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Geology and the Great War - The geology of the Western Front, from Flanders to the Vosges

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ABSTRACT

The western front was completely located in the Paris Basin, from the flatlands of Flanders to the Vosges Mountains. It was thus natural for the Association of the Geologists of the Basin of Paris (AGBP) to make its contribution to the remembrance of the Centenary of the Great War, with the realization of a synthesis of the present state of knowledge on the role played by the geology in this conflict.

This synthesis, begun in 2014, will lead to a publication at the end of 2017.

It will rely on the numerous works which were carried out by geographers and geologists during the war and in the years which followed, and will integrate the new studies, in particular those currently carried out on environmental issues.

The publication will deal with:

- The main geological structures of the battlefield;
- The various geological formations intersected by the front line and their influence on the main battles;
- The major battles replaced in their geological context;
- Thematic chapters on hydrology, underground quarries, mine warfare, ground trafficability, environmental consequences, mineral supplies, new technologies …

KEY WORDS: First World War, Geology, Western Front.

THE MAIN GEOLOGICAL STRUCTURES AND THEIR STRATEGIC IMPORTANCE

The concentric sedimentary belts of the Basin of Paris, with their east-facing cuesta frontslopes protected by the fortifications of the Séré de Rivières system constituted the impregnable "fortress of France". As soon as 1914, the Battle of Nancy had demonstrated the great defensive strength of the cuesta scarp and its outliers (Fig. 1).

The attack from the north, in violation of the neutrality of Belgium, allowed, in spite of the heroic resistance of the Belgians, an incredibly swift advance of the German troops, which were finally arrested by topographic barriers that were oriented on an east-west direction such as the valleys of the rivers Oise, Aisne and Marne, or on a Variscan direction such as the Artois faults.

After the Battle of the Marne, where the Allied forces took advantage of the Tertiary cuesta of the Île-de-France and the valleys of the river Marne and its tributaries, the front was stabilized, and the trench warfare began.

Fig. 1 - The Trenches of Death (Boyau de la Mort, Dodengang), near Dixmude (Belgium). The level of the water table impeded digging, and trenches were raised by piling sandbags.

The last attempt to get through the cuestas of the Paris Basin was the Battle of Verdun in 1916, which ended by the German retreat.

THE GEOLOGICAL FORMATIONS INTERSECTED BY THE FRONT LINE

This future publication will describe the geological formations intersected by the front line and their characteristics in terms of military engineering

From north to east, the front line crossed:
- Quaternary sands (Dixmude) ;
- The Flanders clay (Ypresian in its type locality);
- The chalk of Artois and Picardie (Upper Cretaceous);
- Tertiary formations;
- The chalk of Champagne (Upper Cretaceous);
- The gaize (spongolite) of Argonne (end of the lower Cretaceous);
- The Malm limestones;
- The Dogger limestones;
- The Keuper marls (Upper Trias);
- The sandstone Vosges (Buntsandstein; Fig. 2);
- The crystalline Vosges.

Fig. 2 - La Chapelotte (Vosges). A shelter in the Vosges sandstone (Middle « Buntsandstein »).

THE MAJOR BATTLES: THE EXAMPLE OF VERDUN

The site of Verdun had been chosen by the Germans for strategic and symbolic reasons without particular link with geology or geography (Fig. 3). However, geology explains how the attack was carried out, and how the resistance of the French made it fail.

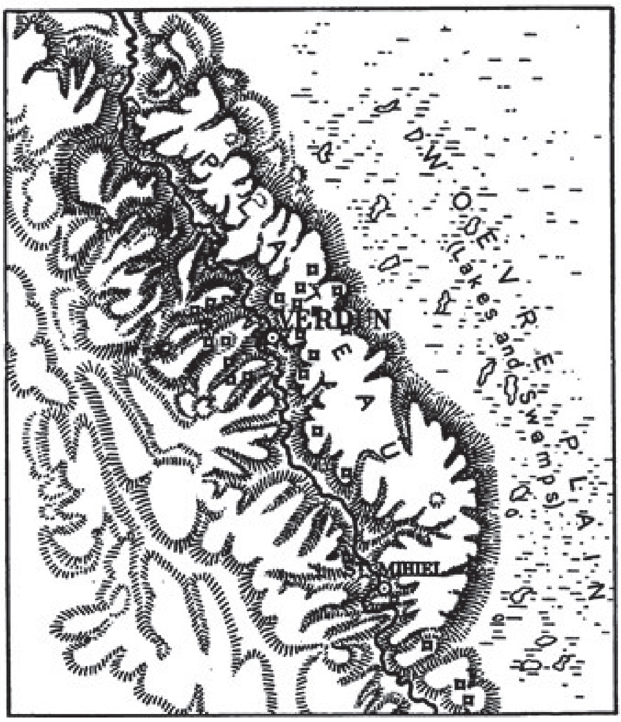

Fig. 3 - The terrain of the Verdun district (Johnson, 1917).

The site of Verdun is a plateau slightly dipping west, which is the backslope of the cuesta of the *Côtes de Meuse*. The caprock is constituted of Middle and Upper Oxfordian reef limestone, under facies which before were called (from bottom to top) Argovian, Rauracian, Sequanian. A particular facies of the Middle Oxfordian is the White Marl of *Les Éparges* which must be mentioned because of the fierce battle which was fought at *Les Éparges*, an outlier of the cuesta, at the beginning of 1915.

The Lower Oxfordian, at the bottom of the ridge is represented by oolitic limestone and marls with cherts. It progressively passes to the Callovian Clays which constitute the Woëvre plain.

The Meuse does not flow below the frontslope of the *Côtes de Meuse*. The river has dug its bed in the backslope and flows northwards, in a direction parallel to the frontslope. Its wide valley seems disproportionate with regard to its flow because the Meuse lost its main tributary, the Moselle after a capture by a tributary of the Meurthe, about 300,000 years ago.

Geology explains why the main attacks had to be launched from the north to the south, through the large way that the Meuse opens in the Oxfordian limestone plateau which is located north of the city of Verdun.

First of all, when the battle began, in February 1916, the Woëvre plain was impassable by the troops because rain resting on its impermeable surface had turned fields into bogs, and created countless marshes and ponds. Troops and artillery should have been concentrated to the few good roads and would have been easy targets for the French guns. So, an attack from the Woëvre was almost impossible.

Erosion has dissected the plateau into ravines which drain towards the Meuse River on the west or into the east.

The German armies moved on both sides of the valley, occupying transversal ridges between the east-west ravines. The Germans thought that a southwards progression across these transversal ridges would be easier than a direct offensive from the east against the ridge of the frontslope. The first attacks from the Woëvre plain had failed as had those upon the Côte de Moselle and the Grand Couronné of Nancy en 1914.

As they anticipated, the Germans had gained much ground after their first surprise attack. But the opposing forces soon came to a deadlock with weeks of incessant slaughter of the attacking waves, the failure of the Germans to ascend the steep scarp of the plateau, and finally the French counter offensive.

Most important of all were its impassable east-facing frontslope, and the endless series of east-west ridges crowned by Sequanian limestone, which gained fame and are now historic sites : *Le Mort-Homme* (Dead Man Hill), la *cote 304* (Hill 304), la *Côte du Poivre* (Pepper Ridge), la *Côte du Talou*…

The defensive value of these crests laid in the fact that each crest dominated a ravine next north across which the Germans must advance in their assaults toward the south; and in the further fact that, in these hills and ridges, artillery positions could be found which commanded practically every German approach.

Another topographic element of great importance is the width of the Meuse valley, which, in wet season, interposes a marshy and muddy barrier between its two banks.

With such an obstacle, it was difficult for the Germans to shift the troops from one side of the river to the other, and to coordinate attacks made from the right side with attacks from the left side. They could not either concentrate their troops on one side, because such a concentration would have made a better target for the French artillery which could pour its fire on the river bed and the upland beyond from the upland spurs which projected into each curve.

On many occasions, German troops once in possession of the meander spurs have found themselves trapped in a peninsula surrounded on three sides by an unfordable stream, and had to surrender.

Johnson (1917) concludes: *The plain of the Woevre and its dominating plateau scarp by forcing the Germans to attack from the north, and the ridges and valleys of the plateau by offering defensive barriers which the Germans could not overcome saved Verdun to the French*.

South of Verdun, the Saint-Mihiel salient conquered by the Germans as soon as 1914 because there the scarp was lower was recovered in September 1918 by the Allied forces, mainly American. The Americans had developed specific geological cards extending far within the enemy lines and describing the physical conditions in enemy territory. In the opposite direction of the attack of the Germans, the Americans had to face the problem of the trafficability of the Woëvre. They made their attack in September, before the rains, and they had mentioned on their maps limestone reefs where crossings could be made.

The American used the 1:80,000 French map, but to draw the boundaries at a larger scale, they made use of aerial photographs. For instance, the limits of the Bajocian limestone could easily be delineated from the photographs.

WAR ISSUES

WATER SUPPLY

After the stabilization of the front, the first concern was the supply of drinking water. The British geologists made a significant number of drillings which allowed to obtain the necessary water and to improve the knowledge of the subsurface, in particular the position of Turonian marls.

UNDERGROUND WARFARE

Mining warfare, which was done at an unprecedented scale, and the digging of underground shelters mobilized the geologists (Fig. 5). Unlike the British and the Americans, the French did not make much use of professional geologists, mainly because the knowledge of their engineers was enough to set up brilliant attacks, and their methods and equipments were used by all the belligerent parties .

The sedimentary nature of the Paris Basin and the near horizontal character of the strata favored a warfare type which would have been impossible in folded or faulted areas, and all the more so in crystalline area. The light dip favored the drainage. Only in Lorraine the Americans had to cope with faults susceptible to favour the infiltrations of water.

The speed of excavation and the required equipment depended on the hardness of the rock, but also of stratification planes, fractures, stratification joints, cleavages...

These factors controlled the type and quantity of timbering that was required. For instance, the highly fractured Bajocian limestone of Lorraine required heavy timber, as dugouts in the sandstone or granite of the Vosges did not need any timbering.

Fig. 4 - Le Lochnagar Crater (Somme). The Lochnagar mine (27 tons of ammonal) was sprung at 7:28 a.m.on 1 July 1916, the first day of the Battle of the Somme.

The Chalk was the formation which was the most favourable to underground works, for it could be dug with a simple pickaxe without using explosives, and needed very little timber. Digging the Chalk made little noise, but the white rock dumps could be conspicuous and draw the attention of the enemy observers.

Clay was easy to dig silently with a spade, but needed timbering or casing. The British had implemented a fast-digging technique originating from civil engineering, the *clay-kicking*, where the digger, lying on a plank at a 45-degree angle away from the working face inserted a tool with a cup-like rounded end with his feet.

In contrast, in the Triassic sandstones and conglomerates of the northern Vosges, both sides used noisy air drills, so that both armies were informed of the operations of their opponents. These operations, however, led to no decisive results.

The charges of the mines were carefully calculated based on the physical characteristics of the rocks. Engineering officers were trained in these calculations.

HYDROLOGY

Another important element of the underground war was the understanding of the seasonal variations of the level of the underground water.

The generalized use of heavy artillery obliged to dig deep shelters that had to be free of water. Protection against the heaviest artillery pieces such as the 420 millimeters howitzers (the *Big Bertha*) needed 15 m of compact earth or 7 m of hard rock. Therefore, shelters could be dug only where the water table never reached this height, except where a natural drainage was possible.

Underground water problems were different according to geological formations. Impermeable layers such as Toarcian or Oxfordian clays were free of water. Fractured limestone, like the Bajocian was always well drained, except at its lower contact with clay.

On the other hand, some formation made up of interbedded clay and limestone formations that are common in Lorraine were a source of trouble because of the irregular distribution of their water content. Bore holes must be drilled in advance before any trench or dugout construction.

In part of the Lorraine sector, the French themselves, in spite of their supposed knowledge of the local conditions made the mistake to locate first line shelters without any consideration of underground water, and these shelters were quickly rendered useless by filling with water. The French were not the only ones to make that mistake.

One of the most valuable services performed by the British geologists was the accurate determination of the ground-water level at different seasons of the year. The British mines were located above the high ground-water level of the spring, while the Germans, who attempted to dig at a lower level, were flooded out of their workings.

Although having mobilized a team of geologists in the occupied city of Lille, the Germans were frequently victims of their ignorance of the local geological features, as the British were better placed to benefit from knowledge acquired by the French, in particular the previous works of Jules Gosselet, from the University of Lille, to whom the British geologists paid tribute after the war.

THE UNDERGROUND QUARRIES

An important feature of the Western Front is the presence of underground quarries, in the Chalk in its northern part, in the Lutetian limestone in its central part.

In Arras, to prepare the offensive of 1917, the British forces decided to re-use the old underground quarries dug in the Campanian chalk (Fig. 5). Miners from the New Zealand Tunnelling Company were brought in to dig 20 kilometres of tunnels in order to link up the quarries and create a network of underground shelters, with a capacity of 24 000 soldiers that would be able to suddenly appear for a surprise attack right into the enemy lines.

Fig. 5 - Arras (Pas-de-Calais), Carrière Wellington. A way out leading to the front.

These quarries have been given the names of New-Zealand cities. The Wellington quarry is now a tourist and remembrance site.

On the northern ridge of the Aisne Valley, a great number of underground quarries have been dug by local people to get building stone from the Lutetian *Calcaire grossier* (coarse limestone). These quarries are locally called *creutes* (local form of the French *grotte*, cave). These quarries offered comfort and safety, provided that the roof was thick enough and there was no risk of rock fall. The entrance was the most vulnerable part, and underground quarries remained vulnerable to gas attacks through joints or cracks due to the quarrying.

The underground quarries have often been used as rear bases for the reserve forces, the territorial forces and the army health services.

The soldiers left many traces, graffiti and engravings which make these quarries remembrance places.

ENVIRONMENTAL ISSUES

In the years which followed the war, the notion of environment did not even exist. The main concern was the loss of 35000 km² of land among which 25000 km² were farmland in 1914. This area which was churned up by shells, covered with trenches, barbed wires, and other military works, remained uncultivated for years, or cultivated in abnormal conditions due to the state of war.

Three zones were defined according to the increasing intensity of the damage: green zone, yellow zone and red zone (Fig. 6).

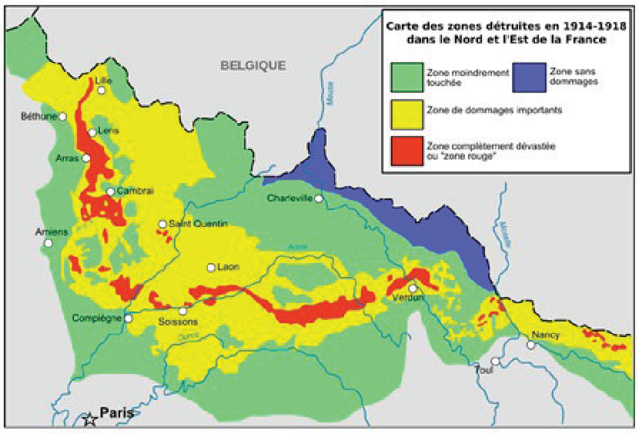

Fig. 6 - Map of the war damage zones (from Guicherd et Maitrot, 1921).

The first concern was reviving the soil to bring back agricultural life. The military works were destroyed, and unexploded ordnance was removed, first of all to recover metals. The unrecoverable gas shells were stored in special deposits like the *Place à gaz* (gas place) in the forest of

Verdun, still strongly polluted by arsenic and other toxic matter.

In 2006, American scientists who worked on the environmental impacts of the bombing in Vietnam turned their attention to the Red Zone of Verdun, which has been untouched since 90 years, and allows seeing the long term consequences of the cratering of the soil surface and mixing of the soil by explosive munitions. They created the term of *bombturbation* for this pedoturbation process.

In 2014, a team of the University Reims-Champagne-Ardenne has launched the project « Impacts environnementaux de la Grande Guerre en Champagne-Ardenne » (Environmental impacts of the Great War in Champagne-Ardenne).

MISCELLANEOUS APPLICATIONS

Geologists were involved in the Great War in many other ways:

- Advice on the suitability of sand or aggregate for making concrete;
- Determination of the origin of concrete from German defences;
- Advice on the site of airfields;
- Experimentation of different mineral materials (agate, sapphire…) for airplane compasses;
- Selection of ultra-pure quartz crystals for use in anti-submarine operations (the first steps to the SONAR).

Some researches carried out for military purposes had a positive impact on geological knowledge after the war:

- Geologic mapping of the North of France;
- Development of seismic reflection (Mintrop, Karcher).

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