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REVIEW

The contribution of Friedrich Albert Fallou to modern soil science

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Abstract

This article deals with Friedrich Albert Fallou (1794–1877), a lawyer by education with a strong interest for soil and geology who published "*Pedologie oder allgemeine und besondere Bodenkunde*" in 1862, that is, 20 years before Dokuchaev's (1883) "*Russian Chernozem*." He is known for having coined the term of "pedology" but his role in the development of the soil science needs recognition, the opinions diverging this far with regard to his importance in terms of pedogenesis, soil profile, soil classification and influence on Dokuchaev. The authors of the present article have translated into French and analyzed in detail each of the chapters constituting the first part ("*Allgemeine Bodenkunde*" 198 pp.) of his book. These pages include many precise descriptions of the soils in a small area near Fallou's place of residence in a hilly part of Saxony (NE Germany) and bear evidence for his remarkable skills as nature observer. His field experience led him to strongly recommend that soils should be studied in situ, using existing cuts, either natural or artificial. He was first to strive for the "*Earth*" to be recognized as a "*Kingdom*" of its own and for the study of the soils to be established as an independent natural science for the benefit of a wide range of potential stakeholders. The present review is intended to demonstrate that despite some shortcomings due to his sticking to a few outdated basic scientific conceptions, Fallou fully deserves to be regarded as an important forerunner of modern soil science.

KEYWORDS
Fallou, forerunner, history, pedology, soil classification

1 | INTRODUCTION

Born in Zörbig (Saxony), Friedrich Albert Fallou (1794–1877) started a professional career as a lawyer after completing his studies at the University of Leipzig. He first held several positions with local governments before opening an office in the town of Waldheim as an attorney specializing on the valuation of soils (Kaden & Fiedler, 2013). At the end of the 1840s, however, he decided to devote all his time as an independent researcher focusing his attention on an in-depth investigation of the soils comprised in a 25 km^2 area surrounding his home. This peculiar, private situation will obviously have an important negative impact on his international repute because even if he occasionally corresponded with some eminent German professors, mostly from the Kingdom of Saxony (Thalheim, 1993), he is left with no university title, little contact to the academic authorities in an era of rapidly changing scientific paradigms, and with only few followers likely to propagate and defend his views (Thalheim, 1993). It has also prompted some university lecturers to heavily criticize his ideas, sometimes

even with particular violence (e.g., Wilckens, 1867; cf. Aeschlimann et al., 2021).

Fallou is best known for his book titled "*Pedologie oder allgemeine und besondere Bodenkunde*" (Fallou, 1862; Pedology or General and Special Soil Science). The volume has two parts of which only the first one, or "*General*" (xi + 198 pp.) will be dealt with here; the second, or "*Special*" (190 p.) is entirely devoted to a description of all soil types included in Fallou's own classification system. The general section consists of a "*Preface*" and "*Introduction*," followed by eight chapters under the respective headings of: "*Genesis*," "*Condition*," "*Nature*," "*Space*," "*Stratification*," "*Diversity*," "*Classification*," and "*Function*" of the soil. For the first time, a complete French version of each of these chapters has been published by the authors of the present article in the journal "Étude et Gestion du Sol" of the French Soil Science Society (Aeschlimann et al., 2010, 2018, 2020; Feller et al., 2008, 2015, 2019, 2020; Frossard et al., 2008, 2011, 2019). This allowed them to gain an in-depth understanding of the wording used and of the exact meaning of Fallou's sometimes complex sentences.

Fallou forged the German word "*Pedologie*" (which by the way occurs rarely in his own opus), a point duly acknowledged by Schroeder (1988), Boulaine (1989), Bicki & Tandarich (1989), Krupenikov (1992), Simonson (1999), Blume and Yaalon (unpublished), Mathieu (2002), among others. Mückenhausen (1997) finds that Fallou "began to take the degree of weathering of the substratum into consideration" even if his classification system is based on geological rather than pedogenetic aspects. For Tandarich et al. (2002), Fallou sees the soil as a separate, natural object but has no real notion of the profile, whereas Asio (2005), on the contrary, feels that he already made use of it. Historians are also divided as to the significance of Fallou's contribution in terms of a pedological school of thought. Some like Asio (2005), "look upon Fallou as the founder of pedology," whereas Johnson et al. (2005) state that most authors consider that modern soil science started with Dokuchaev (1883).

The present contribution aims at assessing Fallou's role in the development of the soil science and at discussing the contrasting views of recent investigators in the light of the new French version. It is also intended to clarify Fallou's discourse in current scientific terms and to analyze his philosophy with regard to the strictly pedological processes, that is, nature and origin of soil, rock alteration and transformation, his concepts of horizon, profile, and taxonomy, and his influence on Dokuchaev, which is disputed by Johnson et al. (2005) and others. Finally, the various functions Fallou attributed to the soil will be critically reviewed.

Fallou's textbook[1] is printed in Gothic characters and written in a somewhat old-fashioned, complex terminology, which owes much to the author's education as a lawyer. All excerpts of his text including the relevant footnotes are *italicized* below and represent direct translations from the original German. The page numbers indicated refer to the original German edition. As far as seemed legitimate, modern, scientific equivalents of the terms he used are presented, but the style, length, and rhythm of his text have been maintained.

[1] See original under: https://www.digitale-sammlungen.de/de/view/bsb10283420?page=1

2 | FALLOU'S PEDOLOGICAL CONCEPTIONS

2.1 | Nature of the soil

Attitude and intentions of the author are best documented in this initial statement (p. iii):

> *It is clearly established that the practice of agriculture first requires a property, i.e. a ground and a soil*[2].(…) *It seems all the more remarkable that as yet very little thought has been devoted to the latter whereas one has been practicing agriculture for immemorial times. Soil science is the youngest of all sciences and it is therefore not surprising if it has not been able thus far to secure a robust body of scientific teaching. Current treatises and handbooks of this science are generally just compilations of various theses on the geognosy*[3] *and geography, agricultural chemistry and plant physiology dealing with clearing, improvement, valuation and agricultural usage of the soil among others.* (…) *In considering and describing the soil first as a coherent whole, then in each of its portions in a detailed manner, I believe to have dealt with the basic concept in a totally exhaustive way and tried to raise soil science to the level of an independent science. It is the first attempt of this kind and I have opened up a new path.*

Fallou gives some of the reasons why he develops this new approach, its broad frame in a new Kingdom, the potential end users as well as the tools needed to attain his goals (p. 3):

> *In the whole nature there is practically no object as disregarded as the soil and on which most human beings have so unclear concepts.* (…) *The soil (solum) of the surface of our Earth is disintegrated, more or less dissolved rock, in part mixed with organic materials and thus completely modified and transformed in its form as well as in its substance and in this way separated from the still solid and undissolved deep rock* (…) *it belongs no more to the underlying rock but like a sort of rock in itself rather constitutes in its whole the proper Earth Kingdom* [4]. (…)
>
> *The scientific soil knowledge (pedology*[5]*) is a natural description of the soil disregarding its link to the plant kingdom and without having to worry about its use for commercial purposes.*

[2] In German, "*Grund und Boden*" means a plot and its utilization, implying often its ownership.
[3] "Geognosy" is the former name of geology.
[4] By analogy to the Plant and the Animal Kingdom.
[5] *From ρέδον, soil and λογία, discourse* (Fallou, 1862).

> *The agricultural soil science (agrology[6]) is the knowledge of the soil in relation to the plant and its agricultural utilization. (…)*
>
> *The instruments we need for the knowledge of the soil in geognostic terms are primarily natural and artificial cuts. (…)*
>
> *The knowledge of the soil is not solely necessary to the landowner, farmer and manager (…) it is even necessary to the soldier, from the general to his subordinates.*

What Fallou exactly assembled under the term of soil remains somewhat confusing. From page to page, he seems to vary in the sense attached to the words soil or earth, which are alternatively qualified as *agricultural soil or earth*, *arable*, *cultivated*, *fertile*, *powdery*, *primitive*, *pure*, *useful*, *wild soil or earth*, and so on, yet without any formal definition of each of them as if they were self-explanatory. He considers as soil all layers of material(s) present on the surface of the Earth derived from the weathering of one or several rocks, including or not organic components, still in their place of origin or transferred somewhere else. The text cited above also shows that for Fallou the underlying rock is not part of the soil.

All the above statements define an idea of the pedology that is perfectly acceptable today. In addition, Fallou repeatedly insists on the overall usefulness of the soils and in chapter 8 (*Function of the Soil*) even tackles the abuses likely to arise from excessively intense agricultural practices (Aeschlimann et al., 2021).

2.2 | Rock alteration and pedogenesis

The formation of the soil is dealt with in his chapter 1 titled "*Genesis of the soil*." Fallou hypothesizes here that the soils of our planet had to initially emerge before the living beings because plants as well as animals first needed a decent substratum to sustain them (p. 48):

> *Of course, this portion of the soil cannot have been formed before some soil was already present, because animal and plants require food and they don't obtain it from the atmosphere but from the soil only. (…) It seems that the higher cultivated plants cannot do without organic matters for their growth, they grow mediocrely or even do not develop at all in a soil in which they fail.*

In several instances, Fallou struggled with several new notions emerging around the middle of the 19th century, which upset the overall mental construction of the soil science he slowly developed over the years. One such example is the claim that plants take their food from the organic portion of the soil, an important argument that is reiterated throughout the book. Fallou obviously refers here to Thaer's (1809) humus theory (Feller et al., 2003), which at his time was about to be superseded by von Liebig's (1840) theory on the mineral nutrition of the plants but he still sticks to this outdated conception at least up to 1860.

Fallou holds that rock alteration occurs mainly through chemical and/or mechanical actions, both being reinforced by the result of biological activities (Aeschlimann et al., 2010). Air and water operate chemically and transform the mineral via oxidation or dissolution. They first tackle the cements binding the various elements of the rock. He sees carbon dioxide as enhancer of the dissolution, initiating a disaggregation of the rock that eventually leads to its complete dissolution.

The mechanical actions are mainly related to water or fire, the air having here minor effects only. Rock fragmentation and hence landscape remodeling are chiefly performed by the water both in its solid or liquid state causing rockfalls, landslides, alluvial and torrent deposits, glacial valleys, and so on. Fallou records many catastrophic events, which sometimes occurred centuries ago. Fire activity occurs essentially underground and manifests itself in volcanic eruptions with ash, pumice and lava emission, creation of faults, and so on.

Displacement and deposition of terrigenous materials are abundantly dealt with and chiefly attributed to waters. Any soil of the planet is classified as either of origin (i.e., sedentary or still remaining in its first place) or alluvial in Fallou's proper wording (i.e., sedimentary or removed from its site of creation). This pivotal criterion is a result of the diluvium and constitutes the keystone of Fallou's model. In his view, all soils belong to one or the other category according to their location during the highest recorded flood level and are either alluvial if situated below this limit (and hence solely created by successive depositions under which, he argues, there is no weathering of the underlying rock) or of origin if placed above it (in which case rock weathering does occur).

As a self-made soil specialist, Fallou does not have the mental flexibility to accommodate unexpected new paradigms into his soil system, for example, that a general flooding of the Earth never happened (Aeschlimann et al., 2021). Toward the end of chapter 2, he acknowledges the fact that glaciations occurred, but nonetheless maintains the idea of an upper flood line segregating his two soil classes, the displacement of terrigenous materials being now chiefly attributed to torrential rains.

Of major importance in the formation of soils are also the biological elements, both fossil and/or present as plant debris, animal carcasses, humus, and so on (p. 48):

> *The soil now present and spread over the surface of the Earth has not been formed uniquely in the way indicated through the joined forces of the inorganic nature supporting themselves mutually, via dissolution and destruction of the bedrock and by displacement and deposition of those debris, but in part also through the biological activity of animals and plants as well as indirectly their decomposition.*

[6] *From αργός, cultivated or cleared field. The soil science is already a natural science of the soil in itself, the expression "natural science of the soil" is therefore only justified as far as one puts an agricultural one against it* (Fallou, 1862).

Due to his expertise in mineralogy and petrography, Fallou's understanding of rocks weathering is decidedly modern. He perceives erosion as being chemical in the course of the geological ages, which entirely fits the present notion of alteration[7]. The role played by carbon dioxide in the alteration process is emphasized as well as the resistance of the various minerals to partial transformation or complete dissolution, which depends upon the rock properties and factors like the topography. Water is of highest importance, not just in the alteration process, but for implementing both transportation and deposition of the terrigenous materials. Granite, basalt, shale, and so on are cited as examples of different rock behaviors with respect to their ability to resist weathering. This allows Fallou to differentiate between constituents like kaolinite and mica arising from complete dissolution followed by recombination into new minerals (what would be called neogenesis today) and elements like quartz remaining untransformed (i.e., of heritage).

2.3 | Notion of the soil profile

As it transpires in particular from chapter 5 titled "*Stratification of the soil*," Fallou is an outstanding observer and field worker[8]. He provides detailed descriptions of the features and interrelations of the various apparent layers of what he terms soil. To what extent, however, do they support either Asio (2005), who believes that Fallou already has a modern notion of a soil profile or Tandarich et al. (2002), who find he does not? Fallou meticulously describes the properties of the various soil layers and their relationships (p. 131):

> *The soil appears first of highly diverse thickness and importance, sometimes as a weak layer, a loose mixture of powdery earth, dust and debris which barely covers the underlying rock, sometimes as an imposing, firmly compact dam of diverse varieties of superposed soils under which the bedrock lies at unknown depth.*

The above sentence reaffirms the pivotal criterion established earlier whereby its first part obviously refers to soils in place, the second to alluvial soils. Since Dokuchaev (1883) a soil profile is generally defined by terrigenous layers (i.e., pedological horizons) of different morphology, which individualized in situ in the course of the formation and evolution of the soil. In other words, these different layers do not result from successive geological deposits. Yet how does Fallou see those *diverse varieties of superposed soils* constituting the alluvial soils: every separate layer as being a pedological horizon as currently admitted or as being the product of a different deposition? He specifies the relationships of the different soil layers to the bedrock as follows (p. 133):

> *The basis is also either very clearly differentiated from the supported soil (i.e., the displaced soil) or directly connected to it without any precise boundary (i.e., the soil in place). The latter is the rule in the region of the soil of origin, very common in particular for grained rocks like granite, granulite, syenite and porphyry. A 5–10'*[9] *of the rock surface is usually altered and becomes gradually dispersed gravel towards the top to finally crop out imperceptibly as soil, in such a way that one does not know what one should attribute to the soil and what to the bedrock, because no defined boundary can be recognized between the two.*

As for the soil in place, Fallou displays a robust pedological understanding of A-, C-, R- horizons with gradual transitions between the various horizons. All upper layers are attributed to a progressive alteration of the bedrock, which may even be observed at the soil it carries. However, in the region of alluvial soils (p. 133):

> *Under displaced soils by contrast the basis forms a neat cut, in river and stream valleys at times even a smoothly polished surface through the friction of river alluvium. First covered with scree debris it is thus usually already separated from its overlying rock.*

For alluvial soils, and in particular the silty, often thick, cultivated ones, Fallou distinguishes between the arable earth and the rest of the soil, the so-called deep fertile soil, both lying on a different basis (p. 139):

> *In the displaced superficial soil, apart from the colour, there is often no apparent difference at all between upper and lower basis, both appear as a sole, homogenous mass. It is hence the more striking at more careful examination to note a considerable difference in content, whereby the lower basis usually 1–5, also well 10%, more pure earth includes and also quite different mineral elements than the upper basis—in the silty soil is this most frequent.*

Fallou obviously describes here a brown leached silty soil with a Bt horizon (enriched in clay + fine silt compared with the superficial horizons)[10], and does not ascribe the textural divergence between the A and B horizons to any pedogenic process (leaching and/or impoverishment of A horizons), but rather to a difference in nature and material deposition, A and B originating from different deposits. A last assertion on how he sees the displaced soils (p. 143):

> *Each layer is clearly a section of the whole that matches a certain time period, the lower always ought to be older than the next successive upper one. This at least is what the look teaches as one cannot imagine a deposit consisting of several layers to have been created all of a sudden.*

[7] The word erosion relates mainly to the loss of soil under the action of water or wind but is still used by geologists to mean rock weathering.

[8] Fallou's description of a leached brown soil is given below p. 4. His treatment of a podzol in relation to so-called "dislocations between layers" is worth mentioning (p. 140): "*Not rare equally in sand deposits in which separated layers of a compact ferruginous sand alternate with loose sand and are recognized already from afar at their white and rust brown coloration.*"

[9] Former abbreviation for foot.

[10] That is a Luvisol according to WRB (1998) for Soil Resources.

Fallou never uses the term of "profile" (but cut instead), nor that of "horizon" (but layer, in German *Strata* instead). This said, he has a perfectly adequate notion of the soil profile as far as the soils in place are concerned, and quite clearly senses that different layers are related to particular forms of pedogenic activity. For the displaced parent material on the other hand, he only understands the various horizons as resulting from temporally different depositions. Fallou behaves hence as a pedologist with regard to the soils in place of origin but as a sedimentologist in terms of the displaced soils.

2.4 | Soil classification

Chapter 7 begins with a discussion of the soil classification systems used at his time (Official Sachsen nomenclature, Sprengel, Protz, Trommer, Schlipf, etc.; Aeschlimann et al., 2020), which are based on cultural, mineralogical, geological, or textural criteria and provide qualifications like "stony soil" or "humic soil," and so on, sometimes combined with characteristics that do not sound very scientific such as "excellent wheat soil" or "good barley soil," and so on. Fallou finds them highly unsatisfactory. He produces instead a soil taxonomy based on the mineralogy and the geology of the parent material. His system follows a strictly Linnean model, organized in two classes defined according to the already mentioned pivotal criterion, both divided into six or four genera, each of which includes in turn several types (species) and even varieties of soils (p. 180):

First class. Terrains of soils of origin

- *First genus. Soil types of quartz rocks*
- *Second genus. Soil types of clay rocks*
- *Third genus. Soil types of mica rocks*
- *Fourth genus. Soil types of feldspar rocks*
- *Fifth genus. Soil types of limestone and magnesia rocks*
- *Sixth genus. Soil types of augite and hornblende rocks*

Second class. Terrains of alluvial soils

- *First genus. Soil types of pebbles*
- *Second genus. Soil types of marl*
- *Third genus. Soil types of silt*
- *Fourth genus. Soil types of moor*
- *Special section. Fortuitous soil accessions (volcanic, blocks, etc.)*

Joffe (1929) criticizes this soil taxonomy for it being based "on purely geognostic or geologic point of view." For Ehwald (1960), "Fallou's pedology was in fact not soil science, but a science of alluvial sediments and weathering crusts." Simonson (1999) formulates a similar reproach, whereas Blume and Yaalon (unpublished) observe that "his soil classification is more a classification of geological substrates than of soil texture classes," and Kaden & Fiedler (2013) describe it as being "mineralogical-petrographic."

Contrary to Dokuchaev in Russia, Fallou addresses the soils of a limited geographical, hilly area in the vicinity of his residence (Mückenhausen, 1997) of which he has an in-depth knowledge. This part of Germany is situated under a relatively homogenous climate and owing to the glaciations its soils are predominantly acid brown ones and not particularly ancient (Kaden & Fiedler, 2013). Under such conditions, the litho-dependence remains the primordial factor explaining the diversity of the soils. In this context, his classification is a coherent proposal that represents a distinct scientific improvement compared with the systems prevailing at the time (Aeschlimann et al., 2020). Also, it is worth emphasizing that Fallou's conception foreshadows the so-called agricultural geology school of thought that led to the creation of the ISSS (International Society of Soil Science) in 1924 (Tandarich, 1998; Tandarich et al., 2002).

3 | DISCUSSION

Scholars today tend to present Dokuchaev as the father of the modern pedology (Johnson et al., 2005), whereas Joffe (1929), Blanck (1949), Fischer (1955), Schroeder (1988), and Asio (2005) regard Fallou as his predecessor. To agree with the latter would imply that Fallou considers the soil as an independent body, topic of a science differing from the geology. In this regard, Fallou's leading role ought to be recognized: he even goes so far as to consider the soil as the topic of a new Kingdom. To study this soil, a new science is needed with its own concepts and tools and Fallou recommends the use of existing field cuts to adequately assess the qualities of a soil. His proposal to establish a collection of soils at the Royal Museum of Mineralogy in Dresden was unfortunately rejected (Thalheim, 1993). New scientific concepts require a precise terminology as Johnson et al. (2005) put it "… had Fallou coined and defined more conceptual terms to showcase and articulate his early ideas, his recognition as a founder of soil science might have come earlier …." This aspect has been confirmed during our French translation. Chapter 6 for instance deals with the soil's "difference" (*Verschiedenheit*) but describes under this term first its *diversity* or variety (pp. 145–148, *Vielfalt*), and then (p. 149) the criteria for the *distinction* between two types of soil (*Unterscheidung*). Another problem arises with the word "*Moder*," which Fallou understands to be organic substances of all kinds. Fallou's overall contribution nevertheless remains significant for he: (1) clearly defines the soil as a natural object different from the rocks; (2) elaborates methodologies for its study; (3) demonstrates a perfect comprehension of the origin for soils in place; and (4) formulates a rigorous soil classification system.

As for Fallou's vision of soil profiles, the truth is somewhere in between Tandarich et al. (2002), who writes that he has not such notion, and Asio (2005), who believes he has. Fallou has indeed a conception of a profile that entirely fits the modern science but only for soils in place, not for alluvial ones owing to a lack of understanding the pedogenetic process. Asio (2005) insists on the influence exerted by Fallou on Dokuchaev via Orth (1872, 1877), yet Dokuchaev (1883) refers once only to Fallou and three times to Orth (Johnson et al., 2005). Dokuchaev (1879) acknowledges Fallou for stressing the importance of the geology in terms of soil research and disagrees with him, because he is guilty of considering the chernozem as a mere alluvial

deposit. To sum up, the low recognition of Fallou's pioneering role is due to his limited formulation capacity, to his social isolation that prevented any appropriate academic acknowledgement, and perhaps also to Dokuchaev's deliberate omission (Johnson et al., 2005).

The emergence of a new geological age named anthropocene calls for the history of the pedology to be revisited, which has hitherto mainly considered naturally occurring soils. According to Richter (2020) the man-induced modifications of the environment nowadays determine some sort of anthropedogenesis. From that point of view, it is interesting to examine how former soil scientists have envisaged the human impacts on the soil. Fallou devotes his whole chapter 8 to describing the many services rendered by the soil with regard, in particular, to the water cycle, as a basis for all living organisms, for the provision of material for building and for a vast number of trades. As such, however, the soils are not ready for agricultural use; the Man has the very important task to assist the Nature in order to make them fertile and to keep them in that condition. Fallou also feels that the general function of the soils may be maintained on the long term and that the Earth offers the potential to recover even from bad agricultural practices arising for instance from deliberate overexploitation.

4 | CONCLUSIONS

In retrospect, quite apart from the fact Fallou forged the term of pedology, he ought to be credited with proposing to study the soil as a natural object independent from the rock. This was a new conception, and a new science would have to be elaborated in consequence. Fallou's observations as a self-taught field naturalist are of exceptional quality and he is able to perfectly describe a soil profile. He advocates for all the soils to be examined in situ using already existing cuts as far as possible. His understanding of the four main pedological aspects analyzed above (nature of soil, rock alteration and pedogenesis, soil profile, soil classification) is correct except for the concept of soil profile. For soils in place (of origin, sedentary), he behaves as a remarkably modern pedologist, but for soils of lower altitudes, which he qualifies altogether as displaced (sedimentary), his deep-rooted conviction that they are of alluvial origin prevents him from analyzing them in an objective, appropriate way with respect to the soil profile concept. Because of this misjudgment, Fallou cannot be considered as ***the*** founder of soil science of which he remains a very important forerunner knowledgeable about soil functions for man and the environment.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were generated or analyzed in this study.

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