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THE DOMINANT SOIL TYPES OF THE BELGIAN LOESS BELT IN THE EARLY NEOLITHIC

Résumé

Sont décrits quatre types d'impact anthropogène au niveau des sols de la région des loess en Belgique : 1. des processus d'érosion et de sédimentation, 2. des travaux de drainage, 3. des additions d'engrais organiques et chimiques, 4. des changements dans l'activité biologique des sols. Ces quatre processus ont guidé l'évolution des sols au cours des 7000 dernières années et sont responsables d'un paysage pédologique plus varié aujourd'hui, comptant 5 types de sols importants dont trois sont dominants et fertiles. Au cours du rubané deux types de sols seulement étaient dominants et avaient pour la production céréalière une fertilité chimique et physique très basse. Cette estimation de la paléofertilité est opposée à celle fréquemment mentionnée dans la littérature qui parle de sols sur loess fertiles à travers toute l'Europe au cours du Néolithique. Si les sols dominants sur loess en Belgique étaient très peu fertiles, ce facteur aura certainement joué un rôle déterminant dans une série de comportements des premiers agriculteurs, tels que le choix du site, la durée de l'implantation et la répartition entre récoltes et élevage.

Mots clefs : Rubané, loess, agriculture, sols, fertilité, Belgique.

Summary

Four types of anthropogenic impact on soils of the Belgian loess belt are described, 1. erosion and sedimentation processes, 2. drainage works, 3. organic and mineral fertilizer applications, 4. changes in the soil biological activity. These four processes have guided the soil evolution in the last 7000 years and are responsable for a more varied soilscape today with five important soil types of which three are dominant and fertile. During the Linear Bandkeramic only two soil types were dominant and they had a very low chemical and physical fertility for cereal production. This estimation of the paleofertility is opposed to the one frequently mentioned in litterature announcing fertile soils all through the European loess belt during the Neolithic. If the dominant loess soils in Belgium had a very low fertility, this factor certainly will have played a role in the behaviour of the first farmers, such as the choice of the site, the duration of the settlement and the relative proportion of crop production versus animal husbandry.

Key-words : Linear Bandkeramic, loess, agriculture, soils, fertility, Belgium.

1. Introduction

In 1938 Buttler concluded that the Linear Bandkeramic (LBK) settlements of Central Europe were nearly all situated on loess soils. Today this statement is still valid for Belgium (e.g. Hauzeur 1987).

Two main trends can be distinguished among the hypotheses on how Neolithic man practised agriculture: (1) by the slash and burn method, mostly associated to an extensive shifting cultivation, or (2) by sedentary or permanent agriculture.

Scientists who made a review (e.g. Barker 1985: 141-143, 167, 170; Whittle 1985: 82-83, 87-88) mention that the first important studies which tackled this subject were more in favour of the shifting cultivation (e.g. Clark 1952; Soudsky 1962; Soudsky et Pavlu 1972); later however most studies came to the conclusion that permanent cultivation was reached by some systems of crop rotation and/or manuring and this as well for central as for western Europe (e.g. Murray 1970; Tempir 1971; Knörzer 1972; Kruk 1973; Jarman et Bay-Petersen 1976; Modderman 1976, 1977, Hopf 1977; Heim 1978; Willerding 1980; Rowley-Conwy 1981).

2. Impact of Neolithic and Post-Neolithic agriculture on the soils

In order to reconstruct the soilscape as it was before man started to clear the forest or the grasslands we must know the processes which transformed those original soils into the soilscape we observe today in the field and on the soil maps. In the following paragraphs we briefly summarize the most important soil genetic processes related to the ever increasing impact of man on soils.

2.1. Erosion and sedimentation processes

Pedological and geomorphological investigations have shown that as long as a forest cover was present, no erosion or sedimentation processes occurred in the Belgian Loess belt, except along the river banks and in the active alluvial plains (Langohr et Sanders 1985a).

Today a very large proportion of the loess soilscape is composed of soils developed in «colluvial» deposits, i.e. sediments which settled down on the foot- and toeslopes and in the valley bottoms after they were eroded from the slopes by sheet-, rill-, and sometimes even gully erosion (e.g. Bolinne 1976, 1977; De Ploey 1979). In some of the oldest agricultural areas such colluvial soils may cover up to 25 % of the land surface (Louis 1971).

As a result of this erosion nearly all the slope and plateau soils on loess are partly truncated. The degree of erosion can go from weak (a few centimetres) up to very severe (more than one metre). The erosion is the result of water runoff over a non-protected soil surface, a process mainly associated to agricultural practices. Among these some have a stronger impact than others; erosion is particularly enhanced by 1. cultivation on steep slopes, 2. furrows made parallel to the steepest slope gradient, 3. elimination of weeds (which protect the soil surface), 4. bare soils in the winter period (when soils are wettest), 5. use of heavy machinery (compressing the surface soil horizons), 6. permanent and intensive agriculture, 7. management practices which lower the organic matter content of the surface horizon.

2.2. Drainage

Artificial drainage of the land is important for good crop production on those soils which have a groundwater table close to the soil surface at the end of the winter and in early spring, when farmers want to start to work on the land. Indeed, a water saturated soil in early spring is a «cold soil» holding up the germination of the seeds and the growth of the seedlings; it is furthermore very difficult to create a good surface soil structure and seed bed when working on such a soil. Improving the drainage will also eliminate the risk of a high groundwater table at the end of the summer or in fall, when crops are harvested. So improving the drainage will increase the length of the growing period, a feature not to neglect in temperate regions with a relatively short crop growing period.

From the preceding it is evident why all the imperfectly and poorly drained loess soils on the plateaus and smooth slopes are today artificially drained. The situation is somewhat different on those lowlands and plains where the soils have a permanent groundwater table within crop rooting depth. The drainage of such soils is much more difficult and expensive and farmers mostly prefer to leave these areas under good productive grassland.

2.3. Fertilizer applications

Two main types of fertilizer can be distinguished: organic and mineral.

Among the **organic fertilizers**, manure from domestic animals certainly is the most important one. A distinction can be made between the direct fertilization of the fields by grazing animals (ovicaprids, pigs, cattle) and a bulk input of manure from stables (mainly cattle).

Manuring of the land by the LBK farmers is frequently mentioned in literature (Whittle 1985: 88; Barker 1985: 142, 147). Yet the theory of manure applications (e.g. Rowley-Conwy 1981) is based on the evidences of the presence of these domestic animals on the LBK sites, and not on direct evidences of manure applications.

The same remark can be made even for the early Roman period for which Lindemans (1952: 20) did not find any precise reference to manure applications but where he comes to the conclusion that anyhow the shifting cultivation did not any more exist in large part of Belgium.

It seems mostly forgotten that any of the two organic manure applications mentioned before represent only a **partial** feed back of the nutrients exported from the harvested land. Only manure collected from extra parcels (graslands, forest) would represent a real benefit for the nutrient balance of the soil. Up to now there seems to be no indication for this type of fertilization neither.

From the point of view of soil chemistry the application of manure represents mainly an input of easely plant-absorbable nitrogen to the soil, other elements like phosphorus, calcium and potassium being of secondary importance. Manuring thus will mainly have an impact on the C/N (carbon/nitrogen) ratio and will change little to the other chemical soil characteristics. When the applications are stopped little or no traceable elements will remain in the soil.

Several types of **mineral fertilizer** were applied by Belgian farmers long before the industrial period already. According to the review made by Lindemans (1952: 43) the Romans were surprised to see the Celtic farmers «fertilize soils with soil». Lindemans (1952: 43-51) further states numerous documents dating from the 13th up to the 18th century who refer to «marl applications», mainly in the loess belt. We know that for some of these regions, no marl exists in the subsoil and most probably reference is made here to the calcareous loess which farmers could extract from 3 m depth and more.

Some of the documents detected by Lindemans mention for some areas the replacement of the marl by limestone from the 16th century on. It seems also that the «black marl» mentioned in some documents would correspond to mud extracted from ponds and marshy alluvial deposits. We can assume that, just as today in the loess belt, the alluvial deposits were calcareous and of course at the same time also rich in organic material and nitrogen. This black marl or pond marl thus represents a combination of both organic and mineral fertiliser.

2.4. Biological activity

Soils which are both acid (pH below 4,5) and nitrogen-poor (C/N ratio above 18 to 20) have a very poor biological activity of deeply burrowing earthworms such as the *Lumbricus terrestris*. When these worms are absent, also moles will not colonise the soil and consequently there will be a complete absence of this type of deep faunal pedoturbation.

However when soils are intensively fertilized with manure and because of the concommitant increase in N content and lowering of the C/N ratio, the population density of the *Lumbricus terrestris* will soon increase. The same will occur when calcareous fertilizer is applied as the increase in pH will activate the microbiological activity and thus the production of nitrogen from the faster decomposition of the organic matter.

We can conclude that as a result of any of both fertilization types, organic or mineral, on acid, nitrogen-poor soils, the bioturbation of the subsurface soil horizons, absent before, will increase enormously. This represents an increase in physical fertility but unfortunately at the same time all previously existing morphological characteristics of the upper soil horizons will gradually vanish; this represents a serious loss of information for the paleo-environment reconstruction based on soil characteristics.

3. The main soil types of the loess belt (Table 1)

In the following paragraphs we will briefly describe the main Actual Soil Types (= A.S.T.) covering more than three quarters of the present-day soilscape of the Belgian loess belt. We will also comment on how these soils probably looked like some 7000 years ago, called here the «Original Soil Types» (= O.S.T.), when man for the first time cleared the natural vegetation for agricultural purposes. The reconstruction of the paleo-soilscape will be based on numerous prospections performed as well in always-forested areas (e.g. Langohr et Vermeire 1982; Langohr et Pajares 1983; Langohr 1983a; Langohr et Sanders 1985a, unpublished data) as on Neolithic archaeological sites situated on old agricultural land (Langohr et Sanders 1985b; Langohr 1986, unpublished data).

In this paper we refer to the present-day surface soils developed in the upper loess sediments deposited somewhere between 18.000 and 25.000 years B.P., or early Upper Weichselian; in Belgium these sediments are commonly called the «Brabantian loess» and are thought to be deposited in cold and dry climatic conditions (Haesaerts 1984); over most of the Belgian loess belt they contained 10-15 % calcium carbonate at the moment of deposition.

The classification of the soils is indicated according to the following soil classification systems :

-USAr : the recent North American soil classification or USDA (= United States Department of Agriculture) Soil Taxonomy (Soil Survey Staff 1975);

-Dudal : Dudal (1953) published one of the first important papers on the genesis of the Belgian loess soils, his subdivisions are largely based on the French soil classification elaborated by Aubert (1952);

-USAo : the old North American soil classification (Thorp et Smith 1949);

-Fr : the French soil classification (Commission de Pédologie... 1967);

-FAO : the FAO soil classification elaborated for the Soil Map of the World (FAO 1974);

-Gr : the recent revision of the West German soil classification (Working Group...1985).

Table 1. Correlation between the Actual Soil Types (A.S.T. 1,..) and the Original Soil Types (O.S.T. 1,...) in the Belgian loess belt.
Soil Types (A.S.T. 1,...,O.S.T. 1,...) : see text.
Fertility status (see 3) : VL = very low, L = low, M = moderate, H = high, VH = very high.

Present-day Soil Type (= A.S.T.)				Original Soil Type (= O.S.T.)			
Soil Type	Extension in loess belt (%)	Fertility status		Soil Type	Extension in loess belt (%)	Fertility Status	
		Chemical	Physical			Chemical	Physical
A.S.T. 1	40-50	M	VH	O.S.T. 1 = A.S.T. 3			
A.S.T. 2	10-20	M	H-VH	O.S.T. 2 = A.S.T. 3			
A.S.T. 3	1-3	VL	L-VL	O.S.T. 3 = A.S.T. 3	50-70	VL	L
A.S.T. 4	15-25	M	H-VH	O.S.T. 4 = A.S.T. 5			
A.S.T. 5	1	VL	VL	O.S.T. 5 = A.S.T. 5	15-25	VL	VL

The extension of the various soil types is based on the information gained from the Soil Association Map of Belgium (Marechal et Tavernier 1974) and from personal prospection data.

For the fertility rating, distinction is made between the chemical and the physical soil fertility; five classes are distinguished (Table 1), from «very high» (=permanent agriculture is possible for this fertility factor without any amelioration) down to «very low» (= after clearing of the natural vegetation only one up to maximum three successive crops can be harvested and many decades of natural vegetation growth are required in order to restore the original fertility).

Actual Soil Type 1 (A.S.T. 1) **: Typic Hapludalfs (USAr) developed in thick (more than 250 cm) loess deposits which rest on a permeable substratum (sands, chalk).**

Correlation with other classifications: Sol brun lessivé (Dudal), Sol brun lessivé (Fr), Gray-Brown Podzolic (USAo), Orthic Luvisol (FAO), Typical Para-Brown Earth (Gr).

These soils represent the largest area of the Belgian loess belt (40 - 50 %). They have a uniform brown color, are well drained, are situated on plateaus and smooth slopes and are mostly since more than 8 centuries under agriculture. They have undergone a total erosion of mostly more than 10 and less than 40 cm surface soil. As a consequence of the erosion-sedimentation processes they form a typical soilscape association with relatively extensive «colluvial soils» situated in the smooth depressions.

The pH of these silty soils is situated between 6 and 7 as well in the surface as in the subsurface horizons, they have numerous (600 - 1000 par square metre at 50cm depth) vertical earthworm galleries up to 0.6 cm in diameter. All these characteristics confer a moderate chemical fertility and a very high physical fertility to these soils. In recent years however the physical fertility is decreasing because of a structure degradation as a result of the use of heavy machinery and pesticides.

The ***Original Soil Type 1 (O.S.T. 1)*** was similar to A.S.T. 3 described hereafter. Indeed, field prospection data based on very detailed macro-, meso- and micromorphological descriptions (e.g. Langohr 1983b; Langohr et Pajares 1983; Van Ranst *et al.* 1983; Langohr et Sanders 1985a; De Coninck *et al.* 1986; Langohr 1986; Sanders *et al.* 1986) , clearly show that the present-day Typic Hapludalf (USAr) of the Belgian loess belt corresponds to an original Ultic Fraglossudalf (USAr) of which about 30 cm are eroded (cfr § 2.1.), which is further plowed to a depth of about 30 cm and in which the bioturbation by earthworms and moles has been so active in at least some period(s) since the soil is under agriculture, that the first 10-20 cm of soil below the plowlayer are completely homogenized. This tremendous impact of the burrowing animals, which are completely absent in the profiles under forest (cfr A.S.T. 3), is a consequence of the fertilizer additions applied to these soils since many centuries (cfr. § 2.3. and 2.4.).

Actual Soil Type 2 (A.S.T. 2) **: Glossic Hapludalfs developed in thick (more than 250 cm) loess deposits resting on a permeable to impermeable substratum (sands, clayey sands).**

Correlation with other classifications: Sol lessivé (Dudal), Sol lessivé modal (Fr), Gray-Brown Podzolic (USAo), Orthic Luvisol (FAO), Para-Brown-Earth to Pale-colored Earth (Gr).

This soil type covers 10 - 20 % of the loess belt. It has a brown color with scattered numerous small light grey mottles between 40 and 100 cm depth, is well drained, situated on plateaus and smooth slopes, is mostly under agriculture since less than 8 centuries and has undergone little to moderate erosion (10 - 30 cm); in some relatively small areas where the soils have been cleared from forest since only 150 years the total erosion amounts to less than 10 cm.

The pH of the soil is situated between 6 and 7 in the upper horizons but mostly decreases in the deeper horizons (between 50 and 120 cm depth); there are numerous vertical earthworm galleries (600 - 1000 par square metre at 50 cm depth).

The chemical fertility of this soil type is moderate, the physical fertility however is high to very high; this is a little lower rating than in A.S.T. 1.

The ***Original Soil Type 2 (O.S.T. 2)*** is also, as for O.S.T. 1, identical to A.S.T. 3 described hereafter. The main difference between A.S.T. 1 and A.S.T. 2 is that latter, because of a shorter period of agriculture, has characteristics which are closer to A.S.T. 3 (= the «forest» profile).

Actual Soil Type 3 (A.S.T. 3) **: Ultic Fraglossudalfs (USAr) developed in thick (more than 250 cm) loess deposits which rest on a permeable to impermeable substratum (sands, clayey sands).**

Correlation with other classifications : Sol podzolique (Dudal), Sol lessivé glossique (Fr), Gray-Brown Podzolic to Planosol (USAo), Dystric Planosol, fragipan phase (FAO), Pseudogley - Para-Brown Earth (Gr).

These soils cover today less than 3 % of the loess belt. Between 30-50 and 90-110 cm depth they present abundant prominent light grey mottles in a brown matrix. They are well drained although a perched water table may occur for short periods on top of the fragipan. This particular horizon, whose upper and lower boundaries are situated at 30-50 and 90-110 cm depth respectively, because of a particular porosity pattern including a complete absence of worm galleries, largely stops the root penetration and occasionally slows down the water percolation. These soils are situated on plateaus, smooth slopes and smooth depressions; in latter landscape position the Planosol characteristics and the associated temporary perched water table on top of the fragipan are more strongly expressed. They are under a forest vegetation since at least the beginning of the Holocene and haven't undergone any erosion since the stabilization of the landscape at the end of the loess deposition (Sanders *et al.* 1983; Langohr et Sanders 1985a).

The soil pH is very low with values between 3,5 and 4,6 in the upper 75 cm of the soil and between 4,6 and 5,1 between 75 and 200 cm depth. Because of the very low plant nutrient status in the upper 35-50 cm, where most plant roots grow, these soils have a low to very low chemical fertility; because of the presence of the fragipan whose upper boundary is at 30-50 cm depth, they have also a low to very low physical fertility.

The ***Original Soil Type 3 (O.S.T. 3)*** is similar to A.S.T. 3. Indeed, these soils have always been under forest vegetation and the only differences between 7000 years ago and today in the context of the discussions of this paper are 1. a possible slight lowering (5-10 cm ?) of the top of the fragipan horizon as result of the biological activity (mainly of roots) in the surface soil horizons, 2. a possible slight decrease in nutrient status, and a concomittant slight decrease in pH of the upper 30-50 cm of the soil because of the forest exploitation by man, with export of wood and bark and no fertiliser return.

Actual Soil Type 4 (A.S.T. 4) : **Aquic Hapludalfs (USAr), artificially drained, developed in moderately thick (1-3 m) loess deposits which rest on an impermeable substratum (sandy clay or clay).**

Correlation with other classifications : Sol lessivé légèrement hydromorphe (Fr), Gray-Brown Podzolic intergrading to Low-humic Gley (USAo), Gleyic Luvisol (FAO), Gley-Para-Brown Earth (Gr).

This soil type covers 15 - 25 % of the loess belt. From below the plow layer they show numerous prominent light grey mottles in a brownish matrix, the quantity of these mottles increases with depth. Today they are well or moderately well drained as result of intensive drainage works mainly carried out since World War II. The landscape positions are dominantly plateaus and very smooth slopes with less than 3° gradient. Most of these soils are under agriculture since more than 8 centuries, it were mainly pastures before the drainage works and crops since then. They have undergone an erosion which is mostly limited to less than 30 cm loss of topsoil.

The surface horizons mostly have a pH situated between 5,5 and 7,0, the deeper soil horizons mostly have lower pH values. There are numerous (600 - 1200 per square metre at 50 cm depth) vertical earthworm galleries up to 0,6 cm diameter. The chemical fertility is rated as moderate and the physical fertility as high to very high.

The ***Original Soil Type 4 (O.S.T. 4)*** is similar to A.S.T. 5. When they have been cleared of the natural vegetation for agricultural purposes these soils have remained for many centuries under grassland, mainly because of the drainage problems. As result of the long period(s) of grazing and dung-input, the carbon/nitrogen ratio of the surface horizons gradually decreased and concomitantly the earthworm and mole activity increased; as a consequence the pronounced fragipan characteristics vanished and the physical fertility increased. Afterwards, and mainly in the 20th century, most of these soils have been artificially drained and brought under a permanent crop rotation thanks to important and continuous additions of fertilizers who raised the chemical fertility to the present level of A.S.T. 4.

Actual Soil Type 5 (A.S.T. 5) : **Aeric and Typic Fraglossaqualfs (USAr) developed in moderately thick (1-3 m) loess deposits which rest on an impermeable substratum (sandy clay or clay).**

Correlation with other classifications : Sol hydromorphe peu humifère à pseudogley (Fr), Planosol (USAo), Dystric Planosol, fragipan phase (FAO), Pseudogley - Para-Brown-Earth (Gr).

Soils of this type cover less than 1 % of the present-day Belgian loess belt. They are somewhat poorly to poorly drained and have a water table up to near the surface in winter and early spring. In summer and fall the water table is completely absent from the soil, or may be present up to 1,5 m depth in small areas. The fluctuating groundwater table causes the presence of numerous light gray mottles from below the surface horizon. The quantity of these mottles increases with depth. These soils are situated on plateaus and very smooth slopes (mostly less than 3° gradient). They are since at least the beginning of the Holocene under forest vegetation and haven't undergone any erosion since the stabilization of the landscape at the end of the loess deposition.

The pH is very low with values between 3,5 and 4,6 in the upper 75 cm of the soil and values between 4,6 and 5,1 between 75 and 150 cm depth. Most roots of the ground vegetation are restricted to the upper 15-25 cm because of the presence of a fragipan horizon (cfr. A.S.T. 3) whose upper and lower boundary are situated at 15-25 and 80-130 cm respectively. The very low nutrient status in the surface horizons and the very shallow root-restricting fragipan horizon confer to these soils a very low chemical and a very low physical fertility; they furthermore present for many plant species a problem of waterlogging in winter and early spring and, although the silty texture but because of the very limited rooting depth, a problem of drought in summer and fall.

The ***Original Soil Type 5 (O.S.T. 5)*** is similar to A.S.T. 5 and the comments about minor changes in the soil characteristics from 7000 years ago up to today made for O.S.T. 3, which has also been always under forest vegetation, are equally valid here.

4. Discussion and conclusions

Of the 5 present-day Soil Types discussed here, three, A.S.T. 1, 2 and 4, which cover together at least three quarters of the total Belgian loess belt, present a moderate chemical and a high to very high physical fertility. However, according to the soil evolution theories elaborated by the author and collaborators and largerly commented elsewhere (e.g. Langohr et Vermeire 1982; Langohr 1983a, 1983b; Langohr et Pajares 1983; Langohr et Sanders 1985b; Langohr

1986; Langohr et Cuyckens 1986), these three soils presented some 7000 years ago (O.S.T. 1, 2 and 4) a low to very low chemical and physical fertility (Table 1).

It furthermore appears that the five present-day soil types correspond to only two soil types some 7000 years ago. A.S.T. 3 and A.S.T. 5 represent the best preserved present-day relicts of these two original soil types who covered three quarters and probably even more of the total loess belt in the period when the LBK farmers settled here. As these two soil types had a very low chemical fertility and a low to very low physical fertility, it becomes evident that the soilscape and its intrinsic characteristics had a much more important impact on man's behaviour in Western Europe than in the Chernozem (= soil with a very high chemical and a very high physical fertility) dominated soilscape of some areas of Central Europe and the Balkans (e.g. Kruk 1973, 1980; Willerding 1980). As these two dominant soil types of the Belgian loess soilscape did not permit a permanent agriculture and as even a shifting cultivation with a rotation of a few decades is questionable, it is clear that subjects like the settlement location, the permanency of the settlement, the proportion of crops and animal husbandry in the farm production, must be interpreted keeping in mind a much larger soilscape variability throughout the European loess belt than what is generally described. These conclusions are rather opposite to interpretations made on soil fertility and/or permanency of agriculture in LBK settlements in Western Europe (e.g. Heim 1978; Lüning 1982; De Grooth et Verwers 1984; Barker 1985; Wittle 1985; Van de Westeringh 1986).

Further research in detailed soilscape reconstruction of the near surroundings of the LBK villages is needed in order to detect the eventual importance of soil types with less extension but higher fertility status than the dominant soil types discussed here. A few of such investigations have already shown that some wetland soils (Gosselin 1986), and particularly soils with a permanent groundwater table (Langohr et Sanders 1985b), could have been of major importance. Research of this kind on many more settlements is however necessary if we want to understand the precise behaviour of these first farmers. In addition particular attention should go to all information, positive or negative, on the fertilization of the agricultural land with organic and/or mineral fertilizers. The fact, for example, that there was apparently little or no cattle stalling in the neolithic houses (Waterbolk 1975) would be an indication that the manure input to crop parcels was rather of a direct type (animals grazing directly on the harvested land) than the application of transported manure. We also know nothing about the eventual use of chalk as an excellent mineral fertilizer for acid soils.

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