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DEFORMATION IN FAULTED WHITE CHALK IN BELGIUM

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Introduction

Chalk is a sedimentary rock whose properties depend on many factors, such as its geological history, its petrography and geological paleostress evolution. In this study, the petrophysical parameters were approached to characterize Campanian White chalk located against fault planes from two Cretaceous outcrop regions of Belgium, the Mons Basin (Harmignies quarry) and the Meuse district including the Maastricht area and NE Belgium (Lixhe quarry). In previous studies, significant matrix strains along fault planes were already associated with Campanian and Maastrichtian faults from the Mons Basin. These transformations brought about systematic changes in the porous network. This porosity is a fundamental physical feature of chalk, related to its mechanical features. The major transformation mechanisms are the pressure solution and the cementation which involve grain arrangements and mass transfers. Generally, an impermeable zone appears between the fault plane and the rock mass. The present study attempts to confirm these outcomes of the Mons Basin and to compare them to those from the Meuse district. Indeed, similar investigations of Lixhe White chalk are carried out to specify changes in texture, major transformation mechanisms and influence of geodynamics framework.

Geological setting and geodynamical context

The two studied regions are characterised by a similar geodynamical context: a globally extensional regime interrupted periodically by compressional events related to regional inversions (Vandycke, 1992, 2002). Thanks to their location in the NW European tectonic framework, these areas exhibit a further interest. Indeed, the Mons Basin, in the northern part of the Paris Basin, is located in between the main structural elements of this part of Europe, such as North Sea, Rhine Graben and English Channel. Moreover, the North Artois Shear Zone (NASZ) crosses the Mons Basin. The Maastricht region is located adjacent to the Lower Rhine Graben and shows connections with the Mons Basin (Robaszynski et al., 2001). Consequently, a stratigraphical correlation is possible between the studied areas. Moreover, their stratigraphical context is well framed by the subsidence histories, related to karstic and tectonic deformation in Mons Basin (Vandycke et al, 1989) and to the Santonian sea level rise and graben tectonics and inversion in NE Belgium (Bless et al, 1986).

Studied material and sampling

The CBR Harmignies and Lixhe quarries, where the samples were taken, are representative of the brittle tectonics of the Mons Basin and the Maastricht region. Their brittle structures are essentially normal faults with a single displacement and extensional joint systems. Our investigations are focused on normal faults whose the fault plane was unaltered and the faulted material was not brecciated. Their displacement was metric and striae were observed on their fault plane. In the Harmignies quarry, the studied faults are located in the "Craie d'Obourg" formation, in the Lixhe quarryand in the "Craie de Zevenwegen" Member of the Gulpen Formation (Robaszynski et al., 2001). Their orientation was respectively N125° 78°S and N115° 65°S. The striae orientation of Lixhe fault plane was 75°W with a slight obliqueness. Moreover, the studied fault from Maastricht region belonged to a closer fault population. On each fault, several cores were taken perpendicular to their fault plane. In the Lixhe quarry, the cores were taken here and there the fault.

Experimentation

The measurements of physical (elastic wave velocity) and mechanical (splitting test, unconfined compression test) properties of chalk were carried out to estimate the matrix strains along the fault plane. These information are explained by a microstructural analysis of a 90 mm thick fringe along a fault plane based on SEM and tomography observations (Darquennes, 2005; Gaviglio et al., 1999, Schroeder et al., 2006) .

Physical properties

The ultrasonic velocity measurements were performed on sawed cores and cylindrical samples to avoid scale effect using classic piezo-electric transducers. The travel time of the wave across the sample is measured and allows computing the ultrasonic velocity. This parameter indicates porosity and anisotropy evolution along the fault plane (Schroeder et al., 2006).

Along this plane, three areas are distinguished on the velocity evolution of chalk cores. From the fault plane to 10 cm from this plane, an increase in ultrasonic velocity is observed indicating a decrease in matrix porosity. This behaviour is lightly different between the two studied regions. Indeed, the maximal ultrasonic velocity value of Lixhe chalk (2385 m/s) is located directly close to the fault plane, while the velocity of the Mons chalk (2155 m/s) increases only at 6 cm from the fault plane. From 10 cm to 20 cm, this parameter is characterized by a drop related to an increase in porosity. After that, the velocity creases lightly and fluctuates around a constant value beyond 20 cm. This constant value of White chalk from the Mons Basin is clearly larger than the maximal velocity of the first area. Thus, a different regional behaviour is well indicated by these experimental results. Indeed, Lixhe chalk samples velocity is maximal close to the fault plane and the Mons chalk is characterized by an opposed effect. Therefore, chalk matrix from Maastricht region is more continuous and less porous next to the fault plane. But it is less continuous and more porous beyond 10 cm. These results seem mostly similar at those from earlier publications (Schroeder, 2003; Gaviglio et al, 1993; 1997; 1999).

Mechanical properties

Cylindrical samples (Ø=2.5 cm) from the different cores are tested to unconfined compression test and splitting test. Three zones are also exhibited on the strength evolution of Campanian chalk from the two regions. The first zone is characterized by a maximal strength. For instance, the maximum is equal to 3.7 MPa at 9 cm from the fault plane in the Lixhe carry and 2 MPa at 5 cm in the Harmignies carry. Beyond 10 cm, the strength also decreases and fluctuates around a constant value. Between the Mons Basin and the NE of Belgium near Maastricht, a lightly different regional behaviour is observed as well. Indeed, the strength of Lixhe chalk decreases lightly next to the fault plane and it is almost constant beyond 20 cm from this plane.

These physical and mechanical measurements provide a good evidence of significant matrix strains along fault plane. But these variations are clearly more accented in the Lixhe White chalk than in the Mons White chalk.

Microstructural analysis

SEM and tomography analysis were applied respectively on a Lixhe and Mons chalk cores to allow understanding of matrix deformation process and the difference of behaviour between the Maastricht region and the Mons Basin. On the 10 first centimetres from the fault plane, the chalk matrix is globally compact and some pore spaces whose the diameter varies from 1 to 5 µm are also present. These spaces are probably related to dissolution process or granular changes. Other evidences of matrix strains are also provided by grain shapes and particle connections. Indeed, several compact grains with angles from 60° to 90°, named neoformed calcite, result from pressure solution and cementation. This basic process involves dissolution along grain boundaries and pore space (Gaviglio et al, 1997) and also implies interpenetrated rhomboedric crystal and calcite connections generating a more compact chalk matrix.

The SEM and tomography also underline the presence of large pores forming channels and wall-like structures partitioning the medium. Their particles are cemented and welded. They involve a more compact zone and limit connections between voids. Thus, the porosity decreases in the chalk matrix (Gaviglio et al, 1997). The tomography allows noticing the majority of these channels initialises from fault plane and branches out into core. Moreover, they join close voids and indicate a fluid circulation possibility propagating the transformation process.

On the fault plane, the matrix continuity is conferred by a maximal particles coalescence. Indeed, the faulted chalk is characterized by a crystal accumulation formed by coating and welding. But the fault plane sometimes exhibits several large voids related to the dilatancy phenomenon.

In summary, the deformed chalk is characterized by a more continuous rock resulting from particles moves, crystallisation in voids and particles group cementing. This news texture generates an increase in matrix density and heterogeneity.

Discussion

This experimentation underlines significant deformations along the fault plane. These changes involve a decrease in porosity and an increase in the continuous character of the material towards the fault plane. For the two regions, these experiments establish a rather similar texture evolution due to a normal fault associated with extensional system:

-a fault plane acted as a dissolution plane : faulted material;

-a compact, continuous and less porous zone : strained material;

-a more porous, less compact and continuous zone : unstrained material.

These variations are more clearly accented in the white chalk of the Lixhe quarry than in the white chalk of the Harmignies quarry. They are probably explained by the geodynamic framework of the Liège area connected to the dynamics of the Rhine Graben that modifies the driving actions of the pressure solution and cementation due to mechanical action and fluids circulation. In spite of these

differences, the chalk presents the same major transformation mechanisms: pressure solution and cementation, and the same transformation stages :
-compression condition : vertical stress;
-grains moves and possibility of dilatancy against fault plane;
-matrix consolidation and fluids circulation caused by a disorganisation of the pore system;
-start of dissolution-crystallisation phenomena following stress increase due to fault slip and drainage.

Conclusion

Stress variation due to fault formation initialises the dissolution/crystallisation phenomena, which represent the major transformation observed in the chalk. It leads to the modification of mechanical and physical properties along the fault plane. These changes also generate variations of the chalk matrix texture and the strained material forms a sort of barrier with a lowered porosity between the unstrained material and the faulted material. These processes occur in both the Meuse district of NE Belgium region and the Mons Basin.

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