METHODOLOGY

b7 Agassiz of the Ice < pronounced *aga-zee*; erratics, striations, drift, till >

"... he engraved on a stone the whole story."
—on a clay tablet that tells of the 4,000-years ago Sumerian king of Uruk, Gilgamesh, who upon concluding that escape from death is futile, turns to lasting works of culture to achieve immortality.[1]

What explanation can one give for a boulder of granite (a plutonic igneous rock) atop a limestone (a sedimentary rock) hill? Such a natural dolmen or "perched" boulder, block, rock, or stone, clearly out of the place of its origin, is called an *erratic*. Erratics are found almost everywhere yet wild in northern Europe and in the northern part of North America. They appear to be strewn across the landscape. Sometimes, because of their distinctive composition they can be tied to a possible source of their origin—an exposure of bedrock of the same composition. Prospectors have sometimes made important discoveries by backtracking resistate indicator mineral grains or following "boulder trains" across hill and dale to their source.[2]

In the first decade of the 1800s, Leopold von Buch (pronounced with a German spirant *ch*) established that many of the erratics that litter the North German plain had their source—referring here to present place names and as needed in the following—in Scandinavia (***Figure b7.1***). In areas where erratics occur, the bedrock is often covered by an uneven layer (at most a few hundred feet thick) of unconsolidated poorly-sorted sediments. Von Buch, initially an advocate for Neptunism (he had been a student of Werner at Freiberg), declared such to be "diluvial gravel" (evidence of the Noachian Flood) washed in from the north.[3] Horace-Bénédict de Saussure (pronounced *so-sur*) (1740-1799), best remembered as the first scientist to successfully assail Mont Blanc (August 3, 1787), had earlier (1760) described evidence for a catastrophic flood from the Alps in the opposite direction.

The modern understanding of the Ice Age is that the low hills and valleys of southern England, Belgium, France and southern Germany remained free of glacial ice and was a mammoth steppe (loessic grassland). To the north was an ice sheet with a Fennoscandian center that joined with ice caps on northern Britain and Ireland. To the south was an ice cap with an Alpine center.[4]

At high elevation on the limestone Jura mountains are erratics of granite, gneiss and schist identifiable as rocks from the Swiss Alps. Between these mountains is the broad valley (Swiss plateau) that contains the lakes Geneva and Neuchâtel. The erratics perch on limestone pedestals which they erosionally shelter. Far earlier, upon a close reading of Saussure, Hutton had been on the right track when in 1785 he had put forward an ingenious (though incorrect) uniformitarian glacial explanation for the Jura erratics paraphrasable as: "Erosion has excavated the valley between the Alps and the Jura. During that same time, erosion lowered the Alps. This lessened its snow fields and, so, the reach of its glaciers. In earlier times, 'there would then have been immense valleys of ice sliding down in all directions towards the lower country.' [5] It was then that the erratics were transported into place."

The modern interpretation finds: No source for the waters of Saussure's imagined flood; and, for Hutton's imagined scenario, only enough time for rainwash dissolution to differentially leave pedestals on which erratics sit as umbrellas but not enough time since for the erosion of the deep and wide valley between the Alps and the Jura mountains. In 1802, John Playfair who visited the type area of the perched erratics described by Sassure, found that the polished and striated bedrock and the ridges and mounds of poorly sorted sediments in the landscape, were evidence of glaciation—"the most powerful engines without doubt which nature employs." His contribution to Hutton's thesis was not taken seriously because from as early as 1787 the same features had been understood to be *irrefutable* evidence for the swift currents of water and mud of the Naochian deluge. In 1815, von Buch (by then a Volcanist) also mapped the boulder trains radiating northwest from the Alps and was inspired to the (false) possibility that the Alps had volcanically exploded into being and that the boulders had traveled as "flights of cannon balls" down Alpine-valley straightways to land high on the limestone Jura 100 kilometers away where rests famous Pierre à Bot gneiss erratic, the size of a small house![6]

Von Buch notwithstanding, **Ignace Venetz** (1788 -1859)[7] revived interest in the idea of more extensive prehistoric glaciation at a meeting of a Swiss natural history society in 1821 when he elaborated on insights that a Valais chamois hunter Jean-Pierre Perraudin (1767-1858) had shared with him in 1820 such as: deep scratches on hard-to-weather rock surfaces of Swiss mountain valleys needed something heavy pressing down and moving to gouge, and this could have been glaciers that in a forgotten past had extended further. Indeed, existing glaciers, during the cold Late Middle Ages were known to have been longer, as 14th-century paintings of Alpine scenery well record. And where Alpine glaciers now cover copper mines worked during the Roman Warm Period, they have been shorter. In 1829, to explain striations on rocks of the Swiss plains, Venetz made bold that during a time colder than any indicated by their known historical length, Alpine glaciers had extend as piedmont glaciers (literally: *foothill glaciers*) that issue from mountain valleys and spread out over the lowland beyond.[8] In turn, Jean de Charpentier (pronounced *shar-pon-tya*) (1786-1855), motivated by Venetz's presentation, made his own observations and found that these supported glacial emplacement of erratics, which understanding, he was bemused to find, was commonplace among the rustics.

In his turn, skeptical of claims in Charpentier's paper, read at Lucern in 1835,[9] was Jean Louis Rodolphe Agassiz (1807-1873). In 1826, he had completed a classification of Brazilian fishes (collected by others; mostly from the Amazon River in which are far more species than in the whole Atlantic ocean). His ichthyology was extended to extinct fishes of Europe and carried forward the thinking of the French zoologist Alcide Dessalines d'Orbigny (1802-1857) that organisms arose by a series of independent and special creations.[10] For Agassiz, each plant and animal species was a "thought of God," and likenesses (homologies) of parts of two or more species were "associations of ideas in the Divine Mind." As this thesis admits no hereditary from one epoch to the next, perceived continuity between different types of organisms is an illusion. Times of extinctions separating epochs had been abrupt times of Earth cooling followed by warming but to a temperature lower than before. The last abrupt cooling he would reason (see below) had formed a static northern ice sheet to as far south as the Mediterranean. The sudden upheaval of the Alps had caused blocks of this ice to slide, striating bed rock and carrying erratics to where they now are now found, as on the Jura.[11]

In 1830, Lyell had published *volume I* of his influential textbook *Principles of Geology*.[12] In this he thoroughly misinterprets loess (***Footnote b7.1***) to be a deposit settled from turgid floodwater from an alpine source. He further ascribes the distribution of erratics to the melting of boulder-laden icebergs dislodged from alpine mountains. "Icebergs thus formed might, we conceive, resemble those seen by Captain Scoresby far from land in the Polar seas, which supported fragments of rock and soil, conjectured to be above fifty thousand tons in weight. Let a subsequent convulsion, then, break suddenly the barrier ..., and the flood would instantly carry down the icebergs, together with their burden, to the low country at the base of the Alps." As Lyell's writings became absorbed, "drift" (a word that in early editions of *Principles* Lyell himself only used in reference to drift wood or drifting floating bodies) was employed to replace "diluvium" by Roderick I. Murchison in 1839 (in his monumental *The Silurian System*) and was then used by Lyell with that new meaning in *Principles*, 6th edition, 1840.[13] Both presumed "drift" to be a cold-water marine deposit now exposed by a regional uplift of the land (and *not* by a worldwide drop in sealevel, as neither subscribed to Nochian flood explanations).The word had crept into common usage for both *till* (*unstratified drift*) and associated *outwash* (*stratified drift*) by the time that James Geikie in *Ice Age and its Relation to the Antiquity of Man*, 1874, described the N. American "Driftless Region" of SW Wisconsin as remarkable for being "free from drift" (unglaciated) within a wide region that bears evidence of many glacial episodes.[14]

To study glaciers at first hand, Agassiz, in 1836, at the side the Aar glacier, Switzerland, assembled a cahoot from loose stone slabs. From there, he and University of Neuchâtel associates studied how alpine (valley) glaciers move, transport rock, and modify the landscape. In 1840, Agassiz published *Études Sur les Glaciers* in which he argued that a vast prehistoric ice sheet "resembling those now existing in Greenland," had once covered all of Switzerland and much of the lowlands of Europe.[15] However, only in 1888 did Norwegian explorer Fridtjof Nansen (at age 27) prove the hypothesis that Greenland is covered by an ice sheet, by skiing (in 41 days) across its extensive flat and monotony relieving sastrugi (Russian: wind-aligned sharp grooves and ridges in a snow field) surface with five companions (as witnesses).[16] Not yet described was the Antarctic ice sheet. Of that terra incognita (first sighting[17] claimed by Russian Navy Capt. Fabian Gottlieb von Bellinghausen in 1820), three visiting expeditions, entirely under sail, were all. (Roald Amundsen wrote: "These men sailed right into the heart of the pack, which all previous polar explorers had regarded as certain death."[18] For the record: Jules Dumont d'Urville (French) in 1840 sighted the coastline he called *Terre Adelie*, Ross (English) in 1841 found the huge bight denting the Antarctic continent and ice shelf that now bear his name, and Wilkes (American) when home in 1842 claimed to have discovered land subsequently sailed (!) over by Ross. (Alan Gurney in *The Race to the White Continent* believes Wilkes had been "fooled by one of the polar regions' atmospheric tricks: the looming that brings into view land below the horizon.")[19]

Agassiz's hypothesis of an Ice Age was that "perched bowlders" (erratics) and the poorly-sorted sediments of moraines mapped as diluvium (or *drift* as it became called), rest on striated bedrock.[20] Sediment transported by ice and deposited directly from ice is called *till* (a Lowland Scots farmers' word introduced by Lyell in 1840 for "unstratified drift"). Till always rests on striated bedrock. Boulders and mud that "fall tranquilly"[21] into place from melting icebergs could account for boulder-clay but they would not striate (groove and scratch) and abrasively polish the bedrock on which they rest. The same dragged and pushed into place under the enormous weight of superincumbent moving glacial-ice would. Lyell's explanation of striations was the passage of icebergs where these became grounded at their base upon hill tops. But this left unexplained the continuation of the striations across dale bottoms. In Canada, J. W. Dawson would reason in 1855 that striations record shoreline scour by iceberg-deposited boulders moved by shifting pack ice while sealevel had incrementally risen.[22] For this notion, the absence of marine shells in most tills was (and is) damningly problematic.

Recessional moraines, Agassiz pointed out, are uniformitarian evidence of prolonged pauses in the overall *slow* "retreat" (diminishing extent) of the glaciers at the end of the Ice Age.[23] In 1846, Agassiz (***Figure b7.2***) was invited to lecture on his ideas in the Lowell Institute in Boston, Massachusetts, and also in Charleston, South Carolina. In the same year he was appointed to the chair of natural history in the Lawrence Scientific School at Harvard University. By his own account, and seemingly antithetical to his stand as a convinced creationist, he was able to win many "converts" to his realization that there had been an Ice Age (which inspired in Henry Wadsworth Longfellow and Oliver Wendell Holmes poetic verse).[24] To doubters he said, "The book of Nature is always open ... Strive to interpret what really exists," and to detractors he said: "If you study Nature in books, when you go out-of-doors, you cannot find her ..." [25] (The Ecclesiastes injunction: "Speak to the Earth and it shall teach thee"). To his American audience the concept of an ice age, in the absence of any known glaciers in this land (at the time already well explored for thousands of miles in all directions), was particularly fantastic.

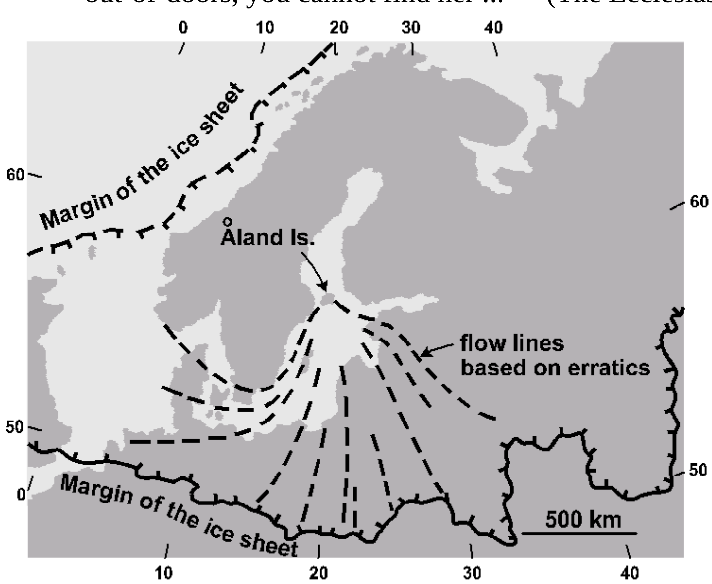

Figure b7.1 [26] Boulder trains of erratics traceable to their source are of Åland (pronounced *air-lund*) Island's distinctive rocks. Lyell, at first reluctant to ascribe to Agassiz's Ice Age, had by 1855 decided that the concordant directions of these bounder trains and bedrock striations, where exposed beneath unfossiliferous boulder clays, is evidence of a once continental ice sheet that had operated as does the (then unexplored) one that persists in Greenland.

Only as late as 1870 did Clarence R. King (who before had briefly studied under Agassiz) discover on September 11 of that year the first, which would be named Whitney Glacier, and three more on Mount Shasta. His account, "Active Glaciers within the United States" appeared in the *Atlantic Monthly,* March 1871.[27] An historical footnote: Josiah Dwight Whitney (1819-1896) during his life, to quote Peggy Champlin: "stubbornly refused to accept the glacial explanation for valleys"[28] and clung to "'catastrophic' theories" that he had been exposed to as a student of Élie de Beaumont. For example, Whitney maintained that Yosemite Valley had formed when, "the bottom of the valley dropped during a series of 'convulsive' upheavals of the mountain chain," when John Muir was correctly urging that the "valley was shaped by glacial action operating over long periods of time." ❏

Figure b7.2 [29] **(Jean) Louis (Rodolphe) Agassiz** (1807-1873) converted many to his vision of a Great Ice Age in contradiction to what others such as J. W. Dawson [30] (who was innocent, as was Agassiz, of any observational knowledge of the workings of existing continental ice sheets) held to be evidence of the Noachian flood. However, in debates concerning evolution of the species, Agassiz spoke for creationism [31] (giving heart to Herman Leroy Fairchild (1851-1943) [32] and later). His road to Damascus and epiphany was:

- an initial rejection of Venetz's hypothesis of a time of great cold when alpine glaciers had been much longer;
- a finding that glaciers do collect and transport materials that fall upon them or that they pluck from the bedrock over which they flow;
- an interpretation of glacial striations as evidence that glacial ice containing rock as cutting tools had moved over the land, scouring it, to deposit these materials as moraines of till and boulders as erratics;
- and, a stunning realization that *diluvium*, so called because of its presumed Flood origin, upon the plains of Europe (and North America) far from presently glaciated mountains, is till and associated outwash.

Dislodged by the San Francisco 1906 earthquake, his statue, upside down, feet in the air and head buried in the pavement, prompted fellow ichthyologist David Starr Jordan, president of Stanford and a staunch new-age Darwinist, to concoct the howler "Oh well, I always thought better of Agassiz in the concrete than in the abstract." (In his memoirs, Jordan gracefully denies having made that quip.)[33]

Footnote b7.1 Lyell's incorrect notion that loess (*see* Topic *c3*) is fluviatile loam is in his *The Student's Elements of Geology*, 1870, but by then he had evidence that it could *not* have been deposited from rushing waters: "In some parts of the valley of the Rhine the accumulation of similar loam, called in Germany "loess," has taken place on an enormous scale [several hundred feet thick]. Its colour is yellowish-grey, and very homogeneous; and Professor Bischoff has ascertained, by analysis, that it agrees in composition with the mud of the Nile. Although for the most part unstratified, it betrays in some places marks of stratification, especially where it contains calcareous concretions, or in its lower part where it rests on subjacent gravel and sand which alternate with each other near the junction. … Although this loam of the Rhine is unsolidified, it usually terminates where it has been undermined by running water in a vertical cliff, from the face of which shells of terrestrial, freshwater and amphibious mollusks project in relief. These shells do not imply the permanent sojourn of a body of freshwater on the spot, for the most aquatic of them, the Succinea, inhabits marshes and wet grassy meadows. … Among the land-shells of the Rhenish loess, *Helix hispida*, and *Pupa muscorum*, are very common. Both the terrestrial and aquatic shells are of most fragile and delicate structure, and yet they are almost invariably perfect and uninjured. They must have been broken to pieces had they been swept along by a violent inundation. Even the colour of some of the land-shells, as that of *Helix nemoralis*, is occasionally preserved."[34]