Bulletin de la Société belge de Géologie	98-2	pp.201-208	Bruxelles 1989
Bulletin van de Belgische Vereniging voor Geologie	98-2	pp.201-208	Brussel 1989

GEOLOGICAL INVESTIGATIONS AROUND THE EASTERN END OF THE BRABANT MASSIF : HISTORICAL OVERVIEW

par Martin J.M. BLESS [1]

ABSTRACT

The borderland between Belgium, the SE Netherlands and the Federal Republic of Germany, the "Euregio Meuse-Rhine", has been the object of international, multidisciplinary geological investigations since 1976.

One of the research projects deals with the Visé-Puth structure at the eastern end of the Brabant Massif. Investigations started in 1976 with a study of the Dinantian deposits, followed in 1977 by a proposal for further analysis of Pre-Permian rocks in the Visé-Puth area. Subsequently, magnetometric and gravimetric measurements were performed in 1979, while several boreholes were drilled at Maastricht and at Valkenburg a/d Geul between 1981 and 1987. This international, multidisciplinary cooperation may be seen as a standard for future projects under the responsibility of a European Geological Survey.

RESUME

Les régions frontières entre la Belgique, le sud-est des Pays-Bas et la République Fédérale d'Allemagne l'"Euregio Meuse-Rhine", est l'objet de recherches géologiques multidisciplinaires internationales depuis 1976. Un des projets de recherche a trait à la structure Visé-Puth à l'extrémité orientale du Massif du Brabant. Les recherches ont commencé en 1976 avec l'étude des roches dinantiennes, suivies en 1977 par une proposition d'analyses ultérieures des roches prépermiennes dans l'aire Visé-Puth. Ensuite des mesures magnétométriques et gravimétriques ont été faites en 1979, tandis que plusieurs sondages étaient forés à Maastricht et à Valkenburg a/d Geul entre 1981 et 1987. Cette coopération multidisciplinaire internationale se présente comme un standard pour de futurs projets sous la responsabilité d'un Service géologique européen.

KEY WORDS

Pre-Permian, Brabant Massif, Visé-Puth structure, multidisciplinary, international geological research.

MOTS CLE

Pré-Permien, Massif de Brabant, structure de Visé-Puth, recherche multidisciplinaire internationale géologique.

1. INTRODUCTION

The first time I met Eva Paproth was in 1967 during the International Carboniferous Congress at Sheffield. Despite, or perhaps rather thanks to her soft voice, she succeeded in fascinating her audience delivering a superb key-note on correlation problems between the Carboniferous Limestone in Belgium and Britain and the Dinantian Kulm deposits along the northern border of the Rhenish Massif in the FRG (Paproth, 1969).

In the following years, we would meet again regularly, either at the Geological Survey at Krefeld or at symposia and excursions. Patiently, she guided me and many of our colleagues through the famous Devono-Dinantian outcrops along the northern border of the Rhenish Massif ; from the "Blauer See" at Cromford in the west to the classic railway section of Oberrödinghausen and the Drewer Quarry in the east.

Thanks to her inspiring enthusiasm, we became acquainted with the secrets and problems of the Late Devonian and Dinantian, taking notes and collecting samples during the day and enjoying a social gathering in the evening hours.

Nobody ever imagined that these field-trips and discussions would lead us some day to the eastern end of the Brabant Massif. Was it fate or our common interests in the Dinantian that brought us together again in 1976 ? Fact is that in that year geologists with very different skills and interest and from various institutions in Brussels, Heerlen, Krefeld, Leuven, Liège and Louvain-la-Neuve bridged all language barriers and cooperated

[1] Université de Liège - Laboratoire de Paléontologie. Place du Vingt Août 7 - B-4000 Liège.

harmoniously in the study and revision of Dinantian deposits in more than twenty boreholes in northern Belgium, the southern Netherlands and the German Ruhr Basin. In less than six months, this multidisciplinary approach resulted in a report on the Dinantian rocks north of the Brabant and Ardenno-Rhenish Massifs (Bless *et al.*, 1976).

Of course, Eva Paproth played a decisive part in the realization of that paper. With her wide experience and versatile mind, always willing to discuss the wildest ideas, she tactfully but firmly directed our steps. This was the beginning of a new, productive phase in our friendship, which was intimately shared by Jos Bouckaert of the Belgian Geological Survey and Maurice Streel of Liège University.

2. EASTERN END OF BRABANT MASSIF

Working with a team of ever varying composition, this "geological mafia" (a nickname invented by Jos Bouckaert) would publish a number of papers with one or more of the following keywords : Pre-Permian, NW Europe, Aachen-Midi Overthrust, and Brabant Massif. Our favourite playground : the borderland between Belgium, the SE Netherlands and the Federal Republic of Germany, also called the "Euregio Meuse-Rhine" (Fig. 1 & 2).

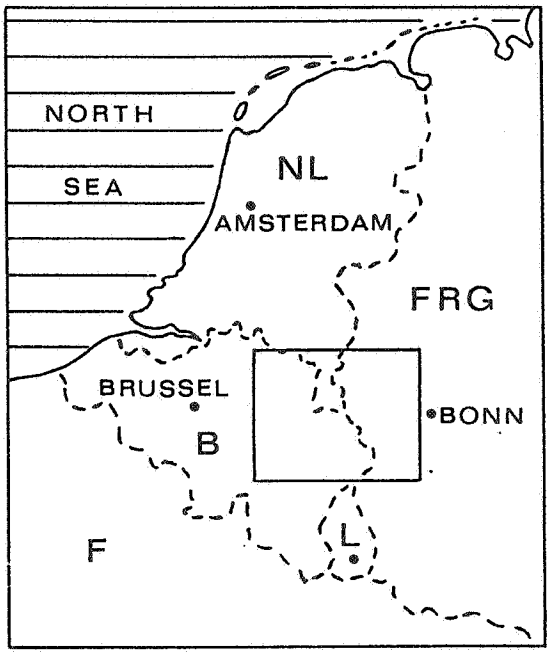

Figure 1. : Location of Euregion Meuse-Rhine in the borderland of NE Belgium, SE Netherlands and Federal Republic of Germany.

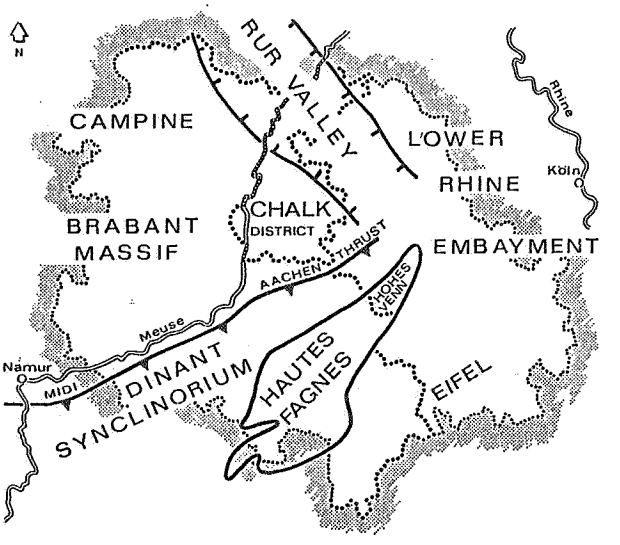

Figure 2. : Map of the Euregio Meuse-Rhine showing location of relevant geological features mentioned in this paper.

Firstly, there was a psychological reason for this choice. It emphasized the international character of the cooperation. In this way, everybody, be it German, Dutch, French or Flemish-speaking Belgian geologists, recognized that he or she would bring in an equal share of knowledge about his or her own province. And thus, this constituted a perfect exercise for a future European Geological Survey, as this should function from 1992 onwards.

Secondly, there were geological arguments. Nowhere else in NW Europe, can so many different tectonic phenomena and geological periods be studied within such a restricted area and at such shallow depth (partly even under outcrop conditions). To the north, there is the NW-SE striking Rur Valley Graben, today locally visible as a depression in the landscape, but with a pronounced inversion structure during the Late Cretaceous. To the east, one of the world's largest lignite deposits is found in Tertiary sediments of the Lower Rhine Embayment. To the south, we find the WSW-ENE striking synclinorium of Dinant, formed in Variscan times, and the SW-NE striking Hautes Fagnes/Hohes Venn with its cores of Cambro-Ordovician rocks covered by sphagnum bogs and marshy woodland. Volcanic rocks and Devonian sediments characterize the Eifel to the southeast. To the west, below a thin cover of Mesozoic and Cenozoic sediments, the easternmost portion of the Wales-London-Brabant Massif is found, which is a structural high of Late Caledonian age extending from southeastern Ireland to the Belgian-Dutch frontier near Maastricht. To the northwest, Tertiary sands and clays - evidence of the youngest marine incursions in this region - are hidden below endless heaths. And in the centre, at the eastern end of the Brabant Massif, is situated the Chalk District, the type area of the Maastrichtian Stage with Late Cretaceous

sediments outcropping below Tertiary sands and Pleistocene gravel and loess in valleys, quarries and sunken lanes. Here, in 1770, the famous Mosasaur skull was discovered in the subterranean quarries of the Pietersberg near Maastricht.

It is only natural that already in the past century this region attracted the attention of geologists from all over Europe : the first French professor of geology Faujas-Saint-Fond (1799), Lyell (1863) from Britain, the Belgian geologists d'Omalius d'Halloy (1828), De Koninck (1844) and Dumont (1849) ; Binkhorst van den Binkhorst (1859), Bosquet (1847), Staring (1860) and Ubaghs (1879) from the Netherlands ; Roemer (1855) and Holzapfel (1888) from Germany.

Therefore, it is not surprising that today a complete library could now be filled with papers dedicated to the geology of this area. Of course, many of these deal with the economically important coal-bearing rocks of the Late Carboniferous in the mining districts of Liège, Aachen, South Limburg and the Campine, as for example the Comptes Rendus of the "Heerlen Congresses" of 1927, 1935, 1951 and 1958. And there are the handbooks summarizing the state of the art, such as the "Prodrome d'une description géologique de la Belgique" (Fourmarier, 1954).

At first glance, this avalanche of information might demoralize the newcomer, because everything seems to have been thoroughly studied. But even a broad brush review of available data reveals that this region will continue to be a real gold-mine for those looking for unsolved geological problems.

3. VISE-PUTH STRUCTURE

For example, the above-mentioned report on the Dinantian rocks emphasized the presence of "an anticlinal structure east of the Brabant Massif, the Visé-Puth Anticline". It was assumed that this structure was the result of updoming of a small evaporitic deposit in its core "formed after Cambro-Silurian and before Frasnian times" (Bless *et al.*, 1976, p. 90).

Already in 1977, the first proposals for further research of the Devono-Dinantian rocks in the area at the eastern end of the Brabant Massif were formulated (Bless *et al.*, 1977). The fact that the Visé-Puth structure is matched by a gravity low was forwarded as one of the arguments in favour of the evaporite hypothesis. Moreover, it was shown that tectonic movements of this structure occurred during the Devono-Dinantian (e.g. frequent important sedimentary gaps), the Late Variscan period and the Late Cretaceous (Kimpe *et al.*, 1978).

Naturally, the possibility that evaporites might occur in the Devono-Dinantian of the Visé-Puth area had become more realistic after the find of extremely thick anhydrites in the St.-Ghislain borehole in southwestern Belgium (Dejonghe *et al.*, 1976). Furthermore, the hypothesis was supported by the then still incompletely known evaporite occurrences in the Devonian and Dinantian of SE Canada (e.g. Hacquebard, 1972) and Britain (Llewellyn & Stabbins, 1970 ; Dunham, 1973).

It was believed that a shallow hole, drilled to a depth of about 500 m, would help to get a better understandig of the Visé-Puth structure. This in turn could form a model for similar structures occurring at greater depth north of the Brabant Massif. We were convinced that investigations as here proposed would stimulate thinking on new, amplified hydrocarbon and base metal prospection possibilities in the Pre-Permian subsurface of an area which had been outside the exploration activities until then. But, since the Geological Survey of the Netherlands did not have the funds for such a project, it seemed as if it were destined to remain wishful thinking.

4. GEOPHYSICAL MEASUREMENTS

Shortly after the publication of the report by Kimpe *et al.* (1978), Eva Paproth and I had a long overnight talk with Franz Kockel at the Bundesanstalt für Geowissenschaften und Rohstoffe at Hannover. Franz immediately recognized the problems and possibilities and became keenly interested. His first reaction was : "Start checking the validity of the old gravity measurements on the Visé-Puth Structure and their interpretation. And then act according to the results".

In less than three months he persuaded the Bundesanstalt not only to cooperate but also to raise the money for a gravimetric-magnetometric survey at the eastern end of the Brabant Massif, which had been up to then a blank in our knowledge of the Belgo-Dutch-German borderland. On his side, Jos Bouckaert made the Belgian Geological Survey cooperate, whereas Eva Paproth and Franz Kockel jointly managed to involve the Geologisches Landesamt Nordrhein-Westfalen in the project.

And so, in May 1979, a Prakla-Seismos team - under supervision of the various geological surveys - performed magnetometric and gravimetric measurements at 920 stations between the cities of Hasselt, Liège, Aachen and Sittard. Among other things, these investigations confirmed the existence of a gravity low on the Visé-Puth structure (fig. 3), and supported both the idea of an increased thickness for the Devono-Dinantian in the Visé-Puth area and the supposition that evaporites might occur here (Bless *et al.*, 1980).

The next logical step was either a seismic survey across the Visé-Puth structure or a borehole on top of it in order to prove the validity of the working hypothesis. The possible advantage of a N-S directed seismic profile was that it could be extended southwards yielding information on the Aachen-Midi Overthrust and the Dinant Nappe as well (an old 1923-Fourmarier hypothesis was revived and modified by Bless *et al.*, 1977). Actually a borehole would be necessary for the interpretation of such a

seismic line. Therefore, a borehole, even a shallow one, was preferred because it would produce tangible proof of the nature of the rocks underneath.

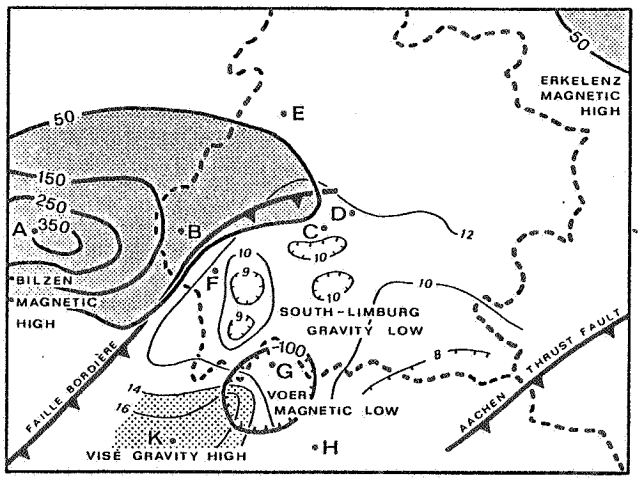

Figure 3. : Map of the Euregio Meuse-Rhine showing extension of the South-Limburg (residual) gravity low between the Bilzen magnetic high (marking the eastern end of the Brabant Massif) and the Visé gravity high (modified after Bless & Bouckaert, 1988). Note also location of small Voer magnetic low bordering Visé gravity high.

A: Martenslinde borehole; B: Kastanjelaan borehole (Maastricht); C: Thermae boreholes (Valkenburg a/d Geul); D: GB 24 borehole; E: Beek-Geverik borehole; F: Heugem borehole (Maastricht); G: 's-Gravenvoeren borehole; H: Val-Dieu outcrop; K: Hermalle-sous-Argenteau borehole.

5. MAASTRICHT BOREHOLES

Again, the main problem seemed to be raising funds. And yet, less than half a year after the publication of the results of the geophysical investigations (Bless *et al.*, 1980), drilling started in April 1981. This time, it was the governor of the Netherlands province of Limburg, Dr J. Kremers, who initiated the search for mineral water in the environs of Maastricht. Mineral water, comparable to that bottled in Aachen, was discovered at Maastricht in 1927 and exploited as "Trega water" until 1960, in which year the well was closed down for technical reasons.

A general geological reconnaissance of the subsurface in the Maastricht area was the second main objective. Two 500 m deep boreholes were drilled : Heugem and Kastanjelaan. These furnished proof of the already postulated increase in thickness of Dinantian strata in the area north of Visé and east of the Brabant Massif (Fig. 4). Moreover, some anhydrite and calcite pseudomorphs after anhydrite in the at least 390 m thick Middle Visean sequence of the Heugem borehole, suggest that the hypothesis of a more important evaporite deposit underlying the gravity low of the Visé-Puth structure is an option still to be investigated in the future (Bless *et al.*, 1981).

Not in the last place, mineral water was found in both boreholes in the Dinantian aquifer. Therefore, it can be concluded that this exploration fulfilled our expectations, the more so since the boreholes yielded a wealth of occasionally unexpected information, as for instance the presence of organic-rich (up to 5.5 % in Kastanjelaan ; up to 2.9 % in Heugem) shales of Visean age, which may have been excellent source rocks for hydrocarbons (Bless *et al.*, 1981).

However, in this project the scientific results themselves probably did not constitute the most important achievement. Undoubtedly, the most remarkable fact was the proof that a pragmatic international cooperation at an almost European scale could be performed by a maximum number of geologists and institutes within a minimum of time. This will be illustrated below.

More than thirty organizations, institutions and companies from five different countries were involved in the technical and scientific support of the project. A joint venture of a Dutch and a German drilling company made the boreholes. Well logging was done by three different organizations from Britain and Germany. Chemical and physical analysis of rock samples was carried out by thirteen institutions and companies from France, the Netherlands, Belgium and Germany. Four laboratories from the Netherlands and Germany performed analyses of the water samples. Geological and paleontological investigations were carried out by twelve different laboratories of universities, museums, industry and geological surveys from the Netherlands, Germany and Belgium.

Thirty geologists from the Netherlands, Belgium and the Federal Republic of Germany, representing eighteen different institutions (geological surveys and other public organizations, industry, universities and museums) produced the final report (Bless *et al.*, 1981).

Drilling activities started in April 1981 and finished in August 1981. The final report went into print in October 1981 and was published on December 31, 1981.

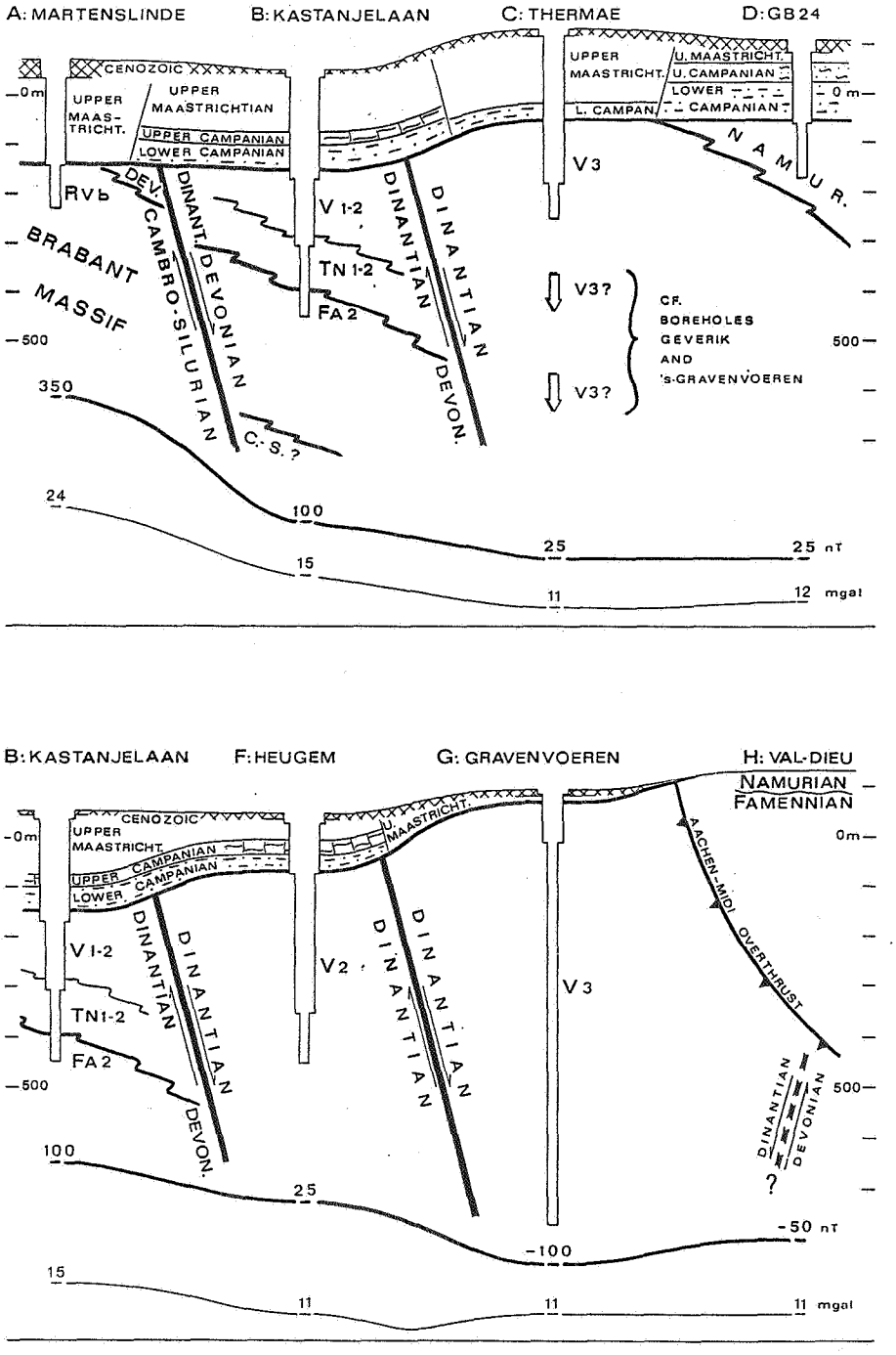

Figure 4. : Schematic sections through Cretaceous and Paleozoic at eastern end of Brabant Massif. For location of sections see figure 3. The eastern end of the Brabant Massif is clearly marked in the magnetometric (upper thick line ; values in nT) and gravimetric (lower curves showing residual gravity in mgal) curves. The extreme thickness of the Dinantian strata in the boreholes Heugem (more than 380 m Middle Visean) and 's-Gravenvoeren (more than 800 m Upper Visean) matches a gravity and a magnetic low respectively. Note influence of Late Cretaceous inversion tectonics on presence/absence of Lower and Upper Campanian sediments in these sections !

Equally remarkable is the fact that the majority of geologists and institutes cooperated without any financial compensation what so ever. Cooperation was based on immediate, full exchange of all the available data and rapid publication of the results. Only the drillers, one of the three logging companies and two laboratories for water analysis were paid by the provincial government of Netherlands Limburg, whereas two more laboratories and one of the geologists were allowed to claim travel expenses and a small part of expensive laboratory work.

For some universities, this was a welcome opportunity for "on the job" training of their students, teaching them in practice the pragmatic approach of geological problems : a harmonious balance between a maximum of quality and quantity and a minimum of time and costs. It also was a good "in company" training for the students, since they were

suddenly forced to cooperate with an international team, on which the results of their own investigations were immediately checked and discussed by others.

For the industry, this was a possibility to obtain information on a poorly explored area without making important investments. This explains the much appreciated support (e.g. supplementary logging, chemical and physical analysis of rock samples, active participation in writing the final report) of companies from France, Germany and the Netherlands.

Although no formal organization existed, practically everyone was willing and - perhaps most surprisingly - able to cope with the extremely tight time schedule. Of course, this required the charming personality of good friends such as Jos Bouckaert, Franz Kockel, Eva Paproth and Maurice Streel, who persuaded people to volunteer in the project and finish it.

The follow-up of this project was in the first place the responsibility of the provincial government. Feasibility studies readily showed that the mineral water from the Dinantian aquifer was too salty for the taste of a large public. But a modern spa somewhere in South-Limburg was considered to a realistic option. It would take four years, however, for these plans to be realized and for the geological investigations to be continued.

6. THERMAE BOREHOLES

In the autumn of 1985, two physiotherapists, Marcel Jaspars and Henk Verschuur, decided to drill for thermal water in Valkenburg a/d Geul, about 10 km east of Maastricht. They approached the Natural History Museum Maastricht for the necessary geological expertise. The formula chosen followed the 1981 example : payment only for the driller and some of the laboratories for water analysis, partial payment of travel expenses, rapid exchange of data and rapid publication of results paid by the client.

To start with, a small team of geologists from Aachen, Brussels, Heerlen and Maastricht was formed, complemented by two students of the RWTH Aachen, which received a rather cold (the winter of 1986 was characterized by long, severe frost periods causing several interruptions of the drilling activities) "on the job" training. When the first borehole had proved to be successful (thermal water of 24.5° C and with a rather low salinity was discovered in the Dinantian aquifer at only 380 m depth ; cf. Bless *et al.*, 1986), two more wells were drilled on the same spot. For the geological investigations, the original team of five geologists was substantially enlarged. Fifteen specialists from eleven different institutes would write the final report (Bless *et al.*, 1987). One and a half year later, in January 1989, the ultramodern spa "Thermae 2000" (a fifty million Dutch Guilder project) opened its doors to the public.

7. STATE OF THE ART

The Heugem, Kastanjelaan and Thermae boreholes confirmed the existence of a basin east of the Brabant Massif with a rather thick infill (possibly 1000-1500 m) of Dinantian sediments (Figs. 3-4), independent of the areas of Aachen and Visé, where the Dinantian rarely exceeds a thickness of 200 m. The origin of the mineral water and the lead-zinc mineralizations, and also the cause of the high-rank coalification in this region still form enigmas to be solved in the future. We can now only speculate about the thickness and nature of the Devonian rocks underneath, clearly out of reach of low-budget exploration. For the time being, a proposal has been formulated to extend a deep seismic "DEKORP-BELCORP" profile from the Eifel and Hautes Fagnes to the north into the South Limburg area in order to unravel some of the mysteries of its subsurface (Bless & Bouckaert, 1988).

Again, money is the bottle neck. But, in the historical context, it seems reasonable that this seismic survey would be included in the Dutch deep seismics programme. Up to now the geological investigations at the eastern end of the Brabant Massif have been paid by the Germans (the 1979 geophysical measurements), the provincial government of Netherlands Limburg (the Heugem and Kastanjelaan boreholes in Maastricht) and by a private organization (the Thermae boreholes in Valkenburg a/d Geul, although these were paid back later by the Valkenburg municipality after they had proved to be successful). And, on the other hand, both Germans and Belgians paid their part of the DEKORP-BELCORP seismic line that now ends at the Belgian-Dutch border near Teuven (Bless & Bouckaert, 1988).

This overview does not tell the whole story of research at the eastern end of the Brabant Massif. In the past few years at least two more deep boreholes have been drilled here : the Beek-Geverik borehole north-east of Maastricht by the Geological Survey of the Netherlands (penetrating at least 800 m of Upper Visean below the Namurian ; cf. Van Tongeren, 1988), and the 's-Gravenvoeren borehole south-east of Maastricht by the Belgian Geological Survey (penetrating at least 840 m of Dinantian underneath the Cretaceous ; cf. Bless & Bouckaert, 1988). However, detailed results have not yet been published. Moreover, a feasibility study for a 700 m borehole at the Dousberg in Maastricht (of importance because it would have been placed either very near to or perhaps already on top of the Brabant Massif) turned out negatively.

Of course, this has not been the only multidisciplinary, international approach to a geological problem. But it is exemplary of what has now become common practice in the Euregio Meuse-Rhine (Fig. 5). Walter & Wohlenberg (1985) proved its usefulness in the German Hohes Venn. Dusar *et al.* (e.g. 1986,1987a, 1987b) are sucessfully working on this basis in coal exploration in the Belgian Campine. Robaszynski *et al.* (1985), Felder *et al.* (1985) and Streel & Bless (1988) have applied this

formula to the study of Late Cretaceous deposits in this area.

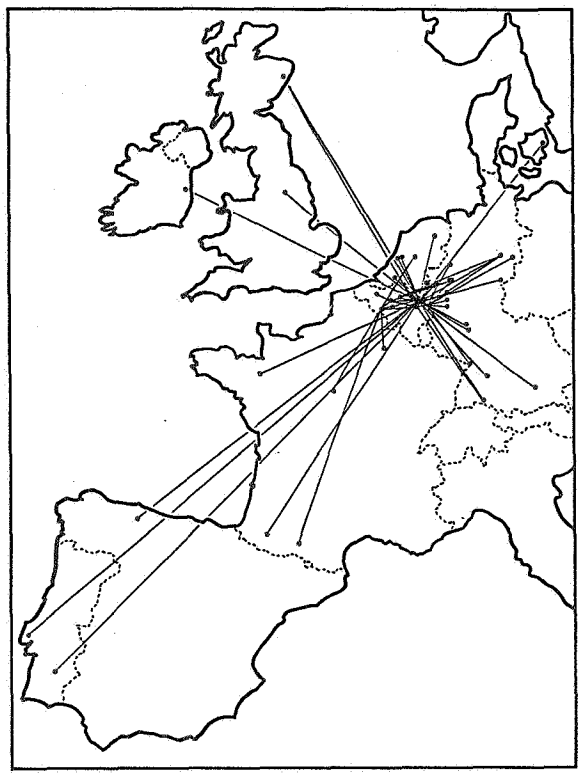

Figure 5. : The West European network of joint ventures as this has been active in geoscientific investigations on the Euregio Meuse-Rhine since 1976. Note that only those places are indicated which can be obtained from the papers mentioned in this report. Otherwise, an even more complex network would result.

8. EUROPEAN GEOLOGICAL SURVEY

There is no need to emphasize the obvious advantages of this kind of cooperation between universities, geological surveys and industry. But the question arises if these projects should depend entirely on the initiative of individuals with the charming personality of someone like Eva Paproth or with the persuasive power of a "godfather" figure such as Jos Bouckaert. At the verge of Europe-1992, it is perhaps more appropriate and realistic to create some sort of European Geological Survey for the selection of projects, their coordination, allocation of funds, control of progress reports and publication of results.

Projects to be supported or initiated by this European Geological Survey should centre on the following keywords :

- multidisciplinary approach
- international cooperation between universities, geological surveys and industry
- well-defined, previously published scientific problems
- short duration, if necessary through step-by-step approach
- free access to samples and data
- rapid publication of results
- low budgets

This European Geological Survey could consist of a rather small team charged with the definition and selection of projects and with their administration. Project managers could be recruted from universities or geological surveys for a maximum period of say one or one and a half year. This would perhaps be a good alternative for a sabbatical year. The projects performed in the Euregio Meuse-Rhine always constituted free courses of recycling, try-outs or becoming acquainted with new developments and achievements in geological sciences.

Since an important role is assigned to the "on-the-job", "in-company" training of students, the engagement of at least one or two students (who are allowed to use the data and results for their theses) should be obligatory.

Most likely, the Euregio Meuse-Rhine will constitute an excellent area for a try-out of the set-up and organization of this future European Geological Survey.

REFERENCES

BINCKHORST VAN DEN BINCKHORST, J.T., 1859 - Esquisse géologique et paléontologique des couches Crétacées du Limbourg. *Maastricht*, 1-268.

BLESS, M.J.M. & BOUCKAERT, J., 1988 - Suggestions for a deep seismic investigation north of the Variscan mobile belt in the SE Netherlands. *Ann. Soc. géol. Belg., 111*: 229-241.

BLESS, M.J.M. *et al.*, 1976 - Dinantian rocks in the subsurface North of the Brabant and Ardenno-Rhenish massifs in Belgium, the Netherlands and the Federal Republic of Germany. *Meded. Rijks. Geol. Dienst N.S.27/3*: 81-195.

BLESS, M.J.M. *et al.*, 1977 - Y a t'il des hydrocarbures dans le Pré-Permien de l'Europe occidentale ? *Prof. Pap. Serv. Géol. Belg., 1977/11*: 1-158.

BLESS, M.J.M. *et al.*, 1980 - Geophysikalische Untersuchungen am Ost-Rand des Brabanter Massivs in Belgien, den Niederlanden und der Bundesrepublik Deutschland. *Meded. Rijks Geol. Dienst, 32/17*: 313-343.

BLESS, M.J.M. *et al.*, 1981 - Preliminary report on Lower Tertiary-Upper Cretaceous and Dinantian-Famennian rocks in the boreholes Heugem-1/1a and Kastanjelaan-2 (Maastricht, the Netherlands). *Meded. Rijks Geol. Dienst, 35/15*: 333-415.

BLESS, M.J.M. *et al.*, 1986 - Gesteenten, fossielen en water van de proefboring Thermae 2000 te Valkenburg aan de Geul. *ISBN 90-6190-025-6 Valkenburg a/d Geul*, 1-40.

BLESS, M.J.M., BOUCKAERT, J., LANGGUTH, H.R. & STREEL, M. (editors 1987) - Upper Cretaceous and Dinantian geology and hydrogeology of the Thermae boreholes of Valkenburg aan de Geul (South-Limburg, the Netherlands). *Ann. Soc. Géol. Belg., 110/1*: 1-99.

BOSQUET, J., 1847 - Description des Entomostracés fossiles de la craie de Maastricht. *Mém. Soc. roy. Sci. Liège*, 353-378.

DEJONGHE, L., DELMER, A. & GROESSENS, E., 1976 - Découverte d'anhydrite dans les formations anténamuriennes du sondage de Saint-Ghislain. *Bull. Acad. roy. Belg., Cl. Sci., 10 janvier 1976*, 80-83.

DUMONT, A.H., 1849 - Rapport sur la carte géologique du Royaume. *Bull. Acad. roy. Sci. Lett., Beaux Arts Belg., 16/11*: 351-373.

DUNHAM, K.C., 1973 - A recent deep borehole near Eyam in Derbyshire. *Natura, 241*: 84-85.

DUSAR *et al.*, 1986 - De Steenkoolverkenningsboring Opoeteren-Den Houw (Boring 168 van het Kempens Bekken). *Belg. Geol. Dienst Prof. Pap., 226*: 1-98.

DUSAR *et al.*, 1987a - De Steenkoolverkenningsboring Gruitrode-Muisvenner Bemden (Boring 169 van het Kempens Bekken) Kaartblad Meeuwen 48W NR. 185. *Belg. Geol. Dienst Prof. Pap., 228*: 1-107.

DUSAR *et al.*, 1987b - De Steenkoolverkenningsboring Gruitrode-Ophovenderheide (Boring 172 van het Kempens Bekken) Kaartblad Opoeteren, 63E 224. *Belg. Geol. Dienst Prof. Pap., 230*: 1-235.

FAUJAS SAINT FOND, B., 1799 - Histoires naturelles de la montagne Saint-Pierre de Maestricht. *Paris*, 1-263.

FELDER, P.J. *et al.*, 1985 - Upper Cretaceous to Early Tertiary deposits (Santonian - Paleocene) in northeastern Belgium and South Limburg (The Netherlands) with reference to the Campanian-Maastrichtian. *Belg. Geol. Dienst Prof. Paper, 214*: 1-151.

HACQUEBARD, P.A., 1972 - The Carboniferous of Eastern Canada. C.R. 7ème Congr. Intern. Strat. Géol. Carbonifère, Krefeld 1971, *1*: 69-90.

HOLZAPFEL, E., 1888 - Die Mollusken der Aachener Kreide. 1. Cephalopoda and Glossaophora. *Palaeontographica, 34*: 29-72.

KIMPE, W.F.M. *et al.*, 1978 - Paleozoic deposits east of the Brabant Massif in Belgium and the Netherlands. *Meded. Rijks Geol. Dienst, 30/2*: 37-103.

KONINCK, L. DE, 1844 - Description des animaux fossiles qui se trouvent dans le Terrain Carbonifère de Belgique. *Liège*, 1-654.

LLEWELLYN, P.G. & STABBINS, R., 1970 - The Hathern Anhydrite Series, Lower Carboniferous, Leicestershire, England. *Trans. Instit. Min. Metall., Sect. B., 79*: 1-15.

LYELL, Ch., 1863 - The geological evidences of the antiquity of man. *London*, 1-520.

OMALIUS d'HALLOY, J.J. D', 1828 - Mémoires pour servir à la description géologique des Pays-Bas, de la France et quelques contrées voisines. *Namur*, 1-307.

PAPROTH, E., 1969 - Die Parallelisierung von Kohlenkalk und Kulm. *C.R. 6ème Congr. Intern. Strat. Géol. Carbonifère, Sheffield 1967, 1*: 279-291.

ROBASZYNSKI, F. *et al.*, 1985 - The Campanian-Maastrichtian boundary in the chalky facies close to the type-Maastrichtian area. *Bull. Cent. Rech. Explor. Prod. Elf-Aquitaine, 9/1*: 1-113.

ROEMER, C.F., 1855 - Das ältere Gebirge in der Gegend von Aachen, erläutert durch die Vergleich mit den Verhältnissen im südlichen Belgien, nach Beobachtungen im Jahre 1853. *Zeitschr. deutsch. geol. Ges., 7*: 377-398.

STARING, W.C.H., 1860 - De Bodem van Nederland. *Haarlem*, 1-480.

STREEL, M. & BLESS, M.J.M. (editors, 1988) - The Chalk District of the Euregio Meuse-Rhine ; selected papers on Upper Cretaceous deposits. *ISBN 90-70705-04-4, Verviers*, 1-117.

UBAGHS, C., 1879 - Description géologique et paléontologique du sol du Limbourg. *Ruremonde*, 1-275.

VAN TONGEREN, P.C.H. VAN, 1988 - OPAC-Project. Jaarverslag 1987. *Rijks Geologische Dienst*, Haarlem, 60-61.

WALTER, R. & WOHLENBERG, J. (editors, 1985) - Geology and geophysics of the northeastern Hohes Venn area ; report on a joint geoscientific venture. *N.Jb. Geol. Paläont., 171*: 1-467.