Physics and Chemistry of the Earth 35 (2010) 903–912

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Selected pioneering works on humus in soils and sediments during the 20th century: A retrospective look from the International Humic Substances Society view

Christian Feller [a,*], Michel Brossard [a], Yona Chen [b], Edward R. Landa [c], Jean Trichet [d]

[a] Institut de Recherche pour le Développement (IRD), UMR 210 Eco&Sols, SUPAGRO, 2 Place Viala, 34060 Montpellier Cedex 1, France
[b] Dept. of Soil and Water Sciences, Robert H. Smith Faculty of Agriculture, Food and Environmental Quality Sciences, The Hebrew University of Jerusalem, P.O. Box 12, Rehovot 76100, Israel
[c] US Geological Survey, 12201 Sunrise Valley Drive, Mail Stop 430, Reston, VA 20192, USA
[d] Université d'Orléans, Laboratoire de Géologie de la Matière organique, B.P. 6759, 45067 Orléans Cedex 2, France

ARTICLE INFO

Article history:
Received 26 January 2010
Received in revised form 7 October 2010
Accepted 21 October 2010
Available online 28 October 2010

Keywords:
Humic substances
Soil
Sediment
Organic geochemistry

ABSTRACT

Organic matter in general, and humic substances (HS) in particular, are involved in many processes in soils, sediments, rocks and natural waters. These include rock weathering, plant nutrition, pH buffering, trace metal mobility and toxicity, bioavailability, degradation and transport of hydrophobic organic chemicals, formation of disinfection by-products during water treatment, heterotrophic production in blackwater ecosystems and, more generally, the global carbon cycle. Before the 1970s, natural organic matter of different ecosystem pools (*i.e.*, soils, sediments, and natural waters) was often studied in isolation, although many similarities exist between them. This is particularly so for HS.

In this historical context, a need appeared at the international level for bringing together environmental chemists, soil scientists, hydrologists, and geologists who were interested in HS to provide a forum for the exchange of ideas, to standardize analytical procedures and agree on definitions of HS. The International Humic Substances Society (IHSS) was founded in Denver, Colorado (USA) in 1981 with several objectives among them "to bring together scientists in the coal, soil, and water sciences with interests in humic substances" (home page of the IHSS web site: http://ihss.gatech.edu/ihss2/index.html).

This paper presents selected pioneering works on humus in soils and sediments during the 20th century with a special focus on the links between the studies of soil HS and the formation, during early diagenesis, of the precursors of kerogens. Temporal coverage includes key contributions preceding the founding of the IHSS, and a brief history of the organization is presented.

1. Introduction

Organic matter (OM) in general, and humic substances (HS) in particular, "are involved in many processes in soils, sediments, rocks and natural waters. These processes include rock weathering, plant nutrition, pH buffering, trace metal mobility and toxicity, bioavailability, degradation and transport of hydrophobic organic chemicals, formation of disinfection by-products during water treatment, heterotrophic production in blackwater ecosystems" and, more generally, the global carbon cycle. Accordingly, HS have received attention from scientists in a wide variety of disciplines. However, before the 1970s, HS were often studied in the disciplinary isolation of a given compartment of the ecosystem (soils, waters, sediments or atmosphere), despite the fact that many similarities exist between HS in the different systems. For comprehensive subject matter coverage of the field, the following modern-era references area available: for a general overview of HS in soil, sediment and water: Aiken et al. (1985) and Hayes (2009); for the organic geochemistry of natural waters: Thurman (1985a); for HS in the atmosphere: Graber and Rudich (2006). The main precursor of an ecosystem approach for the study of HS was provided by the work of Waksman (1936, 1938), and that influence will be a focal point of this paper. Historical perspectives on the study of HS in soils have been provided by Kononova (1961), Stevenson (1985), and Feller (1997).

During the late 20th century, a need appeared at the international level for bringing together environmental chemists, soil scientists, hydrologists, and geologists interested in HS. The goal of the diverse grouping of scientists was to provide the community with a forum for the exchange of ideas on HS, and for standardizing analytical procedures and definitions of HS. The International Humic Substances Society (IHSS) was founded in Denver, Colorado (USA) in 1981 with the motto: "To advance the knowledge and

* Corresponding author. Tel.: +33 466222660.
E-mail addresses: christian.feller@ird.fr (C. Feller), yonachen@agri.huji.ac.il (Y. Chen), erlanda@usgs.gov (E.R. Landa), Jean.trichet@univ-orleans.fr, jgtrichet@sfr.fr (J. Trichet).

1474-7065/$ - see front matter © 2010 Published by Elsevier Ltd.
doi:10.1016/j.pce.2010.10.004

research of natural organic matter" but also "to bring together scientists in the coal, soil and water sciences with interests in humic substances".

But of course there were pioneering works published prior to the founding of the IHSS that shared this synthetic and holistic view of IHSS. During the early and mid-20th century several efforts stand out as producing: (1) a major synthesis of research on humus and HS in different ecosystem compartments, or (2) attempting to integrate a given approach for the study of biogeochemical processes across different disciplines, such as the problem of the origin and the characterization of OM in fossil fuels. These two aspects of this often-forgotten early history of HS research will be the focus of this paper. For case: (1), we will examine the work of soil scientist Selman Waksman and his 1936/1938 treatise "*Humus*" as an example of a major synthesis of work on HS in different compartments of the ecosystem. For case (2), we will focus on the origin of fossil fuel, and the perceived need to integrate across different disciplines that accompanied the emergence of the field of organic geochemistry. Here we will look first at studies on peat as the origin of coal. We will then shift to focus on the Van Krevelen's diagram; used in geology to distinguish different processes operative in fossil fuel formation, which is surprisingly not well known by soil scientists. And as our final case study, we will examine the collaboration between soil scientists and oceanographers to elucidate the formation of kerogen from soil HS during the early diagenesis. A short history of the founding and activities of IHSS will be given at the end of the paper.

These three examples were chosen from the HS literature because they represent a spectrum of success in the realm of information transfer across disciplinary boundaries. Waksman's treatises of the 1930s laid the framework for linking studies of soil organic matter and of coal. The Van Krevelen approach of the 1950s made great strides in characterization of kerogens in coal and oil deposits, but has made limited inroads in the characterization of soil organic matter. The French oceanographic-soil science experiments of the 1970s–1980s were truly unique examples of HS science on a grand scale—applying modern laboratory methods to the study of organic matter diagenesis along transects from land to sea. They share a holistic view of HS, later championed by the IHSS, and are exemplars of the challenges that would be faced by this crosscutting group.

2. Waksman and his book "Humus": a IHSS-like publication from the 1930s

Selman A. Waksman is generally recognized today as a biochemist and microbiologist for his research and discovery of several antibiotics, including streptomycin, which was especially effective in treating tuberculosis. For this, he was awarded the Nobel Prize in Physiology and Medicine in 1952. But his early training (under Rutgers University soil scientist Jacob G. Lipman, the first President of the International Society of Soil Science) and a large part of his professional life was concerned with soil microbiology and with humus. His first classic book on soil microbiology was published with Starkey in 1931. A second book on the topic was published with Waksman as sole author in 1952. The first edition of his book on humus, also a standard for many years, was published in 1936, with a second, and revised edition in 1938.[1] He also published an autobiography *"My life with the microbes"* (Waksman, 1954; French version, 1964).

Evidence of his visionary contribution to the unifying, interdisciplinary, foundation concept of the IHSS is seen in the book *"Humus"*. Waksman and his research collaborators contributed to many aspects discussed in the different chapters. The complete title of the book is:

"*Humus. Origin, chemical composition, and importance in Nature*"

It is divided into three parts:

A. Historical development of our knowledge of the chemical nature of Humus, its formation and its role in plant nutrition (four chapters).
B. Origin and Nature of Humus (nine chapters).
C. Decomposition of Humus, its functions and applications (5 chapters, Outlook, Appendix).

Part B includes chapters about humus in different environments. These include:

- *Humus formation in composts of stable manures and of plant residues; green manures.*
- *Humus in forests and heath soils.*
- *Humus in mineral soils (field, grassland, garden, and orchard).*
- *Humus in peat and in coal.*
- *Organic matter formations in water systems.*

Waksman's goal was to consider all forms of humus in the environment (Part B), and also what we might now call "ecosystem services" provided to society by humus (Part C).

It is important to note that Waksman was largely concerned with the origin and composition of peat humus, and the use and management of peat resources (Waksman, 1938, chapter XI, 1954; 1964). Before Waksman, peat formation was mainly considered in terms of chemical processes; microbial processes were rarely considered. Waksman gave a modern definition (Waksman, 1938, pp. 265–266; Waksman and Stevens, 1928) of peat based on his own works on wood decomposition (Waksman et al., 1928; Waksman and Stevens, 1929), and the roles of water (Waksman and Purvis, 1932) and peat- and water-microbiology:

> *Peat is "a layer of the earth's crust consisting largely of organic matter, which has originated as a result of incomplete and partial [microbial] decomposition of the various constituents of the natural plant materials, due to the anaerobic processes under which plant decomposition has taken place; the nature of the peats depends upon the plant association which has given rise to it and the latter is controlled by the amount of mineral nutrients and reaction of the waters in which the plants are growing; chemically the composition of peat is influenced by the nature of the plant associations from which it has originated and the moisture relations, during and following the periods of its formation and accumulation*".

As he did for other forms of humus, Waksman applied the proximate analysis to humus from different peat profiles, such as a lowmoor peat profile from New Jersey (analysis from 0 to 160 cm depth), and a highmoor peat profile from Maine (from 0 to 580 cm). On this basis, large differences were shown to exist between the lowmoor and the highmoor peat; the lowmoor had a complete absence of cellulose, compared to 6–26% cellulose in the highmoor (Waksman, 1938, pp. 271, 273, Tables 47, 48; Waksman and Stevens, 1928, 1929). Simple compounds (Waksman and Reuszer, 1932) and ligno-protein complexes were also studied by Waksman and Iyer (1932, 1933) from humus peat, as well as for

[1] In a now-fading literary tradition within the sciences, Waksman's "*Humus*" is replete with quotations that introduce the various chapters. The title page bears the elegant quotation from Albrecht Daniel Thaer: "Humus is the product of living matter, and the source of it." For the New Jersey Geological Survey Bulletin on peat published six years later (Waksman, 1942), he chose an Old Scottish saying with a similarly succinct and holistic view of peats and humic materials: "Muck is the mother of the meal chest".