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Not My Fault: Snowball earth in Africa

Lori Dengler/For the Times-Standard
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I'm still in Africa. Namibia is a terrific place for geology. The arid landscape does little to obscure the bedrock. Two hours south of where we were staying, a road cut exposes the Damara Belt tillite near the small town of Franconia. It's a beautiful outcrop – large boulder-sized rocks, small sand grains and everything in between. Geologists will know immediately what "tillite" refers to, a jumbled mix of boulders and sediments that loudly says GLACIERS.

Glaciers cover the land with ice that moves slowly downhill or outward under the force of gravity. As the ice moves, it scrapes soil, rocks and boulders, incorporating them into the flow. When the glacier stops and begins to melt, this load is dumped in a great unsorted pile with all rock and sediment sizes randomly intermixed. Sediments carried by water or wind are sorted according to grain size, larger particles deposited before the fine ones. Mudflows and avalanches can also create unsorted deposits, but only glaciers produce them on a grand scale.

There is nothing particularly unusual about tillites. They are the solidified remnants of the glacial piles and have been produced time and again during the many ice ages that have occurred throughout earth history. But the Namibian tillites are special, and may reflect upon the greatest ice age in the history of the planet.

There is no way that glaciers would form in today's Namibia. It almost never rains and the coldest temperatures in winter may cause minor frosts and the summers soar into the low hundreds. But the Damara tillites were formed around 700 million years ago when the land that is now Namibia and all the continents were in different orientations.

There's not a lot of 700 million year-old rock still exposed on the earth's surface. The movements of the plates have reshaped, metamorphosed and recycled most older rock units. But geologists have found few spots that have sat relatively undisturbed in the intervening geologic periods. The Damara tillite is one of them. It was certainly buried at one time, enough to cement the original loose sediments into firm rock, but not enough to change the structure of the unit.

The Damara belt is sandwiched between carbonate units above and below that contain stromatolites (Not My Fault 6/4). Stromatolites form in warm near-equatorial waters and although these units may have been formed millions of years before and after the tillite, it's hard to imagine that plate tectonics could have quickly moved this chunk of Namibia from near the equator to a polar region and then back again in this time window.

There is a more quantitative way to estimate where this land was at the time the tillites were formed. Some rocks contain a record of the earth's magnetic field at the time when they were formed. When a volcano erupts and magma cools, some of the iron crystallizes into magnetic minerals, which align themselves with the earth's field. Tiny magnetic minerals in sediments deposited into the ocean also orient with the magnetic field as they slowly drift down to the sea floor.

Unlike gravity which points down everywhere, the magnetic field varies as a function of latitude. In its simplest approximation, it looks a bit like the field of a bar magnet, pointing straight down at the north pole, straight up at the south pole and varying in a mathematically predictable way in between. With very careful sampling and laboratory methods, it's possible to extract the ancient magnetic dip angle and estimate what the latitude was at that time.

The Damara tillites cluster close to the equator. Possible tillites of similar age have been found in other areas including Australia and other parts of Africa. There's no weather phenomenon that can create glaciers near the equator and not leave the rest of the earth in an icebox as well. Numerical climate models in the 1960s demonstrated that a positive feedback loop, with ice-covered land reflecting more and more of the sun's energy back into space, could produce a "snowball earth", a name coined by Caltech Professor Joseph Kirschvink in 1992.

One of the objections to the snowball earth hypothesis is how to get out of it. Once most of the planet is ice bound, it's very hard to reverse. Most snowball supporters cite volcanism as the way to warm the planet. Volcanism produces carbon dioxide, and with photosynthesizing organisms that consume carbon dioxide such as stromatolites under ice, carbon dioxide consumption likely decreased, slowly allowing atmospheric levels to increase, warming the planet through the greenhouse effect. Eventually the ice melted and glaciers dumped their loads in many places on earth, including the small corner of Namibia.

Snowball earth is much more complex than what I've outlined here and is still a topic of much debate. Some argue it was not a one-time event, but happened several times in the Precambrian past. There are naysayers that criticize the dating of the rocks or the magnetic data. But I'm sold - touching that outcrop in Northern Namibia made me a believer.

Note: Canadian geologist Paul Hoffman has studied deposits in Namibia for several decades. Here is a short summary of his 1998 Science paper that discussed his results:
https://www.sciencemag.org/news/1998/08/african-hints-snowball-earth

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Lori Dengler is an emeritus professor of geology at Humboldt State University, an expert in tsunami and earthquake hazards. Questions or comments about this column, or want a free copy of the preparedness magazine "Living on Shaky Ground"? Leave a message at (707) 826-6019 or email Kamome@humboldt.edu

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