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Microfabric of Guadalquivir 'Blue Marls' and its engineering geological significance

Microstructure des 'marnes bleues' du Guadalquivir et sa signification en géologie de l'ingénieur

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ABSTRACT: A detailed microfabric study was carried out on samples from the so-called Guadalquivir "Blue Marls" located in Southern Spain using the scanning electron microscope technique. The study has shown that the over all microfabric features of these overconsolidated "Marly Clays" is predominantly a "clay matrix" type. The platy clay minerals within this matrix are arranged in a different manner the most common one being a randomly oriented "aggregate" of clay mineral particles. Some coated silt and sand sized grains mainly organism tests were also present sinking in the dense matrix, where the clay particles were oriented around them . Various areas of local parallel orientation of clay minerals in a "Face to Face" and "Edge to Edge" interaction are also present in all the samples studied. However, a pronaunced parallel orientation of clays along the bedding plan was not apparent here. In addition to this the influence of the "Wetting and Drying" process in the microfabric of this soil was assessed.

Résumé: Un détaillée dùne Microstructure a été réaliseé sur des échantillons de ce qui apparait comme les ""Blue Marls" du Guadalquivir, au sud de l´Espagne, en applicant la technique de microscope électronique a balayuge. L´e´tude a démontre que l´essemble des e´lements de microstructure de ces argiles marls surconsolidée est fondamentalement une "argile matrice" parmi ces matrices, les argiles minerales se présentent dans un ordre diffeénte dont le plus courant est un "agrégat" oriendé au juge´Par hasard. Certains mineraux de la forme de silt and and couverts minéraraux argileux principalement de fossiles sont présents dans la dense matrice où des plaquettes d´argil toutnent autour déux. Pluseurs zonaes orienteés paralélemet vers les minéraux argileux, se retrouvent aussi, dans tous les échantillons examinés. Néanmoins, une orientation paraléle significantive de l´argile , an plan de la sédimentation n´a pas été trés apparente. En plus, l´influence du procés de 'wetting and Drying , dans la microstructure a été étudiée.

1 INTRODUCTION

The Guadalquivir "Blue Marls" formation has been deposited in the Guadalquivir basin, (Southern Spain) in stable marine waters during middle to upper Miocene with out any significant eustatic changes (Perconing 1962). These sediments have been overconsolidated (Liquidity Index less than 0) as a result of great depths of overlying sediments in the past without being lithified. In hand samples the main feature of the unweathered soil is that it is a fine grained clay with massive and compact texture being hard to stiff and a blue and medium grey coloured, but where weathering has occurred it is mottled Orange and brownish gray as a result of mineral oxidation. Numerous inclusions (oxidized Pyrite) are present through out the clay, and also some fissures and vertical joints are common. Occasional almost horizontal sand and silt filled partings probably representing bedding planes are also present.

These highly plastic and stiff clays are extensive deposits in the major part of Guadalquivir basin and generally exhibit frequent engineering problems associated to superficial landslides mostly realted with road cuts and rail ways in the area. Expansion is common in this type of clays containing more than 40 % expansive clay minerals.

Oteo and Sola (1993) reviewed stability of slopes on this soil emphasizing the weathering with the increase of fissuring and influencing the mechanical behavior of the sediment. The main purpuse of this paper is to study the microfabric under the scanning electron microscope and, to explain how the microfabric changes as a result of weathering process common in the area. For this purpose samples from the Guadalquivir blue marl were obtained from Cordoba in a fresh and intact state in large parafined blocks. In addition to microfabric studies tests were carried out on the index properties, and mineralogical and chemical composition of the soils.

2. INDEX PROPERTIES

The properties studied include natural moisture content, atterberg limits, dry density, Grainsize distribution and carbonate content.

The tests were performed on undisturbed samples and average values of these are shown in table 1.

Table 1. Average Properties of the blue marls

Natural moisture content	25%
Liquid Limit	65%
Plastic Limit	35%
Plasticity Index	37%
Activity	0.74
Clasification	CH
Dry Density (g/cm^3)	1.67
$CaCo_3$	25%
Percentage of particles <74μ	98%
Percentage of Particles <2μ	53%

A detailed data on geotecnical properties of this soil is found in Oteo and Sola (1993).

3. MINERALOGY :

The mineralogical composition was determined using X-ray diffraction method of powder of the total sample , and oriented aggregates of the less than 0.002 mm fraction for clay mineral analysis. The semiquantitative procedure of Biscaye (1965) was follwed to give the proportion of minerales present. It was shown a similar mineralogical composition with abundance of phyllosilicates ranging from 67 to % 72 of the total sample ,Calcite being the second mineral present in this soil with an avarage value of 17%. Quartz ranging from 6 to 10%, Feldespar, Dolomite and Gypsum in small amount (less than 5%) were also present.The most common clay minerals present in the 0.002mm fraction were smectite (Ca++ Montmorillonite) and illite in quantities ranging from 44 to 50% for Smectite and 34 to 40 % for Illite. Another clay mineral present was Kaolinite in amounts ranging from 6 to 9%.

Under the scanning electron microscope the clay mineral particles has an irregular form and flaky morphology. The major part of Carbonate minerales is biogenic mostly represented by Nanofossiles (Coccolithis). Small amount of fibrous minerals (sepiolite) are also observed in some of the samples.

4. MICROFABRIC

The microfabric study was performed using the Jeol scanning electron microscope. Observation has made on both vertical and horizontal surfaces. Samples were prepared following the technique discribed by Barden and Sides (1971). After air drying samples were fractured to expose fresh surface and applied (50 to 80) aplication of peeling using the adhesive paper, next they were caoted with Gold in the sputter for five minutes. All samples were prepared in a same manner to avoid posible microfabric disturbance.

Observation of microfabric was made firstly on intact samples to asses the overall feature of the sediment and secondly on samples treated by humectation and desiccation cycles.

Microfabric of undisturbed samples

As it might be expected from natural sedimentary soils the microfabric feature of the undisturbed samples of the Guadalquivir blue marl is heterogeneous and complex where it has been identified several distinctive types of microfabric associations. However in this paper is discussed the most representative and typical microfabric of the soils and only typical micrographs are presented.

The most dominant and remarkable overall microfabric feature observed in all undisturbed samples is basically the "clay matrix" type which consists on aggregates of clays and group of clay minerales, silt and sand grains and microrganism sinking in the clay particles. A typical micrograph of this microfabric viewed under low magnification is illustrated in fig (1).

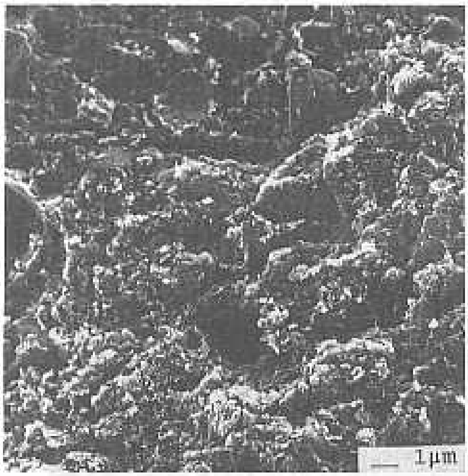

Fig. 1: Clay Matrix.

As it is evident from the micrograph the matrix is fine graind and fairly dense and non oriented where the voids are small and evenly distributed, inter and intra assemblage pores were not identified. This dense structure with un abundance of small voids of less than 1μm diameter is consistent with the compacted texture, and low liquidity index (less than 0) of the sediment where the large primary pores common in marine clays were colapsed under the overburden pressure. The large and circular pore seen in the middle of the micrograph are probably opened through organism locomotion indicating the bioturbation process occuring in the sediment.

In a detailed observation of larger magnifications of the matrix fig (2) it has seen numerous fine silt particles and microrganisms sinking with in the flaky clay minerales that are arranged mainly in a random manner.

Other microfabric elements relativly abundant of this soils are the typical "Honeycomb" structure of Terzaghi and the "Cardhouse" type, the later being less abundant. Representative micrographs of this microfabric are shown in fig (3 and 4).

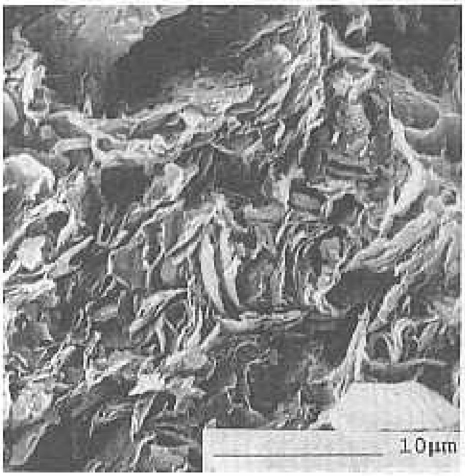

Fig. 2: Detail of the dense matrix. notice randomness of clay particles

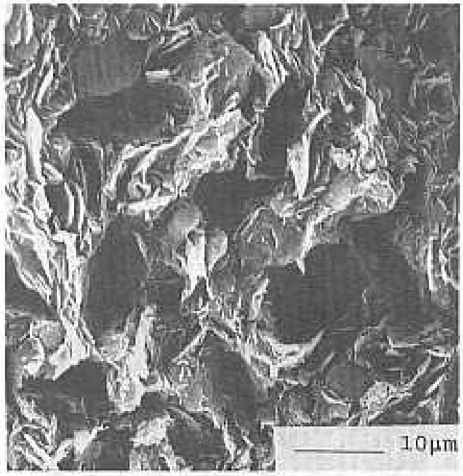

Fig. 3: Typical "Honeycomb" microfabric

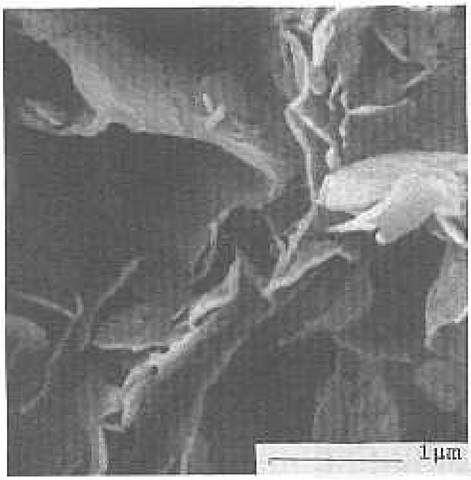

Fig. 4: "Cardhouse" Microfabric. Edge to Face association of individual clay platelets

There exist also several areas of parallel clay minerals orientation in a turbostratic manner along a posible natural shear plan fig (5) indicating the existance of microscopic discontinuities which can influence the macrostructure of the sediment. The main posible natural shear plans appear normally Forming 45 to 60 angle to the bedding and are suggested to be tectonic origen, a process that affects the area where this formation is found (Betic region, Southern Spain).

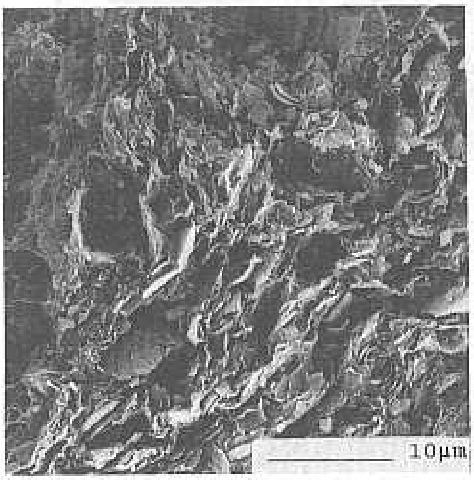

Fig. 5: Parallel orientation of particles along a plan.

The granular areas mainly consist on silt and sand sized quartz and calcite cristals are arranged in a grain- grain particle contact fig (6). And in some of this areas there appeared to be the connector (consisting of randomly oriented clay particles) type microfabric discribed by (Collins and Mc.Gown 1974) that serves as a bridge between the silt and sand grained particles fig (7).

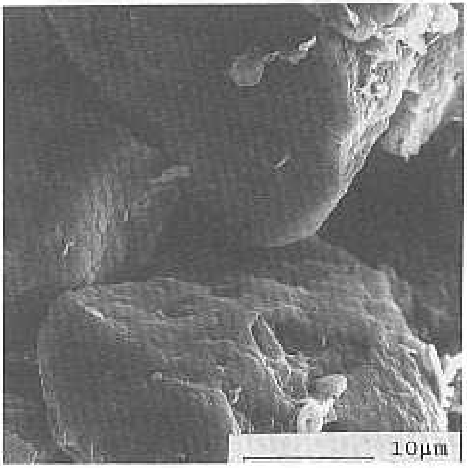

Fig. 6: Grain - grain contact of silt particle

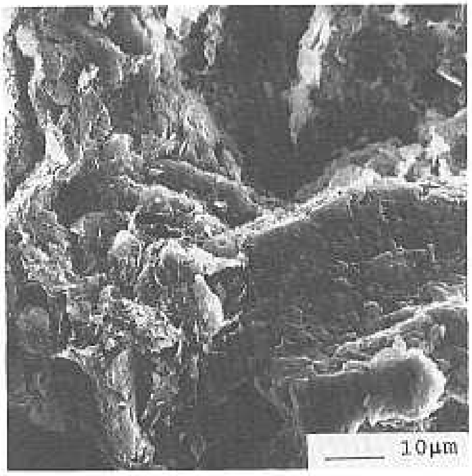

Fig. 7: Flocculated clay connector

The microrganism basically composed by Coccolithis are arranged in an open structure (fig 8) giving abundant intratest pores. Some of the intratest porositis that can significantlly influence the basic properties of the sediments are infilled with cristals of calcite, pyrite and even gypsum, giving a high resistance to the sediment Fig (9).

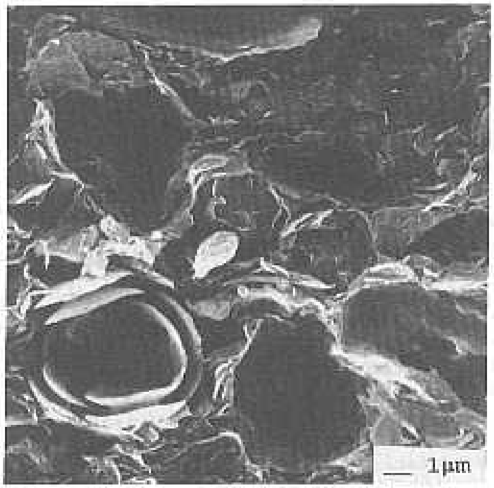

Fig. 8: Arrangment of Coccolithisin the soil.

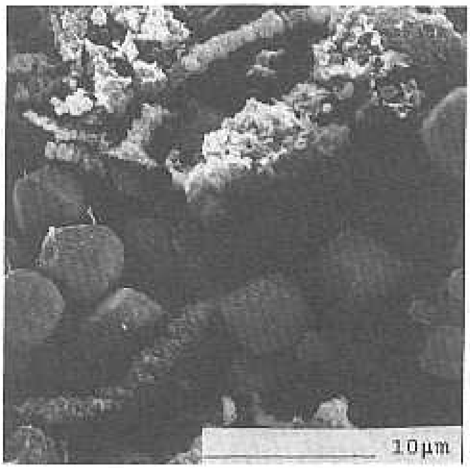

Fig.9: pyrite framboid

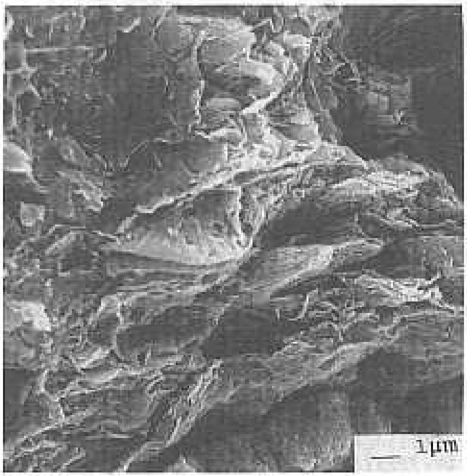

Fig. 10: Parallel orientation of clay minerales around the microrganism

In fig (10) is shown how the associated clay minerales around the infilled organism are arranged forming a dense parallel orientation.

The abundance of clay microfabric type in a random arrangment shown in this overconsolidated soils similar to the primary fabric is suggested to be due to the high amount of silt particles and cementing agents (high carbonate content) preventing the normal realignment of particles in this type of soils and to the biomechanical processe of organisms (biturbation).

Microfabric of soils after wetting and drying cycles

One of the important aspects of this study was to assess the influence of wetting and drying proceses on the microfabric of this samples.

In visu observations and low scale magnification of samples after 25 wetting and drying cycle in the laboratory indicates that there is a dramatical increase of fissuring in the treated samples. The samples were very brittle without cohesion after drying . The increament of fissuring in the upper part of this sediments (where weathering has occured) has been reported by Carlos oteo P.Sola (1993) in field observations.

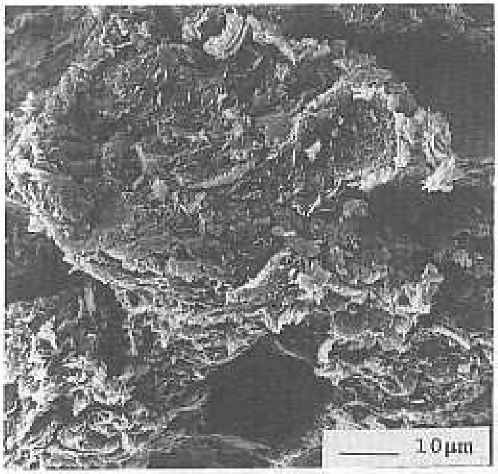

Fig. 11: Typical micrograph of sample after 25 Drying and wetting.

Fig. 12: Note the abundance of individual caly particles and coccolithis

The scanning elecron micrographs shown in fig (11) shows the typical representatve microfabric of the soils after 25 wetting and drying cycles. As it is evident the result is a formation of relatively unstable aggregation of individual particles, and disintigrated organisms Fig (12).

The floculated microfabric type commonly observed in the intact samples was less frequent indicating the breakdown of these arrangments and disruption of the original matrix with the dryng and wetting proceses and abundance of individual clay particles.

This is onsistent with the observation of Barden and Sides (1971b) in Keuper Marl. Here it was abundant the coating of silt particles by individual clay minerales.

In terms of mineralogical composition there is no indication of any significant changes in clay mineralogy as a concecuence of this treatment.

CONCLUSIONS

Guadalquivir Blue Marls consist of mainly Phyllosilicates minerals of about 67%, and Calcite 17%, Smactite and Illite being the most dominanat clay minerales.

The main microfabric feature of this sedimet is a randomly oriented dense clay matrix type. There observe also abundante flocculated microfabric elements typical of soils from marine origen.

The randomness of clays and preservation of original floculated microfabric in this overconsolidated sediment, is attributed to the abundance of silt particls, cementation agents preventing the realignment of the clay minerals and to the bioturbation process.

The local orientation of particles along a parallel plan indicating a natural shear zone which heavily influences the mechanical behavior (shear strength) is suggested to be tectonic origen common in the area.

It is observed that wetting and drying proceses (weathering) modify the microfabric of the Guadalquivir blue marls by breaking down the randomly oriented stable microfabric and forming unstable agrregates consisting of individual particles. And also it has shown that fissuring intensity is increased by this proceses.

REFERENCES

Barden, L., and Sides, L., 1971. Sample disturbance in the investigation of clay structure. Geotechnique, Vol.21, N° 3, p 211.

Barden, L.; and Sides, G.,1971. The influence of weathering on the microstructure of Keuper Marl. Q.Jl.Eng Geol. Vol. 3. pp 259-260

Biscaye, P.E. 1965. Mineralogy and sedimentation of recent deep sea clay in the Atlantic ocean, and adjacent seas and oceans. Geological Society of America Bulletin, V. 76 p. 803-832.

Collins, K., and McGown, A. 1974. The form and function of microfabric features in a variety of natural soils, Geotechnique, Vol. 24, No. 2, pp 223-254.

Oteo,C., Sola,P., 1993. Stability problems in slopes constructed on spanish "Blue Marls" Int. Symposium on Soft Rocks and Stiff Soils, Athens.

Perconig, E. 1962 Españe meridional. Livre Mém Paul Fallot Mém hors serie S.G.F. pp 231-256