PEDOLOGIE, XXV,2, p. 126-133, 3 fig., Ghent, 1975.

MINERALOGICAL COMPOSITION AND ORIGIN OF MARINE CLAYS IN THE POITOU COASTAL PLAIN (France)

R. Nijs

1. Introduction

Between the estuaries of the Loire and the Garonne, the French Atlantic coast is characterized by several extented coastal plains (« Marais » or « marshes ») with a Holocene subsoil, consisting of marine Scrobicularia-clay (the so-called « bri »). In order to gather more information about the origin of this clay, its mineralogical composition was studied by means of X-ray diffraction on oriented clay preparations. The samples originate from the « Marais Poitevin » and their representativity is supported by a detailed soil survey (Nijs 1974). In this important coastal marsh the « bri » can be divided into three facies : the greyish brown recent marine clay or « bri marin récent » close to the shore, the olive grey older marine clay or « bri marin ancien » more inland, and the continental facies or « bri continental » in the parts of the coastal plain most remote from the sea.

2. The mineralogical composition of the « bri »

Figure 1 shows the diffractograms of the « bri marin ancien » taken at La Taillée (Vendée) at a depth of one meter. It clearly shows the presence of well crystallized illite (sharp and high peaks at 10.05, 5.03 and 3.34Å) and kaolinite (7.18 and 3.57Å). After saturation with glycol, the broad peak centered around 13Å (visible in the upper curve) moves to the right and reaches a maximum intensity at 17.1Å. This suggest the presence of an important amount of

(*) Beidellite belongs to the smectite group, that also includes montmorillonite. The distinction between both has been made by saturating the clay with Li^+, and heating it at 250° C.. After this treatment, montmorillonite does not swell up to 17Å after glycol saturation (Greene-Kelly-test, 1953). For the sake of simplicity, no further distinction has been made between beidellite proper and the other minerals belonging to the beidellite group like saponite and nontronite. Hence the term beidellite should be considered here in its broadest sense.

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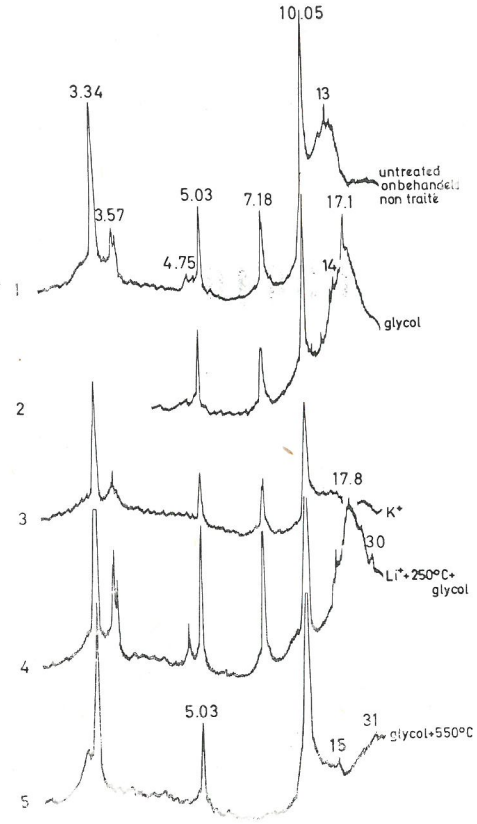

Fig. 1

« Bri marin ancien » (La Taillée) at 1 m depth: X-ray diffractograms of the clay fraction.

« Bri marin ancien » (La Taillée) op 1 m diepte: X-straaldiffraktogrammen der kleifraktie.

« Bri marin ancien » (La Taillée) à 1 m de profondeur: diffractogrammes de la fraction argileuse.

relatively well crystallized beidellite(*), as the peak is still present at 17.8Å after Li^+-saturation, followed by heating at 250° C and glycol saturation. It should be emphasized that the 14Å-peak stays quite clearly visible. The small peaks between 10 and 14Å are probably due to the presence of small amounts of open illite(**) and/or open illite-vermiculite(***) and/or open illite-beidellite mixed layers. After heating to 550° C, all the clay minerals collapse to 10-11Å and only a small reflection remains near 15Å. This indicates the presence of chlorite, of which the amount however is too small to explain the high refraction at 14Å after glycol saturation; apparently vermiculite is responsible for this.

All studied samples of « bri marin », taken at different depths and in different locations of the Marais Poitevin showed similar

(**) Unlike illite, that yields sharp and narrow peaks, open illite is characterized (after Mg^{2+} - or Ca^{2+} -saturation) by a 10 Å-peak with a « tail » up to 11-12 and even 14Å (degrading illite, Brown 1961).

(***) Vermiculite is a clay mineral that opens up to 14-14.5Å if saturated with Ca^{2+} or Mg^{2+}, but fails to swell more, even after glycol saturation.

diffractograms. This clearly proves that the marine clay — « bri ancien » as well as « bri récent » — is characterized by a mineralogical association that remains remarkably constant in depth and over large distances. Pedogenesis does not seem to have influenced the clay composition of this recent soils yet(****).
The mineralogical composition of the « bri » may be summarized as follows :

— dominance of well crystallized illite and kaolinite
— some open (weathered) illite
— some chlorite
— some vermiculite and open illite-vermiculite mixed layers
— an important fraction of generally rather well crystallized beidellite
— some mixed layers of open illite-beidellite
— very few or no montmorillonite at all.

3. The mineralogical composition of the continental Holocene deposits

The most obvious source of this homogeneous clay is the alluvium of the coastal rivers. After being transported to the sea, it could have been deposited as « bri » along the coast. To check this possibility, the clay composition of the purely continental sediments of the coastal plain has also been analyzed.

Figure 2 shows the X-ray diffractograms of a sample from the Sèvre alluvium. They reveal a quantitative difference with the « bri » rather than a qualitative one : the illite content strongly decreases while the beidellite content increases so that after glycol saturation the 17-19Å peak shows a much higher intensity than the main illite peak. All the studied alluvial samples, as well as those from the « bri continental », showed this feature; furthermore, in most of the samples the abundance of mixed layer minerals (especially illite-vermiculite) caused the « flow open » between 10 and 14Å.

This alluvial clay mineral association has been directly inherited from the soils on loess and on Jurassic marls upstream in the basin, as demonstrated by the study of their clay fraction (Nijs 1974), evidently because the soil erosion provides the material of which the alluvium is built up. As the parent material of those soils never contains any beidellite (fig. 3), it is logical to conclude that the degradation of illite to open illite, vermiculite, beidellite (and a

(****) Perhaps the reduced illite crystallisation in the humus-rich top horizon of several « bri »-soils is to be considered as a first step towards illite degradation as a result of pedogenesis (DUPUIS e.a. 1965).

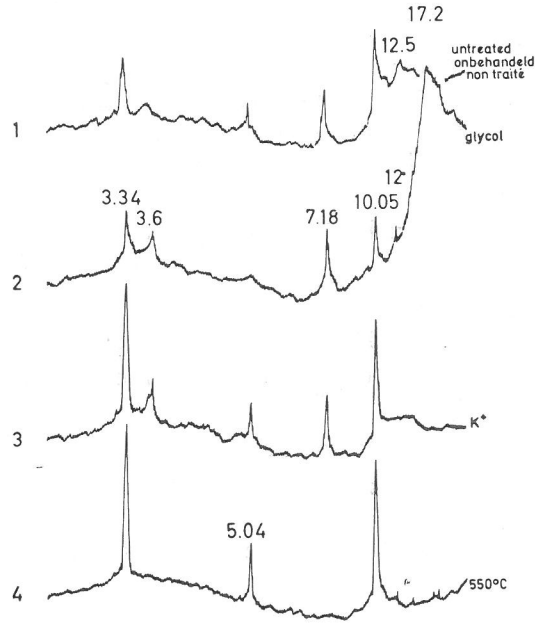

Fig. 2

Alluvium (Coulon) : X-ray diffractograms of the clay fraction.

Alluvium (Coulon) : X-straal diffraktogrammen der kleifraktie.

Alluvions (Coulon) : diffractogrammes de la fraction argileuse.

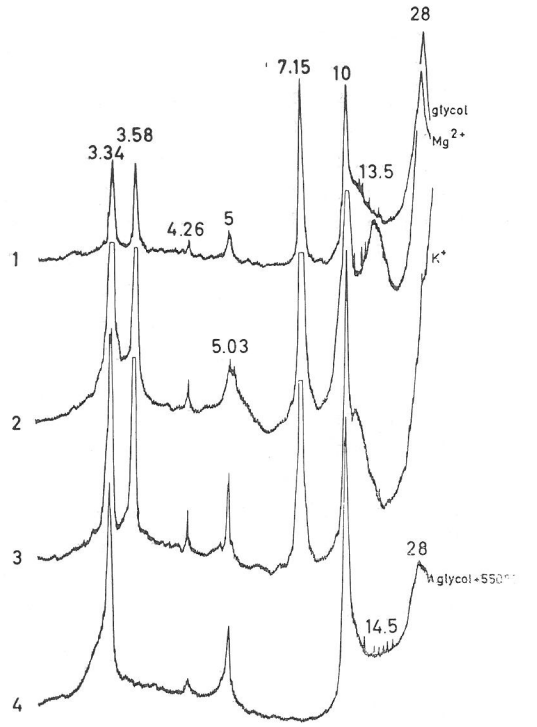

Fig. 3

Callovian marl (Maillezais) : X-ray diffractograms of the clay fraction.

Calloviaanmergel (Maillezais) : X-straal diffraktogrammen der kleifraktie.

Marnes calloviennes (Maillezais) : diffractogrammes de la fraction argileuse.

range of transitional interstratified minerals) seems to be the main pedological processus taking place in this material during soil formation.

4. Relation between marine and alluvial clay — Conclusion

Although the clay mineralogy of most river basins of the region is characterized by a high content of interstratified minerals and beidellite, with relatively few illite, the marine clay deposits consist of much better crystallized illite, less beidellite and few mixed layer minerals. Qualitatively, the mineralogical parenthood is quite clear, making the hypothesis of a far origin of the marine clay superfluous. Probably the quantitative differences should be attributed to agradation in a marine environment (MILLOT 1964) of the detritical interstratified minerals into illite. This process would have been limited to those clay minerals in which the illite framework was still rather well preserved (open illite, eventualy interstratified with vermiculite). The structural difference between illite and vermiculite proper, as well as beidellite, final product of the continental illite weathering, would already be too large to allow an easy agradation. Hence, these minerals — especially the latter — are still strongly represented in the present marine mud deposits (VERGER 1968) and in the « bri » of the coastal marshes.

However, the present alluvial load of the local rivers is doubtless much too small to explain the enormous masses of « bri » with which the coastal marshes are filled up. Most probably there is also an important supply of mud stored rather close to the shore, on the continental flat (Atlas de France; VERGER 1968). There are indications that the bulk of this material has been deposited there as a detritical product from the Jurassic marls during the low sealevel periods of the Pleistocene, that were also periods of very strong erosion on the continent in the areas with a Callovo-Oxfordian subsoil (NIJS 1974). Originally, the mineralogical composition of this material must have been closely related to that of the present alluvium. Obviously, the Flandrian transgression did mobilize these mud masses and — with regard to the preceding remarks — one may attribute to the « bri » — notwithstanding its « marine » nature — a merely undirect continental and local origin.

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Summary

The mineralogical composition of a well chosen set of Holocene marine clay samples from the Marais Poitevin, the most important coastal marsh of France, consists of well crystallized illite and kaolinite, and an important amount of beidellite. Chlorite, vermiculite and other interstratified clay minerals only occur in small amount.

There is a clear qualitative parenthood between this composition and that of the recent alluvium of the local rivers, which makes a far origin of the marine clay superfluous. Quantitatively however, the alluvium shows a lower illite content and a dominance of (mostly interstratified) illite weathering products. As a matter of fact, the mineralogical composition of the alluvium has been inherited from the soils of the region (developed in Jurassic marls), characterized by pedogenetical degradation of illite into open illite, vermiculite, beidellite and a large range of interstratified minerals. In marine environment agradation into illite of the alluvial minerals, in which the illite framework was still rather well preserved, probably took place; hence the marine clay shows a lower content of interstratified minerals and a better crystallinity. Finally, an important part of the enormous « bri »-masses must consist of remobilized sediments stored close to the shore on he continental shelf and accumulated there as a detritical product of Jurassic marls during the Pleistocene periods with a low sea-level and characterized by strong erosion on the land.

Consequently, the origin of the bulk of the marine clay or « bri » in the Poitou coastal plain may be considered as (merely undirectly) continental and local.

Samenvatting

Mineralogische samenstelling en oorsprong van de mariene klei van de kust van Poitou (Frankrijk)

Met behulp van de X-straal-diffraktietechniek werd de mineralogische samenstelling onderzocht van een welgekozen reeks Holocene zeekleimonsters, afkomstig uit het Marais Poitevin, de grootste van de vier kustvlakten tussen de monding van de Loire en de Garonne. Deze zeeklei of « bri » bleek hoofdzakelijk te bestaan uit goed gekristalliseerd illiet en kaoliniet, en een belangrijke hoeveelheid beidelliet. Verder kwamen nog wat chloriet, vermiculiet en geïnterstratifieerde mineralen voor.

Vergelijkt men deze samenstelling met die van het recent alluvium van de plaatselijke rivieren, dan stelt men een kwalitatieve verwantschap vast, die een verre oorsprong van de zeeklei onwaarschijnlijk maakt. Kwantitatief verschilt het alluvium echter door een geringer illietgehalte en een overwicht van (meestal geïnterstratifieerde) illietafbraakprodukten. De kleimineralenassociatie van het alluvium werd immers overgeërfd van de bodems van de streek (Juramergelverweringsbodems), waarin illiet pedogenetisch wordt omgezet tot open illiet, vermiculiet, beidelliet en een hele gamma interstratifikaties. Vermoedelijk werden de kleimineralen van het alluviaal materiaal, waarin het illietrooster nog tamelijk gaaf bewaard was gebleven, door agradatie in marien milieu weer tot illiet omgezet; vandaar het geringer aantal interstratifikaties en de betere kristallisatiegraad bij de zeeklei.

Tenslotte moet een belangrijk deel van de enorme « bri »-hoeveelheden afkomstig zijn van de voor de kust gestockeerde sedimenten, die daar werden afgezet tijdens de afbraak van de Juramergel op het land gedurende de Pleistocene erosiefasen met lage zeespiegelstand. De zeeklei of « bri » zou dus een (hoofdzakelijk onrechtstreekse) kontinentale en lokale oorsprong hebben.

Résumé

La composition minéralogique et l'origine de l'argile marine des côtes du Poitou (France)

La composition minéralogique d'une série bien choisie d'échantillons d'argile marine prélevés dans le Marais Poitevin, le marais côtier le plus important de la côte française, a été étudiée à l'aide de l'analyse aux rayons X. Cette argile ou « bri » se compose principalement d'illite et de kaolinite bien cristallisées, et d'une fraction importante de beidellite. La chlorite, la vermiculite et d'autres minéraux argileux interstratifiés ne s'y retrouvent qu'en faibles quantités.

Il y a une nette parenteté qualitative entre cette composition et celle des alluvions récentes des rivières locales, ce qui rend improbable une éventuelle origine lointaine du « bri ». Cependant, les alluvions en diffèrent dans ce sens, qu'elles contiennent moins d'illite tandis que les minéraux d'altération de l'illite, généralement interstratifiés, y dominent largement. En effet, la composition minéralogique des alluvions a été héritée des sols de la région développés dans des marnes jurassiques et caractérisés par l'apparition d'illite ouverte, de vermiculite, de beidellite et d'une gamme d'interstratifiés formés aux dépens de l'illite par des processus pédologiques. En milieu marin, une

agradation vers l'illite des minéraux alluviaux ayant conservé une structure illitique assez intacte se serait opérée, d'où la meilleure cristallinité et la faible teneur en interstratifiés du « bri ». Finalement, une fraction importante des masses énormes de « bri » doit provenir du remaniement récent de sédiments accumulés non loin en avant de la côte pendant les bas niveaux marins du Pléistocène contemporains d'une forte érosion des marnes jurassiques du continent.

On peut donc attribuer au « bri », malgré son caractère marin, une origine (indirectement) continentale et locale.