, but in geology you do not need the justification, the existence of a formation is proof enough of its reality. While there are several proofs in general to a theorem, the geologist is challenged to find the one sequence of events which led to the present.

reference to Euler and the sphere, but wherein that actually consists is left as a mystery. Rigid motions along a sphere is mathematics, and the understanding of which is essential to the appreciation of tectonic movement. So what does the author present instead of mathematics? Diversions. Historical, literary and personal. This is fine and you can see how writer and publisher alike savors the readability which comes with padding. The text becomes long but far more easily digested. To plow through it becomes in essence not that different from devouring a crime story at the beach. It is a pity. So much would have been gained by a slimmer and more structured approach.

What are minerals? What is really the difference between granite and gneiss, between igneous rocks and metamorphed. And how do you actually date rocks? The reference to slow radioactive decay is not enough, the reader needs to know more. What is meant by the age of a rock? Rocks undergo changes, while its basic constituents are atoms, and it does not make much sense to ask for the age of atoms. Now when rock is metamorphed in what sense does the clock get restarted? Such things are usually never clearly explained in popular books, but the story could not be that different from carbon-dating where the set-up is usually more carefully explained. The author makes the points that minerals show far less variety than the organic world, but the reason he gives is at least not to the mathematician that convincing. Even a few different kind of atoms can give rise to a bewildering variety. Still my expectations may be misled. After all the book is written for entertainment and to ignite interest to be satisfied elsewhere. Why not be content with an extended travel story, which brings home the point that travel can involve much more than to savor ancient architecture. That in the most unpromising circumstances, real riches can be treasured. You need no volcanic eruption to engage your interest. An extinct volcano can be as interesting, and definitely much safer. And the traces of a vanished one, where you least expect it, truly fascinating. Geology invites you around the world, and in so doing, it gives the hint of time-travel. The familiar outlines of the continents, as well as the standard landscapes are but momentary features of a world in transit, in principle not different from the rich variety of cloud formation that is created every day all around the world. But clouds leave no traces. They come and go, but the slower more monumental changes of landscapes, with their concomitant floras and fauna do, if tantalizingly evasively so. To read the past from the few traces it leaves in the present is an engaging, and endlessly fascinating project. The history it reveals is a jumbled, complicated one, still the basic principles of change have been known for a long time, and put into a coherent picture by the recent conception of plate tectonics. As the author emphasizes, the picture presented is the same, it is only our conceptions that change, and make us read it differently. The facts are there, but their interpretations evolve over time as we gain more and more insight.

The underlying lesson is that geology sets the limits and like the collective subconsciousness of Jung it guides our lives, and not only our lives, but the lives of all organisms, and the features of all landscapes. We are at the mercy of those powers, and they will continue to reign long after we are gone. We have reached the moon, but the interior of the earth is *terra incognita* indeed. As inaccessible to us as distant space. In fact we have drilled no hole deeper than six miles, anything below that is known to us only by theoretical speculation and inquiry, not by direct confrontation, and yet the world we know takes

place on such a thin crust.

Geology is also a most applicable field, and geologists are employed all over the globe in the search of oil and minerals; yet, and I find this commendable, there is almost no mention of such mundane links, the story geology has to tell is a bigger one, related to the Myth of our emergence. The excitement is a purely intellectual one, not a commercial one. So maybe if this message comes across, this might be by far enough.

August 27-28,31 2012 Ulf Persson: *Prof.em, Chalmers U.of Tech., Göteborg Sweden* ulfp@chalmers.se