2003 N° 1

GEOLOGIE DE LA FRANCE
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AND SURROUNDING AREAS

Special conference on

"Paleoweathering and Paleosurfaces in the Ardenne-Eifel region"

at
Preizerdaul (Luxembourg)
on 14 to 17 may 2003

Field trip guides

F. Quesnel, coordinator

IGML
Institut Geologique Michel Lucius
Association sans but lucratif

Ponts et Chaussées
Service Géologique

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Géosciences pour une Terre durable
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Field Trip I: May 16, 2003, picnic and afternoon

The "Pierres de Stonne" and the "Borne de fer", as main features of Meso-Cenozoic paleoweathering of the Upper Lorraine and Ardennian Thiérache areas

(Ardennes and Moselle departments, France)

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The Upper Lorraine and the Ardennian Thiérache areas are located in the eastern part of France, South of the Ardenne Massif and the Luxembourg (see the **Geological map** introducing the field trip guides). The geological substratum of these areas is made of Jurassic limestones and marls. The plateaus are covered by weathering profiles whose thickness ranges from around 10 to 30 m. The weathering profiles, usually mapped as "Limon des plateaux" (LP) on the 1/50,000 geological maps, are often rich in heaps or pockets of iron ore (Voisin, 1994) - named "fer fort" in French and "bonherz" in German. They were mined before the industrial revolution and the mining of the Aalenian oolithic iron rich deposits.

The "Pierres de Stonne" are also sprinkled over the plateaus above the weathering mantle - and residual Cretaceous deposits - and are often reworked in the Early Pleistocene fluvial deposits. Voisin (1988) mapped and studied these siliceous residual blocks whose remains are very seldom found *in situ*, in large amount and/or slabs of important size.

We suggest to have a picnic at Stonne, on the top of the hill where the "Pierre de Stonne" was defined in the 19th Century and where few blocks still crop out (**Fig. 1**). Unfortunately, it will not be possible to see any fresh section, so we shall have a look at the different facies of the "Pierre de Stonne" resting along the streets and the public square of the village.

This stop will allow discussions about all the Tertiary residual deposits of the Ardennian Thiérache - Rocroi plateau - Upper Lorraine, of which the "Pierres de Stonne" and the "Landenian" sand, sandstone and conglomerate are the most common features and were recently dated in the Régniowez section (**Fig. 2A**).

Then, we will visit 2 sections. The first one is a quarry of Bajocian formations at Ottange (**Fig. 3**), where limestones and silty marly beds are widely exposed, the latter lithology being probably the parent rock of the thick saprolite cropping out in Upper Lorraine, Luxembourg, Gaume and Ardennian Thiérache. This quarry also exposes the base of the saprolite above the Bajocian substratum and the oxidation front within the limestones. The second section is the "Borne de fer", a ferricrete cropping out in the "Audun-le-Tiche" forest – on the top of a hill whose elevation is one of the highest points of the Jurassic plateau in Lorraine – and capping a thick saprolite – around 30 m – above the Bajocian substratum (**Fig. 3**).

Acknowledgements to Geneviève Farjanel, Laurent Bailly, Véronique Pedroletti, Christian Dupuis and Roby Colbach

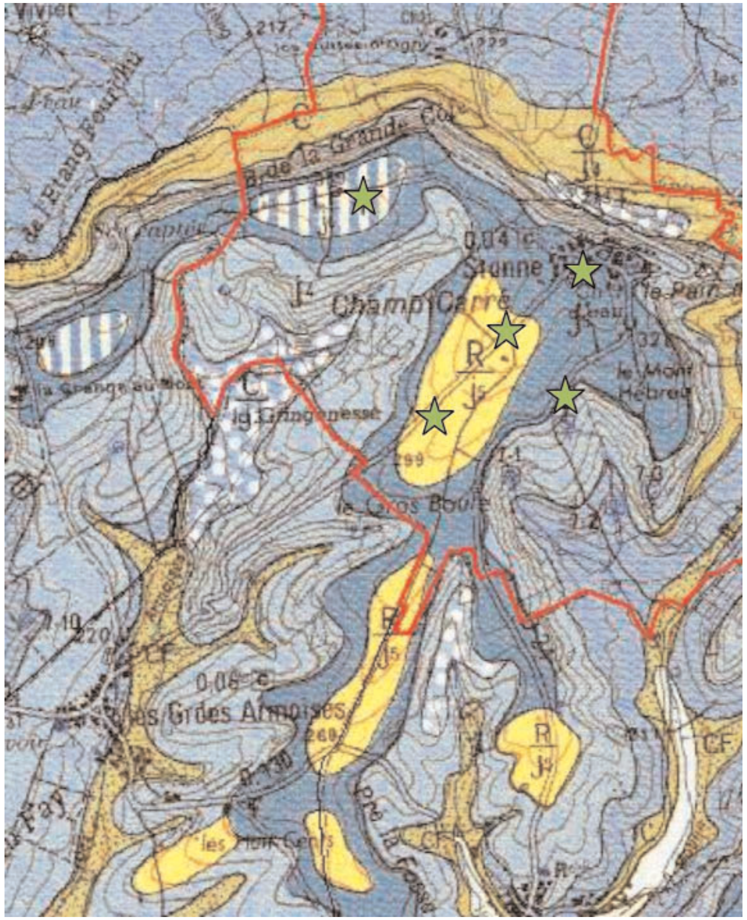


Fig. 1.- Location of the Stonne hill on the Geological map of France at 1/50,000 scale, sheet Raucourt-et-Flaba, n° 87 © BRGM – the red line corresponds to the Stonne village's border – and some isolated "Pierre de Stonne" slabs (green stars) found in fields – coordinates in the French IGN "Lambert II étendu" projection system – X: 787435.830 Y: 2508910.390; X: 787417.980 Y: 2509047.240; X: 787209.730 Y: 2508791.390; X: 787078.830 Y: 2508642.640.

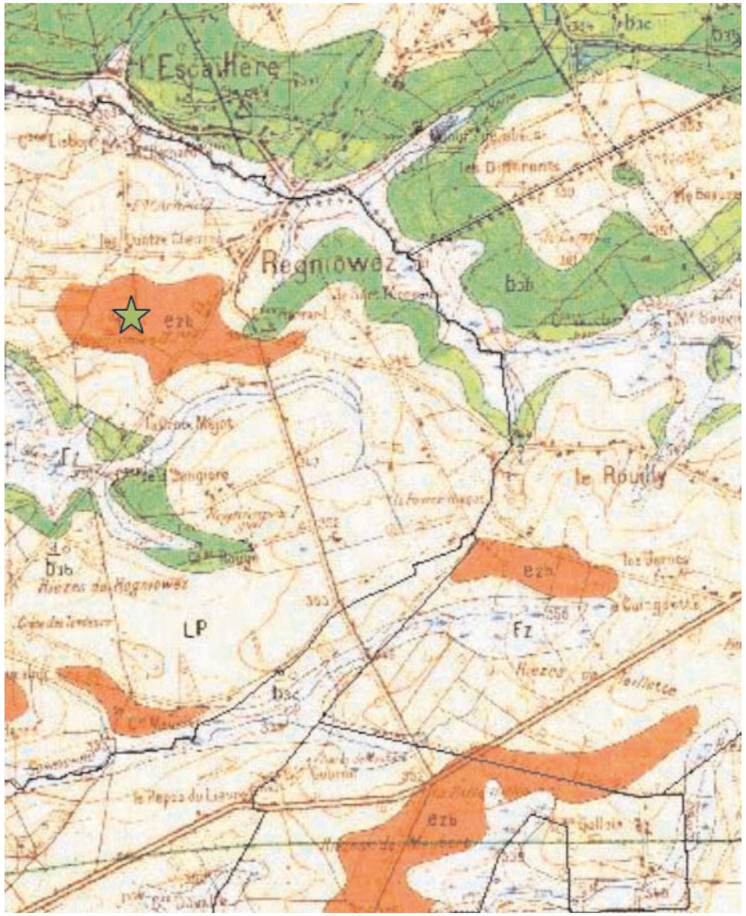


Fig. 2.- A - Location of the Régniowez abandoned sand quarry (green star) – and its coordinates in the French IGN "Lambert II étendu" projection system (X: 749721.840 Y: 2550616.005) – and some Landenian outcrops – in orange – on the Geological map of France at 1/50,000 scale, sheet Rocroi, n° 52 © BRGM

Fig. 2B - Location of the Prez abandoned sand quarries (pink stars) – and their coordinates in the French IGN "Lambert II étendu" projection system (X: 745143.730 Y : 2535264.960 ; X: 745132.160 Y: 2535970.990) – on the Geological map of France at 1/50,000 scale, sheet Renwez, n° 68 © BRGM

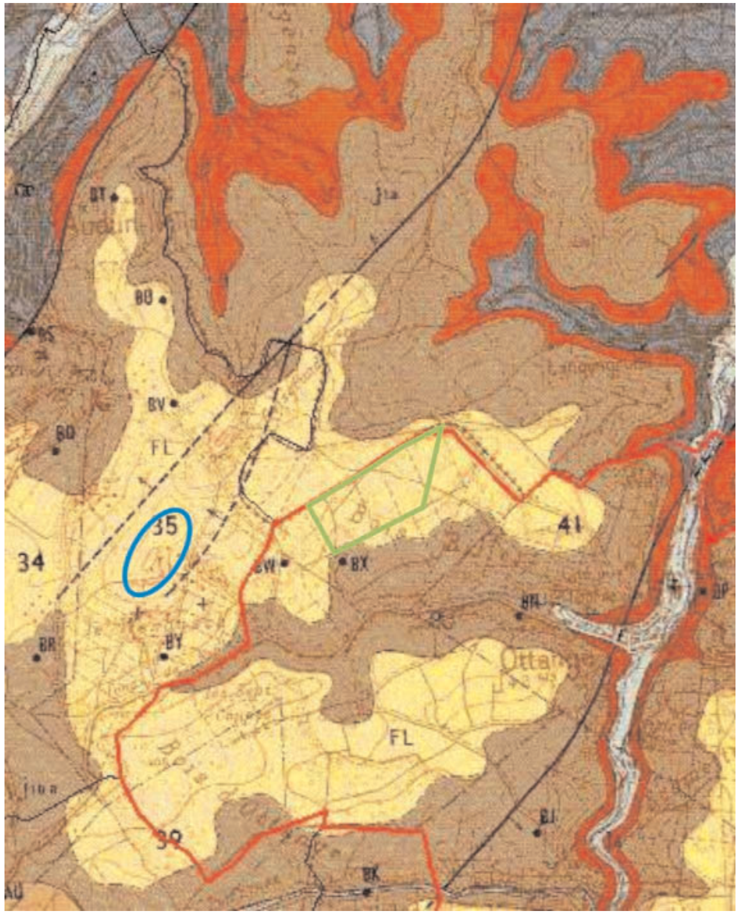


Fig. 3.- Location of the Ottange limestone quarry (X: 865218.800 Y: 2501240.930; green line) and the "Borne de fer" section (X: 863592.970 Y: 2500810.750; blue line) – coordinates in the French IGN "Lambert II étendu" projection system – on the Geological map of France at 1/50,000 scale, sheet Longwy-Audun-le-Roman, n° 113 © BRGM

STOP 1: The “Pierre de Stonne”

The “Pierre de Stonne” is a fine grained sandstone or quartzite, of light grey to beige colour, very often with an ochre to brown patina due to iron oxides. Its most striking feature is its extremely cohesiveness and hardness, so that it defies hammers and jigsaws (Voisin, 1988).

First noted around Stonne (**Fig. 1**) and named “Caillou de quartz” (Quartz boulder) by Sauvage and Buvignier in 1842, these siliceous concretions are named “Caillou de Stonne” (Stonne boulder) by Gosselet in 1880, then “Pierre de Stonne” (Stonne stone) by this author in 1890, and “Grès quartzite de Stonne” (sandstone-quartzite of Stonne) by Cayeux in 1906 (Voisin, 1988). These rocks are considered by Barrois as the equivalents to the Landenian (1) sandstone of the Paris Basin since 1879 and soon compared to the “Grès de Marlémont” (Marlémont sandstone). Other authors attribute the “Pierre de Stonne” to the Oligocene or Miocene (Hummel, 1920; Baeckeroot, 1929; Tricart, 1949; Pierre, 1999) and compare this formation to the Fontainebleau sandstone of the Paris Basin and the Braunkohlenquartzit of the Lower Rhine Embayment (Baeckeroot, 1929).

These residual - but sometimes numerous - rocks were mapped as isolated slabs and more extended outcrops during the successive geological mapping surveys from Thiérache and Upper Lorraine in France to Gaume in Belgium, Guddland in Luxembourg and Eifel and Mosel trough in Germany (Delepine, 1924; Baeckeroot, 1929; Gardet & Capot-Rey, 1929; Lucius, 1948; Désiré-Marchand, 1984; Löhnertz, 1978). Unfortunately, many interesting occurrences have disappeared following constant exploitation of the formation to reinforce the bed of roads and lanes, the angles of barns and farms and first of all to build Neolithic dolmens.

The “Pierre de Stonne” is defined by Cayeux (1906) as a quartzite-sandstone, of which the quartz are unequigranular, angular or rounded, not sorted. The quartz grains exhibit irregular secondary overgrowths and the cement is made of very fine quartz, with a little opal here and there. Cayeux also remarks some typical features: the very frequent hillocky surface of the Landenian sandstones and some deep, uneven and dichotomous holes in the “Pierre de Stonne” which suggest roots features.

Cayeux criticizes the hypothesis of Buvignier and Gosselet who proposed an “atmospheric metamorphism” to explain the alteration of the cortex of boulders by spraying the quartz grains and then cementing the fragments. Many years later some authors write that these relics overlie some peneplains or pre-existing reliefs and are remains of previously more extended duricrusts (Baeckeroot, 1929; Tricart, 1949). Finally Bonte (1960, 1978) evokes a surficial diagenesis of any - weathered - rock or sediment existing at the site where the silicification occurred, therefore establishing a “weathering” theory to explain the origin of the “Pierre de Stonne”.

From south-western Ardenne to Thiérache and Argonne, Voisin (1981, 1988) studied and mapped the siliceous rock occurrences which crop out slightly on the SW part of the Ardenne Massif and more widely on the Cretaceous and Jurassic substrates (**Fig. 4**). He explored neither the Upper Lorraine nor the Belgium, Luxembourg and Germany, where these rocks also crop out on the same formations and also Triassic rocks. For these areas, it is useful to examine the maps and notes of Baeckeroot (1929), Gulinck & Tavernier (1948), Lucius (1948), Désiré-Marchand (1984), Kadolski *et al*. (1983) and Löhnertz (1978).

Voisin (1981, 1988) singles out by petrographic analyses the “Pierre de Stonne” *sensu stricto*, from the sandstone and conglomerate (with flints pebbles of the Cretaceous; quartzite and quartz pebbles of the Ardennian basement), the two latter formerly attributed to the “Landenian” by facies analogies (**Fig. 5 and 6**). He finds the hillocky surface and roots holes as constant features and also remarks that the different facies are very often mingled on field. He finds very useful fossil remains in Landenian sandstone near Signy-l’Abbaye (Voisin, 1981; **Fig. 7**): some rhizomes and hanging roots and some internal casts of *Phacoïdes, Avicula, Tellina pseudorostralis, Cardium basini, Avicula aizyensis*, the two latter allowing to give a marine origin and a Middle to Upper Thanetian age to the original sediment (Determinations by Michel Perreau of Paris VI University).

Voisin interprets all these siliceous relics (“Pierre de Stonne”, Landenian sandstone and conglomerate) as former sediments of different origins: alluvial silt and sand to coarse gravel, very often unsorted and without any fluvial structure preserved, marine Landenian sands, and of course some shoreline remnants which

(1) NB: The “Landenian” stage is a former and today abandoned stratigraphic term, which was subdivided in the Marine Landenian at the base and the Continental Landenian above (Gosselet, 1883; Leriche, 1929). It corresponds to the current Thanetian stage regarding the marine deposits, and to the “Sparnacian” continental formations regarding the upper deposits. The latter exhibit many weathering features and do not correspond yet to a completely defined stage by the international stratigraphic committee (see Dupuis, 2002).

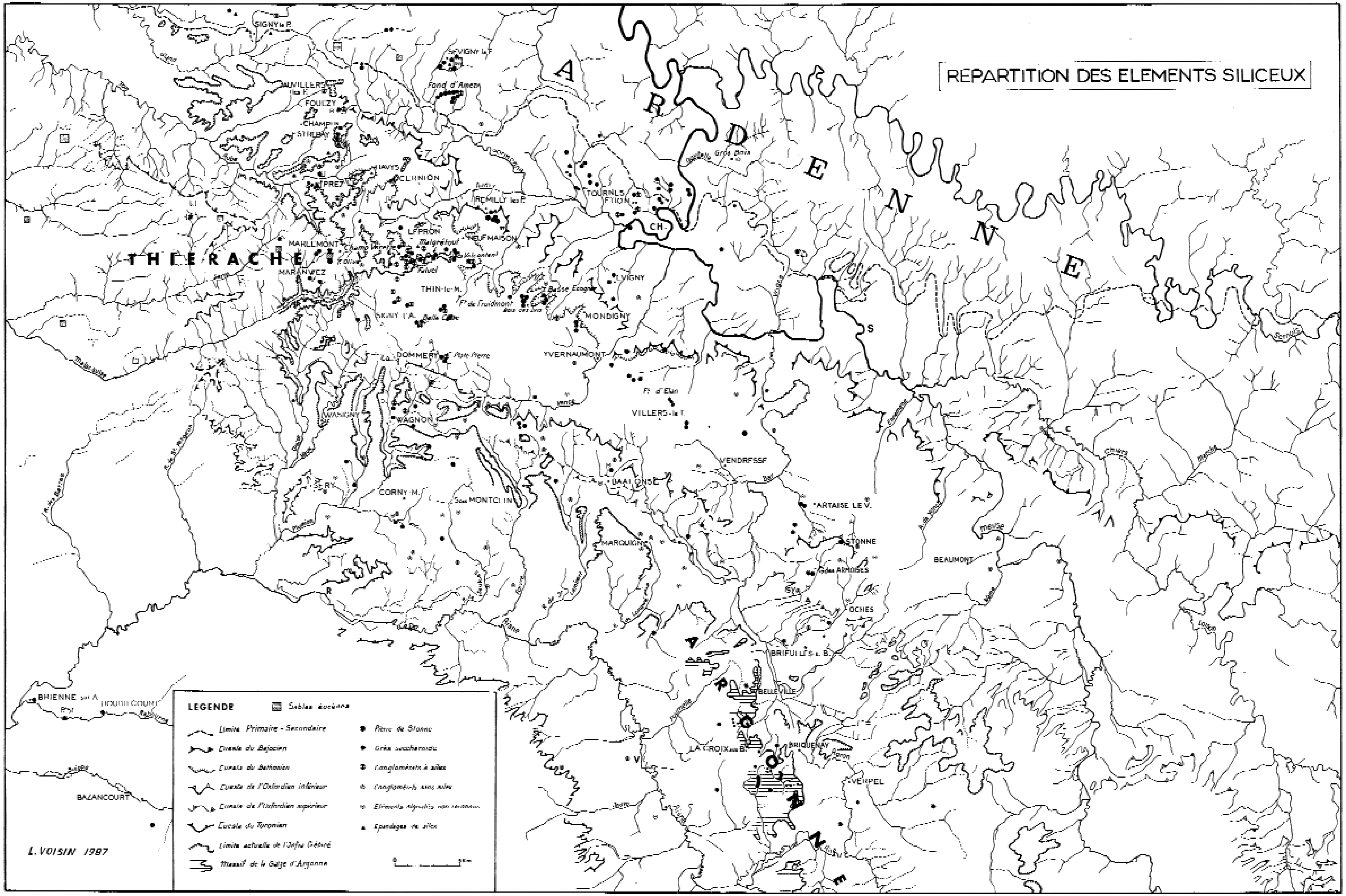
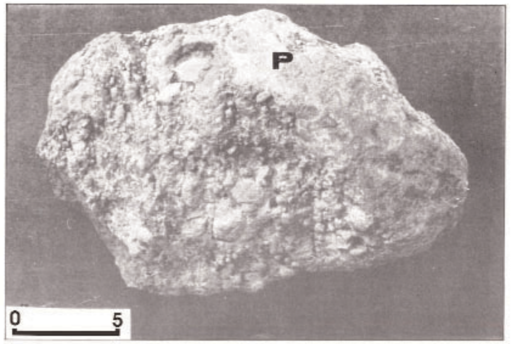
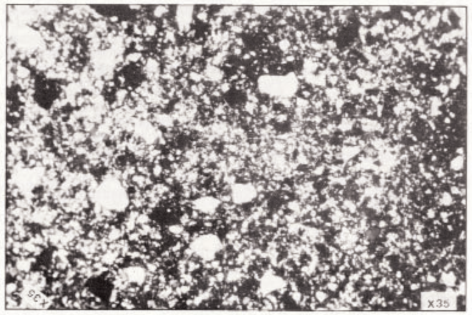


Fig. 4.- Distribution of the siliceous relics ("Pierre de Stonne", Landenian sandstone and conglomerate) in south-western Ardenne, Thiérache and Argonne (after Voisin, 1988).

"Pierre de Stonne" slab at Giraumont



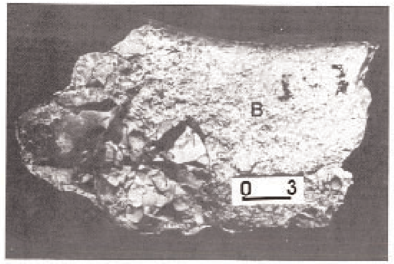
"Pierre de stonne" exhibiting a Lumpy habit; scale in cm, P: area with normal white patina



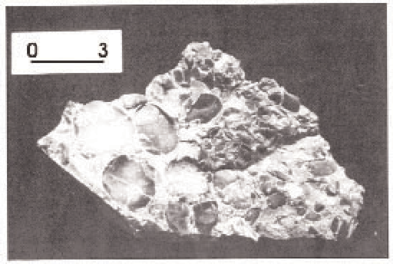
Thin section in a "Pierre de Stonne" of Sévigny-la-Forêt showing unsorted quartz grains

Fig. 5.- Macroscopic and microscopic aspects of the "Pierre de Stonne" sensu stricto *(after Voisin, 1988).*

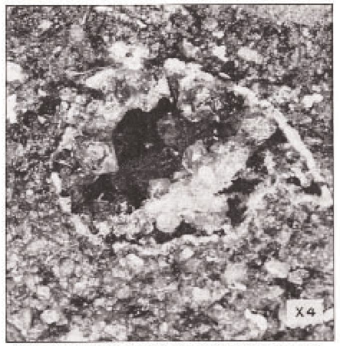
Landenian (or saccharoid sandstone) with a big and unique "root" hole



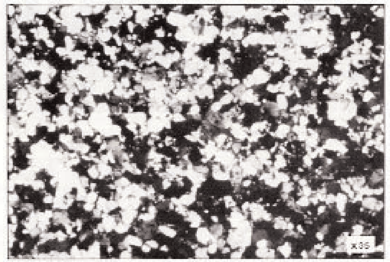
Landenian flint Puddingstone-breccia (near Estrebay) scale in cm



Landenian flint Puddingstone (near Foulzy) scale in cm



Quartz overgrowth in dissolved cast vacuum (Photo R. Behr)



Thin section in a "saccharoid" (Landenian) sandstone (Prez)

Fig. 6.- Macroscopic and microscopic aspects of the Landenian sandstone, conglomerates and breccias (after Voisin, 1988).

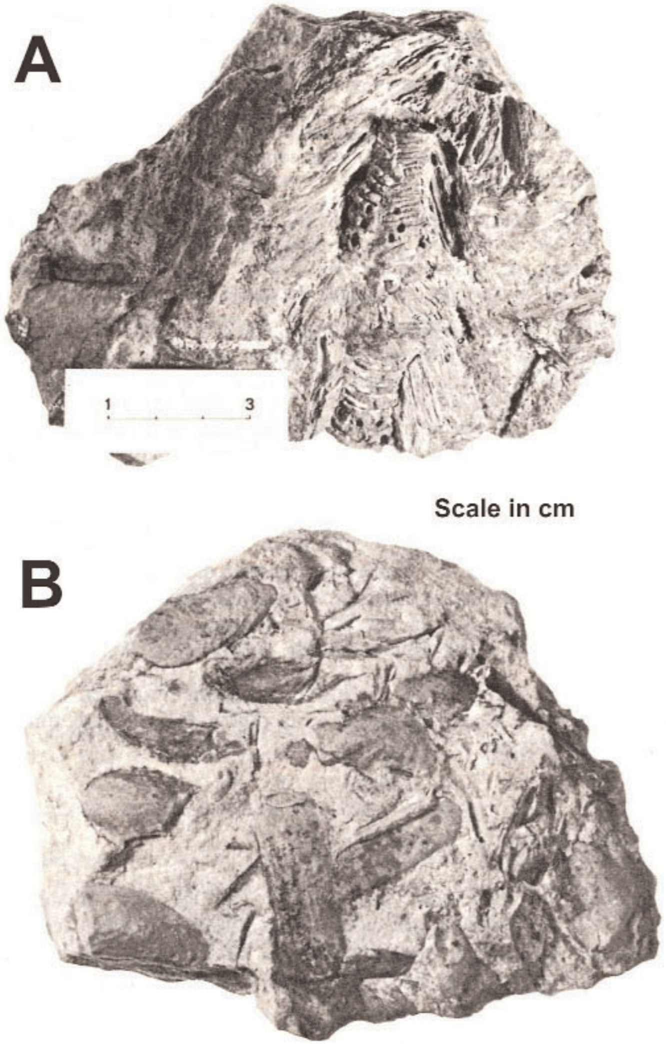


Fig. 7.- Some fossils in Landenian sandstones (after Voisin, 1981; La-Belle-Corre woods, near Signy-le-Petit).

A : Landenian sandstone with rhizomes and hanging roots, Determinations by Jean-Claude Koeniguer from Paris VI University)
B : Landenian sandstone with internal casts of Avicula Aizyensis Desh (Middle to Upper Thanetian of the Paris Basin, Determinations by Michel Perreau from Paris VI University).

he discovered and pointed, often against the Ardennian basement relief. He explains the silicification - after deposition of the whole set - by meteoric water in an area where flows slow down, due to alternating wet and dry seasons, in a continental paleoenvironment with different vegetation strata (trees, shrubs, bushes, high and low grass) thus having different root sizes. Finally, he reconstructs a paleolandscape as a “piedmont” area, rather flat, below the Ardenne relief and compares this to the landscapes described in other parts of the world for such siliceous crusts.

Comparing the Ardenne border with Australian cratons, Léon Voisin wonders in 1988 - at the end of his important and synthetic paper on the “Pierre de Stonne” - whether the development of the kaolinitic weathering profiles of the Ardenne Massif could be synchronous with the formation of the siliceous duricrusts on the piedmont below. At this moment, he has not any definitive answer, due to the absence of geochronological constraints, but solving this question is of utmost importance to understand the paleosurface development and the related geodynamics of this large area.

In 2000-2003, Quesnel and others map the saprolites, siliceous and ferruginous relics of Lorraine and Thiérache, in order to reconstruct the paleosurfaces of the north-eastern Paris Basin and its Ardennian border, then to model the paleohydrogeologic flows of the whole area (Sedimor Project). The points located by Léon Voisin - and former authors - are very often found, Voisin’s facies descriptions and petrographic analyses are confirmed. Then the “Pierre de Stonne” is also found in Champagne, South of the Thiérache, in Upper Lorraine, on the eastern part of the 1/50,000 Thionville sheet (Geological mapping of the France Project), in Luxembourg and in Germany, on Cretaceous, Jurassic and Triassic substrates (**Fig. 8**).

A particular facies soon appears to be a constant feature: the lumpy facies (“faciès grumeleux”) defined by Voisin (1988), for which he had never clearly developed any detailed explanation. In the whole area, many “Pierres de Stonne” show the current ochre patina, and exhibit a nodular to microcolumnar habit, some vertical joints filled with siliceous granules and silica cutans (**Fig. 9**). This allows suggesting a pedogenic origin for the silicification and establishing a link with the Eocene pedogenic silcretes described by Thiry (1981, 1993, 1999) in the southern Paris Basin. Microscopic examinations (**Fig. 10**) do confirm the pedogenic macro-structures, since capping are made of siliceous granules embedded in thinly laminated deposits of opaline silica and titania rich oxides. Illuviations, etched quartz and the leucoxene grains observed in the "Pierre de Stonne" are typical features of the Eocene pedogenic silcretes described by Thiry (1981, 1999), thus constraining the processes involved in the duricrust formation on the considered paleosurface in the north-eastern Paris Basin. This fact also allows proposing a Middle Eocene age for the "Pierre de Stonne". The Sparnacian dating obtained for the weathering and silicification of the "Pays de Caux Sandstone" by Dupuis & Steurbaut (1987) and Dupuis *et al.* (1998) in Varengeville, Upper Normandy, reinforces this Eocene age since this formation - also named quartzitic silcrete - is the strict equivalent to the Landenian sandstone, and crops out from Normandy to Belgium northwards and to Thiérache, the Rocroi Plateau (**Fig. 11**), Upper Lorraine and Luxembourg north-eastwards, where it is mingled with "Pierre de Stonne" on field. Note also that these Eocene silcretes, whether pedogenic ones or Landenian sandstone facies ones, are widespread in England (Summerfield and Goudie, 1980; Isaac, 1981, 1983; Summerfield, 1983), Normandy (Quesnel, 1997), the whole southern Paris Basin (Thiry and Simon-Coinçon, 1996), Brittany (Esteoule-Choux, 1983; Wyns, 1991; Thomas, 1999; Brault, 2002), Anjou-Poitou-Vendée (Wyns, 1996), upon Siderolithic formations in the Massif Central and its borders (Thiry *et al.*, 1983; Thiry & Turland, 1985; Simon-Coinçon *et al.*, 1997) and around the Morvan.

Appendice to the stop 1: The Régniowez and Prez sections (located on Fig. 2A and B)

On the Rocroi Plateau, azoic sand and sandstone are attributed since the Nineteenth century to the "Landenian" by facies analogies with the dated deposits of the northern Paris Basin and the Belgian Basin. Nevertheless none of these was ever really dated.

Some sands of this supposed Landenian formation were studied by Voisin (1996, 1999) in the Régniowez section (**Fig. 12**), on the top of which slabs and lenses are ferruginised, the iron oxides cementing little vegetal twigs in the sand. On the bottom of the section, the sand is well sorted, has a 88 µm median particle diameter and the major part of the grains is well blunt, suggesting a possible marine origin. Here Christian Dupuis observed ghosts of Mollusca casts, unfortunately unsuitable for determinations. In the upper ferruginised sands, no paleobotanic determination was possible, since neither leaf, fruit, nor stem is fossilised. The palynologic analysis was thus the only method able to date the initial sandy deposits. Two samples were taken from the same ferruginous level, prepared in the BRGM Laboratory and studied by Geneviève Farjanel.

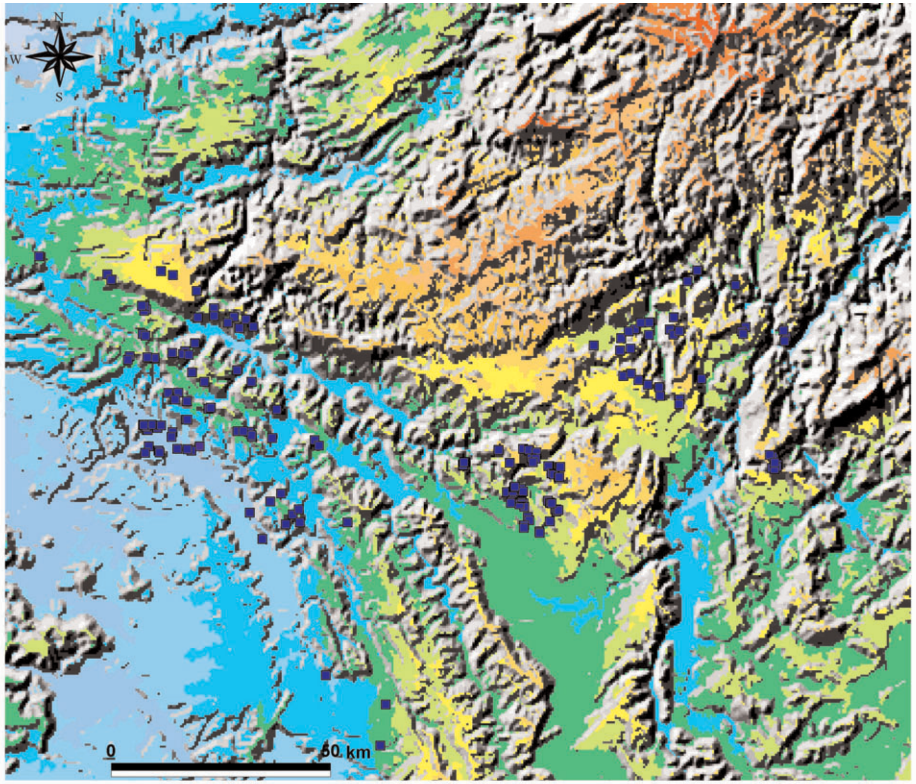


Fig. 8.- Distribution of the "Pierre de Stonne"and "Landenian" sandstone and conglomerate in Thiérache, Rocroi Plateau, Upper Lorraine and Luxembourg upon the map of the benches elevation.

Palynologic determination of the Régniowez ferruginous sand (Geneviève Farjanel and Jean-Jacques Chateauneuf)

The organic matter is made of an amorphous organic matter accompanied by very numerous vegetal tissues of yellow colour and some charcoal fragments.

The microflora is very abundant, well preserved, rather diversified and is represented by the following taxons :

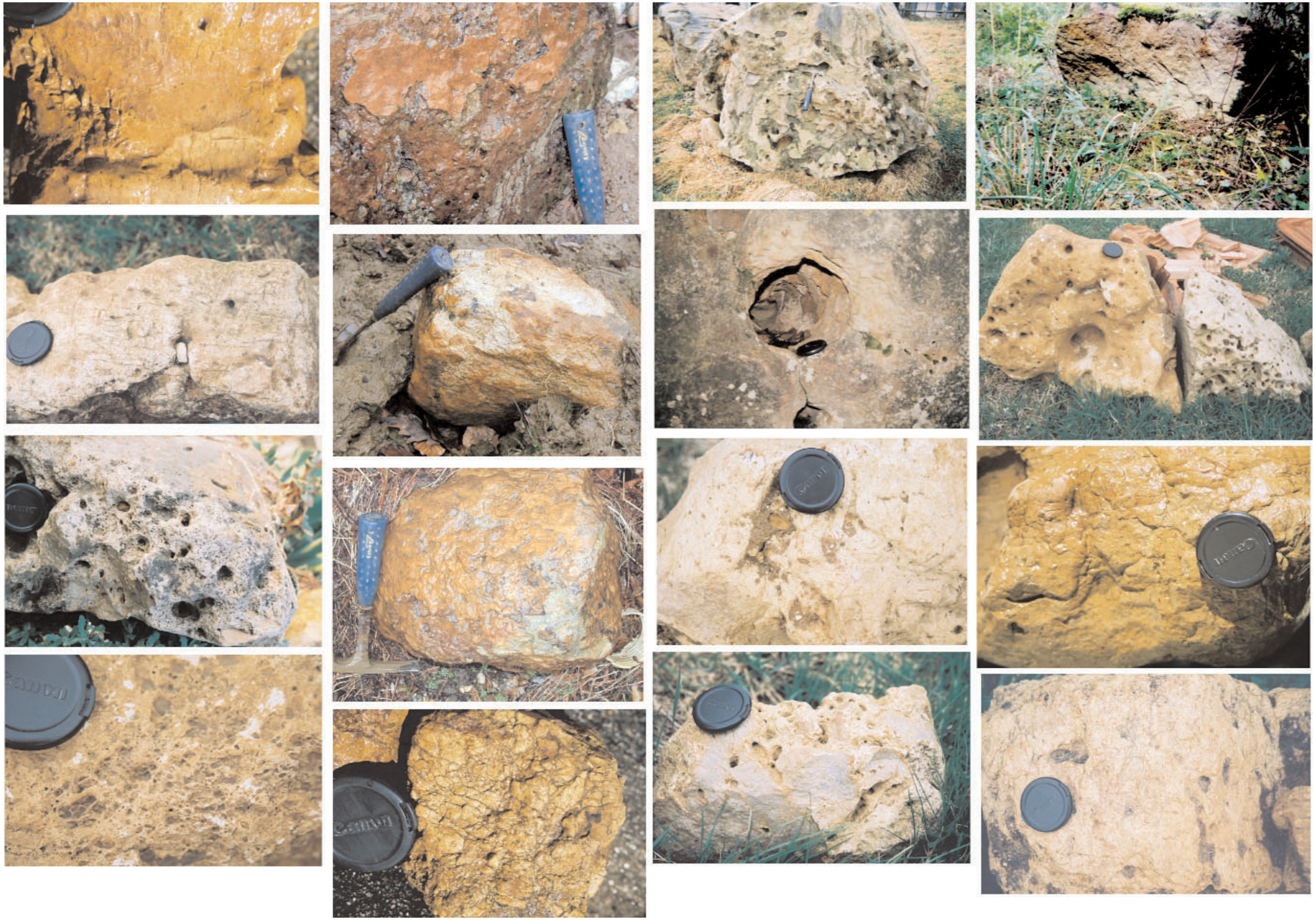


Fig. 9.- Different macroscopic aspects of the "Pierres de Stonne" and Landenian Sandstone in Upper Lorraine, Thiérache and Luxembourg.

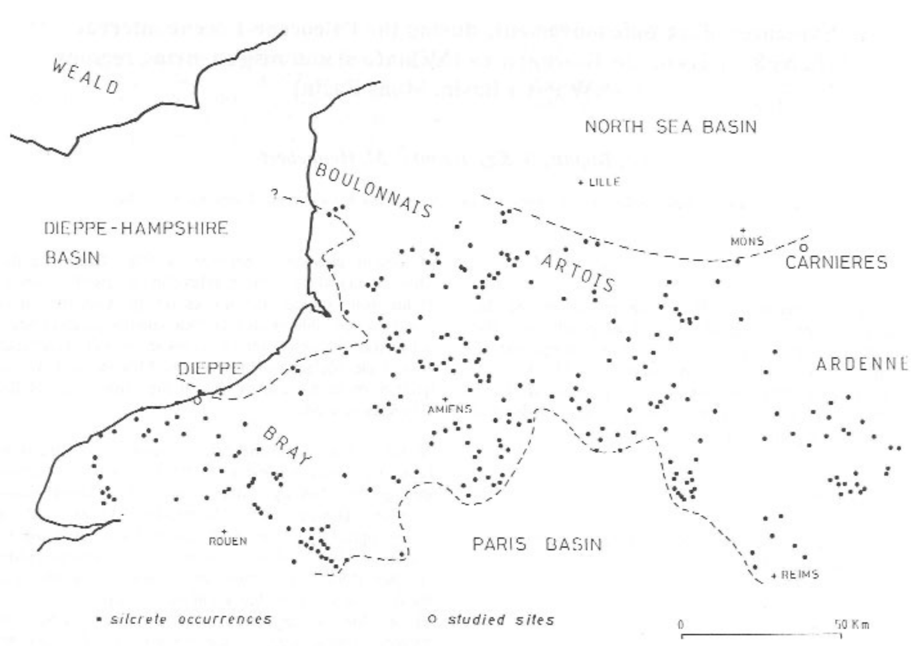


Fig. 11.- Distribution of the Eocene "quartzitic silcretes" between North Sea, Paris Basin, Dieppe-Hampshire Basin and Ardenne Massif, resulting from the weathering of the Upper Palaeocene sands (after Dupuis, 1979; Dupuis et al.*, 1997).*

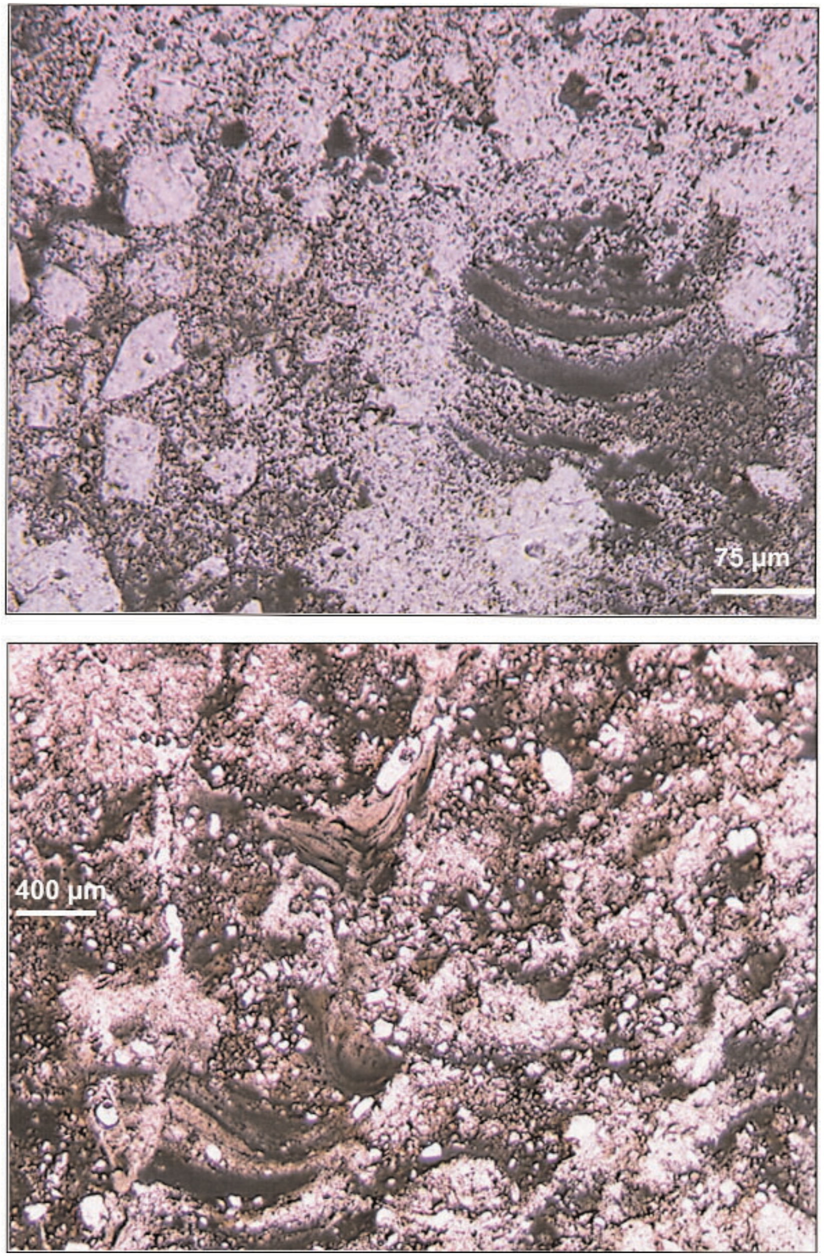


Fig. 10.- Thin section of a "Pierre de Stonne" from Longuyon, showing the typical features of pedogenic silcretes: illuviations made of siliceous granules embedded in thinly laminated deposits of opaline silica and titania rich oxides - probably leucoxene grains - and some etched quartz grains.

Spores

Cicatricosisporites dorogensis
Toroisporis torus
Monoleiotriletes minimus
Leiotriletes adriennis et *L. microadriennis*
Leiotriletes maxoides minoris
Leiotriletes microsinusoides
Leiotriletes microlepioides
Concavisporites sp.
Toroisporis postregularis
Polypodiaceoisporites verruspeciosus
Polypodiaceoisporites potoniei
Goczanisporis verrubacculatus
Punctatisporites crassiexinus
Laevigatosporites haardti
Verrucatosporites favus

Pollens

Monocolpopollenites tranquillus
Monocolpopollenites zievelensis
Arecipites variegatus
Monocolpopollenites sp.
Inaperturopollenites dubuis
Taxodiaceae
Graminidites sp.
Sparganiaceaepollenites sparganioides
Plicapollis pseudoexelsus
cf. *Diporites* sp.
Triatriopollenites engelhardtioides
Triatriopollenites platycarioides
Triatriopollenites paleobetuloides
Corsinipollenites oculis noctis
Subtriporopollenites cf. *campbonensis*
Subtriporopollenites subporatus
Triatriopollenites bituitus
Triatriopollenites sp. *(Myricaceae)*
Caryapollenites sp.
Subtriporopollenites anulatus
Subtriporopollenites constans
Polyporopollenites undulosus
Compositoipollenites minimus
Pentapollenites pentangulus
Polyporopollenites stellatus
Tricolpopollenites asper (Fagaceae)
Emmapollis pseudoemmaensis
Retitricolpites rauscheri
Retitricolpites henisensis
Tricolpopollenites librarensis
Psilatricolporites cf. *megahexactus*
Bacutricolpites variabilis
Scabratricolpites crassiexinus
Tricolpopollenites retiformis
Retitricolpites cf. ilex
Tricolporopollenites sp.
Striatricolporites sp.
Tetracolporopollenites sapotoides
Retistephanocolporites sp.

Age and paleoenvironment

The microflora is ruled by one pollen species: *Plicapollis pseudoexcelsus*; the spores are very abundant and diversified, characterising a hygrophilic environment.

The typical normapols of the Palaeocene are absent. An Upper Sparnacian age seems probable (or from the Sparnacian/Cuisian limit).

An Upper Sparnacian age is given here, thus offering a very important step to confirm a Palaeogene age for the paleosurface on the Rocroi plateau and the adjacent benches.

Another step is the Marlémont Hill on the top of which Landenian sandstone and a few “Pierre de Stonne” crop out, and the Prez abandoned sand quarry where Wealden, Albian and Landenian sand and sandstone are trapped in a karstic pocket (**Fig. 13**; see the location of these sections on the **Geological map** introducing the field trip guides).

In the north-eastern Paris Basin and the Ardenne south-western border, all these residual silcretes ("Pierre de Stonne", Landenian sandstone and conglomerates) and Sparnacian (ex continental Landenian) deposits are thus used as markers to reconstruct the geometry of the Palaeogene surface (**Fig. 14**; Quesnel *et al.*, 2002). These very well developed silicifications should not be confused with the "Meulières" (Millstones) (Ménillet, 1993), nor the sandstones of the Hautes Fagnes area, nor the poorly developed Plio-Quaternary silicifications affecting the Miocene lignitic sands of the Lower Rhine Embayment (Demoulin, 1990). Finally, it should be an interesting point of discussion to compare these silcretes with the cherts of Idenheim which we will see on the German field trip on May 17.

STOP 2: The Ottange quarry [(2)]

The Ottange quarry (located - near the Luxembourg border - on the **Fig. 3**) cuts the Bajocian limestone which exhibits among others some coralline facies and few blue-grey marl beds which are supposed to be the parent rock of the thick saprolites cropping out on the nearby plateaus. This quarry also exposes on its upper part - at around 415 m - the base of the saprolite above the Bajocian substrate and the oxydation front within the limestones (**Fig. 15**).

Some X-Ray diffraction analyses were performed on the marls (supposed parent rock) in the BRGM Laboratories and provided the following results [(3)]:

Sample Blue-grey (parent rock) bottom:

- quartz in traces to low content (~ 20%)
- calcite present (~ 50%)
- microcline in traces
- hematite in infratraces
- pyrite possible in infratraces
- clay fraction in traces to low and containing (on a 100 total):
  . smectite ~ 72%
  . chlorite ~ 6%
  . illite/mica ~ 18%
  . kaolinite ~ 4%

(2) Intermoselle SARL, Carrière d'Ottange, BP 4, F-57840, Ottange, France. Director: Bernard Kubiak (0033 382 50 50 67)
(3) the phase termed "smectite" to simplify the results presentation corresponds more probably to a mixed layer clay illite/smectite with a ~ 40% content of smectite.

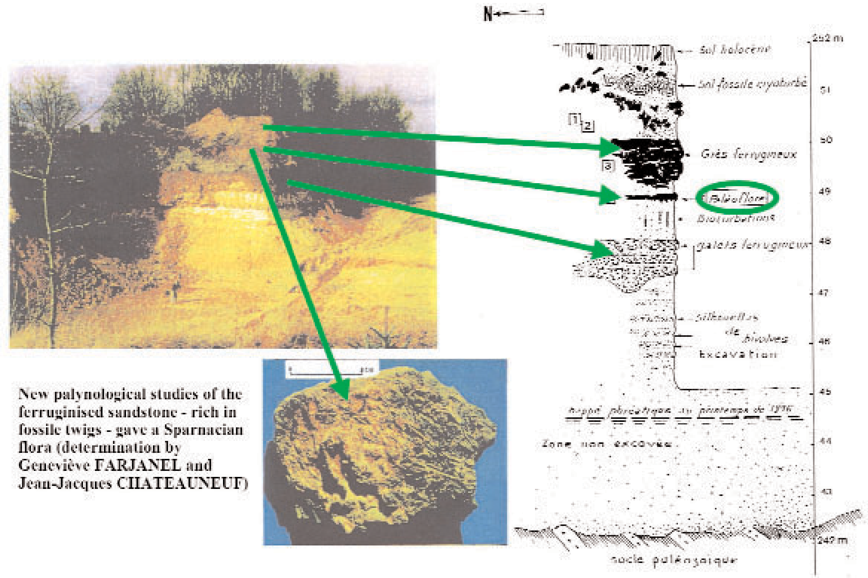


Fig. 12.- The Régniowez section, Rocroi plateau, with iron cemented sandstone on the top (after Voisin, 1996, 1999).

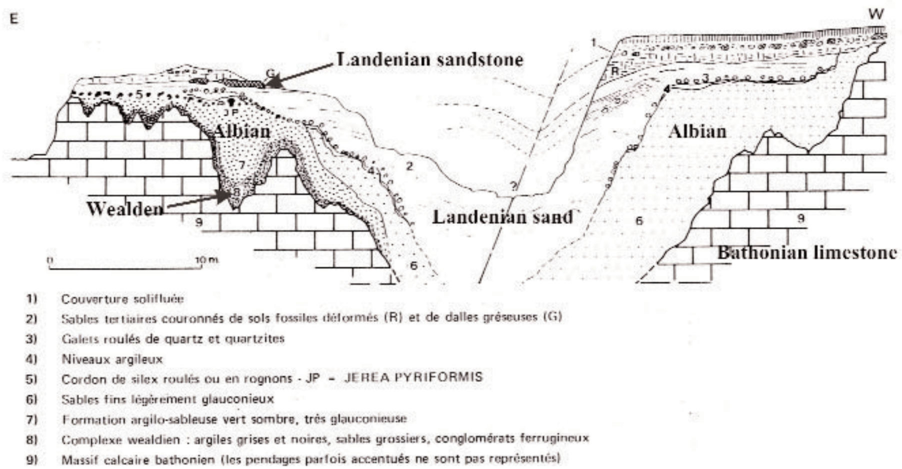


Fig. 13.- The Prez section, Ardennian Thiérache (after Voisin, 1978, 1981).

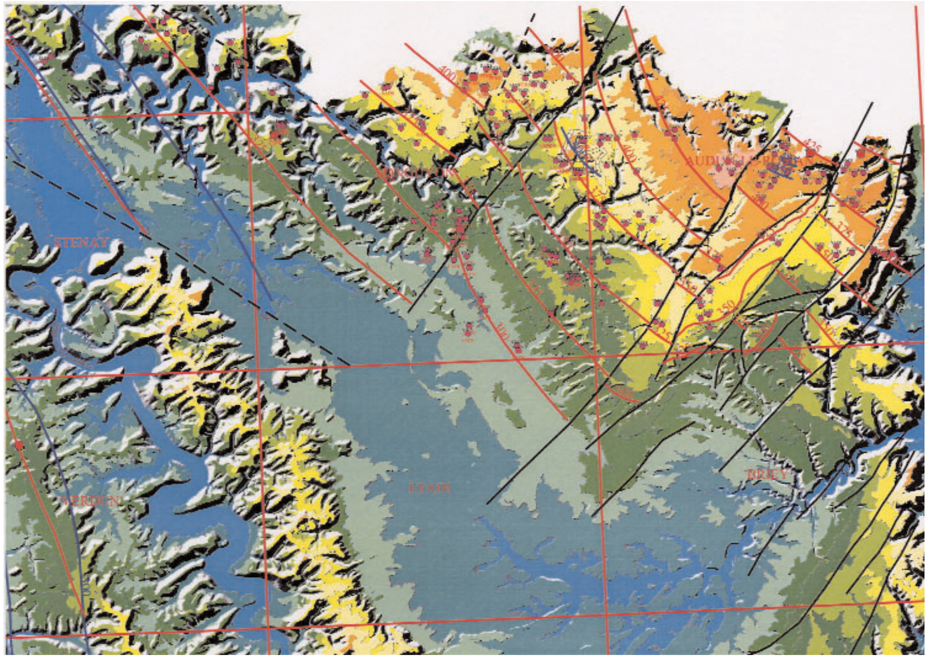


Fig. 14.- Structural map of the Infracretaceous and Palaeogene paleosurfaces in Upper Lorraine and Thierache (after Quesnel et al.*, 2002).*

Sample beige-grey (parent rock) top:

- quartz low to present (~ 30%)
- calcite low to à present (~ 30%)
- microcline in traces
- clay fraction low to present and containing (on a 100 total):
  . smectite ~ 80%
  . illite/mica ~ 18%
  . kaolinite ~ 2%

We will see on the resulting saprolites how this original mineral assemblage evolves.

Fig. 15.- Some aspects of the Ottange quarry (general and detailed photos of the quarry, the oxidation front, the parent rock of the surrounding saprolites).

STOP 3 : The “Borne de fer”

The “Borne de fer” is located south-east of Longwy, very close to the Ottange quarry, on the top of a hill at around 450 m. It was mined for its iron ore from Middle Ages to the industrial revolution in the Nineteenth century, until the Aalenian oolithic iron rich deposits - termed Minette - was discovered and mined. On the hill only saprolite and ferricrete crop out - without any rock of the Bajocian substratum (its unique outcrop is made by the quarry) - so that the thickness of the weathering profile can be deduced as being around 20 to 30 m. Note that the saprolite seems to be very thick in all this area, because the parent rocks were probably more silty and/or clayey before the weathering than westwards or eastwards. The Jurassic deposits have probably such a nature because of the structural setting (Luxembourg Trough) which was active during sedimentation (Le Roux, 1980; Muller, 1987).

No “Pierre de Stonne” was found on the hill, although existing on the benches below. The saprolite is ochre to red and can be seen beneath the trees pulled out after big storms (**Fig. 16**); it is capped by some slabs of ferruginous sandstone looking like a ferricrete, and showing a thickness of 1 to 3 m. These are made of iron oxides and quartz grains (**Fig. 16**). Some X-Ray diffraction analyses were performed on the saprolite and ferricrete from the top of the hill and provided the following results [(3)]:

Sample “Borne de fer” ferricrete

- quartz present to abundant (~ 65%)
- goethite low

Sample “Borne de fer” – ochre saprolite

- quartz in traces to low (~ 12%)
- goethite present
-clay fraction low to present and containing (on a 100 total):
. smectite ~ 10%
. kaolinite ~ 90%
. chlorite possible en traces

then possible amorphous phase, as Iron oxihydroxides (*e.g.* ferrihydrite)

Fig. 16.- Some aspects of the “Borne de fer” (general and detailed photos of the saprolite and the ferricrete).

Sample "Borne de fer" – red saprolite

- quartz present to abundant (~ 60%)
- goethite low
- clay fraction in traces to low and containing (on a 100 total):
  . kaolinite ~ 100%
  . vermiculite and/or weathered chlorite possible in traces

then possible amorphous phase, as Iron oxihydroxides (*e.g.* ferrihydrite)

These results confirm the "due to weathering" nature of the material *i.e.* show that the mineralogical content of the parent rock has been completely transformed during the processes which led to the saprolite and ferricrete. Apart quartz which seems to be inherited from the parent rock, calcite and smectite disappears and new minerals are produced: kaolinite and goethite are found, but no hematite. The latter, if ever produced, could have been changed in goethite. Note that few boreholes - with a motored auger - are planned here in July in order to check the saprolite's thickness and nature. X-Ray diffraction analyses will also be performed on the samples taken in order to study the development and intensity of the weathering processes across the profiles.

A paleomagnetic study was carried out on the "Borne de fer" ferricrete in March 2001 (Théveniaut, this volume), because this ferricrete caps a weathering profile on Jurassic silto-argilaceous formation and may correspond to a scarce remain of an old weathering event of greater importance. Paleomagnetic, rockmagnetic and petrographic analyses reveal presence of a dominant hydroxide contribution with a magnetic remanence carried by goethite.

The "Borne de Fer" ferricrete was sampled on six outcropping profiles, some having different bedding attitude. Two of them are facing each other as inclined towards a karst "pipe". One is slightly tilted, the others being horizontal. We collected 75 minicores using a portable petrol-powered drill. Cores were taken throughout the profile at 5 to 20 cm interval and in order to possibly evaluate some magnetostratigraphic between profile correlation.

All samples showed a strong contribution of goethite on the magnetization with a low and disturbed contribution of hematite. Paleomagnetic direction appeared better defined for the goethite component than for the hematite one. This result confirms the X-Ray diffraction data and thus suggests that the "Borne de fer" is not a true ferricrete *(i.e.* a ferralitic duricrust), but more likely the result of an iron rich sandstone weathering (pyrite oxidised in goethite which cements the sand).

The comparison of the derived virtual geomagnetic pole (VGP) for both component with the new apparent polar wander path (APWP) for stable Europe (Besse and Courtillot, 2002) allows relative dating of the components. The chemical remanent magnetization (ChRM) acquired during the weathering process dates the ferruginization phase. The goethite component pole (**Fig. 17**: pole B1) shows a 120 Ma age, its error circle being between 80 and 130 Ma. Few reversals were measured in the studied profiles, so that the period between 83.5 and 120.5 Ma - Long Normal Cretaceous Superchron - can be rejected. The possible age is thus ante 120.5 Ma or post 83.5 Ma. Given the regional setting, with Campanian and Maastrichtian sediments on the Hautes Fagnes, and important weathering features of the Wealden episode (Yans *et al*., this volume: Field trip I, morning), the 120-130 Ma age seems to be the most probable.

Conclusion

The "Borne de fer" thus corresponds to an old relief (inselberg) of the past - and possibly exhumed - infra Cretaceous paleosurface above a much more widely extended "glacis" whose major features are the Eocene silcretes, therefore being the Palaeogene paleosurface (**Fig. 18**). This approach can also be developed for the huge weathering profiles which cover the Ardenne plateaus (Dupuis, 1992; Voisin, 1995) and whose recent dating - obtained by isotopic tools - gives also Early Cretaceous ages (Yans *et al*. this volume). The next steps of our work will consist in obtaining more datings, in better mapping the weathering profiles and residual deposits in order to reconstruct the current geometries of the paleosurfaces (**Fig. 14**), and their initial ones. Then we intend to model the long term evolution of the landscapes (Gallagher *et al*., 1998; Rohrman *et al*., 2002; Van der Beek & Braun, 1998; Van der Beek *et al*., 1999) between each step in response to the vertical deformation of the lithosphere, the eustatic level evolution and possibly also the climatic imput (CO_2 content of atmosphere).

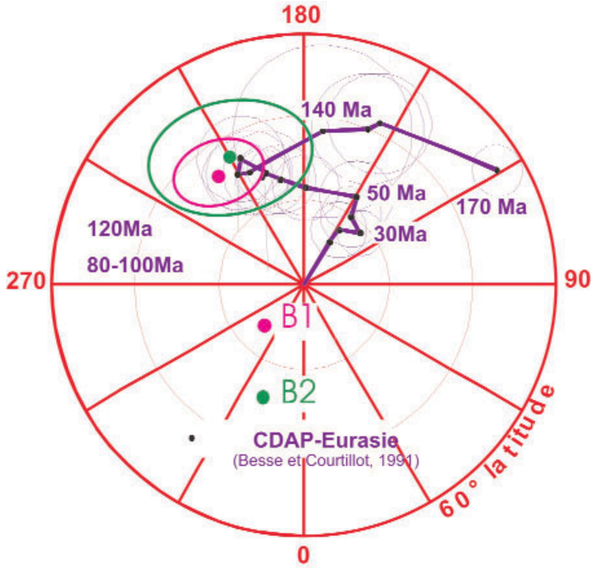


Fig. 17.- Geomagnetic Virtual Poles of the"Borne de fer" with the APWP of Eurasie of Besse & Courtillot (1991).

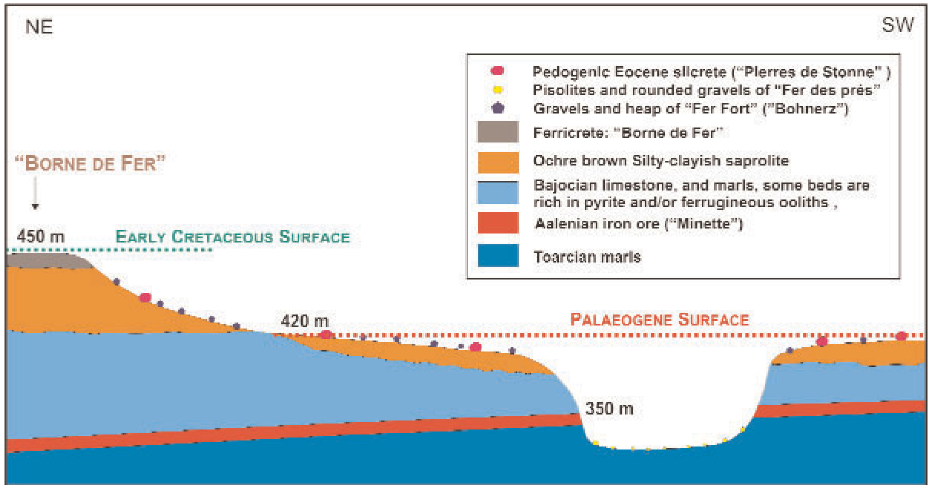


Fig. 18.- Geologic schematic cross section of the "Borne de fer" and its surrounding paleosurfaces (after Quesnel et al.*, 2002).*

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