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Remnants of lithalsas on the Hautes Fagnes plateau (Belgium) are on weathered quartzitic rocks

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ABSTRACT

The ramparted depressions that exist on the Hautes Fagnes Plateau in Belgium, first interpreted in 1956 as the remnants of pingos are best explained as remnants of lithalsas (i. e., mineral paisas), formed from ice segregation within frozen ground (permafrost) of Younger Dryas age. These features have only been described previously from Belgium, Wales and Ireland. Their location, above 500 m a. s. 1. in Belgium, reflects the cold Younger-Dryas climate that have existed at that altitude but it was unclear why similar features did not form on the adjacent Eifel Plateau at the same altitude. We demonstrate here that lithalsas were formed only on weathered quartzitic rocks of the Cambro-Ordovician massif of Stavelot, and probably are associated with local hydrological conditions.

1. Introduction

1.1. CHRONOLOGICAL ACCOUNT

The "viviers" of the Hautes Fagnes plateau (location: fig. 1) are ramparted depressions (fig. 2) which were at first (PISSART 1956, 1963) interpreted as traces of periglacial mounds, more precisely as remnants of pingos. In the Arctic, such mounds are formed under the soil by a growing ice mass and, after its melting, depressions are left with a rampart that consists of material having slipped on the mound sides. Pingos can be as high as more than 40 m, for instance the Ibyuk pingo in the Mackenzie delta.

After discovering in Wales depressions similar to the "viviers", with stratified layers in their ramparts, obviously not the result of human digging (PISSART 1963), this periglacial hypothesis has been unanimously accepted in Belgium. The study of present pingos in

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the Canadian Arctic has shown that the mechanisms of their growth can not be applied to the Hautes Fagnes and can not induce fields of adjacent ramparted depressions like the Belgian forms (PISSART 1974). Cross-sections in the ramparts have afterwards revealed (PISSART & JUVIGNÉ 1980) that the ramparts are, at least in part, the result of accumulating material having slipped down on the mounds. They have also proved that the landforms had appeared during the Younger Dryas (from 13,000 to 11,650 years cal. B.P.).

In the seventies, in Lapland and in northern Quebec, periglacial mounds composed of segregation ice were described; they are much lower than the pingos (maximum 7 m in northern Quebec) and very often develop in great numbers, near each other. After melting, they leave many adjacent ramparted depressions. Such mounds look like paisas, but without the peat cover that is distinctive of the paisas; they are equivalent to the knolls which existed in the hautes Fagnes during the Younger Dryas. As soon as this similarity has been established (PISSART & GANGLOFF 1984), we called the "viviers" remnants of *mineral paisas,* terms proposed by DIONNE (1978). Later, because a Finnish colleague (M. SEPPALA 1986) asserted it was inconvenient applying the Scandinavian word *palsa* to mounds without any peat cover, we proposed (PISSART 1998) to replace, in Belgium, *mineral palsa* by *lithalsa* (a term created by S. HARRIS (1993).

Fig. 1*. Location in western Europe of the figure 3 where are the remnants of lithalsas.*

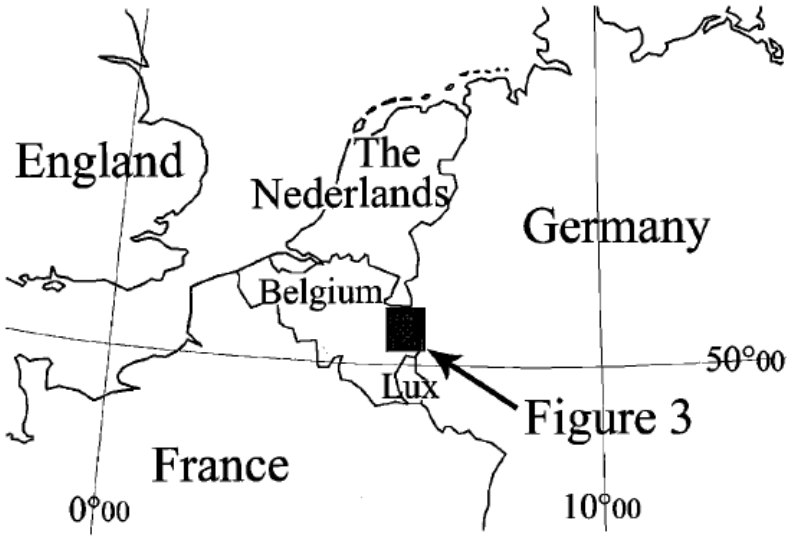

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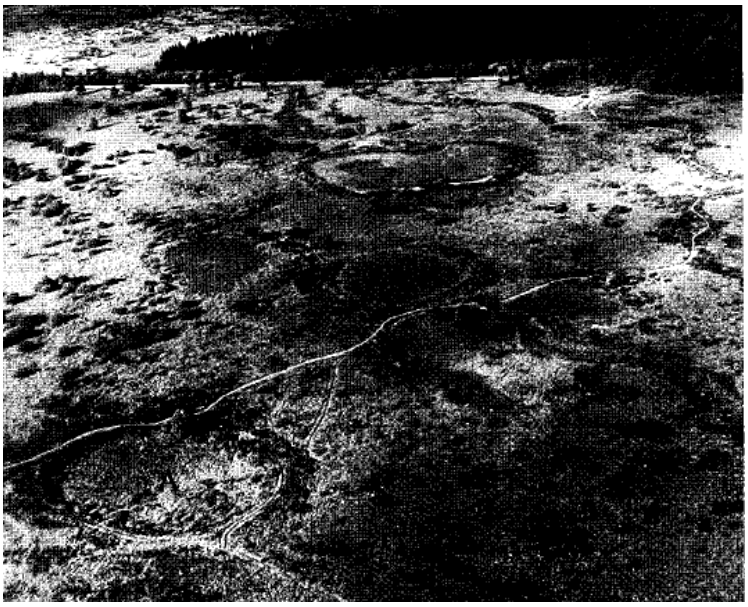
Fig. 2. *"Viviers" (remnants of lithalsas) in the Brackvenn Fagne, S-W of Eupen-Monschau road, in sight in the background (Photo A. Pissart).*



Long since, it was observed that almost all remnants of lithalsas are at altitudes higher than 500 m a. s. 1. ISARIN's study (1997) of vegetation and periglacial phenomena in western Europe during the Younger Dryas has demonstrated that the climate of the Hautes Fagnes plateau had been, at that time, the same as the present climate in Hudsony, where today lithalsas are numerous (PISSART 2000, 2003). A detailed synthesis of what is known about the Hautes Fagnes "viviers" and the lithalsas can be read in PISSART (2000, 2003).

1.2. RELATION BETWEEN "VIVIERS", BEDROCK AND TOPOGRAPHIC FEATURES

Figure 3 is the heart of this paper. On it, contour line of 500 m and waterways have been drawn from the 1:500,000 oro-hydrographic map of the first Atlas of Belgium. Structure map by GEUKENS (1999) has been scanned in the same way and superimposed on the topographic map. We took particular care to well locate the remnants of lithalsas in consideration with the lithological limits and with the contour line of 500 m. We shall

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consider, one after another, the different data appearing on the map and their relationships.

2. Geology

Figure 3 shows there is a close relation between nature of the bedrock and location of the remnants of lithalsas. Almost all of them are located on Revinian 3-4; on the Tailles plateau, they are also present on the Silurian Petites-Tailles Formation (FTP). These strata include thick layers of quartzite seeming a prominent factor in the location of lithalsas.

Let us present these layers after Geukens's paper (1999) and the text of VERNIERS et al. (2001).

2.1. REVINIAN FORMATIONS (CAMBRIAN)

Wanne-Pont Formation (Rv1 and 2) is described by GEUKENS (1999) in this way: Dark green-blue fine slate and green greyish quartzite, alternating with dark slaty quartzite; some rare 15 cm thick conglomerate beds with slaty, quartzitic and sometimes phosphatic pebbles. The lower part comprises black silty slate (called quartzo-phyllades in the older literature), sometimes slate and black finely stratified quartzite. Thickness: 550-650 cm. Thanks to acritarches, fallen into Mid-Cambrian.

La Venne Formation (Rv3-4) is, according to GEUKENS (1999) a heterogeneous unit characterized by the alternation of black slate and dark quartzite. The quartzite is sometimes very clayey and containing mica. In the middle part, very thick beds occur of grey-bluish quartzite which can contain thin gravel layers. The lower part is characterized by a rhythmic siltstone and slate, and also by well-stratified blue quartzite and by sandstone beds containing mica. Thickness: 500 m. Thanks to acritarches fallen into Mid- and late Cambrian.

La Gleize Formation (Rv5) is, according to GEUKENS (1999) too, composed of black slate and silty slate (called "quartzophyllades" in the older literature). This formation is still ill-defined. Thickness: 300 m in the north; unknown in the south. Age: Late Cambrian, based on acritarches.

2.2. PETITES TAILLES FORMATION (ASSUMED AGE: LATE SILURIAN)

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Apart from the areas where Revinian 3 and 4 outcrop, only one important group of remnants of lithalsas is known. They are located on Petite Tailles Formation described by GEUKENS (1999) as whitish quartzitic sandstone, often breccia, compact chloridic slate and conglomeratic sandstone with greenish shales pebbles. Thickness: more than 75 m. Stratigraphic location supposed because only long ranging acritarchs present. It is here a formation mainly quartzitic.

2.3. AMEL FORMATION (YOUNG DEVONIAN)

Two groups of lithalsas were observed outside of the Cambro-Silurian massif. They are located within the military field of Elsenborn (places called Richelvenn and Schneckenvenn). A map, compiled by G. VANDENVEN (1990), shows that these landforms are located on Praguian, more precisely on the Amel Formation (schists and sandstones). Extending the geological boundaries in Germany (RIBBERT 1992) at less than 2 km to the north confirms there is no Cambrian known there.

GEUKENS (1999, p. 186) indicates, in the paragraph where he describes the Petites Tailles Formation: "the unsolved problem of the white quartzites remains; they outcrop in the woods north of Rurbusch (Elsenborn)" and he thus points out that everything is not known on the Hautes Fagnes plateaus where outcrops are rare.

2.4. CONCLUSIONS

From this description, we shall chiefly keep in mind the existence of thick quartzitic beds in the Revinian 3-4 and in the Petites Tailles Formation, where most lithalsas are located. The same beds are not present in other Revinian or Silurian Formations. Consequently, it appears that the remnants of lithalsas are mainly located on quartzitic formations.

3. Altitude (above 500 m)

On fig. 3, the 500 m contour line reveals that remnants of lithalsas quite under this altitude are very scarce: a few ones west of Spa airfield (between 420 and 470 m) and east of Desnié (between 427 and 440 m, at Vert Buisson) are presently the only traces we have found. JUVIGNÉ (2008) indicated some remnants of lithalsas, at about 450 m, at the western end of the Vecquée crest.

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Altitude has a double action on the location of lithalsas: a *climatic* influence we have formerly stressed (PISSART 2003) and an effect on the superficial *weathering* of rocks we had put forward after drillings (PISSART 1974) but, at the time, with very few arguments.

3.1. CLIMATE

On the basis of palaeoclimatological studies by ISARIN (1967), we had previously showed that, during Late Dryas (when the lithalsas appeared), climate at the top of the Hautes Fagnes plateau was the same as nowadays climate in northern Quebec and also in Lapland where lithalsas exist at the present time (PISSART 2000, 2003). Such climate is characterized by cool summers and very severe winters. Isarin's palaeoclimatological variations (established by Late Dryas vegetation and periglacial traces), explain that remnants of lithalsas are found at an altitude of 500 m in Hautes Fagnes, of 250 m in Wales and at sea level in Ireland (PISSART 2000, 2003). However, this climatic influence could not explain, alone, why remnants of lithalsas are restricted to the Cambro-Ordovician Stavelot plateau and do not exist on plateaus, at the same altitude, eastward.

3.2. WEATHERED BEDROCK

On the Ardenne high plateaus, bedrock is, in many places deeply weathered. What is known about the subject was presented in 1995 by J. ALEXANDRE and J. THOREZ; in the same volume, A. DEMOULIN showed the relationship between the weathered rocks and the erosion surfaces. We invite the readers to refer to these papers, but here we summarize the main ideas.

In the past, in whole Ardenne, at high altitude, small sand quarries and kaolin open mines allowed observing, in some places, the deep weathering of geological strata. These working were abandoned a long time ago and, nowadays, most of them do not even appear in the topography. However, when deep trenches were dug for modern highways, the phenomenon appeared again, for a while. The coloured, often reddish beds, have now disappeared under the vegetation which has grown on the highways sides. Records and a few "professional papers" of the Belgian Geological Service have described what could be observed during these important engineering works.

Weathering is deeper if altitude is higher. It is extremely discontinuous; its thickness

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reaches 50 m on the Tailles plateau (COSAN 1969), even 65 m in kaolinic alteration in a digging in the Transinne quarry (DUPUIS et al. 1996). The study is difficult because the close proximity of completely disintegrated beds and of different rocks remained unaltered. A map drawn by DUPUIS (MEILLIEZ et al. 1988) locates outcrops, quarries and borings having revealed kaolinized Palaeozoic rocks in Ardenne and in Brabant; in Brabant, Palaeozoic rocks are often weathered, for instance below Brussels, under 200 m of secondary and tertiary formations (LEGRAND 1968). This weathering is very old, previous to the Late Cretaceous transgression that covered the Hautes Fagnes summits. There, this interpretation results from the presence of strongly weathered beds under 10 m thick (at Hockai) of clays with flintstones. Flintstones indicate that these clays were formed by dissolution of chalk, on the spot, without any other changes (BLESS et al. 1990).

Ardenne rocks, probably exposed since the beginning of the Mesozoic era, have also suffered later periods of chemical erosion, especially during Eocene and Miocene (ALEXANDRE & THOREZ 1995); it is not possible, however, to distinguish the weathering phases between each other. Anyway, what are left of the weathering in Ardenne are the roots of deep erosion, the upper part of it having been swept away.

According to A. Demoulin's map (1995) of the extension of the erosion surfaces, the known remnants of lithalsas are, almost all of them, located on the Presenonian surface; very few (points 2 and 3 of our fig. 3) are located on the Dano-Montian surface, which is also affected by a strong chemical alteration.

At our request, borings were performed by the Belgian Geological Service in 1974 in order to know the bedrock composition close to the remnants of lithalsas. They have been described in detail (PISSART 1974) and their location is given on the aerial photographs of that publication. The conclusions of 1974 are still valid and are summarized hereafter.

In the Brackvenn Fagne and on Malchamps crest, the borings have revealed a deep chemical weathering of the Revinian beds. Decomposed slate had become waterproof clay masses; in smaller quantity, disintegrated quartzites had become more pervious sandy parts. On Malchamps crest, clay with flintstones exists here and there. Everywhere, superficial cover is composed of loess mixed elements from the bedrock.

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Within these formations, chiefly in the quartzitic layers heads, there are small water tables, sometimes on load because their level had risen when the diggings had reached them. Consequently, we thought (PISSART 1974, p. 376) that the remnants of lithalsas found above 500 m are not explained only by climatic conditions due to altitude, but probably also in relation with the extension of the deep physico-chemical alteration which is so important on the High Plateaus.

3.3. CONCLUSIONS

Our map (fig. 3) is showing, without any doubt, a relation between the Palaeozoic geological formations and the location of the remnants of lithalsas. The remnants are situated at altitudes higher than 500 m, because hard climatic conditions prevailed on the High Plateaus, but also because deep chemical weathering affected near the surface the Palaeozoic rocks. It seems, as we had already suggested in 1974, that small water tables within the weathered quartzitic beds have an influence.

4. Remnants of lithalsas

All remnants of lithalsas we know are referred on the map. Many, in the Hautes Fagnes and on the Baraque Fraiture plateau, had been seen on aerial photos a long time ago. Other traces had been observed by very few people, for instance the forms in the Arbrefontaine forest, mentioned as soon as 1984 by Philippe GOFFART, Research Centre of Nature, Forests and Woods, in Gembloux; we had been aware of them thanks to the management of the Walloon Region "Nature and Forests" (acknowledgments at the end of this paper). We also used Google Earth and went to the places in order to find out remnants of lithalsas in Eifel. We found some traces in 3 spots (sites 14, 15, 16), all of them in the northern part of our map (fig. 3), on Cambrian rocks forming the northern end of the Stavelot massif.

On site, we have seen the majority of the remnants of lithalsas we have mentioned, with the exception of the large fields of lithalsas of Malchamps, of the Baraque Michel plateau and o£ the north-eastern Fagnes - because they were known since a long time. More pollen studies should be indispensable in order to prove, by the age of the material filling the depressions, that the hollows are so old that only periglacial conditions can explain them. Without having done such researches, we have kept, on

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our figure 3, depressions with a rampart at least downwards (if they are on gently sloping surfaces), with a broad rampart (not a narrow wall) and having a round design. With straight limits and clear corners, hollows are man-made. Outside peat accumulation can hide low ramparts. If remnants of lithalsas are containing water, man can have extracted their peat either to take advantage of a water reserves in the event of a fire (north-eastern fagnes), or to attract and hunt ducks (Arbrefontaine forests) or even for unknown reasons. Further on, we shall demonstrate that closed depressions surrounded by a rampart are not necessarily filled with peat or water; they can be drained by their subsoil.

Our map does not mention all remnants of lithalsas. Some forms are difficult to found because they are hidden in spruce plantations. Agents of D.N. F. (Division Nature et Forêt du Ministère de la Région Wallonne) have very friendly indicated the depressions they know, but they are working almost only in State and Communal forests, very rarely in private properties.

In very scarce occurrences, for instance in the Brackvenn, one of the most spectacular forms (550 m south-west of Nahtsief parking) could not be flooded (vivier with the letter A on fig. 2). A weir was constructed at the end of an old ditch and it did not induce a flood until the rampart top. We think the bottom of this depression is related to a local water table to which waters can pour. This let us suppose that dry depressions too could be remnants of lithalsas.

In order to consider the relations of all known remnants of lithalsas with geology and altitude, a small scale map is necessary, on which localization of landforms is not precise. It is the reason why we are delivering a few details about the relevant landforms. On our figure 3, we are considering, from north to south, the numbered sites squaring with the headings of the following text.

1. On the Tailles plateau (topo map 55/7-8)

In addition to the well-known viviers at "As Massotais" (Petites Tailles) et near Bihain (La grande Fange), already mentioned by R. & M. Bouillenne in 1937, typical remnants of lithalsas have been observed at both sides of the Baraque Fraiture - Houffalize road, 1 km south-east of the old crossroads. Other likely remnants of lithalsas exist near former quarries 1 km to the south-west of Régné; more detailed studies should be done

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there. All indubitable phenomenons we have observed are however located on the Petites Tailles formation of GEUKENS' map (1999).

2. Massif west of Grand-Halleux, north of Arbrefontaine (map 55/4)

About twenty closed depressions named "mardelles" in a 1997 report by Ph. Goffart present characteristics of remnants of lithalsas (fig. 4). According to a witness, interrogated by M. Guy Lekeu, a forest warden, the most interesting form had been altered when used for duck hunting. Emptying the depression, however, can not explain its high and broad ramparts.

3. Massif east of Grand-Halleux (map 56/1)

A sole very plausible remnant of lithalsa is reported here, at an altitude of 567 m, south of Reuland Wood, 3,700 m east of the church of Recht. This depression is more than 20 m long and its surface is covered by sphagnum moss and bulrushes. Its filling material should be studied to find out its age.

Fig. 3. *Remnants of lithalsas, geology and altitude. Each point represents a group of lithalsas and, sometimes, an isolated remnant. With very few exceptions, they are above 500 m. They are found only on Mid- and Late Cambrian (Revinian 3-4 and Revinian 5) and on the Plateau des Tailles, on very Late Silurian (Petites-Tailles Formation). The geological limits are Geukens' (1999), except in the German part, between Monschau and Simmerath, where the boundaries of Revinian 5 are Ribbert's (geological map, 1992). Only in this area remnants of lithalsas are known on Revinian 5. Numbers 1 to 16 refer to comments regarding each of the 16 sites that are described in the present paper. Sources: Waterways network and 500 m contour line from oro-hydrographic map of the first Atlas of Belgium, scale 1:500,000. Geological sketches from GEUKENS (1999) and RIBBERT (1992). Remnants of lithalsas we personally know.*

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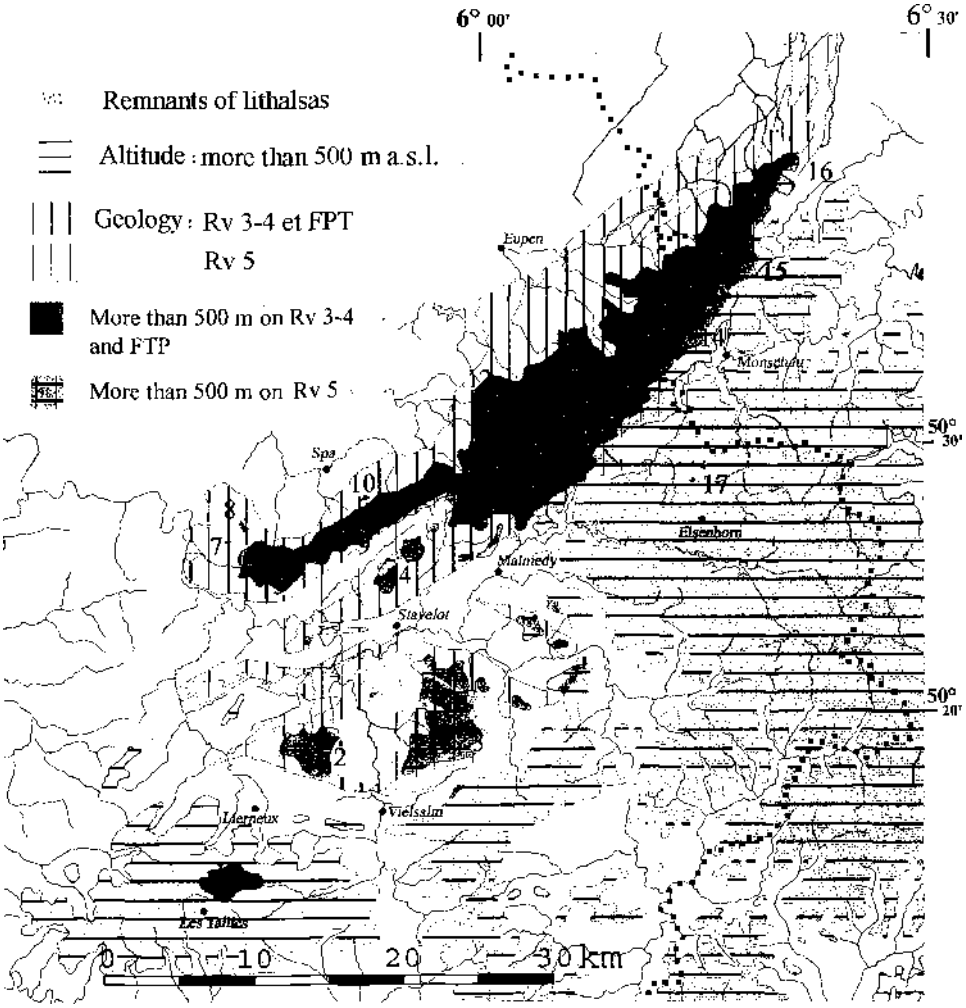

Fig. 4. Aerial vertical view (1952) of lithalsas in the Arbrefontaine forest (number 2 on fig. 3). Ramparts are highly visible on this picture. The largest water feature (black spot with the letter A) is the remnant of lithalsa that was converted into duck trap, as mentioned in text.

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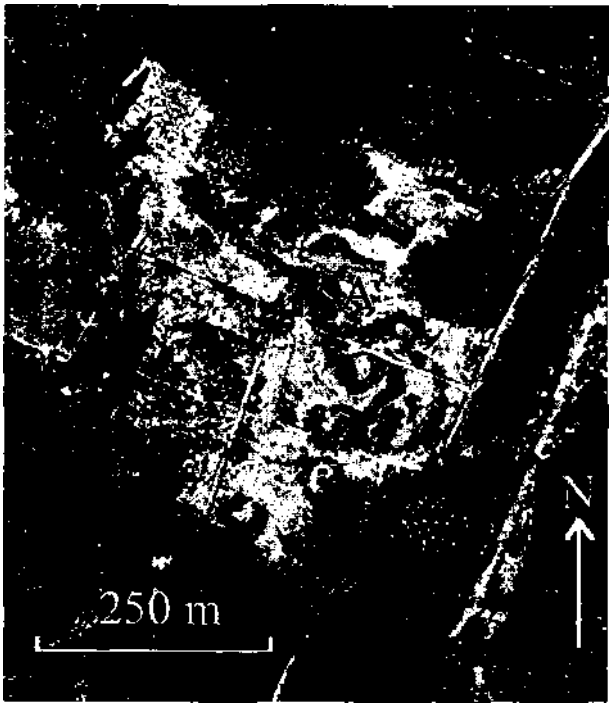

4. 4.6 km north of Stavelot (map 50/5)

Mr. Ziant, of D. N. F. kindly led us to the "Faye le Maire" pass at an altitude of 495 m, and then at an altitude of 508 m, 450 m further to the east. Here, two ponds are indicated on the topographic map. We have interpreted these depressions as remnants of lithalsas.

5. End of La Vecquée crest, north of La Gleize fagnes (1.300-1.800 km E.-S.-E. of Bronrome farm, map 49/8)

Ponds and remnants of lithalsas were located by Ph. Frankart (Research Centre of Nature, Forests and Wood) and shown, on August 30th 1999, to Mr Valière, engineer of Spa forest section and several forest wardens. Botanical surveys of 10 visited sites were published in a report by Ph. Frankart on November 10th 1999, and this report was given to us by Mr Larose, forest warden. Travelling through the field, we found a few more remnants of lithalsas.

6. Bronrome (4 km north of Stoumont, map 49/8)

Three of the ponds situated on the topographic map at an altitude of about 530 m, and approximately 750 m west of Bronrome farm, have evident ramparts and are remnants of lithalsas. They are near a high wind turbine, east of it. The north-est pond on the map, however, is questionable and we dare not interpret it in the same way. These

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ponds had already been reported in 2006 by Rixhon in an unpublished dissertation (University of Liege, Geographical sciences).

7. "Sur la Fagne" (map 49/7)

Juvigné (2008) reminds that Beckers (1970) had reported, on the Harze-La Gleize geomorphologic map, two remnants of lithalsas at an altitude of 450 m at the western end of La Vecquée crest. In an unpublished dissertation (University of Liege, Geographical sciences), S. Collard also has described nearby typical lithalsas and irregular landforms that could have the same origin.

8. Vert Buisson (map 49/4)

S.-S.-W. of Vert Buisson, in meadows east of the high tension wire, there are ramparts of lithalsas, more than 200 m long, stretched downward slope. The joining ramparts are closed downward, a reason why there is no doubt about the origin of these forms. Some smaller depressions exist in other meadows, about 300 m south-west of the last houses of the hamlet, some other forms can be observed in the neighbouring forest. These remnants of lithalsas are located at altitudes between 427 and 440 m; lower we have not found any. Elongated, these forms are stretched on a 3.5 % sloping shelf.

9. Malchamps (map 50/1)

The remnants of lithalsas reported on our map can be seen on the aerial pictures. In addition, we have indicated an isolated depression, surrounded by a rampart and containing some water; it is situated 300 m E.-N.-E. of the place where the Berinzenne-Cour road cuts the Vecquée crest. In the other part of the Malchamps crest, in meadows at both sides of the Spa-Francorchamps road, a few hardly noticeable remnants of lithalsas exist.

10. Spa airport (map 50/1)

In the same direction as the centre line of the take-off runway of Spa airport (west of the road), several typical remnants of lithalsas can be seen at an altitude of 475 m. MET photo 7.23.58 (July 1st, 1968) clearly shows them, as well as other elongated forms, on a higher level than the runway, to the east of the road, at altitudes between 420 and 440 m. Together with the forms at Vert Buisson, they are the only remnants of lithalsas known below 490 m a. s. l.

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11. Baraque Michel plateau (map 50/2)

1,600 m away from the Mont Rigi scientific centre (University of Liege), at the south-south-west, R. and M. Bouillenne reported in 1937 an area with "viviers", at Beaulou, on their figure 1. They studied one of these forms and called it the Marquet Vivier (Marquer was a forest warden who helped them). It is precisely located on the map enclosed in the "Guide du plateau des Hautes Fagnes" by COLLARD & BRONOWSKI (1993).

12. Plenesses, Fagnes farms, fange Leveau (map 50/2)

A field of lithalsas, 3 km to W.-N.-W. of Baraque Michel, in the Grande Fagne, was charted by R. and M. Bouillenne from aerial pictures taken before the war. Their map appears on their figure 2. A more detailed view of the area (before farms were established there) is aerial photo 50/006, scale 1:20000, taken on September 15th, 1962 by Belgian Military Geographic Institute. We used this photo to locate the visible lithalsas. Among them, COLLARD & BRONOWSKY (1993), on their map, are locating the "grand vivier" at an altitude of 560 m. The downward side of the rampart contains peaty parts. We have taken samples of this peat at two different levels and they have been dated by ^{14}C, by Beta Analytic Inc (USA). They found a conventional age of 400 ± 40 year BP and 470 ± 50 year BP which corresponds to 1,460 and 1,440 Year cal. A. D. That peat is not in situ. It was reworked when the morphology of the vivier had been by men changed. Additional studies should be performed to determine when it happened. On the other hand this form is very interesting: it is the only one we know that is fitted in a larger rampart; this distinctive feature suggests that they was a succession of two growing generations, a fact not proved until today. Here too, recent closing of the vivier, to fill it with water, is unfortunate: a study of the ramparts, which could lead to new interesting data, will be more difficult.

13. Fagne Wallonne and Fagne des Deux-séries, N.-E of Botrange - Belle-Croix road (maps 50/2 and 50/3)

Within the bounds of an agreement between the University of Liege and the Walloon Region (D. G. R. N. E.), WASTIAUX & SCHUMACKER (2003) performed here a radar study of surface and subsurface topography of peaty areas. Our charting of the lithalsas results from the report of that study, very kindly communicated by C. Wastiaux. We have also consulted aerial photos of the area which, of course, can not display the forms hidden

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under peat cover discovered by the authors.

Analyzing the distribution of the remnants of lithalsas, WASTIAUX & SCHUMACKER (2003) write in their report (p. 25): "among the factors we must consider," (to explain the distribution of the remnants of lithalsas) "besides sloping, lithological variations could well explain the contrasts. We particularly think of differences in water supply possibilities under the developing lithalsas: different composition of rocks, different fissuring degree, etc. Only a complementary geophysical prospecting, or deep diggings, could solve the question." Our present note confirms this well- founded remark.

14. In north-eastern Fagnes, at latitude of Monschau (map 43/7)

Wastiaux and Schumacker's study also covers the "tourbière royale" (royal peat bog), south of Eupen-Monschau road. Their results have been used too. Northward, aerial photos chiefly helped us to locate the areas where remnants of lithalsas exist. In addition, we scoured Mutzenich, a German village, where topography reveals, here and there in the meadows, that lithalsas were present. But the observations were difficult because of the presence of many houses; only quite clear forms have been reported.

15. West of Simmerath (map 43/8)

West of Simmerath, near and south of Paustenbach, we carefully examined the forms that are close to the Revinian limit. Under this village too, buildings made impossible to observe. Anyway, an important fact is, in this area, that he Revinian limit on RIBBERT'S map (1992) and the limit of the extension of remnants of lithalsas match each other perfectly. Photo 6.7,008 of Travaux Publics (Public Works), here repro duced (fig. 5), excellently shows elongated and circular forms near the Belgian border. Some of them are very elongated along the slope.

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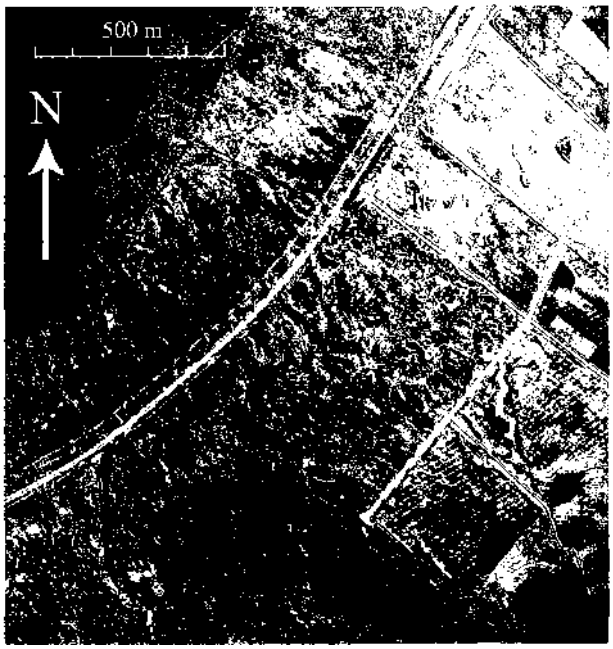
***Fig. 5**. Remnants of lithalsas on the eastern slope of Hoscheit (west of Simmerath, site 15). Elongated and circular features with all the transitions. Photo 7.008 de 1953 du MET. © Service Public de Wallonie Secrétariat général - Département de la Géomatique Direction de la Géométrologie.*



16. In Germany, near the northern border of the massif (map 43/4)

Several remnants of lithalsas have been recognized near the State border, 1.5 km west of Lammersdorf and in the forest 3 km north of the same village. A very beautiful isolated round form has been observed 6 km north of Lammersdorf, at Raffelsbrand.

17. On the military field of Elsenborn (map 50/3)

MET aerial photos 72,372 to 72,374 from 11C mission of Stavelot, are showing very distinctly two small areas, 1,300 m from each other, at Richelvenn and Schneckenvenn. Their typical landforms were discovered a long time ago and, according to geological maps, are located on Lower Devonian. We cannot explain the location there of these lithalsas remnants.

Conclusion

Our map (fig. 3) demonstrates, beyond all questions, that remnants of lithalsas are located almost only on a few geological formations previous to Devonian and characterized by quartzites. Another typical fact is their existence at altitudes higher

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than 500 m, explained by two different factors: climatic conditions that prevailed on the high plateau during Younger Dry as and severe chemical erosion affecting the Palaeozoic rocks near the Mesozoic transgression surface. As we had already said in 1974, it is very likely that small water tables, within disintegrated quartizic beds, played an important role in the occurrence of lithalsas.

These observations allow understanding the reasons why remnants of lithalsas do not exist in the nearby Eifel plateaus, at the same altitude: their bedrock is different.

Acknowledgements

Professor Geukens has friendly re-read our text and given his comments. He also has cautioned using his map in this paper, although saying he would have modified some layouts. Mrs. Cecile Wastiaux has passed us the radar study of surface and subsurface she had made in 2003 with Mr. René Schumacker.

Several remnants of lithalsas have been reported to us by Mr. Hendrick, from Stavelot, and also by Mr Leclercq, director of the Hautes Pagnes Station of the University of Liege.

Engineers of the "Nature et Forêts" administration, Mr. Valière from Spa and Mr Adam from Vielsalm, gave us the opportunity of meeting forests wardens who led us in the forest to show the depressions they knew.

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Thanks to Mr. Larose, we could have access to a 1997 report by Mr. Philippe Goffart to his administration, with a heading «Intérêt biologique et conservation des mardelles du massif forestier d'Arbrefontaine», a report locating some ponds, south of Fosse, on Revinian 3-4 and suggesting they are remnants of lithalsas. Mr. Philippe Goffart wrote us that Professor Jean- Marie Dumont (UC Louvain) had told him in 1984 the existence of those ponds.

Mr. Collignon, director of the Topography Service of MET, has allowed us to check old aerial photos in premises of his administration and give us the permission to reproduce

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the photo shown on fig. 5.

My friend, Jean Grimbérieux, has obligingly translated the text in English.

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