Snowball Earth

G.Walker

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Geology and Astronomy are really the first two exposures to science encountered by the curious child ready to have its imagination fired. Astronomy is about huge space, geology about deep time. The first appeals to the mathematical imagination the second is literally more down-to-earth. Still geology ornamented with paleontology adds a lot of variety and supplies a general narrative into which issues such as the meaning of human life and purpose finds a general context.

The subject of study for the astronomer is the universe, for the geologist the Earth. There is a huge difference in scope, the second only being a small part indeed of the former. On the other hand the actual objects the astronomer gets his or her hands on are secondary, not the stars themselves but tiny photographic emulations (and nowadays pixels); while the objects of the geologists study are so extensive that they cannot be stacked in museums, namely rocks and outcrops all over the world.

The astronomer, as the mathematician, lives in his office, while the geologist is 'out there' with his hammer battling cold or heat, flies or snakes, and actually for the field geologist, this battling with nature and being out there, is a very essential element, in fact one may even suspect the most essential of them all. On the other hand a man needs a purpose, without it his life and surroundings provide but a jumble mumble of which he is bound to get bored. To have a well-defined purpose gives direction and distraction and defines a life.

This book is a presentation of an idea, namely that the Earth once (and in fact several times) was encrusted in ice, not only around the poles, but everywhere! The idea was at first considered, for obvious reasons, hair-brained not to say absurd, but did gradually gain recognition. It is an interesting idea, as it gives an additional dramatic twist to the history of the earth, but unlike the notion of plate-tectonics, which completely revolutionized geology in the 70's and whose impact can be likened to the infusion of evolution into the picture of the organic world brought about by Darwin[1], it is a detail that in no way challenges the way to do geology. In the hackneyed words of Kuhn, it does not introduce a new paradigm in the subject[2]

[1] Of course Darwin was not the first to introduce the idea of the variability of species over time, he had illustrious predecessor as we all know, but he was the first to give a plausible explanation as well as provide rich documentation which by itself provoked many a question and hence subsequent research guided by an overarching principle.

[2] One may possibly qualify this statement and, as does the author, refer to the principle of uniformitarianism that has been dominated geological theories since the 19th century, namely that one should never invoke agents that are not manifested today. That the forces of geology grinds very slowly but over extended times, so very small changes appear dramatic when accumulated over eons. Astronomy is made possible by the vastness of space, geology by the vastness of time. But the meteor hypothesis for the

Now, how can you prove such a thing? Some kind of proof is of course necessary in any scientific claim. Geology is like history a forensic science. In a strict sense it is not experimental, it proceeds by interpreting the tiny traces the past leaves in the present. There is usually a huge discrepancy between an actual event and the trace it leaves, and it is always tempting to overinterpret and let scant material go a very long way. As to the individual there is no check on this, and in a sense there should not be, as individuals we are encouraged to let the sky be the limit and think unthinkable thoughts, but as a social enterprise, which science very much is[3], it is bound to act as a check. The too speculative idea more often than not will end up contradicting facts, whatever what is meant by them. Those are instinctive principles to which all curious minds adhere, without ever having been taught a course in the philosophy of science.

Nothing like the human interest to engage a readership. Hence scientists take pride of place in the narrative. The main protagonist is Paul Hoffman, whom we are first introduced to as he is about to run his first marathon ever at the tender age of twenty-three. We follow him through those 26 grueling odd miles (although only the last few tend to be grueling in a marathon, otherwise you have no business running) to place himself as a respectable 9th at 2.28. That was in 1964, almost fifty years later such a time would not carry a trophy. Hoffman decides wisely that even if he is very good it is unlikely that he would ever win a gold medal no matter how much he trains[4], so he decides to become a geologist instead. Geology allows him to fulfill an old dream namely of living in the Arctic, something which Canada is particularly suited to provide opportunities for. He is employed by the Canadian Geological Survey, which gives him ample freedom to pursue his research. What he does, and why the Arctic is such a necessary location for it, we as readers are not really informed on, apart from a vague reference to studying the movements of tectonic plates. Instead we are served hints as to his powerful and somewhat willful personality. Extraordinarily fit, fond of solitude, driven and passionate about his work, which seems to involve enduring myriads of fly and mosquito bites, dangerous encounters with bears, and the rewards of constantly beholding a stark and beautiful landscape of an extra-human scale, perpetually bathed in summer light. That he eventually finds a partner and marries could surely only come about by the devoted attentions and determination of the right woman. It is all very romantic. But as said, what he actually has been doing all those years we are kept in the dark about, so when he eventually is forced out of the survey for his outspokenness and lack of political correctness we as readers are surprised that he is taken on by Harvard. There must have been much more than meets the eye.

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extermination of the dinosaurs in 1980 was already that; and besides there is really nothing in the snowball theory that contradicts the paradigm of uniformitarianism, in fact when the positions of the continents are yet again in an appropriate place around the equator it may happen again!

[3] Popper famously asserts that science cannot be conducted by a lone individual, it needs a social setting, with different wills and agendas

[4] The remarkable fact about marathon runners is not the actual speed, which most people would be able to keep up with for at least some short distance, but the distances along which they are able to maintain it. There might seem to be a rather marginal difference between a 5.10 min/mile as opposed to a 5.20 min/mile, but let the latter run at the former speed and he may only be able to keep it up for say 10 miles at most, so the former is in a sense more than twice as good as the latter.

Other actors are introduced as supporting roles. Some like Brian Harland and Joe Kirschvink are predecessors who prematurely so to speak launched the idea of a snowball (it is after all very hard to come up with big original ideas in science, most of the big ideas have forerunners), others such as Tony Prave turn up as unfortunate collaborators who are thrown aside, testifying to the disdain for social niceties which Hoffman seems to make a fetish of (or simply the impatience for anything that does not measure up), while Dan Schrag has the fortune to play the role of best friend and sounding-board to Hoffman. There must also be villains, such as unyielding critics, whose constant nit-pickings could drive any sane man into despondent lunacy. It is typical that all of them are referred to by first names. First names such as Paul, Joe and Dan are of course shorter than more distinctive last names. The problem with the presentations of scientists in popular presentation of scientists, is that they all seem indistinguishable. They are all very friendly and open, filled with youthful enthusiasm and impressive erudition, practical as well as theoretical, and generally inexhaustible. It is as if they are all cut from the same stereotype. Maybe because it is true, they tend to be very similar. The portrait of Paul Hoffman stands out in this respect. Still I believe him to be more typical than the stereotype, typical in the sense that most people are typical in their way, and in particular in no way a maverick scientist.

Now how do you prove a claim? From the post-modernist perspective, objectivity in science is just an illusion, it is all a matter of persuasion and social consensus. For the point of view of scientists this is an untenable position, if taken seriously it would make mockery of all their work. Anyway the first position is unassailable, as science is done by humans, and persuasion is indeed what makes for consensus. From a philosophical view what is involved are some shared assumptions, most generally of the independence of the real world and the principles of rational reasons, and more specifically the assumed axioms, or dogmas if you so want, of the discipline in question. Now a proof cannot be conveyed through the pages of a popularized account, even if the arguments can be presented as if they were unassailable. Unless the case of mathematics there has to be direct connections to empirical material and one cannot rely on reason alone. Still it is not impossible to give the gist of it to the general and curious reader, unlike the case of mathematics. Everybody understands what it means for the whole earth be covered with snow, the dramatic consequences of which, and why it is interesting. It is far harder to make sense of the Riemann Hypothesis to the untutored reader, what can be taken for granted in geology needs years of study in mathematics. To a mathematician the case of geology may seem very easy, but of course the ease of the arguments is deceptive. The ideas involved are simple, but to implement them involves technical difficulties in par with those engaging a mathematician in his work.

So after the extended preamble what is involved? In fact what makes people think of such an outrageous idea in the first place, because it is important to point out that such ideas are not the result of idle speculation but are more or less forced upon geologists when trying to interpret the facts on the ground so to speak. Now as noted before the geological record is in term of pure mass the largest documentary evidence any scientist has to work on. It is all out there, lying unprotected out in the open. How can we tell it has not been disturbed? Take the example giving evidence of past ice-ages, namely strange boulders lying on sediments. How did they get there? Moved by humans? Too heavy and too pointless? Stone is immobile by itself, that is why rock is such a good keeper of records[5] . But that of course presupposes that it is undisturbed. Exposed rock is at the mercy of weather and wind and will slowly but inexorably be ground down by erosion. In fact erosion is necessary for the recycling that makes record keeping possible in the first place. Rock turned into dust will eventually find itself carried by water to the sea and deposited as sediment, which will slowly become petrified[6] and buried deeply, in the process making those segmented records which will however be inaccessible for million of years, until tectonic activity leads to orogeny and exposes it to view, not seldom in a very slanted position. Thus if you see a so called drop stone[7], how do you know that this has been undisturbed for 600 million years? This is not meant as a criticism of the conclusions of the geologist, only that many steps in the deductive line of arguments have been left out for simplicity. True, it is impossible to make watertight arguments in a popular book, in fact such arguments are never presented in their complete states anywhere, but instead there are scattered throughout the geological literature as so many pieces of the puzzle, which the experts can put together in their mind, persuasion consisting in the willingness of others to make the same effort. Another instance is the dating of the events, through various clever combinations of measuring isotopic frequencies. And as to the placement of a piece of rock when formed, one looks at fossilized directions of magnetic direction, which are by themselves very hard technically to detect and measure. Add to that the simple idea at those directions are expected to be horizontal at the tropics and vertical at the poles. But how do you measure that, the rocks themselves can be tilted since their formations? It is of course not impossible, but it requires much more argument and empirical study. It is interesting to note that before the acceptance of continental drift, the crust was assumed to be stationary. This would of course have made any investigation as to original location moot, although such pre-assumptions lead to puzzles themselves, as to whether the axis of the earth had changed place visavi the fixed facial features of the earth i.e. the continents. Now leaving aside those minor points, the hallmark of a good theory is that its deduced consequences are manifested. It is always easy to come up with theories that explain a certain phenomenon, but more likely than not, those theories will inadvertedly explain many others things that do not occur at all. So to make a very long story short, Hoffman and his Sancho Pancha Schrag were able to come up with an explanation that beautifully explained most of observed phenomena (and nothing else) and had the requisite empirical grounding. To say that neither geology nor cosmology is

[5] Inscriptions in stones last for a very long time, as do clay tablets with cuneiform writing. What about the media of our own culture? Magnetic storage, and by some considered very vulnerable. Will it all fade away within a near future? On the other hand will it make too much of a difference? After all civilization as we know it, may be far to vulnerable to be sustained, anyway the runway pace of technological advancement seems to undercut its very stability.

[6] A sedimentation rate of 1mm a year seems to be a rule of a thumb (can actually be seen in Rome, where ancient monuments tend to be situated 2 meters below the present ground level), which means given the depths of oceans that it cannot be carried on continuously for many million of years.

[7] So called, because it is assumed that only glaciers can carry big boulders, and that those boulders have been pushed out onto ice and dropped to the bottom when the ice eventually melted

an experimental science is somehow to miss the point. In a sense experiments are still possible, they are only not performed in the easy way that is possible in the traditionally experimental sciences. Questions can still be asked and the outcomes checked, one simply does not have the same freedom of varying parameters.

Now the real challenge of a book like this lies maybe not so much in explaining the science, which as has been noted is a tall order indeed, but to make plausible to the general reader why scientists are passionate by what they are doing, and that they can be motivated by pure curiosity unsullied by practical applications. However, do be honest, even the purest scientist is not entirely immune to the possible applications to his own career and ultimately fame. The desire for fame is however rather universal, which is why it is so easy to convey it, but far from sufficient, there has to be something else. Sweet are the rewards of victory indeed, but sweeter still is the road that leads up to it. Eventual fame is like a mirage at the horizon, very abstract and most likely ephemeral, yet a powerful drive to keep on. However, the most likely people to read a popular book on science may not be the general public, but the intelligent layman, who more often than not is a scientist himself[8]. One may suspect that the market for popular books on science may have shrunk as a result of the rise of formal education. In former times they tended to be the only outlet of scientific curiosity for the ignorant, and were consequently written more in order to instruct than to entertain. Nowadays the entertainment aspect has become much more important to publisher, who in general are more pressured than ever before to make profits.

As to entertainment value, popular books especially on forensic science could benefit a lot from being presented as detective stories[9]. People seem to enjoy such stories, not only because of a taste for blood and mayhem. A detective story if well written presents an engaging mystery and a collection of seemingly disjointed clues i.e. haphazard traces left from the crime. The climax of the story is of course when all those clues have been put together in a coherent narrative of compelling persuasive power. The effect is similar to that one experiences when solving a mathematical problem when all false leads are eliminated and disparate clues are being connected. The difference is that the typical detective story is a fake. The solution is more or less given beforehand in the mind of the writer (or so I imagine) who then works backwards, planting suitable clues. In mathematics and science it is the other way around. The clues are given, but the story is a true revelation. So in other words rather than say starting with the final narrative, which is so often the case in popular writing, by say describing the climate and geography with its concomitant fauna

[8] To stick consistently with the male gender invites of course accusation of sexism, to use the female gender often makes a slightly affected impression, and using both is plain cumbersome. Perhaps the solution is to use the neuter gender and refer to scientists as 'it' as you can do grammatically with children. But no one seems to like that either. Would it not be simplest to think of the male gender as the generic gender, and ignore the possible ramifications? Or maybe always make generic references in the plural when possible. In Swedish man, as a representative of mankind, is grammatically female and referred to as 'she'. In my opinion that does not make Swedes more feminist than others. One should not exaggerate the influence of language on thought and attitudes, many languages, such as Finnish, lack gender altogether.

[9] Something already observed by the historian R.G. Collingwood another representative of a forensic undertaking now a humanistic one.

and flora of a particular region at a particular time, start with the clues, which will provide in the end a more nuanced picture, making clear what is beyond all doubts and what is more like reasonable speculation given the evidence up to what is a fanciful extrapolation of what could possibly be permitted. Of course such approaches would not only tax the reader more, but hopefully for ultimate rewards, but even more so the authors. This book through its approach, at least meets those suggestions half-ways, by emphasizing the connection between the finished interpretation and the subtle clues, without being in the position to delineate those connections in more compelling detail.

March 22-23, 2011 **Ulf Persson:** *Prof.em, Chalmers U.of Tech., Göteborg Sweden* ulfp@chalmers.se