# Variability of the ancient organic supply in modern humus

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**The particulate organic matter isolated from soils and from underlying geologic formations from various french watersheds was studied under the light microscope to determine palynofacies composition. The results reveal that modern humus contain notable amounts of ancient organic constituents inherited from the geologic substratum. This ancient contribution varies both qualitatively and quantitatively, mainly as function of the substratum composition. This implies that the cartography of surface formations and the knowledge of their composition is a prerequisite to the evaluation of the soil organic carbon reservoir and to the determination of its turnover. A more immediate conclusion is to remind us that the coaly debris that occur naturally in soils does not always derive from modern biologic production and from pollution.**

## Introduction

Terrestrial carbon plays a major role within the global carbon cycle. The real role played by plants and soils in buffering atmospheric $CO_2$ concentration is still poorly known. The characterisation of the soil compartment as a carbon reservoir is still the subject of many investigations. The first aimed at the description and at the quantification of soil organic matter [1]. Then, models of organic matter evolution were defined [2,3]. An important issue frequently addressed in the sedimentary fields but usually overlooked in soils, is related to the origin of the organic fraction. Recent studies demonstrate that soils usually contain carbonaceous debris that originate from the underlying substratum, in addition to more or less altered organic material inherited from the plant cover [4,5]. The aim of the present work is to assess the contribution of ancient organic matter. The analytical approach is based on optical identification (palynofacies) of organic constituents present in soils and in underlying sedimentary rocks.

## Study areas

The studied areas were chosen to cover a large set of sedimentary formations and of types of ecosystems.

The first study area is the Peyssiers lacustrine basin. The Peyssiers lake is located at an altitude of 850 m, about 20 km SW from Gap, in the department of the Hautes-Alpes (France). It originates from the artificial damming of a small river. The watershed has a surface area of 5.3 km$^2$. It is mainly constituted with organic matter-rich blue Apto-albian marls [6] and Barremian-Hauterivian limestones. These two lithologies represent 47 and 37 percents of the surface of the watershed, respectively. The actual vegetal cover is mostly




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constituted by grasslands and by forests of beeches and pines. The second study area is the Chaillexon lake catchment, Jura mountain, France. The watershed covers a surface of 910 $km^2$. It is located on the North-western flank of the Jura high Chain [7]. The Chaillexon basin extends from the Mont d'Or to the Morteau plain, at an altitude of 1300 m and of 752 m, respectively. The substratum is mainly constituted with Jurassic and Cretaceous limestones with low organic content (<1% TOC) [8]. However, higher organic matter contents occur in marly horizons dated of the Oxfordian, the Kimmeridgian, the Purbeckian, the Hauterivian or the Albian [4,9]. From a bioclimatic point of view, this watershed is situated in the mountainous stage [10]. The dominant forest cover (Abies and Picea) is punctuated by hydromorphic zones such as Frasnes peat bog. The third study area is the Négron watershed. The Négron is the last tributary of the river Vienne on its left side. The Négron flows into the Vienne at 10 km at the south-west from Chinon. The Négron basin which covers a surface of 162 $km^2$ [11] extends on the Vienne and Indre departments. The basin is constituted with Oxfordian limestones, Cenomanian sands and also with Turonian, Senonian and Eocene limestones and siliceous formations. The study was limited to the Turonian limestones (organic carbon < 0.5%).

## Material and methods

Analyses were carried out both on humus and on underlying sedimentary rocks representative of each of the study area. Because of the intimate relationships between humus and vegetal cover [12,13], soils have been sampled in all the major types of vegetal systems such as cultivated lands, grasslands, and groves of beech, pine and spruce. Following the nomenclature of Jabiol et al. [14] the humus layers were divided into three sublayers successively called: OL at the top which is the litter made of weakly fragmented twigs and leaves, OF composed of leaf fragments and organic faecal pellets resulting from the decomposing activity of the soil mesofauna and OH, the basal layer, made up of faecal pellets exclusively. Beneath lies the A1 layer where the organic matter is associated with the mineral fraction. The samples were prepared according to the method of palynofacies analysis, i.e. by concentration of organic particles through HCl/HF destruction of the mineral matrix [15]. Microscopic analysis shows pollens, microfossils such as acritarchs and kysts of dinoflagellates, more or less altered debris of aerial or aquatic plants, and optically amorphous constituents [15]. Some of the latter constituents are not really amorphous but have a structure - or merely an ultrastructure [16] - which is only observable by transmission electron microscopy (TEM). The degree of diagenetic alteration of the organic constituents can be appreciated by their colour, their progressive darkening with increasing thermal stress being well established [17–20].

## Results and discussion

The results obtained on the Négron and Chaillexon basins will be briefly presented after a more detailed description of those obtained on the Peyssiers watershed. The organic constituents of the underlying sedimentary rocks of the Peyssiers basin on which the soil has been formed mainly appears to be constituted with two types of organic particles (Tab. I): (i) dark amorphous organic matter and (ii) opaque angular debris. The sum of the relative amounts of these two constituents reaches 70.6 to 100% of the total, with a mean value of 93%. Such particles are normal components of the kerogen of mature sediments. The humus and underlying A1 horizons of the Peyssiers basin contain the following types of particles (Tab. II): translucent ligno-cellulosic debris; dark and/or orange amorphous organic matter; opaque angular debris; translucent amorphous organic matter and pollens, spores and other recognisable carbonaceous biological constituents. The litters mainly comprise translucent ligno-cellulosic debris and particles of orange amorphous organic matter. The sum of these two types of debris amounts to about 80% of the palynomorphs. The relative amounts of these two constituents decrease progressively with

**Table I. Organic palynofacies of the geological substratum (Peyssier watershed).**

| *geological substratum* | *ligno-cellulosic debris (%)* | *orange amorphous OM (%)* | *Translucent amorphous OM (%)* | *opaque angular debris (%)* |
|---|---|---|---|---|
| marls | 0 | 0 | 0 | 100 |
| marls | 29.4 | 0 | 0 | 70.6 |
| marls | 7.9 | 0 | 39.4 | 52.7 |
| marls | 4.6 | 0 | 49.7 | 45.7 |
| marls | 5.6 | 0 | 30.8 | 63.6 |
| marls | 3.8 | 0 | 47.2 | 49 |
| marls | 0 | 0 | 33.3 | 66.7 |
| limestones | 0 | 4.2 | 25 | 70.8 |

**Table II. Distributions of organic palynofacies in humus layers *versus* depth (Peyssier watershed). OL: surface litter made of twigs and weakly fragmented leaves; OF: intermediate depth layer composed of leaf fragments and of organic fecal pellets resulting from the decomposition activity of the soil mesofauna; A1: deeper layer where organic matter is associated with the mineral fraction.**

| *humus layers* | *vegetations* | *ligno-cellulosic debris* | *translucent amorphous OM (%)* | *orange amorphous OM (%)* | *spores, pollens (%)* | *dark amorphous OM (%)* | *opaque angular debris (%)* |
|---|---|---|---|---|---|---|---|
| OL | high altitude meadow | 75 | 0 | 5 | 0 | 0 | 20 |
| | Fagus | 30.3 | 21.2 | 30.3 | 15.2 | 0 | 3 |
| | meadow | 75 | 0 | 20 | 0 | 0 | 10 |
| | Abies | 25.9 | 18.5 | 55.6 | 0 | 0 | 0 |
| OF | high altitude meadow | 67 | 0 | 9 | 0 | 18 | 6 |
| | Fagus | 12 | 11.3 | 37.6 | 27.9 | 0 | 11.3 |
| | meadow | 28.3 | 14.3 | 33.4 | 9.8 | 0 | 14.3 |
| | Abies (dark layer) | 5 | 26.3 | 36.8 | 10.8 | 21 | 0 |
| | Abies (red layer) | 5 | 6.7 | 50 | 5 | 23.3 | 10 |
| A1 | high altitude meadow | 0 | 12.5 | 18.7 | 6.3 | 31.3 | 31.2 |
| | Fagus | 2 | 0 | 18.4 | 28.4 | 21.2 | 30.4 |
| | meadow | 6.7 | 0 | 27.8 | 10 | 55.5 | 0 |
| | Abies | 0 | 11.4 | 17.1 | 3 | 28.6 | 40 |

increasing depth. In contrast, the translucent amorphous organic matter does not display any significant trend along the studied profiles. The relative amounts of these debris represent 0 to 22% of the organic matter in the OL horizon and 0 to 12% in the A1 organo-mineral horizon. The amounts of spores, pollens and other recognisable biological constituents never exceed 30% of the organic matter particles, even in the OF and A1 horizon where they are the more abundant. The opaque angular debris and the dark amorphous organic matter – considered as optical markers of the substratum – occur only in notable amounts in the deepest horizon (A1) where they can represent about 60% of the organic particles.

The Meso-Cenozoic marly limestones of the Chaillexon basin mainly contain opaque angular debris which exhibit gel-like homogeneous texture and concoidal breakage [21]. Such debris do not occur significantly in the topsoils. Their abundance increase regularly or sharply with increasing depth under spruce and in dry grassland, respectively. In that latter case the amounts of opaque angular debris increase from 4 to 35% from the OF to the OH horizon [4]. In soils of other ecosystems, the relative amounts of both these particle types vary between 5 and 10%.

The Turonian limestones of the Négron basin are mainly characterised by the presence of translucent angular gel-like particles accompanied by minor proportions of reddish amorphous organic matter. These two palynomorphs occur in the Ap layers of the overlying cultivated soils but at levels which usually do not exceed 6 – 7% for both particle types.

In each of the studied basins, significant amounts (5 – 60%) of ancient organic particles inherited from the geologic substratum occur in the soil A1 layers. The presence of these particle mainly arise from the progressive downward progress of the alteration front of the substratum during soil formation. Additionally, the activity of soil organisms can induce the upward transfert of particles. Another important factor is also the chemical, physical and biological resistance of the ancient organic particles [4]. The abundance of ancient particles depends on the organic matter content of the substratum (Fig. 1). Moreover, there is a qualitative correlation between the substratum particles and the ancient particles found into the overlying soil. For example the limestone substratum of the Négron river produces translucent angular debris typical of immature woody debris, whereas the underlying sediments of the Peyssiers area show angular opaque debris which are typical of geologically mature organic matter from ligno-cellulosic plants.

A synthetical representation of the palynofacies prepared from Meso-Cenozoic rocks from various locations is presented in figure 2 [5,16,21–30]. All the studied formations contain non negligible proportions of organic matter that occurs under different forms such as opaque angular debris and translucent or orange amorphous gels. If one considers that a large part of the French subsurface in constituted with Meso-Cenozoic rocks, it is evident that the overlying soils contains notable amounts of organic matter inherited from the substratum.

## Conclusions

In agreement with recent observations on molecular markers compounds [31], the examinations of soil organic

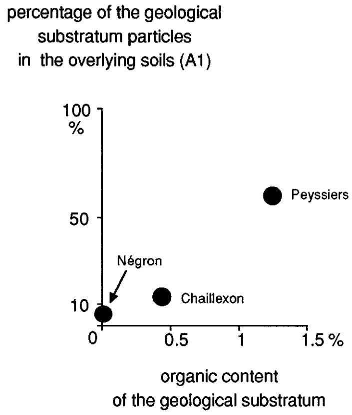


**Figure 1. Contribution of the geological substratum in the organic matter content of the overlying soils (A1) *versus* the organic content of the geological substratum. *Given values for A1 layers are mean values (12 soils, Chaillexon watershed; 5 soils, Peyssiers watershed and 5 soils, Négron watershed). Given organic content of Chaillexon geological substratum is a mean value calculated from marly formations superior to the real value that take into account limestones with low organic content.***

matter under the microscope reveal that they frequently contain particulate organic constituents reworked from the substratum. A similar conclusion was previously established for sediments, e.g. Gadel and Ragot [32] noticed the presence of coaly particles reworked from ancient formations in recent sediments of the Rhône delta. The presence of this material and its proportions must be taken into account in quantitative and/or qualitative organic matter soil studies. A more immediate conclusion is more simply to remind us that the coaly debris that occur in soils does not always derive from recent or present-day local biological production.

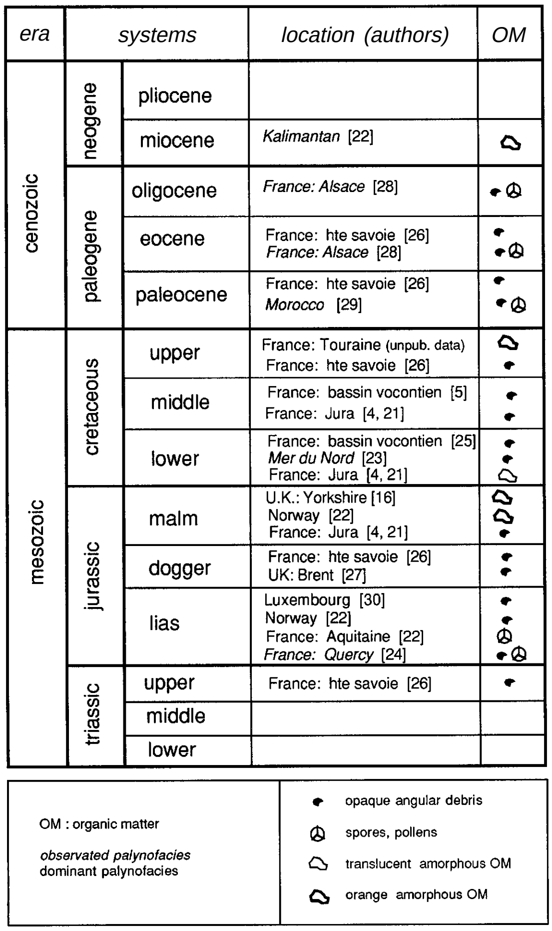


**Figure 2. Examples of organic palynofacies occurring in meso-cenozoic formations.**

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