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SEANCES CONSACREES AUX TRAVAUX DE FIN D'ETUDES

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LITHOLOGY AND WEATHERING OF THE PALAEOPROTEROZOIC ROCKS OF BROWNSBERG (SURINAME)

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SUMMARY.- Brownsberg is situated in the central-northern part of Surinam (South-America). It is a small bauxite capped mountain (Main Bauxite level, Late-Eocene - Oligocene; Aleva, 1984), occupying the western side of the Prof. Dr. Ir. W. J. van Blommestein Lake (Reichart, 1991). Four types of metasedimentary rocks are observed on the western slopes: greenschists, feldspatic metagreywackes, phyllites and metacherts. They were formed during the Trans-Amazonian orogenic cycle of 2.0-1.8 Ga in an extensive basin and were subjected to a greenschist facies metamorphism. These rocks belong to the greenstone belt of the Precambrian Guiana Shield and have a very similar mineralogy. They always occur in varying associations. Weathering starts according to the schistosity or other zones of weakness. Chlorite is the first mineral to be attacked, with liberation of iron and formation of chlorite-vermiculite. The dioctahedral micas muscovite and paragonite do not weather as easily, but finally mica-vermiculite is formed. This high iron content of the saprolite and of the bauxite is a striking characteristic. The heterogenic saprolite consists mainly of kaolinite, whereas the bauxite almost completely consists of gibbsite. The polycyclic bauxite has not been formed *in situ* but was subjected to several phases of transport, weathering and cementation during younger, continental uplifts.

The aim of the project was to study the lithology and the weathering of Brownsberg and to find out whether the weathering mantle can be used for mapping of the underlying rocks.

Geological data about Brownsberg are scarce or almost absent. Some shallow drilling-operations were carried out on the plateau in 1968 by SURALCO, the Surinam Aluminium Company, to determine the quality of the bauxite. Only the chemical data upto a shallow depth still exist, while the reports of Bubberman and Janssen are trackless.

A deep drilling has been carried out earlier but neither drill-core, nor reports could be found.
Rock analyses of Brownsberg published so far concern only two samples taken on the eastern side of the mountain (Ijzerman, 1931).

The samples for this study have been taken at the western slope of the mountain. The reason is that due to strong weathering and dense vegetation, the rocks can only be sampled along deep incisions. Torrents and falls, namely the Koemboefall, Leofall, Irenefall and Mazaronifall form such incisions but occur on the western side. It was also impossible to sample a complete laterite-saprolite profile. Only along the Koemboefall a thick packet (4 m) of saprolite material with some soil materail was observed more upstream, but bauxite deposits were missing there. So, bauxite was sampled on the dissected plateau and their location marked on the road-map of the Brownsberg Nature park (more precise topographic documents were not available).

Although lithology and weathering of Brownsberg could only uncompletely be studied, this study is important as very few geological data exist on this area.

Four types of metasedimentary rocks were detected on the western side of Brownsberg: greenschists, feldspatic metagreywackes, phyllites and metacherts. All have a similar mineralogy (mainly quartz, chlorite, muscovite, paragonite and feldspar, namely sanidine, orthoclase, albite and albite$_{80}$-anorthite$_{20}$) and always occur in assocations. They were formed during the Trans-Amazonian orogenic cycle of 2.0-1.8 Ga in an extensive basin and were subjected to a greenschist facies metamorphism. The rocks are situated in the chlorite zone of the greenschist facies. Analogous to Bosma *et al.* (1984) we can state that these rocks belong to the Armina Formation of the Marowijne

Group. A relationship between the typical low-grade metamorphic chlorite and basic volcanic glass was marked in several thin sections of the greenschists. The crystals of feldspar (e.g. in the heterogenic, poorly sorted feldspatic metagreywackes) are presumable also of volcanic origin. The rocks of Brownsberg show a variable intensity of deformation. Schistosity is everywhere present. This phase of deformation is linked to the Trans-Amazonian orogenic cycle. The original layering is seldom expressed. The local appearance of a second tectonic phase cannot be interpreted geologically as it was only observed during the microscopical examination.

The weathering preferentially takes place along the schistosity and other zones of weakness like cracks. Chlorite is the first mineral to be attacked. This mineral is the most important source of iron for the formation of iron (hydr)oxide streaks, bands, spots or concentrations, mainly occurring according to the schistosity. Due to the increasing degradation of the rocks, saprolite is formed. The saprolite material is characterised by a high heterogeneity and a high concentration of iron oxide. It mainly consists of kaolinite, besides quartz, chlorite and mica with their transformation products, respectively chlorite-vermiculite and muscovite-vermiculite. The different iron (hydr)oxides are hematite, goethite and lepidocrite. Hematite represents a first phase of iron deposition in humid circumstances in an old planation surface. Due to continental uplift during the Davian cycle, the hydrology of the area changed and hematite was slowly transformed into goethite. Goethite is also immediately formed in cavities and cracks. In the matrix, a lot of iron migrations took place. The association goethite-lepidocrocite points to very humid material. The strongly weathered saprolite has oxic or ferralitic characteristics (Stoops & Eswaran, 1985). The bauxite has a heterogenic, conglomeratic composition which points to a polycyclic origin. It mainly consists of gibbsite, besides boehmite, quartz and anatase; and is rich in iron (goethite and hematite). The bauxite-capped plateau of Brownsberg belongs to the Main Bauxite level and is associated with the Late-Eocene to Oligocene planation surface. The bauxite has not been formed *in situ* but results from several transport and weathering phases during some younger, continental uplifts. Its high iron concentration makes it economically not interesting.

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A MINERALOGICAL AND CHEMICAL STUDY OF GALLO-ROMAN AND MEDIEVAL POTTERY FROM BELGIUM, THE GRAND DUCHY OF LUXEMBOURG AND GERMANY

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SUMMARY.- With the present study an attempt was made to provide scientific evidence for the geological sources of the raw materials of selected potsherds from south-eastern Belgium and the adjacent areas. It also aims to check the hypotheses about their historical origin.

Two types of pottery were examined in the laboratory. The first one corresponds with Gallo-Roman wares coming from excavations in the centre of the city of Tongeren (Province of Limburg, Belgium). This pottery is known as "Pompeian Red Ware" because of its typical red surface. Archaeologists hold the view that the finds from Tongeren represent a local production and were made in the three first centuries A.D. The second type of pottery analysed in the framework of this research was collected at Autelbas (Belgium), Diekirch and Echternach (Grand Duchy of Luxembourg) and Trier (Germany). These ceramics are medieval and show colours going to ochre. The samples of Autelbas are of particular interest as they were found in kilns thought to date from the Carolingian Period.

The petrological properties of the aplastic inclusions (i.e. temper) embedded in the potsherds were studied by using polarizing microscopy, whilst chemical analysis of the samples was carried out with atomic absorption spectrometry (AAS). The analysed elements comprise Si, Ti, Al, Fe^{3+}, Mn, Mg, Ca, Na, K, Li, V, Cr, Co, Ni, Cu, Zn, Rb, Sr and Pb. To elaborate a chemical classification and to compare the chemical data with the petrological and archaeological typologies, statistical methods (cluster analysis) were used.

The Pompeian Red Wares available for analysis show a variety of tempering elements. Considering the origin of the temper, four groups were recognized:
- Sherds of groups A and B are typified by aplastics of sedimentary origin, essentially quartz and glauconite. Glauconite only occurs in thin sections of samples of group B.
- Sherds of group C contain abundant muscovite and biotite flakes in association with a some quartz. A metamorphic origin of these materials is most likely.
- Sherds of group D are tempered with mineral and rock fragments of volcanic origin. Major components include clinopyroxene grains (mainly augite), feldspars and glass particles.

There is a positive correlation between the chemical data and the petrological typology, relative to the Pompeian Red Ware. However, it appears that groups A and B cannot be discriminated on a chemical basis. The observed microscopic difference, based on the presence or the absence of glauconite, between the two groups is only arbitrary. This may suggest that both groups of Pompeian Red Ceramics were produced with identical raw materials and derive from the same source area.

As glauconite is omnipresent in the subsoil of Low and Middle Belgium, a local provenance for the pottery of groups A and B can hardly be contested on petrological grounds only. The source of the metamorphic elements enclosed in the material of group C still remains uncertain although the Massif Central, in France, is a privileged region. Considering the nature of the temper of group D, this pottery could come from the Quaternary volcanic province of the Eifel, in Germany.

The mineralogy of the temper of the ceramics of Autelbas, Diekirch, Echternach and Trier is rather uniform. Quartz grains, with a granulometry of about 40 µm, are largely predominant. To characterize this pottery chemical analysis was therefore of utmost importance.

The obtained chemical data are represented by a dendrogram. The potsherds coming from the sites of Echternach, Diekirch and Trier are regrouped. This confirms their common genetic origin. On the other hand, the ceramics of Autelbas contain two branches. The first one holds sherds found in kiln 1, whereas the second one regroups crocks found in kiln 2 and in kiln of Jardin Capelli. This difference in chemical composition between both productions may reflect the use of raw materials with various rates of alterations.

As mentioned above, the pottery of Autelbas was found in Carolingian kilns. This means that the potsherds kept the chemical fingerprint of each kiln. These data can thus be used to identify the origin of other potsherds coming from distant sites. This is the case of two potsherds coming from Diekirch. They are related to the kilns in Autelbas.

Taking into consideration the mineralogy and granulometry of the temper into consideration, we conclude that the used raw material is of eolian origin, most probably loess. This is confirmed by the geological and pedological map of the Grand Duchy of Luxembourg.

Concluding from this research, it is obvious that the mineralogical and chemical typologies of the studied potsherds are linked. The use of both methods is quite useful to help archaeologists in their investigations.

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ETUDE DE LA FORMATION DES APENNINS: MODELISATION NUMERIQUE DE LA DEFORMATION D'UN PRISME D'ACCRETION

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RESUME.- Le processus d'édification des Apennins et la structure tectonique qui en résulte restent de nos jours des sujets controversés, en raison de l'interprétation difficile des données géologiques et géophysiques en profondeur. Dans ce cadre, il paraît intéressant d'utiliser la modélisation numérique afin de comprendre les mécanismes de mise en place d'une telle chaîne.

Le présent travail consiste en la modélisation, au moyen d'un code de calcul par éléments finis, de la déformation d'un corps simplifié (tranche), continu ou faillé, représentant un prisme d'accrétion, typique ou en phase de progression continentale. La déformation est induite par le mouvement d'une plaque sous-jacente (slab) qui déplace la tranche vers une zone frontale (back-stop).

Les essais réalisés permettent de mettre en relation le style tectonique avec des paramètres géologiques, mécaniques et géométriques tels que la profondeur du niveau de décollement, l'inclinaison du back-stop, le coefficient de frottement basal μ_b ou celui de faille μ_f . Cette étude paramétrique est constituée de deux parties.

La première étudie la propagation de la déformation

sous forme de bandes de cisaillement dans un prisme continu. Un coefficient de frottement basal élevé conduit, dans ce cas, à une topographie importante, à un faillage synthétique peu espacé et moins incliné que le réseau antithétique peu développé. Par contre, un coefficient de frottement basal faible induit une topographie moins prononcée, un faillage synthétique espacé et favorise légèrement l'apparition d'un réseau antithétique. Une faible profondeur du niveau de décollement ou un back-stop peu incliné induisent l'apparition d'un nombre relativement important de bandes rapprochées.

La seconde prend en compte la présence de discontinuités dans le contexte d'un préfaillage du prisme (situation géologique probable dans les Apennins). Des frottements importants mènent alors à un empilement des blocs les uns sur les autres alors qu'au contraire, des valeurs faibles propagent les chevauchements d'Ouest en Est selon un style proche de celui observé dans les Apennins.

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MINERALOGY OF VOLCANIC TUFFS AROUND SAGALASSOS (TURKEY) AND THEIR USE IN MORTARS

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SUMMARY.- Lime mortars have been used for many centuries. The Romans spread the lime mortar technique around the whole Roman empire. Many Roman buildings, from the Rhine to Turkey, are witnesses of this important building technique (Cook, 1986). Often, pozzolanas, a generic term to describe all materials which exhibit reactivity with lime and which set, harden and develop strength in the presence of water, were added to improve the quality of the mortar and make them hydraulic. In Sagalassos, a Roman archeological site in the SW of Turkey, lime mortars with pozzalanas were also used.

The aim of this research was:
1. to find indications about the origin of the raw materials, about the preparation of the mortars and about the properties (strength,...) by means of mineralogical petrographical and chemical analysis of the lime mortars used in Sagalassos;
2. to find information about the selection of the volcanic rocks used as pozzolanas in the mortars and about the building up of the volcanic sequence;
3. to derive experimentally the influence of the volcanic rocks on the mortar properties.

The lime mortars (« Opus Caementitium ») of Sagalassos can be divided in two main groups: mortars with chamotte (broken ceramics, mainly used in connection with water constructions, for example aquaducts, water basins, ...) and mortars with volcanic material (mainly used in constructions, for example in walls and as foundation). The first group consists of a matrix of calcite (formed from the carbonation of $Ca(OH)_2$ by taking up CO_2 from the air) and chamotte and limestone fragments as additives. Inclusions of feldspars, zoned augite and biotite are derived from the chamotte. The second group of mortars consists of a matrix of calcite with additive of volcanic rock fragments (pumice and lava) in which feldspars, augite, biotite and diopside are found.

The volcanic sequence, NW of the site of Sagalassos, consists of layers of lava and tuffs around the eruption centre (Gölcük lake). The tuffs consist of an accumulation of submicroscopic crystals and glass (matrix) and inclusions such as rock and mineral fragments. The matrix consists of feldspars (anorthite and sanidine) and the inclusions can be divided into rock fragments (pumice, andesite, sandstone and sporadically syenite) and crystals (plagioclase, alkali-feldspar, zoned augite, diopside, biotite, hornblende and magnetite). Chemically, these rocks correspond to trachy-andesite and trachyte (Wilson, 1991). Abnormal high contents of Sr and Ba are found (Sr from 1829 to 7342 ppm and Ba from 1500 to 8228 ppm). An explanation is yet not clear.

Test objects of mortars were made with commercial and self-made lime and with volcanic rocks and chamotte as additives. The preliminary experiments showed that chamotte addition resulted in the best (strongest) mortar and the mortars made with volcanics showed a strength in the range of historic mortars. Further tests are required to define other parameters in determining the mortar quality.

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PETROLOGY OF EARLY AND MIDDLE DEVONIAN TOURMALINITES FROM BELGIUM

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SUMMARY.- In Belgium tourmalinites occur as pebbles in various Early and Middle Devonian conglomerates. Because of the somewhat unusual mode of occurrence and high tourmaline content of these rocks, they were intensively studied in the years following their discovery in 1877 (e.g. Lohest, 1908). Different hypotheses about their provenance were formulated but remained very speculative. This study provides new petrographical and extended geochemical evidence resulting in some concrete probable sources.

About 70 samples of two Early Devonian (Fooz and Marteau) and three Middle Devonian formations (Rivière, Vicht and Pépinster) outcropping north of the Stavelot-Massif and along the northern border of the Synclinorium of Dinant were collected. Initially, all tourmalinite samples were submitted to thin-section microscopy. This enabled to recognize four petrographical varieties, of which the first one has a metasomatic nature. A second type resembles the previous a great deal, but looks like a clastic sediment in which the matrix consists of the metasomatic mass. The third variety corresponds with hydrothermal breccias while the fourth shows a poikilitic texture. Subsequently the geochemical composition of a selected number of samples was measured using different analytical techniques, including AAS and ICP-MS. The abundances of 12 major and 27 trace elements, inclusive of all natural rare-earth elements, were determined in eight representative rock samples. In addition, about 100 microprobe analyses, mainly on tourmaline grains, were performed with WDX in five selected tourmalinites.

Chemical compositions of minerals occuring in and near veins reflect the nature of the tourmalinising agent (Slack & Coad, 1989). Microprobe analyses of such tourmaline grains show a negative correlation between Fe and Mg, which Cavaretta & Puxeddu (1990) interprete as being characteristic of a granitic context. Other geochemical data and petrographical observations confirm the prominent part played by magmatic hydrothermal fluids during the tourmalinisation of some of our samples.

Although tourmalinising agents may carry many chemical components, it appears that the geochemical signature of tourmalinites largely depends upon that of the host rock (London & Manning, 1995). Major element compositions of tourmalines were plotted in discrimination diagrams proposed by Henry & Guidotto (1985). They suggest a granitoid parent rock for the greater part of the analysed samples. On the other hand, one pebble appears to derive from (meta)sedimentary material. Rare-earth element abundances normalized to chondritic meteorite values or international sedimentary standards yield equivocal results. In contrast with the conclusions of last-mentioned tourmaline discrimination diagrams however most patterns indicate a shaly parent rock, while only the minority of the data argues for a granitoid origin. Unfortunately, petrographic and geochemical data are not always consistent, making it impossible to determine for every individual sample whether it has an intrusive or a (meta)sedimentary origin. This implies that out of the large set of discrimination diagrams to distinguish rocks coming from different tectonic settings, as well diagrams for granitic rocks as those for sedimentary rocks should be taken into account. In both cases, the selected diagrams suggest a volcanic-arc setting for our samples. The existence of such a geodynamic context in relation to Northwestern Europe during Early Paleozoic times has been described frequently (e.g. McKerrow & Cocks, 1995). In particular the northward drift of Avalonia and the closing of the Iapetus between Laurentia and Baltica caused the development of volcanic arcs in Ordovician times respectively along the northern border of the Avalonian microcontinent and along the southeastern border of Laurentia.

Strongly intruded areas, associated with tourmalinisation and originated in the above described geological framework, are plausible sources for the studied pebbles. Palaeogeo-graphic reconstructions of Ziegler (1982) suggest that the most nearby source is the Brabant Massif. Tourmalinites have not been observed there, but the association of calcalkaline intrusives with calcalkaline volcanic rocks is a real geological feature, and the latter are actually represented there. Moreover, large amounts of Early Paleozoic rocks were eroded from the Southern border of the Old Red Continent and deposited in the Early Devonian sediments. This makes the Brabant Massif indeed the nearest probable source, although in this case the underlying granite which caused the tourmalinisation should be found immediately under the post-Devonian cover. Other possible tourmalinite-associated sources are Southeast Ireland, where tourmalinites are found as loose pebbles as well as in situ, and, only for the Middle Devonian conglomerates, the English Lake District. Whenever previously suggested provenances should prove to be incorrect, supply from the North-German-Polish

Caledonides or even more northern areas might give an answer to the problem in case of the Early Devonian deposits. However, it should be remarked that the real situation is far more complex as presented and that there might be different sources for different stratigraphical units. Concerning the Middle Devonian Vicht Formation for instance an eastern source can in the present state of our research not be excluded.

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A STRUCTURAL STUDY OF THE SILURIAN TURBIDITE DEPOSITS IN THE RONQUIERES AREA, BRABANT MASSIF

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SUMMARY.- Since the start of geological research on the Brabant Massif, now almost two hundred years ago, not much attention has been paid to structural elments. During the 19th century researchers focused on the litho- and biostratigraphy of the Lower Palaeozoic deposits. Only in the beginning of the twentieth century people like Lohest (1904) and Fourmarier (1914, 1921) started to show interest in the structural geology of the massif. However, only seldomly real evidence is presented.

Partly trying to fill the gap between stratigraphic and structural data we did a structural analysis in the Inclined Shiplift of Ronquières, 28 km south of Brussels along the Canal Brussels-Charleroi, on the southern limb of the Brabant Massif. In this 1500 m long outcrop, which was previously studied by Legrand (1967), the northern 550 m consist of folded and cleaved distal turbidite deposits of the Ronquières Formation (Gorstian, lower Ludlow; ± 420 Ma). These Silurian turbidites were deformed by the Acadian deformation from the Early to the early Middle Devonian. To the south the slates are overlain with an angular unconformity by gently S-dipping Givetian deposits.

The structural elements observed in the Inclined Shiplift include buckle folds, a slaty cleavage, reverse and normal faults and less pronounced structures such as kinkbands and small cross joints.

As can be seen on the unbalanced cross-section from north to south five major upright gentle to open folds are present. The folds are slightly asymmetric towards the north and the synclines contain parasitic (second order) folds on their northern limbs. The average hinge line of the folds has an orientation of 10/291. A gradual change in plunge direction (011°) occurs throughout the section: from north to south the fold hinge lines describe an arc convex to the west. A pronounced thickening of the subhorizontal layers occurs between the central anticline and the Belvédère syncline. Large thickness changes of the beds were also observed in meso- and microscopic folds.

Throughout the five first order folds the slaty cleavage forms a cleavage fan with a convergence angle of ± 30°. We consider this as being the result of the same progressive deformation: during the ongoing buckling the cleavage was formed and got slightly rotated (fanned) by further buckling. Note that in the Ronquières section the cleavage generally dips to the south, while the average cleavage dip in the Brabant Massif is generally taken to be 70°N.

In contradiction to the trend of the fold hinges, the trend of the virtual cleavage /cleavage-intersections remains constant throughout the outcrop (16/292). This results in a (small angle) transecting cleavage and a change in sense of transection. In the northern part of the shiplift the cleavage transects the folds in an anticlockwise fashion (+ 005°) and in the southern part a clockwise transection is present (-003°). Transecting cleavage can be interpreted as a result of transpressive deformation and a transpression can also be inferred from the concave-to-the-north pattern of the fold hinges and the strike of the cleavage along the entire southern rim of the Brabant Massif.

In contradiction to Legrand (1967) we find as well S-as N-dipping reverse faults with a small displacement forming conjugate sets. Normal faults seem to be constricted to the southern part of the outcrop where they cross-cut the angular unconformity. The intersection of both the normal and reverse faults has a constant orientation (10/290). Legrand (1967) stated that some of the faults mainly had a lateral displacement. However, we did not find any evidence for lateral slip. Furthermore, we suggest that a relatively large displacement occurred along Fh before the Givetian and that the stratigraphic position of the strata in the synclinal complex (part south of Fh on fig.1) is below the beds of the northern part of the outcrop.

Poorly developed small subhorizontal top-to-the-south kinkbands are present, locally causing a sigmoidal deformation of the slaty cleavage. Also, small transverse NNE-SSW-trending joints are present in two steeply dipping sets with their line of intersection perpendicular to the general trend of the area.

The orientations of the structural elements described above all have in common a WNW-ESE trend with a plunge of ± 10° WNW, roughly indicating a NNE-SSW direction of tectonic transport and a regional tilting to the WNW. However, the fanning pattern of the fold hinges points to a minor gradual change in direction of shortening, which might be an indication for transpression.

Several cross-sections are constructed which can be considered as representing increments of the deformation history: a first section by neutralising the fault displacements; a second one by partly unfolding the cross-sections to establish a parallel pattern of the slaty cleavage (assuming the cleavage initially formed parallel throughout the outcrop) and a third one by completely unfolding the section. In combination with the results of a March analysis done by Sintubin (pers. comm. 1996), these sections allow us to estimate the progressive relative shortening of the cross-section. The original length was shortened by at least 53%. Development of the slaty cleavage was the most important shortening factor, causing a shortening of ± 43%, followed in importance by the «pre-cleavage folding». «Post-cleavage» buckling was less important and the effect of faulting can be ignored (the probably large but unknown displacement along Fh is not taken into account.

A relative chronology is put forward, starting with the development of five asymmetric gentle folds, some of which have small closed folds on their northern limbs. During and after the deformation of the slaty cleavage (dated in the Brabant Massif as 401 Ma by Michot *et al.*, 1973), continued buckling increases the fold amplitude of the five first order folds and causes the cleavage to fan. Some of the reverse faults can be considered as fold accomodation structures. Localised small kinkbands form, followed by further reverse faulting. During the deformation and uplift of the massif, tilting to the WNW occurs, erosion takes place and stress relaxation causes the joints to form. The extensional period during the Givetian (and possibly earlier) causes the formation of normal faults along pre-determined zones of weakness and inversion of Acadian reverse faults.

For the tectonic evolution of the Brabant Massif as part of E-Avalonia, we refer to the model presented by Van Grootel *et al.* (1997): from the Early to early Middle Devonian the Acadian deformation caused the inversion of a Silurian foreland basin to form a foreland fold belt. We add however that this deformation probably had a transpressional component in at least a part of the Brabant Massif.

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BRITTLE TECTONICS AND GEOCHRONOLOGY OF THE TELETSKOYE LAKE (ALTAI RANGE, SOUTH SIBERIA)

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SUMMARY.- The Teletskoye lake, situated at the northern end of the Central-Asian fold belt, in Altai, South Siberia, is a long (± 80 km) narrow (± 4 km), and deep (± 300 m of water, ± 1000 m of sediments) rift basin, surrounded by steep slopes which extend the basin up to 2800 meters. The lake is situated at

the contact zone between two different geodynamic terrains.

Analysis of the brittle structures, using remote sensing techniques together with field investigations, paleostress reconstructions and joint set analysis, revealed new indications for the tectonic nature and of the very young age (less than 1 Ma) of the Teletskoye lake graben. It was also proven that many of the recent structures evolved along pre-existing weakness zones, like a mylonitic shear zone and a suture zone. Paleostress reconstructions and seismic profiling indicate that the basin formation occurred in two phases, the first of which corresponds to the opening of the southern sub-basin, due to strike-slip movements on diagonal trending faults. In a second phase the regional stress state changed from sub-lateral to sub-meridional principal compression. This resulted in the reactivation of a wide strike-slip fault zone between the geodynamic blocks, and in the final east-west opening of the basin. The paleostress analysis indicates that both terrains react differently to an external stress field, yielding significant stress variations.

$^{40}Ar/^{39}Ar$ step-wise heating results on 2 biotite and 1 amphibole separated from mylonitized gneisses belonging to the shear zone, yield concordant apparent plateau cooling age of 380 ± 4 Ma, suggesting rapid cooling. This timing corresponds to the emplacement of granite-gneiss domes. Another sample of a mylonitized gneiss belonging to the same unit, however distinctly enriched in amphibole blasts, yields a discordant amphibole age spectrum with a plateau age of 260 ± 5 Ma. This age is thought to reflect a ductile shear event associated to the Permian thrust and strike-slip faulting, described for the Teletskoye region. Brittle reactivation appears to be limited to narrow zones and remains so far undated.

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CONTRIBUTION A L'ETUDE DE LA LIMITE CRETACE TERTIAIRE DE LA REGION DE KALAAT SENAN (TUNISIE CENTRALE): PALYNOLOGIE ET AMMONITES

Bénédicte EGGERMONT[1]

RESUME.- La coupe de l'Oued Settara dans la région de Kalaat Senan, quelques 50 km au Sud de la section type d'El Kef offre la possibilité d'une étude très fine du passage Crétacé-Tertiaire.

Le niveau jaune de la limite K/T, plus complètement enregistré qu'au Kef, a été identifié dans une succession hétérogène épaisse de 5 cm au dessus des marnes maastrichtiennes. Cette succession consiste en 5 couches (en ordre ascendant): (1) une argile foncée épaisse de 2 cm, (2) le niveau jaune de la limite, principalement constitué de nodules centimétriques aplatis de jarosite, de gypse et d'oxyde de fer, (3) une mince couche d'argile brunâtre, (4) une couche discontinue de silt gris et (5) une argile brune hétérogène montrant de petites ondulations. Ces couches sont ensuite couvertes par l'argile sombre caractérisant la base du Danien.

L'étude palynologique* nous indique que la crise K/T n'affecte nullement les dinokystes. On note seulement quelques apparitions soit légèrement avant (*Danea californica*), soit légèrement après. C'est surtout la composition des associations qui se modifie. Dans la distribution des palynomorphes, les éléments marins (dinokystes, acritarches et Scytinascias) dominent tandis que les apports continentaux (spore-pollen) restent faibles. Les fluctuations importantes des pourcentages de palynomorphes nous ont permis de proposer un schéma du niveau marin relatif mettant en évidence un important épisode transgressif 3 cm en dessous de la limite.

Une nouvelle collection de 213 ammonites dans les sections de l'Oued Settara, de l'Oued Raïne et de l'Oued Hachini (El Kef) autorise pour la première fois la construction d'un tableau détaillé de la répartition verticale des espèces dans le faciès marneux du Maastrichtien terminal du Centre Ouest tunisien, et en particulier dans le stratotype international de la limite K/T (El Kef). Au total, quatre sous-ordres, neuf familles, dix genres et seize taxons y ont été identifiés** L'abondance des spécimens collectés ainsi que leur très bonne conservation démontrent le grand intérêt de ces gisements. Une récolte systématique par tamisage y est possible. Cela permettrait dans l'avenir une étude statistique très enrichissante, une meilleure définition des espèces de la fin du Maastrichtien et également de préciser les modalités de la disparition des ammonites.

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* étude réalisée en collaboration avec R. Rauscher de l'Institut Géologique de Strasbourg
** étude réalisée en collaboration avec P.Ward de l'Université de Washington, Seattle

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STRUCTURAL ANALYSIS ON THE EGERSUND-OGNA ANORTHOSITE MASSIF, SOUTHERN NORWAY: STRAIN ASSOCIATED WITH DIAPIRIC EMPLACEMENT

Hans-Balder HAVENITH[1]

SUMMARY.- The Egersund-Ogna massif (± 20 km in diameter) belongs to the Rogaland anorthosite complex in Southern Norway. Emplacement of this massif took place 931± 2 Ma ago, some 60 myr after the last recorded Sveconorwegian deformation (Schärer *et al.*, 1996). Absence of external tectonic constraints during plutonism implies that the deformation, as observed inside the inner margin of the Egersund-Ogna massif, is due to the emplacement mechanism itself. This deformation is characterized by a concentric foliation corresponding to the flattening plane of plagioclase and orthopyroxene megacrysts and also to the layering plane of anorthosite and norite.

Bidimensional (macroscopic) analysis of sections through these mega-crysts was realized in the Egersund-Ogna massif. Roughly 1500 sections were studied on 1 or 3 surfaces depending on the morphology of the outcrop, permitting the calulation of some 50 ellipsoids. The algebraic method proposed by Milton (1982) based on 3 arbitrarily oriented sections was used in a number of cases. A complementary geometrical approach was used to approximate an ellipsoid by means of 1 or 2 elliptical sections. Structural analysis also comprised plotting down orientation of foliation planes and shear-senses, as well as studying fold structures.

Inside the inner margin of the massif the strain ellipsoids permitted to distinguish a zone where stretching is subvertical from zones with subhorizontal elongation. Vertical stretching, isoclinal folds with axial planes dipping outward from the massif as well as shear zones indicating the relative upward movement of the Egersund-Ogna massif relative to the adjacent anorthositic massif are evidence of a diapiric mode of emplacement. On the other hand, most ellipsoids show a horizontal elongation, characteristic of a lateral expansion of the anorthositic mass at the final stage of emplacement. Likewise conjugate shear zones and shear zones parallel to the strike of foliation and to the contact support horizontal extension of the margin.

Analysis of the strain distribution and of the orientation of the foliation plane shows that, near the contact with the neighbouring intrusions, strain is very important and the foliation steep. The part of the border in contact with the surrounding migmatitic gneiss displays much less deformation and the foliation is also less inclined.

It is concluded that the adjacent massifs, emplaced simultaneously, constituted a more resistant barrier to the expansion of the Egersund-Ogna body than the enveloping gneisses; the latter, softened by partial melting, permitted an extended lateral expansion of the massif into its envelope.

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ETUDE STRATIGRAPHIQUE ET SEDIMENTOLOGIQUE DU CALCAIRE DE TOURNAI

Françoise LARANGE[1]

RESUME.- Le calcaire de Tournai, d'âge Carbonifère inférieur, correspond, pour les auteurs, au Tournaisien supérieur (Ivorien) ainsi qu'à la base du Viséen; cependant, aucune certitude n'existe à cet égard.

Ce mémoire comportait deux aspects. Le principal était d'affiner la stratigraphie du Calcaire de Tournai par une étude systématique des conodontes qu'il contient, l'autre de réaliser une étude sédimentologique.

Les échantillons analysés proviennent de deux sondages effectués par CCB dans la future carrière de Barry, 7 km à l'est de Tournai. Ils sont numérotés 587 (profondeur: 250 m) et 589 partim (profondeur: 70 m).

Les conodontes sont des corps denticulés, d'environ 1 mm, formés de phosphates complexes. Ce sont d'excellents fossiles dateurs (Cambrien-Trias).

Le Calcaire de Tournai étant reconnu pauvre en conodontes, il a fallu faire une étude systématique, avec dissolution de 1 kg de roche, prélevé tous les deux mètres dans les sondages 587 et 589.

Le résultat obtenu a été comparé à la biozonation traditionnelle de l'Ivorien belge (zones à *P.c.carina* et à *Sc.anchoralis*) (Groessens, 1975). Malgré la présence de quelques rares spécimens de *P.c.carina* au sommet de la séquence de Tournai, aucun autre guide ou sous-guide des zones précitées n'y a été trouvé. La présence de *Ps.multistriatus*, de *P.c.carina*, de *Ps.oxypageus* et de *P.mehli* juvénile a permis d'établir une meilleure corrélation avec l'Ivorien du "main shelf" irlandais (Jones et Somerville, 1996). Cette comparaison permet d'affirmer qu'il n'y a pas de Viséen à Tournai, ni même de Tournaisien supérieur de la zone à *Sc.anchoralis* et que la limite supérieur du Calcaire de Tournai doit sûrement se situer par comparaison avec le modèle belge, avant l'apparition d'*Eo.bultyncki*.

Le Calcaire de Tournai est subdivisé en deux ensembles lithologiques différents: un faciès wackestone-packstone à la base, surmonté d'un faciès mudstone. Ils sont séparés par le "Gras Délit", passée d'argilite qui constitue un excellent niveau repère dans quasi tout le gisement carrier. Dans son ensemble, le calcaire est soit micritique, plus ou moins argileux et imprégné de silice, soit très pur.

L'étude sédimentologique comprend une description macroscopique du sondage 587, ainsi que l'analyse de 125 lames minces, soit une tous les deux mètres de ce même sondage.

Les résultats de l'étude pétrographique, mis en parallèle avec les résultats des analyses chimiques fournies par CCB (une analyse par fluorescence-X pour chaque mètre de carotte), laissent entrevoir quatre épisodes dans le Calcaire de Tournai. Du plus vieux au plus jeune:

- le premier montre une diminution progressive de la teneur en argile,
- le deuxième est une zone de transition marquée par une forte concentration en phosphates,
- le troisième met en évidence la plus forte concentration en argiles et un assemblage faunique transporté,
- enfin, le quatrième présente une diminution de la teneur en argiles et lui aussi, une faune partiellement transportée. Ce dernier marquerait le début d'une recolonisation.

Ces résultats ont ensuite été soumis à une analyse par correspondance dans le cadre d'un modèle sédimentaire déjà établi en Angleterre par M. Hennebert et A. Lees (1991). Ce modèle se base sur la présence de relais au sein des composants de roches carbonatées, relais liés à des gradients environnementaux. La position des échantillons au sein du relais est exprimée par l'indice de relais. En Angleterre, les variations d'indice de relais ont été interprétées en termes de profondeur. A Tournai, la séquence inférieure au Gras Délit peut être interprétée en ces termes. Toutefois, dans la partie supérieure, l'apport argileux important empêche d'utiliser ce modèle de manière fiable.

Le modèle de Gutschick et Sandberg (1983), établi pour le Mississippien des U.S.A. et basé sur le lithofaciès, la couleur de la roche, les conodontes et les traces fossiles, a permis de situer l'environnement de dépôt du Calcaire de Tournai autour de la limite de la zone d'oxygène minimum.

On peut conclure de cette approche sédimentologique que le premier épisode correspond à un assemblage faunique normal, type faciès Bayard (milieu oxique) (Lees, Noël et Bouw, 1977), que le deuxième est une transition vers un troisième peu propice à la vie (zone d'oxygène minimum) et que le quatrième épisode marque le début d'une recolonisation.

En conclusion, il n'y a pas de Viséen à Tournai et la limite supérieure du Calcaire de Tournai serait située dans le modèle Ivorien belge, avant l'apparition d'*Eo. bultyncki*.

Suite à un apport terrigène important après le Gras Délit, le Calcaire de Tournai a évolué de manière différente par rapport à ses équivalents dans les autres régions de Belgique. Le Calcaire de Tournai se serait déposé à une profondeur relativement grande, au pied du talus.

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VARISCAN PROGRESSIVE NON-COAXIAL DEFORMATION IN THE CALEDONIAN STAVELOT-VENN MASSIF (BELGIUM). A SUPERPOSITION OF CRENULATION CLEAVAGES IN SALMIAN 2 SLATES

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SUMMARY.- The southern part of the Stavelot-Venn Massif is a Caledonian inlier in the Ardennes Allochton. The structural style is dominated by an EW-striking isoclinal upright fold system, cut by longitudinal and transversal faults. Caledonian-oriented structures contrast with the N60E-fold structures in the only Variscan-influenced Devonian cover. A Variscan low grade metamorphism is imprinted on the southern part of the Stavelot-Venn Massif, and is most prominent in the Mn-rich Salmian 2 and 3 slates.

A thorough investigation of the cleavages and the general strain environment was undertaken, as microstructural evidence was believed to be crucial in solving the discussions concerning Caledonian or Variscan age of the structures. Observations were made along an EW-profile, starting from Salmchâteau up to Dochamps, mainly in homogeneous Salmian 2 slates.

Several cleavages can be distinguished macroscopically in the field, microscopically in thin sections and with X-ray texture analysis. Several characteristic features allow a division into three cleavage populations. Both the relative age and the kinematic implications of these populations will be discussed below.

A penetrative slaty cleavage can be recognised throughout the whole study area. This fabric forms the axial planar cleavage of the isoclinal folds and has therefore a relative constant, nearly bedding parallel orientation (EW65S). More gentle dips occur in the most western outcrops (Lierneux, Dochamps). The axial symmetric pole figure indicates pure flattening strain. This cleavage is uniformly pre-metamorphic, as it is found as inclusions in porphyroblasts.

A discrete, post-metamorphic crenulation cleavage is present in the outcrops bordering the Devonian unconformity (Recht, Salmchâteau). The orientation of this crenulation fabric is comparable to the orientation of the slaty cleavage observed in the Devonian. Moreover both phyllosilicate textures are indicative of the identical non-coaxial deformation event.

At a larger distance from the unconformity (Tier du Mont, Tier dol Preu, Ottré) a multiple crenulation fabric has formed, consisting of two gradational crenulations. Both cleavages have a shiny surface, and a rather gentle dip of less than 50°. Their strike is not very constant, but averages around N40E. A characteristic feature is that the cleavage intensity varies over dm distance (zonal character). Their intersection with the bedding plane is parallel to some slight but clear ondulations of the bedding. This typical disposition points towards a close genetic linkage. Both crenulations are post-metamorphic.
In the most western outcrops only a broadly spaced crenulation cleavage can be recognised (Lierneux), or is not present at all (Dochamps).

As can be concluded from the proposed observations, the development of the slaty cleavage and the crenulation is separated by a metamorphic event. This metamorphism is Variscan in age. Therefore we have assumed a Variscan age for the crenulation fabric, an assumption that is consistent with the pole figure of the discrete crenulation fabric, that indicates an equal strain environment on both sides of the unconformity. A Variscan age for the large scale EW-folding and contemporaneous formation of slaty cleavage therefore becomes very doubtful. A Caledonian age would on the other hand explain for the different quantity and character which is associated with the slaty fabric and is consistent with other indirect evidence, like the presence of cleaved slate fragments in the basal Devonian conglomerate.

The formation of the discrete crenulation fabric is closely related with the Variscan deformation recorded outside the Stavelot-Venn Massif. This is however not obvious for the multiple crenulation fabric.

The multiple crenulation fabric can not be explained as a conjugated system of cleavages or as a ductile SC-fabric. A recent model however explains how progressive shear (in general: non-coaxial deformation) in well foliated rocks can result in the progressive formation of crenulation cleavages. Two main features of simple shear that are important in this model are the direction of incremental shortening and the progressive rotation of material lines. The formation of a multiple crenulation fabric cannot be explained in detail here, but the proposed model explains the orientation (both strike and dip) of the observed crenulation cleavages, as well as the systematically horizontal intersection of both cleavages. Also the absence or poor development of a crenulation fabric in a locally more shallow dipping slaty fabric can be explained. Apart from fitting all the geometrical constraints, the zonal character of the crenulations and their relation with undulations is often associated with a shear environment.

On the other hand the application of this model implies a westward-directed deformation. This is consistent with other, more scarcely available strain markers in this area, but it contrasts with the N30W-oriented Variscan deformation with which it is assumed coeval.

The reason for this anomalous strain regime is believed to be the internal Caledonian fabric of the southern part of the Stavelot-Venn Massif. It should indeed be clear that structures formed by a first and intense deformation event drastically change the rheologic characteristics of the tectonic entity, and should be taken into account when evaluating the influences of a second deformation. In this particular case the EW-striking structures introduce a strong, large scale anisotropy to the system that prevents ductile NS-shortening.

The southern part of the Stavelot-Venn Massif has experienced both Caledonian and Variscan deformation. As a consequence of pre-existing structures only part of the ductile Variscan strain (the EW-component) is accommodated within this part of the Caledonian inlier. Several features, of which a multiple crenulation cleavage is the most prominent one, are therefore indicative of a westward deformation event, and not of the, in this region, classical Variscan NW-deformation. The origin of this strain refraction is probably the internal fabric of the massif as ductile NS-shortening, either by folding or rearrangement of phyllosilicate fabric, is believed to be impossible.

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SPATIAL VARIABILITY OF HYDROGEOLOGICAL PARAMETERS IN AN ALLUVIAL AQUIFER: INFLUENCE ON THE TRANSPORT OF CONTAMINANT

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SUMMARY.- This work, performed on the pumping site of Dinant-Anseremme Prieuré, fits in a hydrogeological study aiming at determining the protection areas around pumping wells.

The site is characterized by the presence of two interconnected aquifers: an alluvial unconfined aquifer and a fractured limestone aquifer. Our main goal was to develop a detailed 3-D model allowing to take the vertical heterogeneities within the alluvial formations into account and including groundwater fluxes from the underlying limestone aquifer.

The methods used in this study were the following:
- defining the geological and hydrogeological context of the site on the basis of the drilling data and of the geophysical prospection;
- interpreting analytically the pumping tests and launching a tracing test campaign in order to determine *in situ* the local hydrodispersive parameters characterizing the two aquifers;
- setting up a 3-D numerical model integrating all collected data while considering local heterogeneities and the geometry of the geological layers.

After calibration on each measured break-through curve (obtained from the tracer tests), the aggregation of the calibrated parameters in the model has allowed to simulate the actual groundwater flow and pollutant transport conditions. It has allowed the determination, on the basis of convective isochrone calculation, of the protection areas IIa and IIb on the Dinant-Anseremme Prieuré pumping site.

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FACIES ANALYSIS AND GEOCHEMISTRY OF THE TRAVERTINE DEPOSITS OF BASKÖY, SOUTH-WESTERN TURKEY : IMPLICATIONS FOR CLIMATIC CHANGES DURING THE HOLOCENE

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SUMMARY.- The travertines in the village of Basköy, near the archaeological site of Sagalassos, have been petrographically and geochemically investigated. These travertines can be dated as being Holocene. U/Th dating of one section indicated an age of 9000 ± 600 BP (Y. Quinif, personal communication). Other travertines were dated younger than 1st-2nd century AD, based on ceramics found in the travertines (Poblome, 1996). Six types of travertine facies can be distinguished: travertine around plants, detrital travertine, platy travertine, algal travertine, larval travertine and layered travertine. These travertines were deposited in a fluvial, barrage system. Remains of palaeoriverbeds can still be found and are filled by siliciclastic and travertine pebbles.

Today, the fluvial system no longer exists. It must have largely disappeared by 1350 BP, since the travertine walls were already used for carving graves by that time (Waelkens *et al.*, 1997). Throughout several sections in the travertines, a systematic decrease in the oxygen isotopic composition of the calcites occurs and is interpreted to reflect an increase in the precipitation temperatures. Variations in the oxygen isotopic values around the linear trend can be explained by seasonal variations. Higher $\delta^{18}O$ values are due to precipitation during spring, lower values formed during summer. A change to higher precipitation temperatures around 9000 ± 600 BP, is confirmed by other authors who reported a similar change to warmer and wetter environmental conditions at this time, due to the switch to full interglacial conditions (Alayne-Street and Perrott, 1990 ; Hoddell *et al.*, 1991). The data presented confirm that ancient travertines can contain records of palaeoclimatic changes.

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CONTRIBUTION A L'ETUDE DE L'ETABLISSEMENT DES RECIFS WAULSORTIENS EN IRLANDE DE L'OUEST

François-Xavier DEVUYST[1]

REMSUME.- Les mudmounds waulsortiens, qui ont joué un rôle majeur dans les mers du Carbonifère inférieur, ont fait l'objet d'une recherche intensive depuis quelques dizaines d'années (Lees, 1964; Lees & Miller 1985; Lees & Miller, 1995). Grâce à ces recherches, nos connaissances ont considérablement évolué. Un aspect n'avait toutefois jamais été pris en considération: l'étude de la partie basale des récifs waulsortiens et des phénomènes qui se produisent lors de leur installation sur le fond marin.

Notre étude poursuivait deux objectifs:
1) étudier en détail les phénomènes qui accompagnent l'installation d'un récif waulsortien;
2) comparer la séquence d'installation de récifs qui diffèrent par leur position stratigraphique, géographique et environnementale.

La région étudiée se situe dans l'Ouest de l'Irlande où les récifs waulsortiens sont les mieux développés. Par ailleurs, les roches y ont subi une tectonique relativement modérée et les calcaires y présentent une empreinte diagénétique moins marquée qu'en Belgique. De plus de nombreuses coupes et forages exposent les parties basales de récifs.

Nous avons étudié quatre de ces coupes basales dont trois affleurements et un forage. Ces coupes sont réparties sur un transecte S-N qui suit la progression de la transgression marine qui a affecté presque toute l'Irlande au cours du Dinantien. Elles représentent donc un bon échantillon de temps dans le Tournaisien supérieur, en allant du dernier tiers de la biozone à

conodonte *Polygnathus communis carina* au sommet de la biozone à *Scaliognathus anchoralis europensis*. Elles reflètent donc aussi des situations géographiques et environnementales diverses.

Chaque coupe a fait l'objet d'un échantillonnage très serré sur un intervalle de 3 à 6 mètres. L'étude pétrographique de détail, base de notre travail, a porté sur un total de 162 lames minces. Pour chaque lame mince on a étudié d'une part les restes d'organismes ou bioclastes et, d'autre part, la texture et la structure du sédiment. Les organismes ont été répartis en 39 catégories et leur abondance évaluée semi-quantitativement (échelle de 1 à 4), ou quantitativement (comptage) pour les foraminifères pluriloculaires et les bryozoaires branchus. La texture a été analysée sur base d'une échelle de Dunham améliorée (13 types texturaux) et les boues calcaires ont fait l'objet d'une nouvelle classification en 11 catégories et sous-catégories. La structure du sédiment a été caractérisée par une dizaine de paramètres tels que la préservation des frondes de fenestelles ou les types de cavités. On a aussi quantifié grossièrement 4 composants non calcaires: argile, dolomite, silice et pyrite.

L'étude détaillée de chaque coupe et la comparaison entre les quatre coupes permettent de dégager les conclusions suivantes:
- lors de l'installation d'un récif waulsortien sur le fond marin des changements se produisent principalement au niveau de la texture et des composants non calcaires, mais aussi au niveau des organismes;
- ces changements sont, pour la plupart, différents de récif en récif, surtout en ce qui concerne la faune et la flore. Cependant un certain nombre de paramètres présentent une évolution similaire lors de la genèse des quatre récifs étudiés.

Ces résultats nous amènent à identifier deux gradients environnementaux:
1. un gradient régional (S-N) dont les variations très nettes sont interprétées en termes de bathymétrie;
2. un gradient local, propre à chaque installation de récif, dont les variations, beaucoup plus subtiles, sont liées à l'arrivée des faciès waulsortiens.

Le gradient local est caractérisé par l'arrivée progressive de petites entités micritiques subrécifales dites 'précurseurs', et par la présence systématique d'une zone de transition. Cette dernière se distingue des sédiments régionaux à plusieurs égards et précède, sous la forme d'une auréole péri-waulsortienne ('pré-récif'), l'installation du récif proprement dit.

Le gradient régional confirme et précise les conclusions de nombreux autres auteurs sur le profil bathymétrique du fond marin en Irlande au Carbonifère inférieur et sur la migration du phénomène waulsortien sur ce profil. Il nous permet aussi de proposer quelques ajouts au modèle des Phases du Waulsortien de Lees et Miller (1985 et 1995).

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GROUNDWATER RECHARGE IN SEMIARID AND ARID REGIONS A SPATIAL ESTIMATION FOR THE COUNTRY OF SYRIA

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SUMMARY.- This study is an attempt to spatially estimate the average continuous groundwater recharge of Syria using a soil-water budget simulation model: BOWAHALD* (Dunger, 1997) and a GIS.

The work was divided into two major phases: 1) the creation of a "global" grid-based data bank, and 2), its use for the actual estimation of recharge. The grid-based data bank contains climatic variables, and soil and vegetation parameter variables, which originated from point and polygon data respectively. This data bank consists of a raster (grid) with 20 by 20 km grid cells containing mean variable values. Its creation required the point and polygon data to be adapted in order to be combined. The climatic variables of average monthly precipitation and potential evapotranspiration where estimated onto a grid using geostatistics and GIS software. Five physical soil parameters (hydraulic conductivity, field capacity, saturation soil-moisture content, wilting point, and capillary rise) were approximated from a pedological map (1:1,000,000) based on mean texture. They were averaged into the grid cells with the help of analytical GIS operations. Finally, a vegetation class was assigned to each cell.

Once the data bank completed, the model BOWAHALD* was run for each grid cell to estimate the average monthly continuous groundwater recharge. BOWAHALD* models four components (interception, infiltration, evapotranspiration and percolation) of the land-based hydrologic cycle to estimate whether soil moisture is in sufficient abundance for deep percolation (which is approximated as recharge) to take place. Snowfall, runoff, depression storage, interflow, and the general heterogeneity of soil profiles with depth were not modeled in BOWAHALD*.

The final result is a thematic grid map of the average annual continuous groundwater recharge in Syria. Only 10.5% of Syria are affected by continuous recharge, which ranges from 5 to 713 mm/year. The total annual recharge estimate is of 5.2 km3. This result is validated by the FAO Aquastat estimate of renewable annual groundwater resources in Syria.

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PRELIMINARY DIAGENETIC STUDY OF THE CARBONATE SEQUENCE IN THE IONIAN ZONE OF ALBANIA

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SUMMARY.- Present-day oil- and gas reservoirs of Albania are situated in the Ionian zone in the External Albanides (Moorkens *et al.*, 1994). In the framework of an oil-company sponsored consortium project a transect in these External Albanides has been selected to work out a tectonic model (research in progress) and a diagenetic model in order to diminish the risk of prospecting in foreland / fold and thrust belts.

The oldest sediments in the Ionian zone are Permian or Triassic evaporites. The studied outcrop near Saranda consisted of a dolomite-shale and a dolomite-evaporite unit, separated by a fault. Deposition most likely occurred in a lagoonal setting. The diagenetic history of both units was very diverse. Porosity in these dolomites is low, but evaporite-dissolution brecciation might occur locally and improve potential reservoir quality.

The evaporite-dolomite sequence is overlain by a carbonate sequence. The majority of these carbonates are Jurassic to Eocene pelagic limestones with intervening coarser grained turbidites and gravity flows. The major oil reservoirs consist of fractured limestones, containing four macroscopically identifiable vein systems. In the diagenetic history the main phenomenon is, apart from compaction, the formation of four fracture systems. These are all cemented with a petrographically similar orange luminescent and sector zoned calcite cement. Also their trace element contents (Mg, Mn, Fe, Na, Sr) are similar. An analysis of the fluid inclusions of the calcite cement made clear that the veins are cemented at a temperature around 50°C. The analysis of the stable isotopes of the calcite cement revealed $\delta^{18}O$-values varying from -4 to +3‰ VPDB and $\delta^{13}C$-values ranging between 0 and +4‰ VPDB. A large scatter of stable isotope values is recognized even within one single vein system. The stable isotope data should be interpreted as the result of mixing fluids. It is possible that the relict fluids of an evaporative origin are involved. The formation of the veins is followed by a phase of stylolitisation. Along these stylolites dissolution occurs locally. The major reservoir is, however, built up by a later phase of fracturation which caused the existing veins to reopen and also created microfractures. It was demonstrated that the intervening turbidites may also form major potential reservoirs. These turbidites are differentially impregnated with hydrocarbons. Scanning electron microscopy (SEM) revealed a well-established porosity network within the impregnated zones. Non-impregnated zones were fine grained and did not show any porosity.

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HYDROGEOLOGICAL MODELLING OF THE GROUNDWATER FLOW AROUND THE POND "DE STER" AT ST.-NIKLAAS

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SUMMARY.- The lithostratigraphy of the phreatic aquifer was derived from literature and complemented with the observations made during the installation of eleven observation wells. The hydraulic parameters of this groundwater reservoir were determined with a

double pumping test. By the simultaneous interpretation of all observed drawdowns with an inverse numerical model the optimal values of the horizontal and vertical hydraulic conductivity of the Tertiary reservoir and the specific elastic storage of all layers (Tertiary and Quaternary) along with a joint confidence region were derived. The latter gives information about the accuracy with which the parameters were derived, an advantage over classical interpretation methods. The average infiltration rate for the steady state simulation as well as the infiltration fluctuations for the transient flow were considered as known. Using all the above cited data in a three dimensional finite-difference model the steady and transient groundwater flow around the artificial pond "De Ster" in the phreatic reservoir at St.Niklaas was simulated. The sensitivities of the different hydraulic parameters showed that the draining river heads were the most sensitive of the undetermined parameters. Consequently, they were used in a trial and error calibration of the model. The steady flow was simulated in the present situation, in a situation for a small exploitation rate and in a situation without the pond. A limited number of head fluctuations helped calibrating the transient flow which resulted in a value for the storage coefficient near the watertable. With this calibrated model the head fluctuations were calculated for a twenty year period over the entire area. For different sites the probability distribution of the hydraulic heads was studied. Under the water divide and a river the hydraulic heads posses a normal distribution, the pond possesses a double normal distribution as a consequence of two different flow regimes. Twelve samples were taken from the observation wells. Chemical analyses determined the groundwater quality and the results were classified according to Stuyfzand (1986).

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LA GROTTE DE LA BELLE-ROCHE ETUDE SEDIMENTOLOGIQUE ET CHRONOSTRATIGRAPHIQUE

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RESUME.- La grotte de La Belle-Roche est localisée à Sprimont (Liège, Belgique) sur le versant droit de la vallée de l'Amblève à 160 m d'altitude. Elle est entièrement comblée de sédiments et contient les plus anciens artefacts jamais trouvés dans le Benelux ainsi que de nombreux restes d'une paléofaune attribuée au Pléistocène moyen ancien (Cordy *et al.*, 1993).

Les dépôts qui remplissent la grotte se répartissent en cinq couches essentielles, de la base au sommet:
-un gravier fluviatile en place d'un ancien chenal souterrain de l'Amblève situé 60 m plus haut que le lit actuel de la rivière; c'est le "gravier de La Belle-Roche";
-trois couches fossilifères citées ci-après de bas en haut et connues sous les noms respectifs de: "limon inférieur"; "blocaille moyenne"; "cailloutis supérieur". Celui-ci contient des artefacts du Paléolithique inférieur;
-un plancher stalagmitique daté par U/Th de plus de 350 ka.

Le paléomagnétisme est normal dans toutes les couches du remplissage; il a été attribué à l'Epoque Brunhes.

La stratigraphie des niveaux paléontologiques atteste la continuité de l'évolution de l'environnement. On passe d'une faune de climat froid dans le "limon inférieur" et la "blocaille moyenne" à une faune de climat de transition dans le "cailloutis supérieur" puis à une faune de climat tempéré immédiatement sous le plancher stalagmitique.

L'ensemble de ces données chronostratigraphiques a permis d'estimer antérieurement l'âge des couches fossilifères de La Belle-Roche à environ 500 ka (stade isotopique 13 ou 15).

Dans ce travail, nous avons réalisé l'étude sédimentologique des dépôts de remplissage et une étude chronostratigraphique du gisement.
Les principaux résultats de notre étude sont les suivants:
La matrice des trois couches fossilifères a été soumise à l'analyse granulométrique comparative avec des loess typiques de moyenne Belgique. Il ressort de cette comparaison que les distributions granulométriques des échantillons des trois couches fossilifères sont semblables à celle des loess.
L'arrivée de loess à La Belle-Roche dans un paléoenvironnement périglaciaire est conforme avec les paléofaunes de climat froid du "limon inférieur" et de la "blocaille moyenne". Le transport dans la grotte des matériaux des trois couches fossilifères peut dès lors être attribué à la solifluxion périglaciaire .

La détermination de blocs et cailloux de chaque couche du stratotype montre que les trois niveaux fossilifères contiennent une majorité d'éléments calcaires du substratum local, mais aussi des galets provenant d'une ou de plusieurs terrasse(s) de

l'Amblève située(s) à l'amont de la grotte; nous l'(les) appellerons "terrasse(s) de Fraiture".

Dans ces conditions, les artefacts, uniquement présents dans le "cailloutis supérieur", ne proviennent pas de la (des)"terrasse(s) de Fraiture", mais ont été abandonnés sur l'itinéraire de la coulée de solifluxion correspondante. Ceci implique la présence de l'Homme à La Belle-Roche.

Ces données sédimentologiques montrent que les matériaux des trois couches fossilifères résultent de coulées de solifluxion à matrice loessique qui, sur leur itinéraire, ont prélevé des galets de la (des)"terrasse(s) de Fraiture" et des cailloux calcaires du substratum avant de se mettre en place dans la grotte.

Les silex utilisés par l'Homme ont probablement été prélevés autour d'un placage de craie à silex situé à proximité de la grotte plutôt que dans les alluvions de l'Amblève qui ne contiennent qu'environ 2% de silex dont la plupart sont trop petits pour être taillés.

Grâce aux profils longitudinaux de terrasses fluviales de l'Amblève de l'Ourthe inférieures (Ek, 1957), le "gravier de La Belle-Roche"peut être raccordé à la terrasse d'Eben-Sint Gertruid du modèle chronostratigraphique des terrasses de la Meuse de van den Berg (1996). Or, la terrasse de Sint Geertruid a un âge d'environ 1 Ma, correspondant à l'Evénement paléomagnétique normal de Jaramillo (van den Berg, 1996). Le paléomagnétisme normal du "gravier de La Belle-Roche" peut donc être attribué à l'Evénement de Jaramillo plus qu'à l'Epoque Brunhes.

Les couches fossilifères de La Belle-Roche se sont déposées sur le cailloutis après l'abandon de la grotte par l'Amblève, car en l'absence du cours d'eau, les sédiments non fluviatiles qui arrivaient sur le gravier ne pouvaient plus être évacués.

Si on accepte un âge de 1 Ma pour le cailloutis fluviatile et un âge de seulement 500 ka pour les couches fossilifères, il faut admettre l'existence d'une lacune stratigraphique correspondant à 500 ka entre le "gravier de La Belle-Roche" et le "limon inférieur". Cette lacune est difficile à admettre, car si le cailloutis était resté en affleurement dans la grotte, en attente du dépôt fossilifère pendant environ 500 ka, soit une quinzaine de stades isotopiques alternativement chauds et froids, on serait en droit d'attendre sur le gravier l'une ou l'autre ou plusieurs des formations suivantes: 1) un quelconque concrétionnement, 2) des ossements, 3) des blocs de calcaire tombés du plafond. De plus du "gravier de La Belle-Roche" est localement effondré dans des poches de dissolution et il a été suivi dans ce mouvement par le "limon inférieur" sus-jacent.

Les données sédimentologiques et chronostratigraphiques décrites ci-dessus nous permettent d'envisager l'hypothèse que les couches fossilifères de La Belle-Roche se seraient déposées rapidement après l'abandon du niveau de terrasse comprenant le "gravier de La Belle-Roche", soit vers 1 Ma. Le paléomagnétisme normal des couches fossilifères correspondrait à l'Evénement Jaramillo plutôt qu'à l'Epoque Brunhes et correspondrait donc à un âge compris entre 0,98 Ma et 1,08 Ma.

Enfin, il est clair que l'Homme a abandonné des outils sur le site de La Belle-Roche et que ces artefacts ont été entraînés par une coulée de solifluxion à l'intérieur de la grotte. Le nouveau modèle proposé impliquerait dès lors la présence de l'Homme en Haute Belgique il y a 1 Ma.

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