Silicon [1]

"*All our belief in objects... rest(s) on the idea that time does not bite into them.*" [2]

Other than runners passing through, only old people were on the beach in Chicago at 7 a.m. A man and a woman with high butts, long legs, and bathing caps faced each other, jumping up and down, preparing for a swim. First they swung their arms; then they touched each other's toes. Their very pale skin reflected the thin, clear light, and even from fifty feet away, I could see the detailed imprints of age almost as perfectly as sneaker tracks in the sand.

Aging skin and masses of sand share qualities: soft, impressionable. The oldest sand is always quartz, and each crystal is a hard little fist that has toughed it out over billions of years of erosion. The older the sand, the more difficult it is to tell a crystal's age, because its mineral inclusions have washed away. Radiometric dating techniques—such as parent uranium decaying to lead daughter, or parent potassium to argon daughter—require the presence of the daughter minerals if only in tiny amounts, but in a very old grain of sand only the pure quartz persists.[3] Generally, quartz crystallized in the unrepeatable moment of igneous rock-making about 4.6 billion years ago. In Wisconsinan time (25,000 years ago), the last ice sheet entered northeastern Illinois. It dragged its burden south from the Canadian Shield, carrying some of the oldest exposed rock in the world (2.5 billion years), and picking up more stuff along the way. This accumulated glacial burden is likely what sifted through my fingers on Hollywood beach on Lake Michigan, in Chicago: a fine, yellow-tan mix: quartzite, yes, as well as white Silurian dolomite, pink

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[1] Si, atomic number 14
All information not otherwise cited comes from a visit to U.S. Silica, in Ottawa, Illinois, in 2003, and a phone conversation with Professor Alfred M. Ziegler, Department of the Geophysical Sciences, University of Chicago, 2003. Also: USGS Mineral Commodities Summaries and Mineral Yearbooks: 1994, 2002–2009: http://minerals.usgs.gov/minerals/pubs/commodity (accessed: 11.14.09); and Raymond Siever, *Sand* (W H Freeman & Co, 1988); and F. J. Pettijohn, Paul E. Potter, and Raymond Siever, *Sand and Sandstone* (Springer Verlag, 1987).

[2] Bergson, Henri, *Creative Evolution*, tr. Arthur Mitchell, 1998, Dover, p. 8

[3] "As an example, the parent-daughter system used to determine the age of the Earth is the uranium-lead system. The decay of the parent uranium isotopes to daughter lead isotopes in samples of the Earth, Moon, and meteorites indicates that all the planets in our solar system formed 4.5 billion years ago."
Uranium-238 to Lead-206: 4.5 billion years
USGS: Elements, Isotopes, and Radioactivity, http://minerals.cr.usgs.gov/gips/na/radio.html (accessed 2.4.13)

granite, greenstone, basalt, chert, diabase, and occasional "lumps of steel mill slag and worn brick."[4]

Silicon is the second most abundant element on earth, following oxygen, and makes up about 24% of the earth's crustal rock. It is chemically analogous to carbon,[5] which we associate with living matter, but less abundant than carbon in the universe at large. If you ignore traditional distinctions between living and inert matter and arrange them on a continuum, the silicon content of entities decreases as complexity (and carbon content) of that entity increases: "silicon to carbon in the earth's crust is 250:1; in soil: 15:1; in mammals: 1:5000."[6] The human body holds about five to ten grams of silicon. Its physiological necessity is debated but it seems to be important if not crucial for the growth of bones, and for the formation of connective tissues. Finely divided, and inhaled as silica dust, it is carcinogenic (mesothelioma).

The sand on Hollywood Beach is combed every early morning by a bulldozer leaving intricate tractor tread marks. By 10 a.m. in mid-June these had been erased by a steady lake-effect wind that sorted sand by size, lifting and dropping heavier sand sooner, and lighter, smaller grains later, ribbing the beach in stripes of fine and coarse. By late afternoon a stronger wind had whipped up glowing golden oblongs of frenzied grains that skimmed across the beach like dolphins riding waves. The glowing dolphin blobs made a gleeful whizzing more felt than audible, like too much caffeine tightening and zinging the nerves at the back of my neck. Saltating sands—from the French for "jump"—build the architecture of giant desert dunes. If you can imagine the sound of one sand grain, jumping, how many would it take to mistake the sound for cannon fire? "Booming sands" in the desert have been "likened to trumpets, pipe organs, foghorns, thunder, low-flying propeller aircraft, and moaning."[7] It seems that no one can adequately explain this. Layers of sand slipping over other layers, on the slope of a dune, cause grains to jump in and out of empty spaces, creating multiple vibrations—this is one attempt at an explanation; sand as both particle and wave.

On a USGS map of the upper midwest, the St. Peter sandstone deposit is shaped roughly like a frog with no arms swimming down from Lake Superior with its head in Illinois, or

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[4] Raymond Wiggers, *Geology Underfoot in Illinois*, Mountain Press, 1997

[5] Both carbon and silicon have four electrons in their outer ring, and occupy group 4 of the periodic table, along with germanium, tin, and lead.

[6] Eugene G. Rochow, *Silicon and Silicones*, Berlin Heidelberg: Springer Verlag, 1987, p. 155

[7] Franco Nori, Paul Sholtz, Michael Bretz, "Booming Sand"; September 1997; *Scientific American Magazine*

like a health class diagram of fallopian tubes connecting to the uterus. The fallopian tubes extend into the upper peninsula of Michigan and the lower fifth of Minnesota, with the uterus thickening in Northern Illinois. This two-dimensional plotting of a four-hundred-million-year-old sandstone deposit doesn't include the part that dips down so far below the surface of the ground that coal and other minerals are mined above it—so far that it isn't reasonably considered "existent," at least in commercial terms. But extensions of the deposit resurface from underneath these deep folds in Missouri near St. Louis and in northern Arkansas. At the U.S. Silica plant in Ottawa, IL, the St. Peter deposit is anywhere from two to ten feet below the surface, making it one of the cheapest imaginable mining operations because there is so little overburden to remove. The perfectly round, relatively pure, quartz sand, which settled on the edges of the midwest Paleozoic sea, is covered only with many thousands of years of silt, equivalent to house dust.[8]

Larry, my guide at U.S. Silica, claimed "we make sand" which was funny to me after trying to wrap my head around the depths of geological time required for the independent, autopoeitic crystallization of quartz. We drove into a wide, shallow hole, about a hundred to a hundred and fifty feet deep, the thickness of the sandstone deposit. U.S. Silica blasts the face of the rock with what miners all over the country described to me as "Oklahoma bomber explosives," a mixture of ammonium nitrate fertilizer and diesel oil, also called ANFO. The stone, almost friable by hand, decomposes into an avalanche of particles. A high velocity water jet washes and pushes the sand into PVC pipes. Pumps move the heavy 50% sand/50% water mix to the plant, where it is dried and separated.

At the silica plant you can see down through the maze of expanded steel mesh staircases and lacy floors into different levels where various processes are happening. It was like climbing through a Piranesi drawing. In the first bath, turbulent water lifts the lightest particles up and over the top lip and the heaviest drop and slide out the bottom. After this preliminary grading into big and small, each of the two categories is dumped on a wide conveyor belt and heated from below; the clumpy sand, hot now, with no visible liquid, drops into a closed bin where it is heated until dry, then conveyed on belts to the sorters. The sorting process uses a patented device specific to this plant which couldn't be shown to visitors for proprietary reasons. Larry described it: fans blow at a curtain of falling

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[8] "The depositional environment of the St. Peter is much debated. It has characteristics of both eolian and marine origin. It is likely a combination of both, beginning as a massive dune field that was overtaken and reworked by a marine transgression (that is, transgressive barrier bar sequence) and transformed into a series of offshore bar deposits, oriented northeast to southwest." Missouri Department of Natural Resources, Geological Survey Program (http://www.dnr.mo.gov/geology/geosrv/imac/stpetersandstone.htm, accessed 1.8.13)

sand and the heaviest particles drop first into a slot, then successively lighter grains drop into slots further and further away. It sounded exactly like what the wind does on Hollywood Beach, only patented, and secret. Some of the smallest sand was sent to the mill to be ground into a kind of flour used as filler for epoxy resins and in the reflective paint on roads. Until a few years prior to my visit, the mill used to grind this sand with flint rocks imported from France but that limited resource has been exhausted. Some of the last remaining flint rocks in the world lay heaped in a pile outside the plant, rare as diamonds and obsolete. To replace them, Adolf Coors of Colorado, beer manufacturer, began manufacturing perfectly spherical ceramic balls to grind Ottawa sand. One worker in the glass-enclosed control room looked at a computer screen and tested the degree of impurity of sample batches in a small lab set-up. Another worker, wearing overalls and a respirator, left the glass-enclosed room to attend to irregularities inside the moving machine, which included six cylinders turning slowly enough that you could count the rotations.

"Making sand" means separating and recombining it. Blending percentages of different size particles is the key to sand's exchange value, and how it becomes a commodity tailored towards different applications. Glass, foundry, and oil and gas drilling are the primary markets for Ottawa sand, which is famous for its purity and its sphericity. These are followed by a myriad of minor specialty industries, each requiring its own combination of grades. The hot sand is blended into the requisite mix as it is poured directly into the customer's vehicle—truck, train car, or a barge on the Illinois River. The sand was still hot—150° F—unless cooler sand was required but 100° was the coolest they could get it. They bagged some sand and stacked it in a warehouse but very little—most of the sand moved in a continuous motion from blasted hillside to plant to hot truck bed (lined with clean aluminum) and down the road—no pause.

Because Ottawa sand is so old and round and pure it is perfect for filling the holes left when oil and gas are extracted. "Oil frac sand" for which St. Peter sandstone is famous, is pumped into these cavities, filling the gaps to prevent cave-ins but also allowing additional oil and gas to flow into the areas around each grain, for continual extraction of more oil and more gas. This sand is also used for "fracking." When I visited, U.S. Silica shipped frac sand all over the world, including Saudi Arabia, where you'd think there might already be enough sand, and for which the shipping fees must have been enormous. A third of their production was dedicated for this purpose and they still had to ration how much they could send to each client. (By 2011, the primary market for frac sand had shifted definitively to the U.S.)

Previous pits from a century of sand mining bordered the road leading to the office, filled with swampy life: ducks and geese and green reeds and flowers edging the picturesque cliff-like palisades, though these were not of course canyons caused by river water flowing but by our collective geophagy. When I visited, U.S. Silica was working two mines, one had six months left and the other six years. But another eighty-five years of material remained in the area across the river, where the company owned an additional seven hundred acres. This was mostly still farmland but they had already been granted mining rights for a portion of it. This portion included several potentially historical archaeological sites. “Tens of thousands of Indians used to live in this area,” said Larry, “and there are graves everywhere but no human bones remain.” What they had found were “tools, arrowheads, campfires, artifacts... If any of these are historically important, the site will be carefully excavated and all remains placed in a museum before their mining operations move in.”

The sand grains on the beaches in Northern California are huge compared to those in Illinois. In the mid 1980s I lay flat on a tiny beach at the foot of a cliff near the Golden Gate Bridge next to Sam, who was a graduate student at Stanford, studying the movement of water through porous underground aquifers. I had a job at a coffee shop, and was reading Lucretius’ atomist poetics from 55 B.C.E. for the first time: “...there must be an ultimate point in objects...This point is without parts and is the smallest thing that can exist. It never has been and never will be able to exist by itself, but only as one primary part of something else. It is with a mass of such parts, solidly jammed together in order, that matter is filled up....To these nature allows no loss or diminution, but guards them as seeds for things.” [9] We were cold from the ocean; the sand was hot from the sun. For Lucretius, cold and heat were both particulate. We flattened ourselves against the hot sand, hoping the cold particles would slide over us and the hot particles soak in. From that myopic perspective, our faces inches from the ground, we began to collect individual sand grains on the white towel, each one stabbed with the tip of a finger slightly sticky with salt: opaque lapis blue, dense shiny black, translucent violet, spring green, amber, striped yellow and red.

Sand on that section of Pacific coast is almost entirely greenstone and radiolarian chert. “Radiolarian: any of 3 classes of usually spherical marine protozoans having radiating threadlike pseudopodia and often a siliceous skeleton of spicules.”[10] This is what they said about the color of chert: “varies ...” The most common colors were “dusky red to dark reddish brown... (but) red and brown chert becomes grayish green, dark greenish, gray, or grayish yellow green... or may give a white, very light gray, grayish orange, or

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[9] Lucretius, *De Rerum Naturum (On the Nature of the Universe*), tr. R.E. Latham, 1951, Penguin, p. 44-45

[10] Merriam Webster’s Collegiate Dictionary, 10th Edition

light bluish gray ...often stained with yellow and brown ... or black or bluish black ... others contain pale gray and pale green... Bright red, bright orange, bright yellow...”[11]

This kind of sand was produced not from igneous rock formation but from life in the sea. Unlike most other living things (except horsetails, a beach grass, and some bacteria), radiolaria use silicon instead of carbon to build their bodies. In the early 1800s, Friedrich Wohler (famous for his production of urea from inorganic ingredients) wondered if silicon could serve as an alternate basis for (artificial) life. The fantasy of silicon life persists, and we have tried to move towards it, body part by body part. I can almost understand the desire to repack one’s aging breasts with globules of gel as I watch my own skin begin to wilt. But if the breasts get re-packed, then the butt, and the upper arms, and the cheeks look sad in comparison, and the whole thing needs redoing. Why not follow through with the original to the end, and look forward to the mystery of starting again. An astrobiologist working with NASA[12] dismissed the viability of silicon-based life because of the element’s inability, compared with carbon, to form enough of a variety of chains, rings, and poly-amorous couplings. Some carbon compounds contain tens of thousands of carbon molecules, while the most silicon molecules that have been observed stitched together is about six.

Silicon for computer chips is made from ultra pure quartz sand that has been reduced in a carbon arc furnace. “Chips” are slices from a single perfect crystal grown from this pre-refined product using the Czochralski process: melt ultra pure silicon in a quartz crucible in an atmosphere of inert gas (like argon or helium); introduce a rod with a small silicon seed crystal to this melt, and gradually raise and twist this rod up and out of the melt, pulling the new perfect crystal with you. It will be about eight inches in diameter and four feet long and you will have to cut off the bottom where most of the impurities will gather. Slice it 0.029527 inches thick.[13]

Silicones on the other hand are flexible polymers with the ability to repel water and to “breathe” gas. A windbreaker I inherited from my mother is hanging in my closet; I don’t know what the old-fashioned grey-blue material is called, but it doesn’t “wick”—a bit slick but not shiny; maybe it used to be water-repellent but it isn’t even water resistant now. The material has aged. It feels slightly waxy. It has a center pocket in the front,

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[11] Julius Schlocker, “California sand: Geology of the San Francisco North Quadrangle, California,” Geological Survey Professional Paper 782, 1974

[12] Ben Clark, NASA Astrobiology Institute, “Could life be based on silicon rather than carbon?” http://nai.arc.nasa.gov/astrobio/feat_questions/silicon_life.cfm, accessed: 6.27.09

[13] Silicon wafers are cut to different thicknesses, based on their diameter.

which closes with a horizontal zipper. When my mother wore it, this pocket was usually full of something vegetable, a handful of flower bulbs, or sphagnum moss—replacing the breasts with an unexpected form—awkward and lumpy, right in the center. In an old photo on our fridge my mother is wearing the windbreaker: a woman with thick-framed dark glasses and wildly blowing short gray hair. The mast of a sailboat and a portion of white sail fill up most of the picture. In this photograph, the wind fills the pocket; she had already lost one of her breasts by the time it was taken, and so the shape of her chest is undefined. When I inherited this windbreaker I wondered if there might still be something in the pocket, and didn't unzip it for a long time. I wondered the same thing when I inherited my father's hunting jacket, the back of which is one huge pocket designed to hold a dead bird.

The day we spent at the beach in California Sam had been telling me about his dissertation which was almost finished. He explained how the same thing can be described accurately in two different ways but not at the same time, and therefore could be statistically either one of those two things. His project addressed the problem of groundwater contamination by nuclear wastes and how to devise means to calculate how quickly and in what ways contaminated water would percolate through an aquifer. Time was important—it was not a question of whether this stuff would move, but when, how fast, and in what manner. Sam's project combined uncertainty with determinism. He was dying then, but didn't know how soon—it would be six years before protease inhibitors were developed. He was on an experimental protocol, but not one that was working. I understood for a moment that statistics was not simply a default mode for guessing what we don't yet know for sure (but will be able to know eventually, in a deterministic universe), but an attempt to deal deterministically with fundamental unknowing.[14]

If quantum theory gives us permission to imagine anything as what it is and what it's not simultaneously—both particle and wave, matter and anti-matter—how does this help? In one of the nuclear explosion dreams I had been having at the time, I watched my two lovers dematerialize into tiny glittering points like pixels on a computer screen. Sam,

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[14] Roland Omnes, *Quantum Philosophy*, 1999, Princeton, p. 185 "If we consider an object as a physical system, an 'assemblage of particles whose mutual interactions are known,' from this perspective an empty bottle, in quantum principles will only take into account the particles forming the bottle, and will therefore treat on an equal footing a multitude of different objects....This is due to the fact that the atoms that make up the bottle could, without changing their interactions, adopt thousands of shapes to form a thousand different objects: two smaller bottles, six wine glasses, or a chunk of melted glass. Once could also separate the atoms according to their kind and end up with a pile of sand and another pile of salt. A rearrangement of the protons and electrons to transmute the atomic nuclei without modifying the nature of their interactions could also produce a rose in a gold cup."

who was not my lover, dematerialized too, like them, and he also stood there, fully formed and watching, next to me.

"All life is a struggle in the dark. As children in blank darkness tremble and start at everything, so we in broad daylight are oppressed at times by fears as baseless as those horrors that children imagine.... This dread and darkness of the mind cannot be dispelled by sunbeams ...only by understanding of the outward form and inner workings of nature."[15] Such comfort Lucretius took in explanation. For him, there was no reason to be scared. The gods were busy with their ideal world and not involved in human affairs, so we didn't need to fear them. And because there was no afterlife, death also should cause no fear. Why worry? Better to spend your time learning about the world and finding pleasure in its granular textures. In 2000 C.E. the *New York Times* confirmed what Lucretius described in 55 B.C.E.: "Space is not an infinitely divisible continuum—it is not smooth but granular, and the Planck length gives the size of its smallest possible grains...10 to the minus 35 meters, or a decimal point followed by 34 zeroes and then a one."[16]

By late-afternoon Hollywood beach in Chicago had collected a lot of different kinds and ages of bodies. I noticed two exhausted horizontal men, lying several hundred feet apart, one off to my right and one to my left. I spied them angularly from up on my elbows, under the wide brim of my hat. They had both submitted to early burial by their children. One man on his back, eyes closed, with an enormous belly, had lost his arms, and the already prodigious tower that was his stomach was being supplemented with gothic spires made by a girl and a boy dripping wet sand in blobs from a bucket. The second man, lying face down, arms raised above his head, had become a dune from the armpits down, and one small boy lay on top of this sandy father-mountain, his small head turned in my direction, eyes bright with victory, but wary of the unstable ground beneath him. [17]

For the first half million years of the history of the earth, allegedly, all sequential order was regularly and rigorously rearranged, surface crusts diving into the liquid magma and liquid rock splashing up through fissures and in response to meteor bombardments. After this archeon age in which earth's history is unintelligible, a slow accumulated relative record began to be left as the earth cooled and there was less tumult. But even this has not been a quiet time, with each layer still undergoing wrinkling, squeezing, re-heating and

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[15] Lucretius, p. 61-62

[16] George Johnson, "How Is the Universe Built? Grain by Grain," *The New York Times*, December 7, 1999

[17] Psammophilic: "sand-loving"

metamorphic activity. James Hutton, “father of modern geology,” famously described the situation in *Theory of the Earth* (1795) as one of “episodic renewal” not “unilinear decrepitude.” Fueled by the recognition that granite is an igneous rock, the discovery of deep time suggested the presence of a restorative force of uplift so that “the world may cycle endlessly rather than eroding once into ruin.”[18]

(This excerpt is part of *In The Aura Of A Hole,* and was also published in *Ghost Nature*, Green Lantern Press, 2014, ed. by Caroline Picard)

[18] Stephen Jay Gould, *Time’s Arrow, Time’s Cycle*, 1987, Harvard, p.6