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Some Major Scientists (Palissy, Buffon, Thaer, Darwin and Muller) Have Described Soil Profiles and Developed Soil Survey Techniques Before 1883

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Abstract

Soil description, soil profiling and the use of instruments and methods for soil mapping have existed in Europe long before the admitted emergence of soil sciences at the end of the 19th century. Some little-known but definitely precursory works by major scientists of the 16th, 18th and 19th centuries are reported in the present paper. These are works by (i) Bernard Palissy (1510–1590), inventor of the auger for soil sampling (1563 & 1580); (ii) Georges-Louis Leclerc de Buffon (1707–1788), who minutely described soils and pedological traits such as ferro-manganese concretions accounting for geochemical cycles (1734 & 1748); (iii) Albrecht Daniel Thaer (1752–1828), who developed a methodology to take soil samples and to describe and map soil variability in cropped plots (1809); (iv) Charles Robert Darwin (1809–1882), who published detailed drawings of pedo-architectural profiles and gave the description of a rainfall simulation (1837); (v) P.E. Müller who gave wonderful descriptions of soil profiles and soil associations with a pedogenetical approach and can be considered as the main forerunner of pedology; and (vi) some others such as Bartram (1739–1823) and Orth are evoked.

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Introduction

One of the basic activities of the pedologist consists in describing soil profiles; another is the use of a tool called the auger for sampling and for visual inspection in mapping soils. There is no doubt that these sampling and mapping tools had become of current use by the 2nd half of the 19th century, with the emergence of the applied science of agricultural geology and of the fundamental science of pedology (Yaalon, 2000). Both Dokuchaëv's publications (1883) and the comprehensive description of soils and the profile and pedogenetic processes conducted by the Swedish forester P.E. Muller in his analysis of podzolisation (1879, 1884, French transl. 1889) deserve to be mentioned here. Yet one is entitled to wonder about the possible existence of prior scientific studies on soil description, sampling and mapping.

Actually, such studies do exist, as testified by a number of little-known texts produced by some famous naturalists and agronomists of the past centuries from the 16th to the second half of the 19th century. Among those, texts by Bernard Palissy (first pub. 1563 & 1580, read in their 1880 edition); Buffon (first pub. 1783 & 1789, 1819 ed.); Bartram (1791); Thaer (1809, French transl. 1811); Darwin (1837 & 1881); Orth (1870, 1877) and Müller (1879, 1884) have been selected for the present paper. Yaalon (1989) has discussed other forerunners like W. Cobbett, J. Morton and C.S. Sprengel.

1563, 1580: The Auger and Its Use Described by Bernard Palissy

The Frenchman Bernard Palissy is best-known as a ceramist, but he is also widely acknowledged as a foundational figure in the fields of the earth sciences, geology, paleontology and the agronomic sciences – the latter thanks to the ideas he developed in his 1563 and 1580 writings on the nutrition of plants from «salts». He is not so well-known as the possible inventor of the auger as a tool for soil prospecting. He was in any case the first to describe a soil-sampling auger, and to explain its use in drawings. In the following extract from his «Admirable Speeches» taken from his complete works in their 1880 ed. p.114 (in French), he dramatizes questions and answers about the quality of soils, among other topics, through the dialogue of two characters called «Théorique» and «Practique» (T & P). The style and spelling (which would have to be in Elizabethan English for the sake of authenticity) will be somewhat modernized in the translation for practical reasons.

T. "*You have treated me with a lot of learned arguments, yet I am not wholly satisfied as to the most expedient way to discover the aforesaid marl.*"

P. "*I can advise you as to no more expedient a method than that I should use myself. Should I desire to find any marl in a province where the necessary tool does not exist as yet, I should look for all and any of the augers which the potters, brick-makers and tile-makers use for their trade, and I should use them to manure a plot in my field to see if the soil had been improved in any way, and then I should seek for one that was long enough, and had a hollow socket at one end, where I would adjust a stick, and across the other end I should make sure it had a handle (. . .) in the shape of an auger, and this done, I should drill and bore away with the full length of the whole handle at all the ditches in my estate, and then I should take the said tool out and examine the concave side to tell which kind of soil had been dug out, and after cleaning the hollow, I should remove the first handle and insert one that was much longer, and I should drill the auger back deeper into the same hole in the soil with this second handle, and thus, having several handles of different lengths, I should determine the nature of the deepest layers; and not only should I dig the ditches of my estate, but I should bore all over the fields, until at length some testimony of the presence of the aforesaid marl were found at the end of my tool, and if it were, I should dig, at the very place it had been found, a sort of well.*"

T. "*Indeed. But what if there should be some hard rock beneath the surface? For such is the case in many places . . .*"

P. "*In truth that would be tiresome, though in many a place the rocks are soft and tender, especially when they are still planted in the ground.*"

In this text, Bernard Palissy mentions the auger ("la tarière") as if such a tool was already known, but he actually starts from a well-known tool created for a completely different use and adjusts it to the problem of soil prospecting. At the technological level, he provides us with the idea of the extension-pieces; he also makes it plain that this tool is designed for a double use: that of soil prospecting, and that of the detection of marl to be used as manure for soil reclaiming. It is to be noted that in the last exchange ("*in many a place the rocks are soft and tender, especially when they are still planted in the ground*") Palissy reveals to be an accurate oberver of the horizon of rock alteration.

Further investigation into the origins of the French word "tarière" (auger) seems to prove that Palissy was the first to use such a tool for soil prospecting. A complete file on the word "tarière" was kindly handed on to us (TLF, 1981) by the Institut National de la Langue Française (INALF, CNRS). This file includes about 80 quotations from a varied assortment of notes and entries taken from a number of ancient and contemporary dictionaries. According to the *Grand Larousse de la*

Langue Française (1978), the first occurrence of the word "tarière" (which takes its etymology from the low Latin *taratrum*) seems to be dated from 1212, when it had the meaning of "a tool used by carpenters, wheel wrights, etc., to bore holes into wood pieces". The *Dictionnaire de l'Académie Française* (1835) defines the word "tarière" in its zoological use, as referring to "the elongated organ situated at the end of the abdomen of some female insects which use it to deposit their eggs into the ground or plants or under the skin of animals" (that is the form of ovipositor called "terebra" in English). The Dictionnaire de Trevoux (1752) mentions the word as "a tool used by miners for drilling into the ground", which is the sense we are concerned with.

If these historical written sources are to be relied on, then Bernard Palissy was indeed the first to describe our pedological "tarière", or auger. A few years later, in 1605, Olivier de Serres describes an identical tool (which he calls "taravelle"), which he says is used as an instrument for planting (Godefroy, 1937–38). By the 18th century, the auger, also called "gauge" (in French: "sonde") had become a popular instrument for the study of soils – as testified by its frequent occurrence in writings by Buffon (1783–1788, but also the description of 1734, cf. below), Pattulo (1759, pp. 15, 16, 24), Turbilly (first anonymously published, 1760, p. 12, with a descriptive sketch p. 332), La Salle de l'Etang (1768, pp. 110–112), Delaillevault (1763, p. 64) and Thaer (1811–1816, Vol. 2, p. 1666, cf. below). However not all the authors who mention it are enthusiastic about the implement; La Salle de l'Etang, for instance, criticizes it, considering that "*this invention is neither so wonderful nor so useful to agriculture as was once imagined (. . .) good ploughmen (. . .) even regard it as superfluous.*" (1768). Lastly, a fellow-resarcher, Rossignol (2001) found that an auger appeared in a humourous drawing by the book illustrator Granville (1803–1847) representing a "Most Stubborn Field-Mouse" using an auger to dig his mouse-hole.

1734: Description of Soil Horizons, Erosion and Geochemical Cycles by Georges-Louis Leclerc de Buffon

Georges-Louis de Buffon (1707–1788) was a major naturalist. The publication of the 36 volumes of his *Histoire Naturelle* made him famous worldwide, but Bourde (1967, pp. 238–239) also regards him as one of the founders of rural economy. François de Neufchateau (1804, quoted by Boulaine, 1989) claims that Buffon once suggested that "*men of letters should establish a literary society concerned with land discernment*". This is proof of Buffon's interest in agriculture in general, and soils in particular. At last, according to Kunholtz-Lordat

(1958), Buffon should even be apparently acclaimed as "the founder of Pedology".

Even without going so far, one must acknowledge Buffon's astounding skills in the matter of soil observation, as testified by the following extracts about mould from his *Histoire Naturelle des Minéraux*, in the section entitled "Of Vegetable Mould" ("De la Terre Végétale", *Oeuvres Complètes de Buffon*, 1819, Vol. 5).

Buffon occasionally calls vegetable mould ("terre végétale") a loamy soil ("terre limoneuse") when he explains that he intends to "*trace the origin and formation of loamy soil*" and its effect "*on the production of most second generation minerals*" (pp. 402–403). Buffon's formulation sounds undeniably familiar to pedogeneticists and geochemists.

This passage is followed by a long discourse on the favourable or unfavourable conditions of mould accumulation.

First, the presence of man is considered harmful for mould (p. 407, 498):

> *"We shall see that this layer of rich, prolific soil is always much thicker wherever Nature reigns supreme than in places inhabited by man . . . (for) it cannot gain in depth in places where man and fire (this destructive minister of man's) . . . annihilate . . . the animal creatures and the vegetable kingdom . . . Suffice it to compare long-inhabited countries with newly discovered ones: in the latter, forests, mould, alluvium everywhere; only dry sand or naked rock in the former".*

Next, Buffon ponders the topographical factors in erosion (pp. 407–408):

> *"The layer of vegetable soil is thinner on top of the mountains than in vales and plains, because rain-waters wash it off the summits and slopes of the eminences, carrying the mould downhill."*

There ensues the beginning of a horizon identification:

> *" . . . One should follow attentively the way Nature proceeds in the production and successive formation of this vegetable mould. First entirely composed of animal and vegetable detriments, it remains for a great number of years an uncohesive, unductile and very thin, dry, blackish dust, liable to catch fire and burn like peat. The ligneous fibers and solid parts of plants can still be recognised in this mould; but as time goes by, through the intermediary agency of air and water, these dry mould particles acquire more ductibility and turn into loamy soil: this process of reduction and transformation I have observed with my own eyes."*

In this description, Buffon establishes a distinction between what we would call today the organic horizons and the underlying organo-mineral and mineral horizons, even if we have learned that the latter do not directly and exclusively result from the transformation of the former (which is Buffon's thesis).

Buffon then proceeds to examining soils and the account of detailed observations:

> *"In 1734, I ordered a plot of about seventy acres to be probed by several auger drills, for I wanted to know how thick the good soil was in that place, where I had formerly had a number of trees planted, with satisfactory results. The ground had then been divided into several acres; and the boring being performed at all four angles of each acre, I noted the different depths of soil, the thinnest being of two feet, and the thickest, three feet and a half. I was young at the time, and was hoping to be able to observe what effect my tree plantation would have on the different depths of soil, which was good and rich soil all over. The later borings indeed enabled me to observe that everywhere the thickness of the soil layers had remained approximately the same, and I also noticed the transformation of mould into loamy soil. The said plot lies in a plain situated above the highest hills of Bourgogne; for the most part, it has always remained fallow from time immemorial; and as there is not a single eminence to tower over it, the soil is exempt from any mixture of clay or chalk, lying as it does over a horizontal layer of hard limestone.*
>
> *Under the turf, or, rather, the old moss that covered the ground, a thin layer of black crumbly soil could be observed everywhere, composed of the product of the decayed grass and leaves of the preceding years. The layer just below was compounded of brown, unadhesive soil; but the deeper layers underneath the first two took by degrees more consistence and a yellowish colour, all the more so as they were deeper under the surface. The deepest layer, lying at a depth of three or three and a half feet, was a reddish orange colour; and the soil was extremely rich and ductile and stuck to the tongue like "bol"* (swelling clay in French).
>
> *In this yellow soil, I noticed the presence of several grains of iron ore; at the deepest level, they were black and hard, but were only brown and still crumbly in the top layers. It is therefore obvious that animal and vegetable detriments which first constitute the mould, gradually form, through the agency of air and water, the yellow or reddish soil which is the real loamy soil we are concerned with; just as it is undoubtedly obvious that the iron contained in plants find themselves in this soil, and assemble into grains . . . As the borings* (performed in 1748) *proceeded, observing carefully the different materials they brought to the surface, I concluded, without any possible doubt, that the loamy soil was*

carried down to great depths into the joints and cleavages of the lower layers, which were all clay, by the infiltration of waters. This loamy soil first clung to the surface of the clay clods; it then managed to inflitrate the clay layer; after which, piryte concretions of a flat and orbicular configuration could ordinarily be observed in the clay, connected by a sort of cylindrical cordon of the same pirytish substance, and the said cordon always led to a joint or cleavage filled with loamy soil. I then became convinced that this soil was a major contributor to the formation of "martial" pyrites . . . These observations convinced me that this bog-soil, produced by the complete decomposition of animals and plants, is the foremost provider of iron grains for iron ore, and that it also produces the most part of the elements neccessary to the formation of pirytes . . . The amount of iron to be found in loamy soil is so stupendous at times, that we might call this soil "a ferruginous soil" . . . . (Buffon's underlining)

This is followed (421–423) by the descriptions and formation conditions of iron-manganese concretions. Iron specialists should take a look at these admirable pages and particularly at the passage below:

"But how does this mineral matter manage to sort itself out from the great mass of loamy soil and aggregate into such regular, tiny grains, in such large numbers, in so perfect a manner, that there is not a single one of them the surface of which fails to gleam with a metallic sheen?"

Buffon's explanation, of course, rests on hydrodynamic processes. But a more and more detailed description of pedological traits (here, concretions) ensues:

"Should the spheric grains of iron ore be divided into two hemispheres, then one would observe that they are all composed of several thin concentric layers, and that the biggest present a definite cavity, usually filled with the same ferruginous matter, which has not however acquired the same density, and which will crumble easily, like the iron grains themselves when they begin forming in the upper layers of the ferruginous soil; so that, in every grain, the outer layer, which is endowed with the metallic sheen, is the most solid and the most metallic, because it has been formed first, and, as such, has received, through infiltration, and collected, the purest ferruginous molecules, filtering the lesser pure through to produce the second layer of grain, and so on with the third and fourth layers, until the center can contain only the most soil and least metal."

These extracts show Buffon's astounding observation skills at all levels, from profile to concretions; his global approach to surficial formations with the study of materials transfer; his desire to explain the soil's successive horizons, even if, in pedogenetic terms, his interpretations have been somewhat invalidated since; and also his extraordinarily precursory reflection in the analysis of a major geochemical cycle – the cycle of iron – to which he already gives a "biological" dimension when considering the part played by organic matter.

1791: William Bartram, Traveller and Observer of Soils of the United States

William Bartram (1739–1823) was an astounding naturalist and observer of the subtropical milieu of 18th century United States. He is the author of a book entitled "Travels through North and South Carolina, Georgia, East and West Florida, the Cherokee Country, the Extensive Territories of the Muscogulges, or Creek Confederacy, and the Country of the Chactaws", first published in the USA in 1791, and republished in England in 1955 and 1988; long passages from Bartram's work were translated into French and commented on by Chatelin in 1991. The two examples given below are taken from the latter edition. In the first one Bartram relates his travels across West Florida and the part of Lousiana called the Black Bell which was to become a cotton production area; most of the soils there are "black cotton soils" (which would now be called "Vertisols" in the contemporary pedological classification). Bartram describes the area as follows:

> *"The upper stratum or vegetable mould of these plains is perfectly black, soapy and rich, especially after rains, and renders the road very slippery: it lies on a deep bed of white, testaceous, limestone rocks, which in some places resemble chalk, and in other places are strata of subterrene banks of various kinds of sea shells, as ostrea, etc. These dissolving near the surface of the earth, and mixing with the superficial mould, render it extremely productive"*

This passage is particularly remarkable for its precision and the pre-pedogenetic discourse on the parent material weathering. A few pages above, in the course of a development about iron ore, Bartram gives an excellent description of what is probably an iron pan (cuirasse latéritique in French):

> *"the highest tops of hills provide great amounts of iron ore similar to that encountered in New Jersey and Pennsylvania which is called bog-ore; the ore occurs throughout the soil in both big separated masses and small fragments; it is heavy and appears to be rich in this especially useful metal; but a remarkable characteristic of these soil-borne stones is that they are swelled, somewhat resembling scoria, as if they had suffered from a violent fire."*

One has to wait for the publication of the famous journey of Buchanan in South India (1807) to get a description of this soil horizon (iron pan) and the name of "laterite" for such a soil material.

1812: Mapping and Agricultural Soils Analysis by Daniel Albrecht Thaer

Thaer must be the most renowned agronomist of the early 19th century, owing to the fame of the 4 volumes of his "*Grundsätze der rationellen Landwirtschaft*", first published in German (1809), then translated into French in 1811–1816 "*Principes Raisonnés de l'Agriculture*" and in English under the title "*The principles of practical agriculture*" (Thaer, 1856).

In his *Rational Principles*, Thaer broaches all the subjects pertaining to agriculture (taken in its widest definition, including stock-breeding and sylviculture), in all its implications, whether socio-economic or biophysical (fertility, animal and vegetable productivities). Based on the elaboration of quantified fertility indicators, his analysis of the durability of farming and production systems is astoundingly prescient – even if the theorical premises of his system (the «humus theory») were later revealed to be erroneous. Thaer's work is remarkable for more than one good reason: he collected with minute precision a large number of quantitative data (producing over 1,600 pages of text with thousands of data); he established a typology of the contemporary farming systems, classifying them into 8 or 9 different categories, and even almost modelized the functioning of the major exploitation systems.

What will be reported here is Thaer's approach of the problems of variability, mapping and soil analysis. This aspect of soil quality and its evaluation takes up to 50 pages of Volume 2 in the section entitled: "*The different kinds of soil, their estimation, their use and properties, in correlation with the component parts of the soil.*" (Thaer, 1811–1816, French ed. pp. 115–166)

To begin with, Thaer underlines the necessity of:

> "*ascertaining the composition* (of soil) *by first relying on its exterior specificities. After colour, the most positive signs of the presence of humus in a soil are its lightness, a characteristically musty smell and the presence of white growths of lichen humosus. Clay can be recognized at touch, since it is characterized by its stickiness and unctuosity; sand feels rough under the fingers when crumbled, and is clearly revealed under the scrutiny of a weak lense . . . The presence of chalk can be ascertained by the effervescence caused by its contact with acids . . .* (V.2, p. 138) *When assessing the value of a soil, the examination of its component parts must be immediately followed by the*

measuring of its thickness. By thickness, I mean that of the surface layer commonly called « vegetable mould », which is homogeneous and uniformly impregnated with humus. (V.5, p. 139)"

This leads Thaer to a genuinely pedological discourse on studying soil (V.2, pp. 164–166, §575) worth quoting in its totality:

"*In order to perform an accurate description of a plot of land, relying both on the nature of soil and the mixture of the component parts of this soil, a description which may at once serve as a guideline for the assessment of its value and for the choice of crops and crops rotation it is most suitable for, it is necessary to proceed by regular, carefully-determined steps. If the plot has not been divided (and thus distributed) by planks, a cross-ruling must be effected by parallel lines distant from 5, 10 or 15 perches, according to whether the nature of the soil seems to be changing or not.*

At the same time, one should survey the plot to be assessed at a sufficiently large scale, that is about four times the scale used for territorial maps. On this map, the parallel lines will be reported, and crossed so as to obtain 5 to 10 perches-wide sections, or stations. These stations, extending from one line to the other, must be numbered; then the ground must be surveyed along those lines. Apart from the men in charge of measuring the ground with a surveying-chain, two more are needed, one with a spade, who will have to do the digging, and another with a basket, who must collect and carry the soil samples. The surveyor must take care both of the mapping and the procedure, unless he has an aide for the latter. The agronomist examines the nature of the soil and supervises the whole operation. Whenever he observes a change in the nature of soil, he stops and notes the station on the map; he then scrutinizes the soil more closely; and wherever he thinks it worthwhile, he orders some spadefuls of earth to be collected, if necessary as much as a pound of it, and has it put into a cornet paper bag or a small canvas bag, on which the number or letter of the station must be printed. The places where the changes in soil nature have been noticed are located and reported on the map as accurately as possible; on top of which, one will not fail to note whether the changes in the nature of soil are abrupt or gradual. All other observations pertaining to the soil poperties enumerated before will be reported on the procedure under the station number.

And thus the whole ground is surveyed following the parallel lines which have been drawn, which allows for the first step of the geological mapping.

To proceed to the latter, there are different possibilities; the most efficient being to figure on the map the various mixtures of soil compounding the ground, using different shades of water colours to indicate the lightest gradual changes; eminences and hollows will be represented by hachures, as is the common usage; the lesser or greater amounts of humus impregnating the ground are to be figured by black dots, which will be all the more concentrated as the proportion of humus is greater; so that positive signs will indicate everything worth noting. Such a map will enable one always to keep in sight an accurate representation of the available land and to take such steps as will be deemed most appropriate. The procedure will make it possible to draft a more precise description relative to the numbers on the map.

Additional information, such as uphill and downhill slopes and water-courses, may figure on that map; but for a more detailed information about such matters, levels might need to be taken with the appropriate tools. Levels can be measured in different directions, after which a profile may be established. Should there be a definite change in the lowest level of soil, worth mentioning and further analysing, this can be rendered on the relief profile by the use of colours indicating the depth of the different layers.

If that is the case, when the levels are measured, one must also use the auger or ground lead and dig it into the ground as deep and as often as necessary without much difficulty.

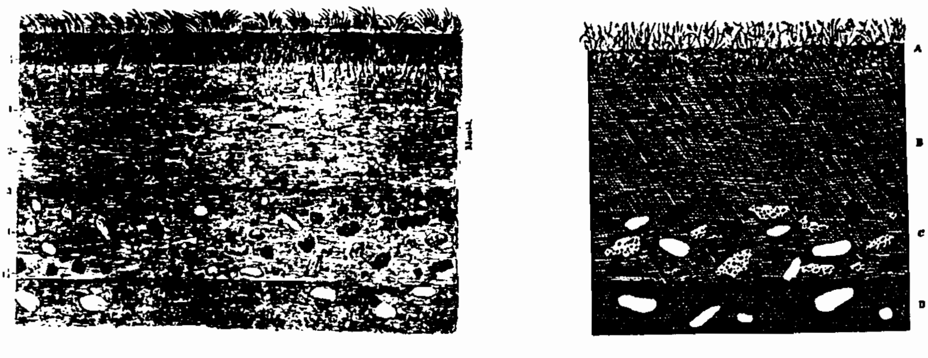
When the different component parts of ground are uneasy to make out through mere exterior observation, or when one feels inclined to proceed to more accurate examination, the soil must be submitted to a chemical analysis. But a mere visual comparison of the samples collected in the different stations, effected by degrees first in their damp state, then in their dry state, will make it possible to determine which are homogeneous and which are not, making in most cases the recourse to chemical analysis unneccessary.

More than any other, this operation will reward the enlightened agronomist for all his pains, for it will allow him to find answers to previously unaccountable phenomena, while enabling him to bring solutions to the problems encountered in the exploitation of his estate."

It must be acknowledged that Thaer presents us here with a real pedological mapping at the plot scale, not only for inventory and soil distribution analysis but also for the elaboration of thematic maps (depth, humus content, etc.). The only lack concerns the use and interpretation of air and satellite photographs, but this would be asking too much from a 1809 study! The extraordinary conclusion on the primacy of observation of the soil and its variations deserves to be pondered as well.

1837: Pedological Profile Drawings by Charles Darwin

In 1881, Darwin published his last scientific writings, entitled *The Formation of Vegetable Moulds Through the Action of Worms with Observations of their Habits*, translated into French as *Rôle des vers de terre dans la formation de la terre végétale.* In this work, Darwin reveals to have been an astounding precursor in the field of the earth sciences, in such varied subjects as erosion, matter transfer at the scale of the bigger watersheds, alteration and pedogenetic processes, ecology, soil bio-functioning and pedo-archeology (Feller et al., 2000). But although this work was published in 1881, Darwin's first communication on the matter actually took place on 1, November 1837 before the Geological Society of London; it was entitled "On the Formation of Mould" (Transactions of the Geological Society of London, Vol. 5, pp. 105–108). In writing, the communication consists of three pages, including the profile of a soil under pasture, entitled «mould», meant to illustrate the part played by worms in the burying of various materials, such as cinders or ashes, pieces of burnt marl and quartz pebbles, deposited 15 years earlier at the soil surface (Figure 1 A). The piece is most remarkable for its extremely clear identification of horizons.



A B

Figure 1. Diagrams of soil profiles presented in Darwin 1837 (A) and Darwin 1881 (B)

- *Original caption of figure 1A (Darwin, 1837): Section of field: A, cinders; B, burnt marl; C, quartz pebbles.*
- *Original legend of figure 1B (Darwin, 1881): Section reduced to half the natural scale, of the vegetable mould in a field, drained and reclaimed fifteen years previously; A, turf; B, vegetable mould without any stones; C, mould with fragments of burnt marl, coal-cinders and quartz pebbles; D, subsoil of black, peaty sand with quartz pebbles.*

On the 1837 illustration (Figure 1A), Darwin describes, from top to bottom (original measurements in inches):

– 0–0.5: the turf, or root mat

– 0.5–3.0: the vegetable mould, that is horizon A1. (on the printed reproduction of 1837, a darker sub-horizon with a considerable amount of remaining roots is perceptible in A11 between 0.5 and 1.0 inches. (It is hard to tell whether this is the rendering of an observation of Darwin's, or just an artistic liberty of the engraver's, as the subdivision is no longer apparent in the 1881 edition, Figure 1B.)

– 3.0–4.5: a layer *«of fragments of burnt marl, (conspicuous from their bright red colour), of cinders, and a few quartz pebbles, mingled with earth.»*

– 4.5– ?: *«the original black peaty soil. We thus find, beneath the layer, nearly four inches thick, composed of fine particles of earth mixed with decayed vegetable matter, those substances which had been spread on the* <u>*surface*</u> *fifteen years before.»*

The soil profile diagram of 1881 (Figure 1B) is definitely unlike the first wood engraving and looks different from the 1837 profile. But it is still interesting, because of the horizons denominations in A, B, C and D, even if the terms used in the nomenclature are not pedological. Darwin's caption reads: « *A, turf; B, vegetable mould without any stones; C, mould with fragments of burnt marl; coal-cinders and quartz pebbles; D, subsoil of black, peaty sand with quartz pebbles.»*

In the 1881 edition are presented sketchily or in great detail numerous other profiles (10 altogether) of what we would call today «archeological profiles». Figure 8 of the 1881 edition and its caption have been selected for illustration (Figure 2).

Darwin always takes pains to establish a clear distinction between undisturbed and disturbed material (cf. the comment upon FF layer on his Fig. 8).

While describing these profiles, Darwin is also one of the first to show the existence of «stone-lines». This has been abundantly commented upon by Johnson (1990, 1999).

Of course, these are not Darwin's only contributions to pedology, and many others have been reported elsewhere (Feller et al., 2000, 2003). In the passage where Darwin minutely studies the part played by worms in lands' «stripping» (that is, erosion), he has the brilliant idea of simulating rain in order to study what would be called today the stability of faunic aggregates and their transport downhill by rainfalls. As far as

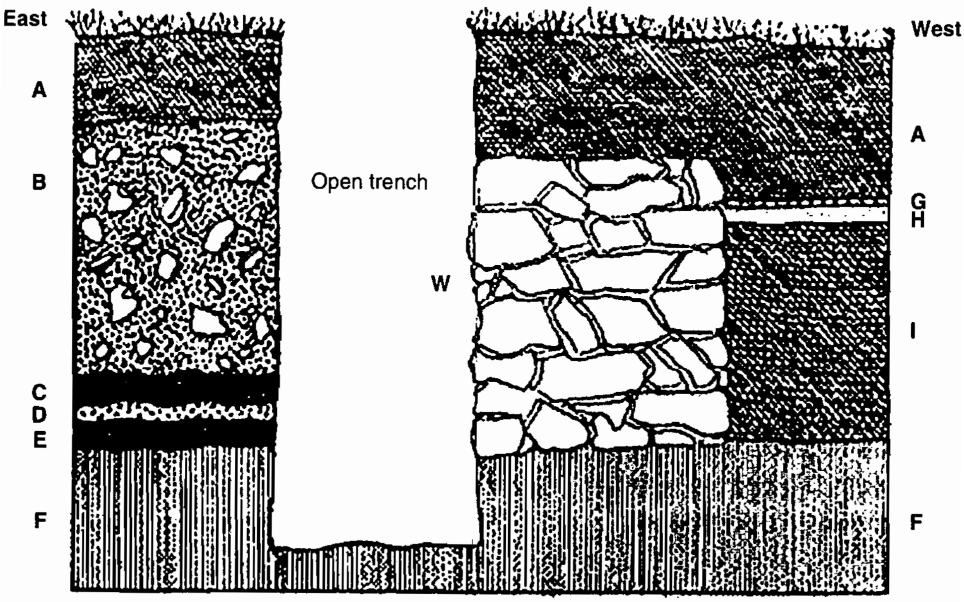


Figure 2. A pedo-archeological profile presented in Darwin 1881.

Original legend (Darwin 1881). Section through the foundations of a buried Roman villa at Abinger. AA: vegetable mould; B, dark earth full of stones, 13 in. in thickness; C, black mould; D, broken mortar; E, black mould; FF, undisturbed subsoil; G, tesserae; H, concrete; I, nature unknown; W, buried wall.

we know, Darwin's is the first rain simulator (Darwin, 1882, pp. 223–224). We shall report below an extract from this text:

> *"I was led to believe that a considerable quantity of fine earth is washed quite away from castings during rain, from the surfaces of old ones being often studded with coarse particles. Accordingly a little fine precipitated chalk, moistened with saliva or gum-water, so as to be slightly viscid and of the same consistence as a fresh casting, was placed on the summits of several castings and gently mixed with them. These castings were then watered through a very fine rose, the drops from which were closer together than those of rain, but not nearly so large as those in a thunderstorm; nor did they strike the ground with nearly so much force as drops during heavy rain. A casting thus treated subsided with surprising slowness, owing as I suppose to its viscidity. It did not flow bodily down the grass-covered surface of the lawn, which was here inclined at an angle of 16° 20′; nevertheless many particles of the chalk were found three inches below the casting. The experiment was repeated on three other castings on different parts of the lawn, which sloped at 2° 30′, 3° and 6°; and particles of chalk could be seen*

between 4 and 5 inches below the casting; and after the surface had become dry, particles were found in two cases at a distance of 5 and 6 inches."

1870–1877: A. Orth

According to Mückenhausen (1997, p. 266), descriptions of soil profiles from the surface to parent material in soil surveying and soil mappping have also been achieved/performed by the German scientist Orth, as early as the 1870–1877 period. The complete relevant section of the Mückenhausen's paper will be quoted below.

"With the book «Die geologischen Verhältnisse des norddeutschen Schwemmlandes und die Anfertigung geognotisch-agronomischer Karten», Orth (1870) prepared the basis geologic-agronomic maps of the Prussian Geologische Landesanstalt at the scale of 1:25,000. This new presentation was so important at that time that it was displayed at the World's Fair in Vienna in 1873 (Orth 1874). While earlier soil maps either reproduced essentially the texture of the Ap-horizon or were based on the geological conditions, for Orth the soil profile down to the parent material was the basis for the map. Thus the whole soil body and its variety in the landscape was examined and represented (Orth 1873, 1875, 1877b). With the publication (Orth 1877a), "Die naturwissenschaftlichen Grundlagen der Bodenkunde", Orth contributed greatly to the development of an independent soil science."

1879, 1884: The Natural Forms of Humus and the Birth of Pedology with the Danish Forester P.E. Müller

It was Müller in his noteworthy works (1879, 1884) who laid the present day scientific bases of the study on the different forms of humus, and even of a general survey of soil genetic processes in cold and temperate climates. His book, "The natural forms of humus" (1889), which included in French the works previously quoted, can be regarded as a treatise, still vadid nowadays, on the changes of brown soils to podzols (Feller et al., 2005; Jabiol et al., 2005). A few quotations of Müller's work (1889) are provided below (translated from French):

(p. 11/12) – *"In order to study the physical properties of a forest soil . . . the soil has been prepared as it is usually done when research is carried out on* *the structure of an organism, with the same dissection and microscopy techniques. The separate parts of the soil have been examined "in situ", in the natural conditions of deposit, before calling up the chemical analysis to explain whenever possible what the eye could not elucidate . . . At first sight, it looks irrational to study a complex mixture such as an alluvial soil, as if it were a whole, organized and homogeneous . . . But the study reveals that the various conflicting actions did not lead to any chaotic but fixed forms, . . . but to varied types of forest soil . . . considered as an organized entity. As usual in nature, the different types are not clearly delimitated, they intermingle; yet each may be considered as characterized by specific traits."*

(p. 12/13) – *"Among all the different forms that can be encountered in the soil of beech forests, I particularly studied two, very clearly contrasted in character and practical meaning. The distinctions relative to the superficial layers of beech forest soil should in my opinion be based on these two . . . I propose to name the two principal types . . . of humus . . . from beech forest "Mull" (mould)*[1] *and "Torf" (peat)*[1]*"*

(p. 14/15) *"Terreau de hêtre (Buchenmull)". Following the description of the vegetation:*

"Soil aspects. The soil . . . is covered by a more or less thick layer of isolated (plant) remains scattered on the soil. When the cover is taken apart, the darkish brown surface . . . of the soil has a gravelly and granular aspect. The line between the cover and the soil . . . is quite marked . . . This earth is as completely loose as . . . tilled . . . garden earth".

This is followed by a very detailed description of the soil profile with its different layers, microscopy (of coherent elements, in particular), mechanical and chemical analyses, and by a long study (pp. 20–28) on the litter decomposing organisms, mycelia and earthworms, with quantitative data:

(p. 29) "*Tourbe de hêtre (Buchentorf)*". After a description of the vegetation, very different from that of the "Mull", the soil aspect. "*If the soil is dug with a spade, . . . a layer of tenacious black-brown humus, is found: the peat (mor); then, beneath, a grey-white, grey or black-grey sand . . . the sand is clearer, the farther from the peaty layer . . . (then, is found) . . . a layer of earth having a red-brown or brown color . . . and under it, some sandy clay, some sand*". The grey sand is denominated "*bleichsand*" ("sable plombifère", plumb sand[3]) and the brown-red layer "*Ortstein*". This is followed, with drawings, by a very detailed description of the tenacious and felted peat. He noted importance of mycelia and lack of earthworms (pp. 33–44)."

Transient formations, mould-peat (mullartiger Torf) are then described (pp. 45–64); in general, they do not contain earthworms but numerous insects and mycelia.

The different forms of humus, based on the existence of two stages in the humification process 1 – "*The mechanical division of organic remains*", and 2 – "*The mixture of organic remains and mineral earth*", (according to Müller), are then discussed.

The classification scheme proposed for humus present in beech forests is:

"*Echter* (Genuine) *Mull. Perfectly divided, loose without cohesion. Does not contain more than 10% organic substance, with no free humic acids . . . well mixed with the mineral earth . . . through the work of animals . . . and the action of water*".

"*Mullartiger Torf. Perfectly divided, loose without cohesion*". (Afterwards, idem to Echter Torf).

"*Echter Torf.* (Real mor) *Imperfectly divided, firm, tenacious, coherent. Contains 30 to 60% organic substance with free and soluble humic acids; imperfectly mixed with the mineral earth, owing, almost solely due to the action of water.*"

These few quotations only provide an incomplete idea about this exceptional work which came complete with colour and black-and-white plates of soil profiles, with indications of all the changes between brown soils and podzols, and the plant–soil relationships over a few meters (Figure 3). In addition, even the very first edition of 1878 attached the greatest importance to the biological processes, and especially soil fauna. In 1878, Darwin's book, *The formation of vegetable mould through the action of worms*, had not been published yet. It was abundantly quoted in Müller's second memoir (1884).[4] Müller's study opened up the era of biological Soil Science as far as uncultivated soils were concerned.

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[3] "Sable plombifère" was the translation of "bleichsand" given by H. Grandeau in 1889. According to an anonymous referee who reviewed this paper, Grandeau confused "blei" (= plumb) with "bleich" (= colourless). Therefore "bleichsand" would mean "colourless sand".
[4] In Müller's first memoir (1879), Darwin is only quoted through another author (Fogh). It seems that Müller was not aware of the first short publication (1837) of Darwin, *On the formation of mould.*

Figure 3. Section of an oak "Krattbusch" and the soil below. Under the leaves layer the superficial grey mould passes little by little to the yellow sand of the subsoil; outside the bush, where the soil carries a heath vegetation, heat peat, plumb sand and Orstein have been formed. Oak roots are roughlky drawn. (Müller, 1889, figure 14, page 159).

Conclusion

Great naturalists have always been good observers. Where soil studies are concerned, this rule still applies, and the instances selected for the present study are all the more interesting since most of the authors reported here were not necessarily specialists in the field – which incidentally accounts for the fact that these minor aspects of their works may have gone unnoticed. This does not prevent their studies from being quite impressive, for each chosen author may be considered as a great precursor in the matter of soil description and soil mapping. After them, the earth sciences had to wait until Dokuchaev (1883) to see the rebirth of soil description, soil profiles and soil mapping methods similar to those that are in use today.

Acknowledgement

Dr. Anne-Marie Carasson, Antilles-Guyane University (France) helped with translation into English.

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In : Warkentin B.P. (ed.) Footprints in the soil : people and ideas in soil history

Amsterdam : Elsevier, 85-105. ISBN 0444521771