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U/Th dating of the Annevoie-Rouillon travertines

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Abstract. The carbonated travertine's accumulations near sources or in rivers constitute very good environmental indicators (Ford & Pedley, 1996; Guendon J.-L. et al., 1997; Guendon J.-L. et al., 2003; Ollivier, 2006 ; Roiron, 1997). They can record climate variations, fluctuations of the basis level, epirogenic movement and eustatic variations. Among climate substitution variables, let's quote the pollen collections, the plants debris and the geochemistry. Moreover, the travertines can be dated by the uranium series disequilibrium method, or radiocarbon. In Belgium, there are some sites of travertines deposits: Annevoie-Rouillon, Casteau, Chaumont-Gistoux, Hoyoux's valley, Orval, Treignes, Vierset-Barse (Geurts, 1976). The travertines of Annevoie-Rouillon are famous because they have been the subjects of litho-stratigraphic, palynological and geochemical studies (Paepe, 1965; Bastin et al., 1968; Geurts, 1976; Janssen & Swennen, 1997). These studies have been made in the stratigraphic series of the behind-dam in the carbonated rudites and arenites carbonates and clays. A new examination of the deposit has permitted to discover the witnesses of the dam basis which present more compact facies with plant debris. Those facies are able to be dated by the uranium series disequilibrium method. The sampling has been made in two types of facies: the travertine itself and speleothems in little cavities in the travertines. The first have not permitted to have reliable ages because of impurities in the calcite. The second have been dated from the beginning of the Holocene. Those datings confirm the Holocene ages of the stratigraphic series studied by Bastin and Geurts. Moreover, those ages imply that the Meuse River occupied an altitudinal level equal or lower than its present level just after the last glaciation. Future studies would consist in drillings under the level of the river to look for the basis of the travertine edifice.

Keywords: Holocene, Meuse valley, environment indicator, speleothem

1. Introduction: the site of Annevoie-Rouillon and the previous studies

The travertines of Annevoie-Rouillon constitute one of the most famous sites with travertines in Belgium. This travertines massif develops at the outlet of the "Ruisseau d'Annevoie" river to the Meuse valley (Figs 1 & 2). The river has cut this formation with two massifs at the right and left border of the river (Fig. 3). Those formations are constituted by travertines rudites and arenites, more or less cemented, with debris of plants and stems. The stratification is nearly horizontal with channels (Fig. 4). Those travertines have been studied by Paepe (1965). Bruno Bastin (B. Bastin et al., 1968) and Marie-Anne Geurts (1976) analysed the travertine by palynology. They demonstrated the Holocene age of those formations. Janssen & Swennen (1997) applied oneself to the petrography and geochemistry. Cors et al. (1998) have also studied the travertines by palynology and ostracodes.

2. The target of this study and the sampling

We can explain this formation as an accumulation of travertine rudite and arenite with loams and clays behind a dam formed by more massive facies like laminated carbonates. Indeed, the travertines building across a river are constituted by a succession of dams with laminated and indurated facies. Behind it, carbonated sands with concretions around plants debris accumulate. Here, the hypothetic dam must be between the travertine sands and the Meuse River. We have found some pillars along the road Namur-Dinant and in some gardens which are the witnesses of the dam, which probably has been mined for building stones. The facies is a stems travertine, more indurate than the sand facies (Figs 5 & 6). Some surfaces have a dip between 45° to 50°, from upward to downward, indicating the direction of the paleoflow in accordance with the topography.

The facies of the dam are more favourable than the behind-dam formations for uranium series disequilibrium method datings. We have investigated the lower accessible levels of a massif in a garden, 2 meters above the Meuse altitude, by

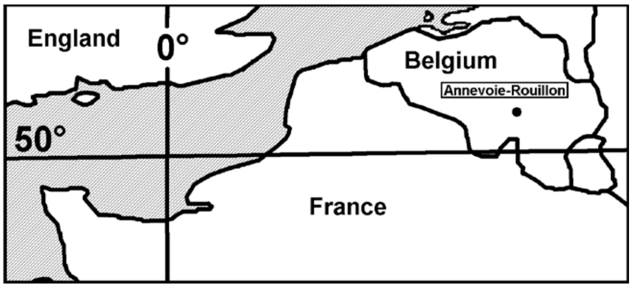

Figure 2. Location of the studied site.

Figure 1. Section in the travertines formation, along the road to Annevoie. They are the travertines rudites and arenites behind the dam.

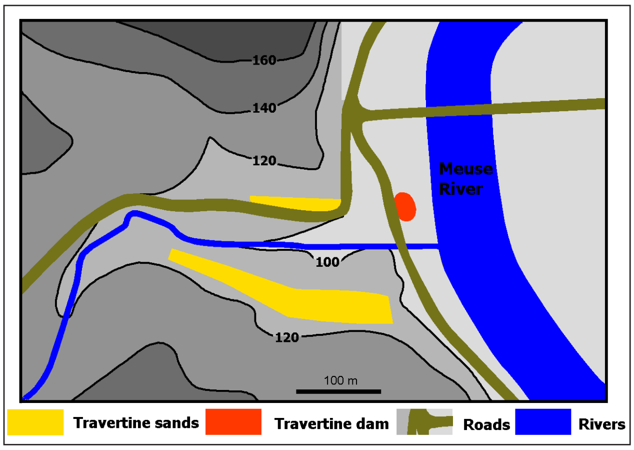

Figure 3. Map of the studied site. The travertines rudites and arenites behind the dam are in yellow. The two main massifs are in left and right bank of the river which has cut the whole formation after its erecting. The location of the main witness of the dam is in red.

Figure 4. An aspect of the behind-dam travertines facies: a channel.

Figure 5. A residual pillar of the dam, along the road Namur-Dinant.

Figure 6. Example of the facies of the dam.

drilling (Figs 7 & 8). We have made 7 boreholes and obtained 4 meters long cores. Some little primary cavities are present in the travertine with decimetres' dimensions. In these primary little caves, develops secondary flowstones (Fig. 9).

3. Dating

The presence of continental carbonates in Quaternary formations permits to date those sediments by the U-series disequilibrium method. Until now, the ages of travertines were obtained by the palynology. Two types of rock can be dated: the travertine itself and the speleothems in little cavities of the travertine. Those speleothems are younger than the travertines at the same stratigraphic level, or almost synchronous.

Figure 7. The travertine massif under the pillar of the figure 5. The red ellipse indicates the site of the drillings.

The reliability of a U/Th age is linked to the respect of initial conditions. The geochronometer is based on the absence of ^{230}Th in the carbonate during the chemical precipitation. Along the time, ^{234}U decays in ^{230}Th. The ratio ^{230}Th/^{234}U constitutes our geochronometer.

The first condition of reliability is that ^{230}Th must be absent at the initial time in the carbonate. This condition means that the geochronometer begins at the time 0. Unfortunately, it is possible that the carbonate contains non radiogenic ^{230}Th at the initial time, coming from clayed minerals or some oxides or hydroxides present in the water.

The second condition of reliability is that the geochemical system must remain closed during the life of the formation. If this condition is not fulfilled, some isotopes can leave or enter in the system, modifying the geochronometer. The weathering can easily provoke departure or admission of uranium because this element is soluble when it has the oxidation state +6.

In the case of travertine, both conditions can be easily broken because of the porosity of the material and its exposure to the rain. It is why, in the case of Annevoie-Rouillon, the presence of speleothems is a stroke of luck. This stalagmitic calcite is very compact and doesn't show any weathering mark. It is also very pure. Of course, the ages of speleothems are younger than the age of the travertine at the same stratigraphic level. The isotopic results and the chronologic interpretations are in the Fig. 10. The four samples AN-III are travertines in stratigraphic succession. The samples AN-I are coming from another core. All those samples are not affected by the weathering. AN-IV and AN-V include each two samples of two flowstones, sample 1 being younger than sample 2.

4. Interpretation

The ages found for the travertines are analytically without reproach but have too low ^{230}Th/^{232}Th ratios. The limit ratio is generally estimated at 20. The conclusion is that the ages are older than the real one because of a contamination by foreigner ^{230}Th which comes from detrital contaminants like clayed minerals. The speleothems are very much interesting. The ^{230}Th/^{232}Th ratios are good. The dating of the speleothems is reliable. We must obviously consider that the travertines of this stratigraphic level and of lower level are older. The ages of each analysed speleothem are consistent.

Those speleothems developed after the construction of the travertine's dam. This is older than 11.500 ± 1.500 y BP. The basis of the dam is presently concealed under diverse infrastructures (houses, gardens ...), it is also older. The position of the results towards some proxies in the frame of Holocene is given in the Fig. 11. One sees that the first levels of the travertine are situated in the beginning of the Holocene or even in the Alleröd, supposing that the precipitation of the carbonated is stopped or very slowed down during the Younger Dryas (Fanning

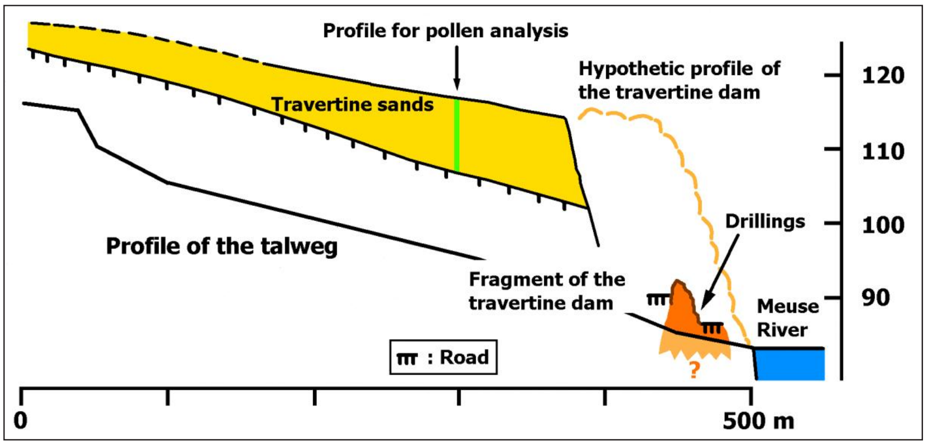

Figure 8. Diagrammatic section oriented W-E of the site. The profile for pollen analysis is an example because several profiles have been made by M.-A. Geurts.

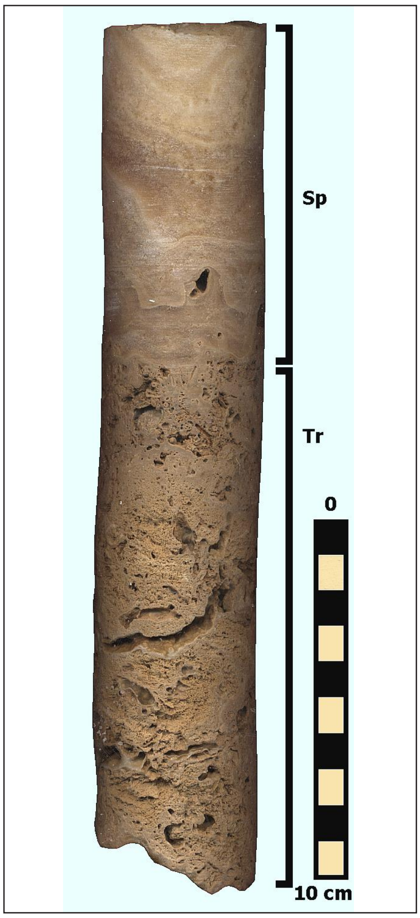

Figure 9. Example of a core with a first part constituted by a speleothem (sp) and a second part which is the travertine oneself (tr).

& Weaver, 1997; Goslar et al., 2000; Hughen et al., 2000; Johnsen et al., 1992; Muscheler et al., 2000; Muscheler et al., 2008).

We have tried to date the travertine itself by the radiocarbon method. Of course, one must take in account the dead carbon which is coming from the dissolution of the Palaeozoic limestone by running and seepage waters. Nevertheless, apart from any correction linked to a model, this dating should provide a confirmation or not of the U/Th ages. Two samples around the places of the speleothems have been analyzed at Orsay by Dominique Genty on the travertines. The two ages are: 9310±160 B.P. and 10075±245 B.P. D. Genty has taken the correction ^{13}C for the calibration into account. The correction of the dead carbon has been taken with a value of 15%, which is a value found in some speleothems in caves.

5. Conclusion

The general conclusion is that the visible basis of the travertine's dam at Annevoie-Rouillon dates from the beginning of the Holocene. Maybe the invisible basis, under the ground of the garden or the road dates from the Alleröd. Those conclusions confirm the chronologic interpretation of the palynology: the maximum of accumulation of travertine's sands behind the dam takes place during the Boreal and Atlantic periods. Those data are important to study the geomorphologic evolution of the Meuse valley and the paleoclimatologic context. The consequence is that, at the exit of the last glaciation, the Meuse River was at an altitude close to the present altitude. The continuation of this study would be the investigation of the basic levels under the present ground level.

6. Acknowledgements

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Echantillon	$[U]_{ppm}$	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	$[^{234}U/^{238}U]_{t=0}$	Age (en m.a.)
AN-III(1)	0,679 ± 0,016	1,459 ± 0,034	0,341 ± 0,017	1,8 ± 0,1	1,519	44,3[+2,7/-2,7]
AN-III(2)	0,610 ± 0,010	1,403 ± 0,023	0,310 ± 0,012	1,8 ± 0,1	1,45	39,5[+1,8/-1,8]
AN-III(3)	0,611 ± 0,017	1,476 ± 0,038	0,284 ± 0,010	1,81(± 0,06)	1,526	35,5[+1,5/-1,4]
AN-III(4)	0,632 ± 0,012	1,415 ± 0,026	0,318 ± 0,016	1,63(± 0,10)	1,465	40,7[+2,5/-2,4]
AN-IV(1)	0,871 ± 0,010	1,487 ± 0,014	0,105 ± 0,012	grand	1,504	11,9[+1,5/-1,4]
AN-IV(2)	0,923 ± 0,009	1,530 ± 0,013	0,101 ± 0,009	21 ± 16	1,548	11,5[1,1/-1,1]
AN-V(1)	1,183 ± 0,015	1,496 ± 0,014	0,067 ± 0,003	16 ± 3	1,503	7,4[+0,4/-0,3]
AN-V(2)	1,132 ± 0,016	1,515 ± 0,016	0,077 ± 0,002	16,3 ± 2	1,527	8,7[+0,3/-0,3]
AN-I(6)	0,791 ± 0,024	1,417 ± 0,039	0,309 ± 0,124	2,2 ± 1	1,465	39,4[+20,5/-17 ± 4]
AN-III(6)	0,703 ± 0,013	1,496 ± 0,026	0,191 ± 0,013	2,2 ± 0,2	1,529	22,7 ± 0,013

Figure 10. Table of the isotopic results and ages.

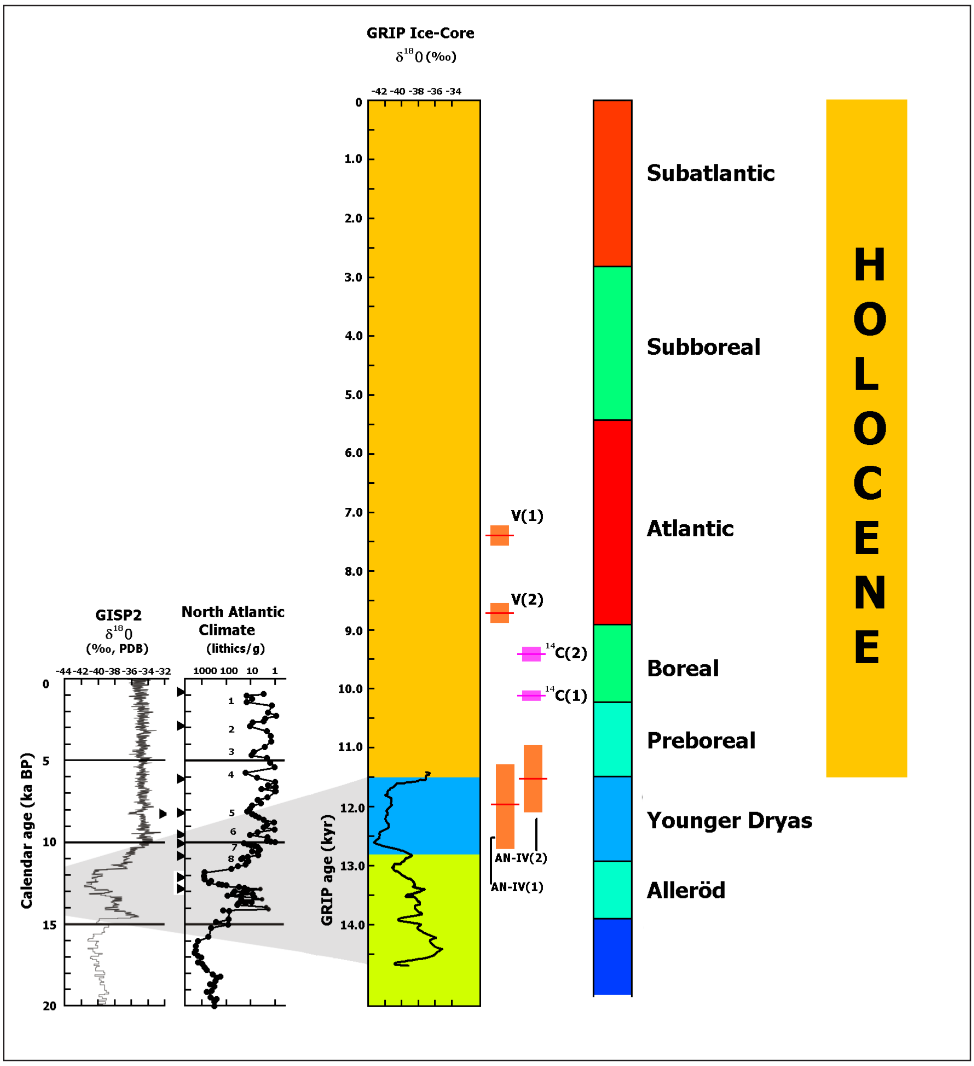

Figure 11. Position of the datings results in geological time scale.

preparation for U/Th datings. The reviews of Yvonne Battiau-Queney and Laurent Bruxelles have been much appreciated.

7. Bibliography

Bastin B., Paepe R., Pissart A., 1968. Compte rendu de l'excursion du 185 juin 1968 consacrée à la stratigraphie des limons près de Liège Vivenis et de Gembloux Tongrinne et aux dépôts de travertins d'Annevoie-Rouillon. Annales Société Géologique de Belgique, 91, 4 , 617-624.

Cors M., Wansard G., Rekk S., 1998. Étude du pollen et des ostracodes du travertin d'Annevoie-Rouillon (Belgique): reconstitution de l'évolution paléoenvironnementale au cours du Boréal et de l'Atlantique. Acta Geographica Lovaniensa, 37, 47-63.

Fanning, A.F. & A.J. Weaver, 1997. Temporal-geographical influences on the North Atlantic conveyor: Implications for the Younger Dryas. Paleoceanogr., 12, 307-320.

Ford T. D. & Pedley H. M., 1996. A review of tufa and travertine deposits of the world. Earth Science Reviews, 41, 3-4, 117-175.

Geurts M.-A., 1976. Genèse et stratigraphie des travertins de fond de vallée en Belgique. Acta Geographica Lovaniensa, 66p, 20 tableaux.

Goslar, T., M. Arnold, N. Tisnerat-Laborde, J. Czernik & K. Wieckowski, 2000. Variations of Younger Dryas atmospheric radiocarbon explicable without ocean circulation changes. Nature, 403, 877-880.

Guendon J.-L., Magnin F., Quinif Y., 1997. Les travertins quaternaires de Meyrargues (S.E. de la France). Synthèse des données actuelles et implications. Etudes de géographie physique, suppl. XXVI , 47-50.

Guendon J.-L. et al. 2003. Les travertins de Saint-Antonin : séquence géobotanique et climato-anthropique holocène. Karstologia, 41 , 1-14.

Hughen, K.A., J.R. Southon, S.J. Lehman & J.T. Overpeck, 2000, Synchronous radicarbon and climate shifts during the last deglaciation. Science, 290, 1951-1954.

Janssen A., Swennen R., 1997. Diagenetic modification within travertine deposits in Southern Belgium. Etudes de géographie physique, 26, 79-80.

Johnsen S.J., Clausen H.B., Dansgaard W., Iversen P., Jouzel J., Stauffer B., Steffensen J.P. 1992. Irregular glacial interstadial recorded in a new Greenland ice core. Nature, 359, p. 311-313.

Muscheler, R., J. Beer, G. Wagner & F.R. C., 2000. Changes in deep-water formation during the Younger Dryas event inferred from 10Be and 14C records. Nature, 408, 567-570.

Muscheler R., Kromer B., Björck S., Svensson A., Friedrich M., Kaiser K.F., Southon J., 2008. Tree rings and ice cores reveal 14C calibration uncertainties during the Younger Dryas. Nature Geoscience, 1, 263–267.

Ollivier V., Guendon J.-L., Ali A.A., Roiron P. & Ambert P., 2006. Evolution postglaciaire des environnements travertineux provençaux et alpins : nouveau cadre chronologique, faciès et dynamiques morphosédimentaires. Quaternaire, 17, (2), 51-67.

Paepe R., 1965. Découverte d'un foyer dans les travertins d'Annevoie-Rouillon. Bulletin Société belge de Géologie, de Paléontollogie et d'Hydrologie, 74 , 305–315.

Roiron P., 1997. Apport des flores de travertins à la reconstitution des paléoenvironnements néogènes et quaternaires. Etudes de géographie physique, suppl. XXVI , 39-42.

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