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Title: Calcareous concretions in the Levriere (tributary of the Epte, secondary tributary of the Seine, Eure department)

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# Calcareous concretions in the Lévrière (tributary of the Epte, secondary tributary of the Seine, Eure department).

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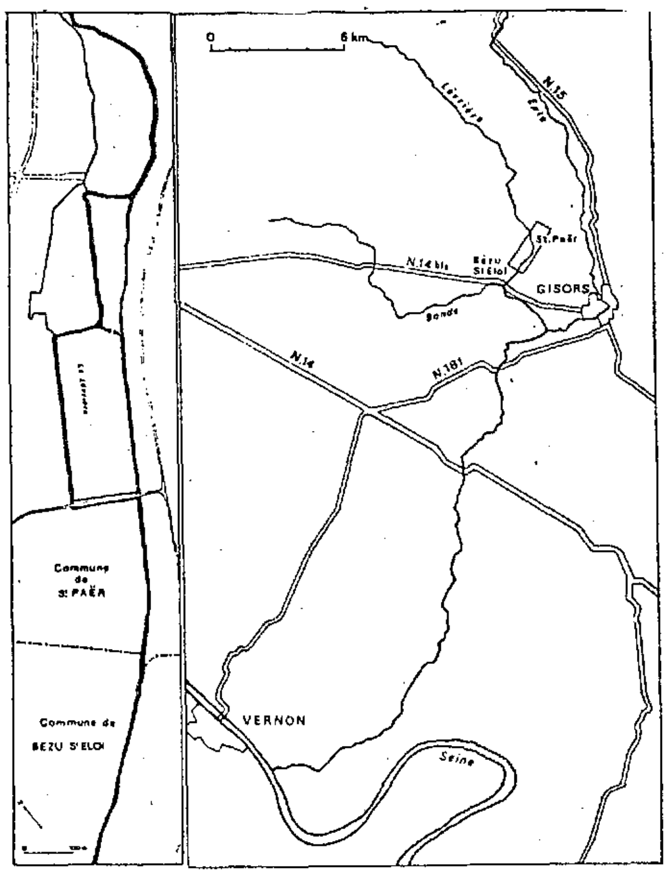
## Introduction

From research carried out on a section of the Lévrière, we observed concretions (granules, nodules, which were sometimes joined together) partly covering the river bottom.

Such calcareous precipitations have already attracted the attention of many researchers [Bourcart, Borzi A. (1883), Butcher R.W. (1932), Couteaux M. (1969), Cornet J. (1899), Fremy P. (1926), Lohest M. (1899), Forir H. (1904), Meunier S. (1899), Symoens J.J. (1947 & 1967), Tilden J.E. (1897), Van Oye P. (1937), Wallner J. (1934)]. Their work has above all centred on the determination of the vegetation enclosed by the precipitations.

We propose to make besides a ~~examination~~ petrographic examination of the calcareous precipitations and to see if their origin is connected to a biological activity, or if it is purely a case of a physical-chemical precipitation.




Position of the water course

## Calcareous concretions in the Lévrière

### 1. Hydrological background

The Lévrière is a small river of the Normandy Vexin, which rises south east of the Bray country (at an altitude of 120 m) and which travels about 30 km before entering the Epte below Gisors.

Its average flow is less than 1 $m^3 s^{-1}$ and the average current velocity is about 0.30 $m\ s^{-1}$. The depth, which is variable, rarely reaches 1.50 m; the width of the river bed never exceeds 12 m.

The river flows over clay and flint for the length of its course, which explains the consistency of the bottom which is dominated by fine sand and fragments of flint and siliceous material where it is not mud.

The section under discussion, about 2 km long, is limited upstream by a mill race. Below this obstacle the water flows swiftly for a hundred metres, then more slowly (with some meanders and widening of the bed). The bottom, pebbly near the mill race, shows finer and finer particles as one moves downstream until it forms sand and mud banks. The first calcareous concretions are seen at the level of the separation of the river into parallel channels lying NW-SW, a kilometre below the mill race (Fig. 1).

The course of the Lévrière, at sites at the communities of Saint-Paer and Bézu-Saint-Eloi, has been the subject of consistent treatment, the scattering of powdered chalk (particles of several microns), with the aim of:

1. Dissipating the mud;
2. Following the evolution of the phenomenon; and
3. Studying the action of chalk on mud.

The treatment by chalk has created a change in the morphology of the river bed after a progressive cleaning of the mud banks: some of them, having completely disappeared, have given place to concretions, which is the subject of the present note.

### 2. Macroscopic and microscopic study of the concretions

#### A Macroscopic study

They occurred in the form of granules (the size is in the order of mm) or of nodules (in the order of cm), rather rounded, ovoid or cylindrical, forming a crust when they are joined together.

Their natural colour is chestnut, but after a long time in the open air, the surface exposed to the light takes on a whitish or blue-mauve tint. Dissected, the concretions offer alternate light and dark zones of different hardness (photo 1, sheet 2). Their density is low (wet density 2.0; dry density 1.4) and the current sweeps them along easily by rolling them and saltation . There appears to exist a connection between these movements and the size of the zones.

In addition insect larvae (larvae of the Goeridae family, Silo) establish bridges between certain concretions, so that the forming of the concretion no longer appears around the granules and nodules, but only on the surface exposed to light. The concretion spreads out, making a crust which covers the whole. This phenomenon can occur over several square metres.

B Microscopic study

On a thin plate (sheet II, photo 1) the concretion appears very porous. The empty spaces represent light zones, while dark zones are joined up by shafts (sheet II, fig. 2). The shafts, like the dark zones, consist of crystals which are shown to be calcified partitions of algal filaments of a basically radiating orientation. The crystals (smaller than a micron) are arranged in rings or according to the orientation of a cylinder representing the filament, with a specific morphology for each type of alga. Their diameter is between 2 and 10 $\mu$. The concretion always begins with a dark zone and discontinues, anchored in a central matrix (fragments of silex, limestone, brick, charcoal, sheaths of insect larvae, sand etc.). The last dark area, little different from the earlier, suggests that the incrustation is produced at the same time as the algal activity.

With the aid of M. Bourrelly, Professor at the Muséum d'Histoire Naturelle de Paris, we have identified the following algae (previously isolated from the concretions using 10% hydrochloric acid):

Stigonema (Cyanophyceae, unknown species). This alga lives in water or on wet rocks. Stygonemaceae are filamentous Cyanophyceae characterized by the formation of lateral branches following the evolution of a cell divided from the trichome lengthways. Propagation is effected by hormogones, hormocysts, spores, solitary gonidia or part of chroococcoïdal masses. They live in thermal fresh water or are underground. Otherwise they are in the same family as Chamesiphonaceae or Rivulariaceae.

Lyngbya calcarea (Tilden) Symoens (Cyanophyceae)

L. martensensiana Menegh var. calcarea Tilden. The encrusted filaments have a diameter of about 7 microns, they are more or less straight. Trichomes are without constrictions at the septae and at their extremities have a diameter of 5.5 $\mu$ to 6 $\mu$. The length of the cells is from 1.3 to 2-2.8 $\mu$, the anterior cell is rounded and there is no cap. This diagnosis was given by Tilden in 1897 and this alga was reported in different calcareous incrustations in North America and in the Tatras, the Namurous, the Somme, and the Hérault in Europe. The sheath of this Cyanophyceae is firm.

Gongrosira species (Chlorophyceae). This filamentous alga has a thallus strongly encrusted with limestone and the small branches are abundant. The width of filaments varies between 10 to 15 μ, the small branches having a narrower diameter. The cells of the filaments are 13 to 18 μ long but are 12 to 21 μ for terminal branches of the main axes. Gongrosira waa found at Messina (Sicily) in 1883 and described by Borzi on the walls of an old aqueduct and only found again in Belgium in 1948 (incrustations on pebbles in a stream of the Hautmont wood).

From the measurements taken, both from the concretions collected from cages left on the river bottom, and from those kept in running water in tanks in the laboratory, it appears that their growth is in the neighbourhood of 1 mm a year (sheet III). At the time of this last experiment the debris of eruptive rocks (rhyolite, free of all calcium carbonate deposit) put in the running water flowing over the concretions, were covered again with carbonate domes 1 mm large. These domes are a result of the development of air circulating round the colonising algae; their juxtaposition and the piling up of the successive colonies creates a rounded outer appearance of the concretion. The dark areas can be compared to the arches of a bridge and the pillars which connect them to the piles. The clear zones thus correspond to the spaces between the piles supporting the dark zones. The piles are the point of departure of the whole colony of which the greatest growth takes place in spring, summer and autumn. (Fig. 2, sheet II)

Photo 3 (sheet II) taken with an electron microscope shows the different stages of the incrustation of the algae: it is made of material growing in the membrane of the filament, then progressively reaches the centre. It is also vertical and perhaps the crystal rings mark the stages of these deposits. It is probable that a precipitation takes place around the filaments, in the mucilage of the algae, explaining their occasional union.

These first observations allow one to envisage that the accumulation of calcium carbonate is at the same time both intra- and extra- cellular. The studies are undertaken in order to make sure about the nature of the organelles of the cell which participate in the formation of the initial calcareous deposit.

3. Conditions of the formation of the concretions

The solution of calcium carbonate by $CO_2$ is facilitated at the gravel surface by conditions of pressure in excess of atmospheric pressure. (....?....) The development of different concretions occurs following a process shown by the following equilibrium:

$$[CO_3H]_2\,Ca \rightleftarrows CO_3Ca + H_2O + CO_2$$

In addition, the rise in temperature and pH, associated with the encrusting activity of the algae, favours the precipitation of calcium carbonate in a very weak solution. (14 mg/l in water at 25° C)

The analyses carried out during the field studies from January 1970 to February 1971 corroborate the preceding remarks. In effect the main variations occur between the source and site 2 and between sites 4 and 5. Graphics 1-10 (sheet IV) show that:

1. As soon as it emerges, the water at the stream bed surface is impoverished of $CO_2$, bicarbonates, calcium, but enriched in oxygen (mixing of the water) and at the same time the water becomes more alkaline;
2. Certain variables, such as pH and $CO_2$ are stable going downstream (site 5):
3. Bicarbonate, calcium, conductivity augment slightly at sites 3 & to reach a maximum at site 5, explained by the contribution of the Bonde river which emerges upstream of site 5 in the Lévrière;
4. The water temperature decreases while flowing downstream: it is subjected directly to the air temperature which is cold in winter;
5. At the source, the rough water cleans the silex nodules present at the bottom of the arrival basin, making them completely clean and smooth to the touch.

   The first kind of concretions (granules) develop upstream of site 2 as far as site 5 (crusts) with a maximum thickness of 50 cm from site 4.
6. The chemical analysis of the incrustations shows the following average content:
   - $CO_3Ca$: 80% (in the form of calcite determined by the microscope polarising and by X rays);
   - $CO_3Mg$: 13%
   - organic matter: 5% (proportion by loss on combustion)
   - diverse (trapped grains of mud, clay, diatoms): 2%

Among the parameters of the environment described above some react on the activity of algal colonies. One would say that incrustations are maximum in time and space, when the conditions of precipitation of calcium carbonate by biological means are favourable. Among the rest:

1. Incrustations increase very little in winter, but very much in spring, summer and autumn (maximum photosynthesis);
2. Concretions like photosynthesis go on increasing from site 2 to site 4 and 5 in summer, parallel with the warming up of the water.

The scattering of chalk has eliminated mud and brought to light the anterior concretions at the area of silting up, explaining the increase in the number of nodules in the section treated. It is certain that the artificial deposits of chalk are not at the origin of the concretions; on the one hand, they appear upstream of all chalk distribution and on the other, from site 2 the water course reaches a pH approaching a pH of saturation point.

Conclusion

The results of the microscopic studies of the concretions speak volumes; they are constituted solely of encrusted algal filaments, above all with calcium carbonate. This structure explains the physical properties of the incrustations (weak density and high porosity).

Without departing from the possibility of a physico-chemical precipitation of calcium carbonate, from the presence of algae and above all from the study of its activity one should reach the conclusion that the precipitation is essentially biological. Diverse experiments have allowed one to clarify the way algal colonies have developed and to establish a relatively precise measure of their growth.

As borings in the original river bed and in the channels excavated in the last century have revealed several levels of concretions separated by mud banks, it is certain that the alternate concretions and mud are not a new phenomenon and that it occurred many times in former years.

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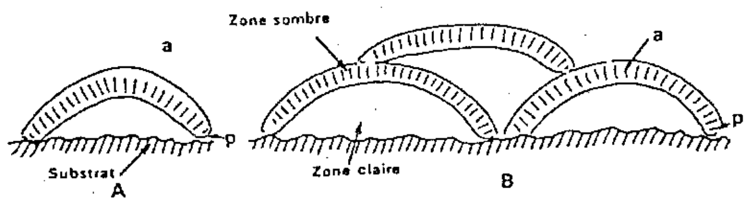
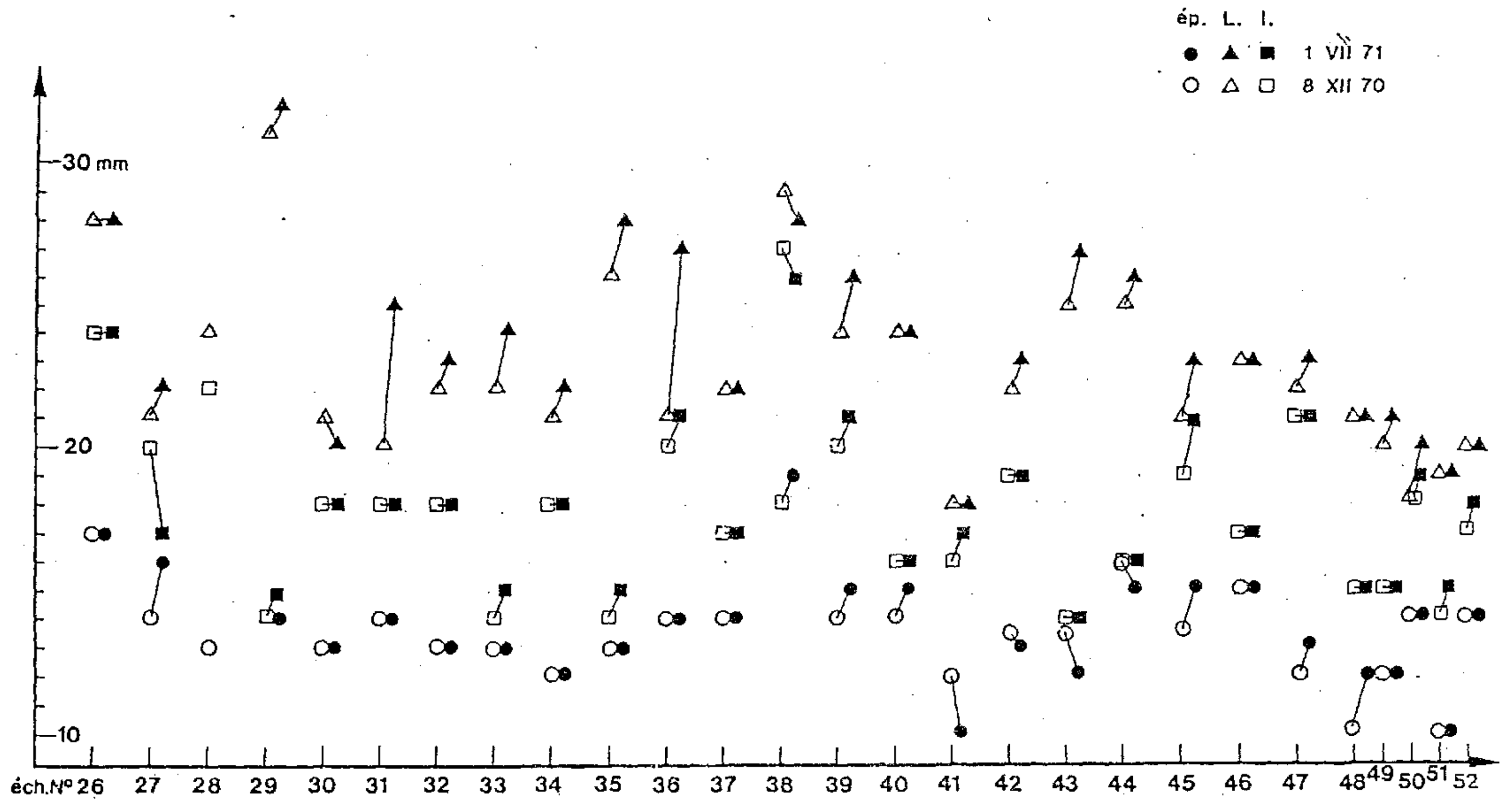
1. Cross section of a concretion. It shows alternating light and dark zones of different hardness (x 6)




2. A. Plan of one arched colony

   B. Juxtaposition and piling up of several colonies
   They show the external rounded aspect of the concretion

3. Algal filament of the concretions (x = 1 100)




Measurements of the growth of the concretions in the Lévrière

PLANCHE III. — *Mesures de croissance des concrétions de la Lévrière.*

(ép. = épaisseur, L. = longueur, l. = largeur, étant convenu que L. est la plus grande dimension mesurable sur la concrétion ; l. la plus grande dimension mesurable dans le plan perpendiculaire à L. et ép. la plus grande dimension mesurable perpendiculairement à L. et l.)

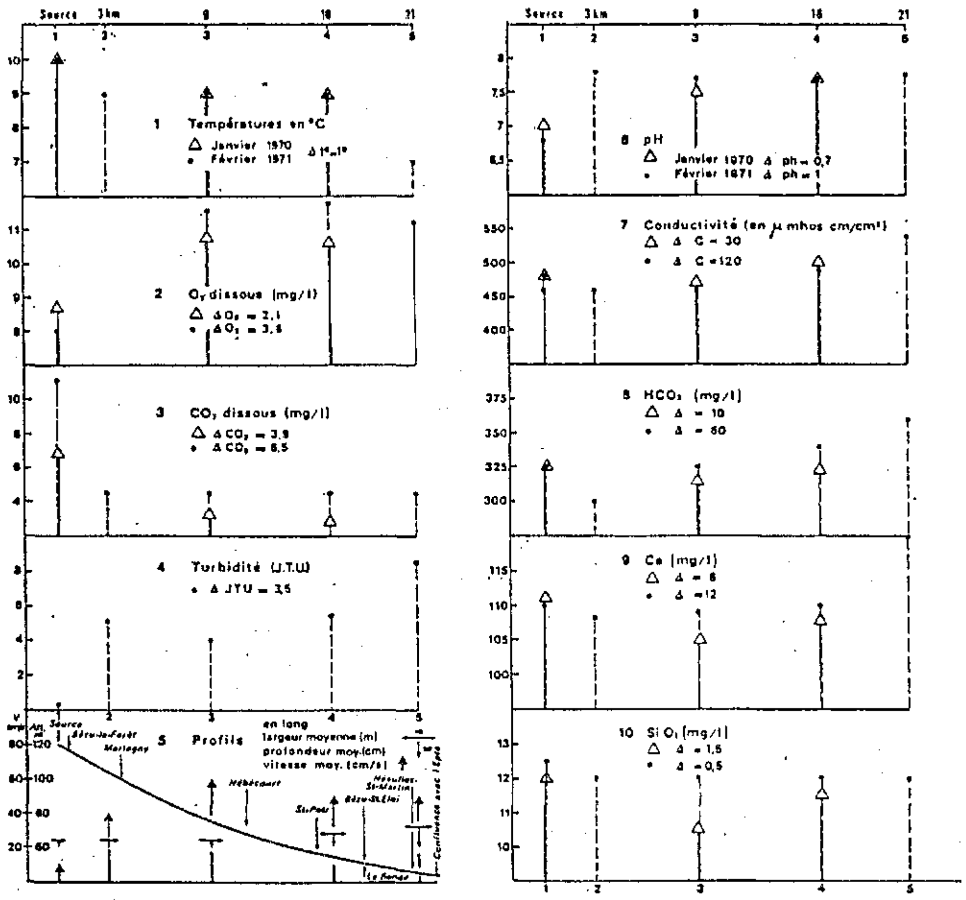



FIG. 1, 2, 3, 4, 6, 7, 8, 9, 10. — *Physico-chimie des eaux de la Lévrière.*
FIG. 5. — *Profils de la rivière aux endroits de prélèvements.*

PLANCHE IV.

Physico-chemistry of the water in the Lévrière

Fig 5. Profile of the river at the sites of previous deductions

**Notice**

Please note that these translations were produced to assist the scientific staff of the FBA (Freshwater Biological Association) in their research. These translations were done by scientific staff with relevant language skills and not by professional translators.