Geologica Belgica
Département de Géologie
de l'Université de Liège

2nd Belgian Geological Congress

Maison de la Métallurgie, Liège

7-8 september 2006

Organizing committee
Jacqueline Vander Auwera
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GEOLOGICA BELGICA MEETING 2006
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2nd BELGIAN GEOLOGICAL CONGRESS
LIEGE, BELGIUM, 7 – 8 September 2006

PROGRAM

Thursday September 7th

8H00-9H00: WELCOME OF PARTICIPANTS
9H00-9H10: Opening of the meeting: the word of the president (D. Laduron)

CLIMATE AND ENVIRONMENTAL GEOLOGY

9H10-9H30: Yans J., Dupuis C.
Dating of the weathering processes in the Ardenne area (Belgium)
9H30-9H50: Quinif Y.
U/Th dating of a near water-table speleothem in the cave of Han-sur-Lesse - Implications on geodynamics evolution of Ardenne
9H50-10H10: Petermans T., Rosset P., Foriers E., Camelbeeck T.
Evaluation and mapping of local site effects and seismic hazard: case studies in Mons Basin and Brussels region
10H10-10H30: Petit J., Taillez A., Verheyden S., Chou L., Mattielli N.
First steps towards Cu and Zn isotope geochemistry in estuarine environments

10H30-10H50: COFFEE BREAK AND POSTER SESSION

10H50-11H10: Missiaen, P., Van Itterbeeck, J., Folie, A.,. Markevich, V.S., Van Damme,D., Dian-Yong, G., Smith, Th.
The Subeng mammal site (Late Paleocene, China): evidence for a unique woodland on the dry Mongolian Plateau
11H10-11H30: De Vleeschouwer F., Van Vliët-Lanoé B., Fagel N., Richter T., Boës X., Gehrels M.
High resolution petrography of impregnated peat columns containing tephras. Principle, applications and perspectives
11H30-11H50: Renson V., De Vleeschouwer F., Fagel N., Mattielli N., Nekrassoff S., Streel, M.
Contribution of elemental and lead isotopes geochemistry to archeology in a Belgian peat bog (Hautes Fagnes)
11H50-12H10: De Batist M., Artemov Y., Beaubien S., Greinert J., Holzner C., Kipfer R., Lombardi S., McGinnis D., Naudts L., Schmale O., Schubert C., Van Rensbergen P., Zuppi G.M. & the CRIMEA project members
The "Clathrate Gun" did not fire bubbles…
12H10-12H30: Van Rooij D., Blamart D., Foubert A., Henriet J-P.
Offshore record of British-Irish ice sheet fluctuations during the last glacial cycle: implications for deep-water sedimentation

12H30-13H30: LUNCH BREAK AND POSTER SESSION

SEDIMENTOLOGY-PALAEONTOLOGY-STRATIGRAPHY

13H30-13H50: Poort J., Kaulio V., Depreiter D.
Thermal signals in gas hydrate seeps and mud volcanoes: NEW insights in a highly dynamic system
13H50-14H10 : De Putter Th., Weyssat M.O., Liégeois, J.P., Decrée S.
The Idjill Group (West African Craton, Mauritania): geochemistry, and Fe, Sr, Nd isotopes of a Palaeoproterozoic iron formation, witness of the "Great Oxidation event" (GOE)
14H10-14H30: André L., Cardinal D., Opfergelt, S.
Silicon Isotopes as a New Tracer to Quantify Superficial Processes: the geological perspective
14H30-14H50: Boulvain F., Coen-Aubert M., Da Silva A-C., Grassineau N., Yans, J.
Sedimentology, magnetic susceptibiliy and high-resolution carbon isotope in the Middle Frasnian of the Ardenne area (Belgium): high-amplitude and rapid eustatic variations as potential cause of the punctata event?
14H50-15H10: Mabille C., Humblet M., Boulvain F.
Sedimentology and magnetic susceptibility of the Couvin Formation (Eifelian, SW Belgium): carbonate platform initiation in a hostile world
15H10-15H30: Maziane-Serraj N., Hartkopf-Fröder C., Thorez J., Streel, M.
The Chanxhe section (eastern Belgium), a reference for the neritic Late to Latest Famennian transition (Upper Devonian)

15H30-16H00: COFFEE BREAK

16H00-16H20: Vanmeirhaeghe, J.
Review of the stratigraphy and chitinozoan biozonation of the Middle and Upper Ordovician of the Condroz Inlier (Belgium): evidence for lateral or only intra-biozonal facies changes?
16H20-16H40: Herbosch A., Debacker T.N., Piessens, K.
The stratigraphic position of the Cambrian Jodoigne Formation redefined (Brabant Massif, Belgium)

MAGMATIC AND METAMORPHIC PETROLOGY

16H40-17H00: Demaiffe D., Wiszniewska J., Brassinnes S.
A new alkaline and carbonatite province in NE Poland
17H00-17H20 : Berger J., Féménias O., Mercier J.-C., Demaiffe D.
Fossil oceanic lithosphere in Limousin (French Massif Central): geodynamic evolution of pre-Variscan events in W. Europe
17H20-17H40: Liégeois J.P., Fekkak A., Bruguier O., Errami E., Ennih N.
Lower Ediacaran age (630-610 MA) for the Sarho Group: an orogenic transpressive basin development during the metacratonic evolution of the Anti-Atlas (Morocco)
17H40-18H00: Machiels L., Elsen J.
Study of the natural zeolite deposits of coastal Ecuador

Dinner will be organized after the session for those who registered.

Friday September 8th

8H00-8H30: WELCOME OF PARTICIPANTS

GEOPHYSICS

8H30-8H50: Licour L., Rorive A., Mengeot A.
Hydrogeology of the aquifer of the Devono-Carboniferous Limestones of Hainaut : A karstified medium, a non-karstic behaviour - Resources and general kind of flow
8H50-9H10: Van Camp M., Vanclooster M., Dassargues A., Crommen O., Petermans T., Verbeeck K., Meurers B., van Dam T.
Hydrology and gravity at the Membach station, Belgium
9H10-9H30: Naudts L., Greinert J., Artemov Y., De Batist M.
The use of acoustic seafloor backscatter measurements for quantitative and qualitative characterization of methane seep areas
9H30-9H50: Germay C., Dagrain F., Richard T.
Fields Applications for the scartching test
9H50-10H10: Deceuster J., Cattelain P., Kaufmann O.
Geophysical study on an archaeological gallo-roman site at Matagne-La-Petite, Belgium

10H10-10H30: COFFEE BREAK + POSTER SESSION

MINERALOGY-ORE PETROLOGY

10H30-10H50: Namur O., Charlier B., Fransolet A.M., Vander Auwera J., Hatert F.
Ti and Al substitutions in phlogopites from the Suwalki massif-type anorthosite, NE Poland
10H50-11H10: Hatert F.
Transformation sequences of Copper sulfides at Vielsam, Stavelot Massif , Belgium
11H10-11H30: Fransolet A-M., Hatert F., Bernhardt H-J., Theye Th., Maresch W.
Occurence of sursassite, Mn 2Al 3(SiO 4)(Si 207)(OH) 3, in the Lienne valley, Stavelot Massif
11H30-11H50: Boni M., Dejonghe L., Balassone G., Coppola V.,Gilg H A.
Zinc nonsulphide deposits ("Calamine") of Belgium
11H50-12H10: Decrée S., De Putter Th., Marignac Ch., Liégeois J-P., Demaiffe D.
The genesis of the Nefza Pb-Zn ore deposit (Northern Tunisia) : comparison with central Tunisia deposits and evaluation of the geodynamical control
12H10-12H30: Pirard C., Hatert F.
Sulphides and selenides from thrust-slice 2400, Musonoi mine, Katanga, D.R. Congo
12H30-12H50: Haest M., Muchez P., Dewaele S., Tyler R.
Metallogenesis of the Dikulushi Cu-Ag ore deposit in the Lufilina foreland (Democratic Republic Congo)

12H50-13H30: LUNCH BREAK AND POSTER SESSION

TECTONICS

13H30-13H50: Debacker T.N., Vanmeirhaeghe J.
Pre-Devonian, Brabantian (?) deformation within the southern Condroz inlier (Ruisseau des Chevreuils, Dave, Belgium)

13H50-14H10: Delstanche S., Laduron D.
Geological structure of the eastern border of the Cambrian Givonne-Massif and its Devonian cover (Muno, Belgium)
14H10-14H30: Van Baelen H., Sintubin M., Muchez P.
Kinematic significance of an angular unconformity during progressive shear deformation: evidences from the sourthern border of the Lower Palaeozoic Rocroi inlier (Naux, France)
14H30-14H50: Coenen B., Debacker T.N., Van Noten K., Verniers J.
Lateral variations of deformation style in virtually coaxially deformed sequences: the example of the upper Silurian of the inclined shiplift at Ronquières, southern Brabant Massif (Belgium)
14H50-15H10: Sintubin M., Kenis I., Urai Janos L.
About boudins and mullions in the high-Ardenne slate belt

15H10-15H30: COFFEE BREAK

15H30-15H50: Van Noten K., Kenis I., Sintubin M., Urai Janos L.
Quartz veining in the high-Ardenne slate belt. New evidences from the Rursee area, north Eifel, Germany
15H50-16H10: Spagna P., Vandycke S., Yans J., Dupuis R.
Hydraulic and brittle extensional faulting in the wealden facies of Hautrage (Mons Basin, Belgium)
16H10-16H30: Darquennes A., Vandycke S., Schroeder C.
Petrophysical Deformation in Faulted White Chalk in Belgium
16H30-16H50: Vilasi N., Swennen R., Mezini A., Roure F.
Fracturing and fluid flow evolution in the upper Cretaceous to Paleocene strata of the ionian zone (Albania)
16H50-17H10: Dewever, B., Swennen, R., Berwouts, I.
Fluid flow history in the sicilian fold-and-thrust belt : implications for hydrocarbon exploration
17H10-17H30: Breesch L., Swennen R., Vincent B.
Reconstruction of fluid flow evolution in outcrops along a NS-transect in the northern Oman mountains, United Arab emirates
17H30-17H50: Féménias O., Diot H., Demaiffe D.
Deformation and geochemical evolution of pre-orogenic granitoids during deep crustal thrusting (yeu island, french variscan belt)

POSTERS

Berger J., Ennih N., Demaiffe D., Liégeois, J.P.
Reactivation of a cratonic boundary in an intraplate setting: the Cenozoic alkaline lavas from Djbel Sahro (anti-Atlas, Morocco)

Bertola C., Boulvain F. Poty E.
Magnetic susceptibility and high resolution correlation in Belgian Tournaisian

Bolle O., Diot H.
Magmatic fabrics in Sveconorwegian postcollisionnal magmatic bodies (southern Norway) revealed by their anisotropy of magnetic susceptibility (AMS)

Charlet F., Verschuren D., Bessems I., Olago D., Muzuka A., De Batist M.
Two glacial-interglacial cycles of lake-level change in equatorial East Africa documented by high-resolution seismic sequence stratigraphy from Lake Challa (Kenya)

Da Silva A-C., Boulvain F., Mabillle C.
Application of magnetic susceptibility on different carbonate platform type

De Batist M. and the ENSO-CHILE Project Team (Arnaud F., Boës X., Beck C., Bertrand S., Brümmer R., Chapron E., Charlet F., Charlier B., De Vleeschouwer F., Fagel N., Juvigné E., Loutre M.F., Magand O., Mélières M.A., Pino M., Renson V., Roche E., Sabbe K., Sterken M., Thorez J., Urrutia R., Vargas L., Verleyen E., Vyverman W.)
An 18,000-year multiproxy lacustrine record of climate variability in south-central Chile (40°S): Lago Puyehue, Chilean Lake District

De Vleeschouwer F., Gérard L. , Streel M. , Mattielli N. , Fagel N.
Pre-anthropogenic geochemical fluctuations in a Belgian peat bog

Dusar M., Lagrou D.
The Cretaceous of the Hinnisdael underground quarries in Vechmaal (commune Heers, Belgian Limbourg)

El Desouky H. , Muchez P., Dewaele S., Boutwood A., Tyler R.
The stratiform Copper mineralization at Lufukwe, Lufilian foreland, Democratic Republic of Congo

Macheyeki A.S., Delvaux D, Kervyn F, De Batist M.
Active faults and fault segmentation in the Ufipa plateau, SW-Tanzania

Mathys M., Baeteman C., De Batist M.
The Quaternary geological evolution of the Belgian Continental Shelf: a sneak preview

Missiaen T., Henriet J.P., Halleux L., Martens R.
High resolution geophysical investigations of an old WW1 munition dump site

Missiaen T., Slob E., Versteeg W., Donselaar M.E.
Comparing different geofysica methods in the Verdronken land van Saeftinge

Missiaen T., Versteeg W.
Very high resolution seismic investigations over a buried wooden ship wreck

Moernaut J., De Batist M., Charlet F., Heirman K., Chapron E., Pino M., Brummer R.
Holocene earthquake-triggered mass-wasting events recorded in the sediments of Lake Puyehue (South-Central Chile)

Namur O., Charlier B., Higgins M.D., Vander Auwera J.
The marginal gabbro of the Sept Iles intrusive suite (Quebec): constraints on the parent magma composition of the mafic layered intrusion.

Naudts L., De Batist M., Criel W., Poort J., Van Rensbergen P., the SONIC Team, Klerkx J., Granin N., Khlystov O., Duchkov A.D., Duchkov A.A., Obzhirov A., Chensky A., Kapitanov V., Wuest A., McGinnis D., the INTAS Project 01-2309 members
Gas hydrates, mud volcanoes and gas seeps in lake Baikal

Naudts L., Greinert J., Artemov Y., De Batist M.
Geological and morphological setting of 2778 methane seeps in the Dnepr paleo-delta, northwestern Black Sea

Nkono C., Féménias O., Mercier J-C., Demaiffe D.
Differentiation processes in the alkaline lava series from Bioko Island (Cameroon Line)

Popescu I., De Batist M., Lericolais G., Nouzé H., Poort J., Panin N., Versteeg W., Gillet H.
A quadruple bsr in the black sea: a potential proxy of past climate conditions ?

Roe, H.M., Baeteman C.
Pleistocene coastal evolution and sea-level change of the lowlands of western Belgium: The record from the Woumen borehole, near Diksmuide

Sadigh H.
The study of Pushte-Jangal anticline in northeast of Kuhdasht

Spagna P., Van Itterbeeck J.
Lithological description and granulometric study of the ealden facies in two borehole core drilled in the " cran aux iguanodons de Bernissart " (N-W of the Mons Basin, Belgium)

Streel M., Somers Y., Dusar M.
No important hiatus in the late Westphalian C and early Westphalian D strata of the Campine Basin (north eastern Belgium).

Taillez A., Verheyden S., Petit J., Chou L., Maerschalk C., Mattielli N.
Stable lead isotopes ratios in a multi-source polluted environment : the Scheldt estuary

Vandenbroucke T.R.A.
Upper Ordovician Global Stratotype Section & Points and the British historical type area: a chitinozoan point of view

Vander Auwera J., Dupont A., Bogaerts M.
Two distinct ferropotassic A-type magmatic suites were emplaced at the end of the

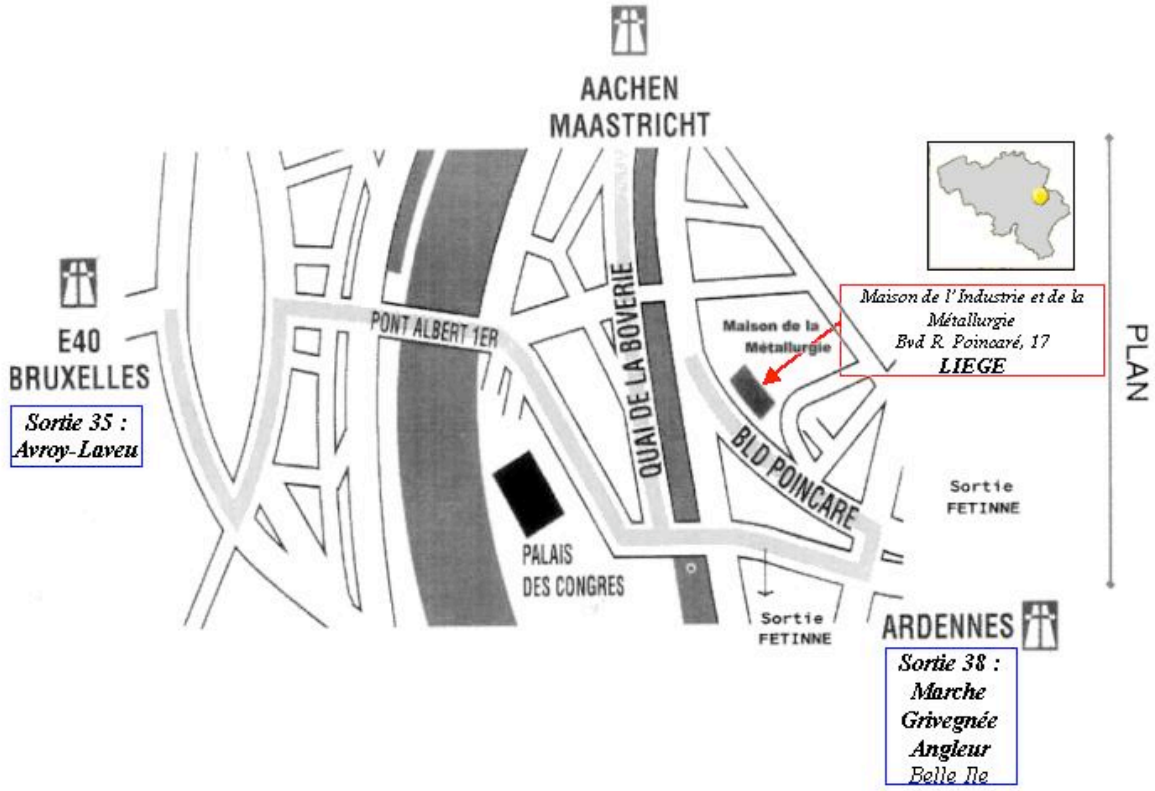
Sveconorwegian orogeny

Van Rooij D., Huvenne V., Blamart D., De Mol B., Henriet J-P. & the IODP Exp. 307 shipboard party.
Origin, control and evolution of contourite drifts associated with cold-water coral banks, offshore ireland.

Verheyden S., de Jong J., Taillez A., Petit J., Mattielli N
Cd isotope fractionation in the Scheldt estuary: preliminary results from MC?ICP?MS on reference material, suspended particulate matter and sediments ? Implications for tracing of pollution

LOCATION

La Maison de la Métallurgie et de l'Industrie
Boulevard Raymond Poincaré 17
4020 Liège



PUBLICATION

It will be possible to publish the extended abstracts presented at this meeting in a special issue of Geologica Belgica. Interested authors should contact the executive editor : Jean Clair Duchesne (JC.Duchesne @ulg.ac.be).

ABSTRACTS

SILICON ISOTOPES AS A NEW TRACER TO QUANTIFY SUPERFICIAL PROCESSES: THE GEOLOGICAL PERSPECTIVE

André L. [1], Cardinal D.[1] & Opfergelt S.[2]

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Silicon, the second most abundant element on Earth, is present everywhere from the lithosphere to the hydrosphere, biosphere, pedosphere. Small variations in abundance ratios of Si isotopes can now be measured very precisely (~0.1‰ in δ^{29}Si), providing a tracer for a variety of physical, chemical and biological processes recorded in siliceous rocks, organic bodies and fluids. In particular, the biosynthesis of siliceous skeletons and phytoliths as well as SiO_2 chemical precipitations induce isotopic fractionations of various intensities depending on the characteristic features of these organic-inorganic processes.

A recent geological application on micro-subsamples (at 500µm scale) from several major rock types of the ~3.8-Ga-old Isua Greenstone Belt (IGB, southern West Greenland) and surrounding Eoarchaean terrains will be detailed. With a large overall range of variations (-1.45‰<δ^{29}Si<+0.35‰), they demonstrate strong involvement of surface fluids enriched with dissolved Si. The resistance of Si-isotopes to metamorphic resettings and metasomatic overprints is also established. Metabasaltic pillows and metasediments display similar ^{29}Si-enriched signatures, suggesting that emergent surfaces of the Eoarchaean protocrust were composed of slightly weathered, hydrothermally altered, mafic-ultramafic bodies. Isua magnetite-quartz Banded Iron Formation (BIF) is strongly depleted in ^{29}Si relative to all coeval rocks. This depletion supports Rayleigh-controlled precipitation from seafloor-vented hydrothermal fluids. In contrast, banded quartz-pyroxene rocks (from Akilia Island, some 150km southwest of the IGB), which some authors have identified as BIF-related, yield quartz with Si-isotopic composition (δ^{29}Si=-0.18‰) similar to metamorphic-derived quartz (δ^{29}Si=-0.26‰). This supports their derivation from tectonic reworking of ultramafic protoliths penetrated by metamorphic silica and is at variance with their proposed role as harboring earliest biogenic tracers.

FOSSIL OCEANIC LITHOSPHERE IN LIMOUSIN (FRENCH MASSIF CENTRAL): GEODYNAMIC EVOLUTION OF PRE-VARISCAN EVENTS IN W. EUROPE

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Relicts of an oceanic lithosphere have been found along the suture zone between two major allochtonous units in the Variscan orogenic belt of Limousin (Western French Massif). The ophiolite bodies are dispersed along a 25 km long band. They display the typical association of 1) partly serpentinized mantle-derived rocks (diopside-bearing harzburgite, harzburgite and dunite with localised pods of chromite), 2) partly amphibolitized mafic magmatic rocks (troctolite, wehrlite, gabbro) and 3) (probably) the base of the dyke section. The volcanic sequence (basaltic pillow-lavas) has not been discovered. The olivine-bearing units (troctolite, wehrlite) are highly serpentinised while the pyroxene-bearing (gabbro) units are partly amphibolitised. The various amphiboles from amphibolites-metagabbros were equilibrated at low pressure (< 2kbar). Comparison with hydrothermally altered gabbros in ocean-floor setting (data from worldwide ophiolites and ODP) show that the metamorphic overprint on the Limousin oceanic lithosphere is of hydrothermal ocean-floor type with only minor effect (greenschist facies mylonites along shear zones) of the Variscan regional (=orogenic) metamorphism. The discovery of epidosites and pseudo-rodingites (Ca-Al rich rocks with hydrogrossular, prehnite, actinote, …) confirm the ocanic origin of this suite of rocks. Aluminous amphibolites with sapphirine-corundum-gedrite-kyanite have also been found in a major thrust zone in some ophiolite bodies. They probably represent a HT-MP (granulite) metamorphic event and could represent the metamorphic sole upon which the ophiolite was obducted (analogy with the Oman ophiolite).

The abundance of troctolites, the scarcity of magmatic amphibole and the low An content (An_{82}) of most primitive plagioclase argue for a mid-ocean ridge (MOR) rather than a supra-subduction zone (SSZ, like Troodos) ophiolite type. Moreover, the presence of diopside-bearing harzburgite and minor lherzolite in the mantle section indicates that the Limousin ophiolite belongs to the intermediate lherzolite-harzburgite ophiolite type (LHOT). This kind of ophiolite corresponds to slow-spreading oceans; it is intermediate between to fast-spreading harzburgite (HOT) type and the ultra-slow-spreading lherzolite (LOT) type of oceanic crust.

Integrating these new data in the evolution of the Variscan belt of Western Europe suggests that the ocean was probably not very large (comparable to Red Sea or Central Atlantic) but it was nevertheless quite long, it has been observed from Galicia to the Bohemian massif.

The absence of pervasive orogenic metamorphism in the ophiolite and the true oceanic type of this fossil lithosphere are typical of Devono-Carboniferous (~360 Ma) oceanic relicts found in the Bohemian massif. The ophiolitic remnants from Limousin would represent fragments of a ocean (Paleotethys?) obducted to the south upon the passive Arverne domain during Early Carboniferous. Closure of this oceanic domain by north-dipping subduction has leaded to the Carboniferous collision characterised by early south-verging nappes.

REACTIVATION OF A CRATONIC BOUNDARY IN AN INTRAPLATE SETTING: THE CENOZOIC ALKALINE LAVAS FROM DJBEL SARHRO (ANTI-ATLAS, MOROCCO)

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The Sarhro volcanic series belongs to the Cenozoic volcanic province of NW Africa. It is located in the Anti-Atlas (Morocco) on the northern boundary of the West African craton where major Pan-African magmatic and tectonic events occurred. The timing of the volcanic activity is here concentrated around two periods: 10-6 Ma in a southern domain and 5-2 Ma in a northern domain. The composition of lava flows and domes covers the whole range of undersatured alkaline lavas: nephelinite with olivine and pyroxene phenocrysts; tephrite with pyroxene, sanidine and plagioclase phenocrysts; tephro-phonolite with sanidine, pyroxene and feldspathoid (nosean, hauyne, nepheline) phenocrysts and phonolite, with sanidine and feldspathoid phenocrysts. The existence and composition of the numerous pyroxene and olivine megacrysts and associated clinopyroxenite xenoliths argue for a polybaric differentiation of the parental magma. A two magma chamber differentiation model is proposed with a high-level chamber and a deep-seated chamber, probably at the crust – mantle transition.

The cause of this Miocene-Pliocene volcanic activity is still debated. The Sarhro and Sirwa (150 km to the west) volcanic provinces are parallel to the main Pan-African structures and are located between the South Atlasic Fault (SAF, to the north) and the Anti Atlas Major Fault (AAMF, to the south). These major discontinuities have been active since the Pan-African orogeny: seismic together with structural data show while the SAF (N60°E) has presently a transpressional fault with a sinistral lateral movement and the AAMF (N120°E) with a dextral strike-slip component. Moreover, the compressive active tectonics in the Atlas mountains show that the maximal stress σ_1 is globally oriented N-S. Within this scheme, the whole structural data can be summarised by a Riedel system in a transpressional context. The SAF and AAMF are the main Riedel fractures (R) and the smaller fractures (N 20°E and N 170°E) are the R' faults. The N-S alignment of volcanoes in Sarhro is parallel to the extensional direction in this Riedel system.

The volcanic activity in this area is thus globally controlled by the convergence of the African and European plates (Alpine orogeny) and locally by the reactivation of older (Pan-African) faults. Our model dismisses the classical plume hypothesis proposed for the genesis of this alkaline volcanic province. It also shows that cratonic boundaries and more generally orogenic suture zones are favoured locations for magmatic activity in an intraplate setting.

MAGNETIC SUSCEPTIBILITY AND HIGH RESOLUTION CORRELATION IN BELGIAN TOURNAISIAN

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In the frame of this work, biostratigraphy, magnetic susceptibility and sedimentology were used in order to propose high precision lateral correlations between the reference sections of the Belgian Tournaisian: Rivage (north-eastern border of the Dinant Synclinorium), Gendron-Celles (southern part), Anseremme (southern part) and Yvoir (northern border). These sections present a succession of limestone layers with a few more argillaceous units and are located in different sedimentation areas (Poty, 1997).

For sedimentological approach, 8 microfacies were defined and integrated in a homoclinal carbonate ramp model. This also allowed the drawing of lithological curves reflecting the bathymetric evolution. Four coral zones (Poty, 1985), 8 foraminefera zones (Hance *and al.*, in press) and 3 conodont zones (Groessens, 1974) were defined in the Tournaisian, together with 4 third order sequences in Tournaisian (Hance *and al*., in press). The sequence stratigraphy model henceforth used is that from Plint and Nummedal (2000). The innovation brought in regard with the Vail model is the use of the 'falling stage system tract' notion as well as various erosion surfaces.

The magnetic susceptibility (MS) method was never used in the entirety of Belgian Tournaisian. In this case, the MS curves clearly show a break representing an erosion surface between two system tracts and also present a perfect opposition with microfacies curves. It is proposed from it that the MS is strongly influenced by carbonate productivity, by the presence of fossils and by the global sea level fluctuations. It is essential too to position each lithology in its depositional environment and to observe its spatial distribution to interpret the magnetic susceptibility curves.

MAGMATIC FABRICS IN SVECONORWEGIAN POSTCOLLISIONNAL MAGMATIC BODIES (SOUTHERN NORWAY) REAVELED BY THEIR ANISOTROPY OF MAGNETIC SUSCEPTIBLITY (AMS)

Bolle O.[1], Diot H.[2]

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Magmatic bodies such as granitoid plutons and dykes usually display an ill-defined and, hence, not easily measurable magmatic fabric, expressed by a shape-preferred orientation of the rock-forming minerals. An anisotropy of the magnetic susceptibility (AMS) also arises in these rocks from the crystallographic- and/or shape-preferred orientation of the magnetic rock-forming minerals. The AMS and magmatic fabrics are coaxial in many magmatic rocks, i.e. K_1 (the long axis of the ellipsoid describing AMS in a low applied magnetic field) is parallel to the magmatic lineation and K_3 (the ellipsoid short axis) is perpendicular to the magmatic foliation. Hence, AMS measurements have been extensively used in the last two decades to determine weakly-anisotropic magmatic fabrics. These AMS studies reveal that magmatic fabrics record the deformation related to magma flow and/or to emplacement in a regional strain field. Hence, valuable information on the magma emplacement kinematics and, often, on the crustal deformation kinematics are provided. Mapping of magmatic fabrics, through AMS measurements, may also help in locating magma sources.

The AMS technique has been successfully applied to Sveconorwegian (Grenvillian) postcollisionnal intrusions from southern Norway. The postcollisionnal magmatism of the Sveconorwegian orogen is represented by two distinct, but penecontemporaneous suites: a hornblende + biotite granitoid suite (HBG suite; ca. 1.00-0.92 Ga) and an anorthosite-mangerite-charnockite suite (AMC suite). The AMC suite is found mainly in the Rogaland anorthosite province (ca. 0.93-0.92 Ga). Selected AMS studies conducted on igneous bodies belonging to the two suites will be presented and their implications for the late magmatic and tectonic evolutions of the Sveconorwegian orogen will be discussed.

Magmatic bodies such as granitoid plutons and dykes usually display an ill-defined magmatic fabric, expressed by a shape-preferred orientation of the rock-forming minerals. Measurement of such a weakly-anisotropic fabric using traditional means is tedious and time consuming. The fine grain size may be another complicating factor in dykes. An anisotropy of the magnetic susceptibility (AMS) also arises in these rocks from the crystallographic- and/or shape-preferred orientation of the magnetic rock-forming minerals. The AMS fabric (described, in a low applied magnetic field, by an ellipsoid whose axes are labeled $K_1 \geq K_2 \geq K_3$) and the magmatic fabric are coaxial in many magmatic rocks, i.e. K_1 is parallel to the magmatic lineation and K_3 is perpendicular to the magmatic foliation. Given this relationship, and since the AMS technique is rapid and highly sensitive, AMS measurements have been extensively used in the last two decades to determine weakly-anisotropic magmatic fabrics. These AMS studies reveals magmatic fabrics recording the deformation related to magma flow and/or to emplacement in a regional strain field (the latter case is extremely frequent in granitoids, but is also known from volcanic dyke swarms). Hence, valuable information on the magma emplacement kinematics and, often, on the crustal deformation kinematics are provided. Mapping of magmatic fabrics, through AMS measurements, may also help in locating magma sources.

ZINC NONSULPHIDE DEPOSITS ("CALAMINE") OF BELGIUM

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The Belgian nonsulphide Zn deposits represent the historical basis for zinc mining and smelting industry in Europe. The zinc ores were called "Calamines" and consist of a mixture of Zn carbonates (smithsonite, hydrozincite) and Zn silicates (hemimorphite, willemite and Zn clays), with a variable content of Pb minerals. The results of the study on these old deposits could be of utmost importance for the genetical interpretation and exploration of other, more promising nonsulphide zinc ores around the world.

The "Calamines" are considered as oxidation products of primary sulphide ores. The most important was the La Calamine orebody (more than 600.000 tons of Zn metal) that was continuously exploited for several centuries. Nonsulphide ores were also exploited at Schmalgraf, Engis, Dickenbusch, Fossey, Rocheux-Oneux, Welkenraedt and in other smaller deposits (all no longer accessible for study). The primary Zn-Pb sulphide mineralization consists of post-Variscan hydrothermal veins and replacement bodies, mostly occurring at the top of Dinantian (Visean) limestones. The sulphides intersect the Paleozoic rocks and are truncated and unconformably covered by Late Cretaceous sediments (Santonian Aachen Fm.). The same setting has been observed for the nonsulphide ores, suggesting an Early to Mid-Cretaceous weathering, consistent with other geological and geochronological data on paleoweathering in Europe. The extensive occurrence of willemite, that appears to be the first deposited nonsulphide mineral, is a striking particularity of the Belgian "Calamines". Most fluid inclusions of willemite (80%) and all inclusions in smithsonite are monophase (aqueous). Ice melting temperatures suggest salinities between 0 and 5 wt. % NaCl equiv. Homogenization temperatures of the more rare two-phase inclusions (liquid+vapor) in willemite display a large variation between 80 and 190°, an interval matching the temperature ranges of other willemite ores throughout the world, so far considered of hydrothermal origin. However, structure and mineralogical association of the Belgian willemites argue against deposition of this mineral from hot hydrothermal fluids. The data show an exotic depositional sequence: willemite(±hemimorphite I)-smithsonite-hemimorphite II, with micro- and macrocrystalline willemite occurring as cement of internal (karst?) breccias.

The stable isotope variation of Belgian smithsonites and cerussites is very similar to the range measured in other supergene nonsulphide deposits like the ones of SW Sardinia or Skorpion in Namibia. Smithsonites exhibit a limited range of $\delta^{18}O$ values from 27.1 to 30.6‰, averaging 28.4‰ ± 0.8‰ V-SMOW. This points to a relatively uniform isotope composition of the oxidizing waters and constant temperatures of smithsonite crystallization. Carbon isotope values show a considerable range from -11.6 to -1.6‰. This indicates at least two carbon sources: ^{13}C-depleted carbon derived from the organic matter in the soils and ^{13}C-enriched carbon originating from marine carbonate host rocks. Cerussites have oxygen isotope values ranging from 16.8 to 19.3‰, averaging 17.8 ±1.0‰ and carbon isotope values of -18.4 to -14.7‰. In conclusion, the metallic deposits of Eastern Belgium have suffered a polyphase history, which started with a possibly Jurassic sulphide mineralization, followed by oxidation under high silica activities and consequently by supergene weathering. However, it is possible that the deposition of the willemite concentrations could have been derived from low-temperature, localized hydrothermal processes operated by deeply reaching oxidizing fluids. Smithsonite and hemimorphite, often developed at the expenses of willemite, have all the characteristics of supergene oxidation products.

SEDIMENTOLOGY, MAGNETIC SUSCEPTIBILIY AND HIGH-RESOLUTION CARBON ISOTOPE IN THE MIDDLE FRASNIAN OF THE ARDENNE AREA (BELGIUM): HIGH-AMPLITUDE AND RAPID EUSTATIC VARIATIONS AS POTENTIAL CAUSE OF THE PUNCTATA EVENT?

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Recent works have highlighted a global and rapid carbon isotope excursion in the Middle Frasnian *punctata* conodont Zone, called "*punctata* event". The cause(s) and consequence(s) of this carbon perturbation are still equivocal and require multidisciplinary and detailed investigations. Previous works focused investigations on the upper part of the Arche mud-mound (Arche Member) and the overlying shales (Ermitage Member) at Frasnes (Ardenne area, Belgium). Very recent works however demonstrate the presence of a new mound level (La Boverie Member, Boulvain & Coen-Aubert, in press) between the Arche Member and the Bieumont Member, including the stratigraphic interval of the *punctata* event. We here provide a multidisciplinary study about sedimentology, magnetic susceptibility and stable isotope geochemistry of the upper Arche, La Boverie and lower Bieumont Members (*punctata* to *hassi* conodont Zones) in the Ardenne area (Belgium), historical area of the Frasnian, to document that the "*punctata* event" could be related to eustatic variations.

RECONSTRUCTION OF FLUID FLOW EVOLUTION IN OUTCROPS ALONG A NS-TRANSECT IN THE NORTHERN OMAN MOUNTAINS, UNITED ARAB EMIRATES

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Foreland fold–and–thrust belts represent an important potential for hydrocarbon exploration. A thorough knowledge of the processes that influence the porosity and permeability of the reservoirs is necessary for exploration in these complex areas. Diagenetic processes, related to fluids expelled during nappe emplacement, are one of the major factors affecting reservoir parameters. Reconstruction of the fluid flow and diagenesis in relation to the deformation history is thus of major importance.

With this philosophy in mind the fluid flow and diagenesis is studied in outcrop analogues along a NS-transect across the Northern Oman (Musandam) Mountains (UAE). The Oman Mountains were formed during two major compressive phases. A slice of oceanic crust and upper mantle, together with ocean basin to slope sediments and volcanics were obducted onto the eastern continental margin of the Arabian Platform during the Late Cretaceous. The second compressional event was responsible for the formation of the Northern Musandam Mountains by thrusting of the whole autochthonous and allochthonous package 15 km westwards along the Hagab thrust on top of Hawasina basin sediments. This event caused internally large-scale folding and steep reverse faulting. The exact timing of this event is still debated but took place somewhere between the Paleocene and the Miocene. These different faulting phases are expressed in the field by the occurrence of 2 different types of faults. The first type is represented by the Hagab thrust which is present in Wadi Batha Mahani, the transition between the Dibba Zone and the Musandam platform and which crops out in the tectonic Hagil window. The second phase of faulting, internally in the Musandam platform, occurs as steep reverse faults which crop out in several wadis such as Wadi Ghalilah, Wadi Bih and Wadi Sham.

In these locations near thrust faults and reverse faults, expressions of fluid migration like veins and replacive dolomites can be placed in a dynamic framework of the Northern Oman Mountain formation and their petrographic and geochemical characteristics will be reported in order to give information about the origin of the fluid and temperature of precipitation. In a later stage of this study these data will be used as input for a fluid flow model across the studied NS-transect.

Cancelled

RELEVANCE OF ACTIVE FAULTING AND SEISMICITY STUDIES TO ASSESS LONG TERM EARTHQUAKE ACTIVITY IN INTRAPLATE NORTHWEST EUROPE

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We provide a synthesis of the long-term earthquake activity in the region of Northwest Europe between the Lower Rhine Embayment and the southern North Sea. Re-evaluated historical earthquake and present day seismological data indicate that an important part of the known seismic activity is concentrated in the Roer Graben. Nevertheless, the three strongest known earthquakes with estimated magnitude equal to or greater than 6.0 occurred outside of this active structure, respectively in the northern Ardenne, the southern North Sea and the Strait of Dover. Because in plate interiors, the present seismic activity does not necessarily reflect past and future activity, we discuss the necessity to use the geologic record to infer long-term earthquake activity. Thus, we present a synthesis and discuss the relevance of our paleoseismic investigations in the Roer Graben. They provide evidence that large earthquakes with magnitude up to 7.0 occurred since the late Pleistocene. It is also shown that tectonic deformation is close to or below the accuracy of current geodetic techniques. Thus it is necessary to have longer periods of observation to compare present geodetic deformation rates with the observed seismic moment release and the geologic strain rates.

TWO GLACIAL-INTERGLACIAL CYCLES OF LAKE-LEVEL CHANGE IN EQUATORIAL EAST AFRICA DOCUMENTED BY HIGH-RESOLUTION SEISMIC SEQUENCE STRATIGRAPHY FROM LAKE CHALLA (KENYA)

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A high-resolution (3.5 kHz) reflection seismic survey of Lake Challa (Kenya-Tanzania), a 97-m deep volcanic crater lake on the lower East slope of Mt. Kilimanjaro, revealed at least 215 meters of acoustically stratified lake deposits. Analysis of seismic facies and onlapping features, in conjuncton with 14C-dating and sedimentology of a 3-m surface core, indicates that the 10 major stratigraphic units (and their sub-units) recognised in the seismic sequence represent distinct phases of lacustrine sedimentation associated with late-Quaternary lake-level fluctuations. At least the uppermost units, which represent late-Glacial and Holocene sedimentation, seem to be mainly composed of fine-grained authigenic and aeolian detrital mineral inputs, intercalated only at the periphery by occasional mass-flow deposits from local collapse of the inner crater wall. Isopach mapping of each stratigraphic (sub-)unit over the dense seismic grid (mean interval 150 m) reveals repeating patterns of sediment distribution across the lake floor, tracing quantifiable lake-level fluctuations during the Holocene, the late-Glacial period, the Last Glacial Maximum, and the penultimate glaciation. Extrapolation of available radiometric ages on the uppermost units together with the inferred sequence of late-Quaternary lake-level change suggests that the acoustically visible lacustrine infill of Lake Challa covers the two last glacial/interglacial cycles.

LATERAL VARIATIONS OF DEFORMATION STYLE IN VIRTUALLY COAXIALLY DEFORMED SEQUENCES: THE EXAMPLE OF THE UPPER SILURIAN OF THE INCLINED SHIPLIFT AT RONQUIERES, SOUTHERN BRABANT MASSIF (BELGIUM)

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The inclined shiplift at Ronquières, situated at the southern edge of the Lower Palaeozoic Brabant Massif, contains two perfectly exposed sections of deformed, low-grade metamorphic, lower Ludlow distal turbidite deposits, unconformably overlain by virtually undeformed, gently S-dipping, diagenetic Middle Devonian and younger deposits. Both outcrop sections, one along the W-side and one along the E-side, were first described by Legrand (1967). This author described the large-scale, two-dimensional geometry of the deformed upper Silurian beds in both sections, was able to demonstrate the pre-Givetian age of the convergent cleavage fans, and also pointed out the importance of reverse and normal faults. However, although both sections show significant differences in structural geometry, the analysis of Legrand (1967) was largely two-dimensional, and the geometrical differences between both sections were mainly attributed to lateral fault movement, for which no evidence was presented. Later, Debacker *et al.* (1997, 1999) re-examined the eastern outcrop section in more detail. Although largely confirming the observations of Legrand (1967), these authors also tried to visualise the deformation in three dimensions and were able to demonstrate subtle variations in fold orientation across the section, resulting in a variable cleavage transection angle. This was explained by considering the folds as large-scale en-echelon periclines, which formed in an overall coaxial deformation regime. In contrast to the suggestion of Legrand (1967), none of the faults were found to show indications of lateral or oblique-slip movements: all faults show striations with an almost perfect dip-slip orientation. However, this study largely neglected the western section. More recently, a large-scale synthesis of outcrop observations suggested that, from a structural point of view, the inclined shiplift occupies an almost central position along the southern rim of the Brabant Massif, thus supporting the coaxial nature of the deformation at this locality (Sintubin, 1997, 1999).

In order to adequately compare both outcrop sections, a detailed structural analysis was performed at the W-side of the inclined shiplift. This study confirms, amongst other features, 1) the subtle change in fold trend, changing from WNW-ESE in the south to NW-SE in the north, 2) the virtually constant cleavage trend and 3) the dip-slip fault movement. However, despite the virtually coaxial nature, differences do exist between both sections. Both the W-ward divergence of the fold hinge lines and a comparison of both outcrop sections seemingly suggest that the amount of folding-related shortening is higher on the E-side than on the W-side. Possibly, this difference in shortening is taken up by reverse faulting, apparently occurring more frequently on the W-side. In addition, the geometry of the southern, intensely folded and faulted part is almost completely different in both sections. Finally, also more subtle, small-scale differences exist, such as the local presence of mullions on the W-side, seemingly absent on the E-side.

Whatever the cause of the observed differences, the observations show that, even within virtually coaxially deformed sequences, quite significant lateral variations in deformation style may exist.

APPLICATION OF MAGNETIC SUSCEPTIBILITY ON DIFFERENT CARBONATE PLATFORM TYPE

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Introduction

Magnetic susceptibility (MS) technique is frequently used in order to correlate and to reconstruct palaeoclimatic changes in Recent sedimentary rocks [1]. For a few years, magnetic susceptibility was also applied to palaeozoic rocks for correlations [2, 3]. According to these authors, magnetic susceptibility signal is mainly related to lithogenic inputs (magnetic minerals like magnetite and clay in opposition with unmagnetic minerals like carbonates) and lithogenic inputs are mainly related to sea level variations. So a transgression will be associated with decreasing magnetic susceptibility and a regression will produce a MS peak. This relationship between MS and sea level allows to produce correlations which are intercontinental, facies independent and of a better precision than biozones [2].

Magnetic susceptibility measurements were performed on different carbonate systems (platform types). The first case is the shallow water carbonate platform of the Frasnian of Belgium, the second case corresponds to the carbonate mounds and atolls which are lateral time equivalent of the previous one. The last case corresponds to the mixed siliciclastic-carbonate (carbonate) ramp of the Eifelian of Belgium.

Results

In the shallow water carbonate platform of Belgium, magnetic susceptibility allows to perform precise correlations between the sections (fourth order correlations). A strong relationship between MS and facies (increasing MS with more proximal facies) and MS and fourth order sequences (increasing MS at the top of a regressive sequence) is observed [3, 4]. This relationship confirms the strong link between magnetic susceptibility and sea level variations.

In the Frasnian carbonate mounds and atolls, magnetic susceptibility brings also good correlations between the mounds. It seems that magnetic susceptibility values are also linked to facies but in an opposite way. Actually the higher MS values are corresponding to the deepest facies and MS increases during transgressive phase. The sedimentation rates of the carbonate mounds and the surrounding deposit are very different and probably controls MS signal.

In the eifelian mixed siliciclastic-carbonate (carbonate) ramp, magnetic susceptibility provides also good correlations. As for carbonate mounds, magnetic susceptibility increases slightly during transgressive phases[6].

Conclusions

We present here a synthesis of magnetic susceptibility measurements applied on the three main carbonate platform types (carbonate platform, ramp and isolated platform (atolls)).

In the three cases, it appears that magnetic susceptibility is related to main sea level changes but in an opposite direction.

For the carbonate attached platform, a transgression will decrease magnetic susceptibility (in agreement with [2] theory) but for the atolls and the ramp, a transgression will increase magnetic susceptibility. In these two cases, the lithogenic inputs will not be the main parameter but sedimentation rate and wave strength will also influence the amount of magnetic susceptibility (a strong carbonate production will dilute the magnetic minerals and an important agitation will probably scatter the minerals). It highlight also that correlations between different carbonate systems are highly speculative because of the different origin of magnetic peaks.

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PETROPHYSICAL DEFORMATION IN FAULTED WHITE CHALK IN BELGIUM

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Chalk is a sedimentary rock whose properties depend on many factors, such as its geological history, its petrography and geological paleostress evolution. Petrophysical parameters were approached to characterize, in particular, Campanian white chalk located against fault planes from two regions of Belgium, the Mons basin and the Maastricht region (Lixhe). Significant matrix strains along fault plane were already associated with Campanian and Maastrichtian faults from the Mons basin. These transformations brought about systematic changes in the porous network. This porosity is a fundamental physical feature of chalk, related to its mechanical features. The major mechanisms are the pressure solution and the cementation who involve grains arrangements and mass transfers. Globally, an impermeable zone appears between the fault plane and the mass rock. The present study attempts to confirm these outcomes of the Mons Basin and to compare them to those from Maastricht region. Indeed, similar investigations of Lixhe white chalk are carried out to specify changes in texture, major transformation mechanisms and influence of geodynamics framework.

The measurements of physical (elastic wave's velocity) and mechanical (splitting test, unconfined compression test) properties of chalk provide good evidence for estimating the width of transformed zone. They indicate respectively porosity, heterogeneity and strength modifications. They are explained by a microstructural analysis of a 90mm thick fringe along a fault plane, based on SEM and tomography observations. The chalk is characterized by pore-size variations, different intergranular connections, various grain shapes, wall-like structures and channels. At the grain-scale, they provide evidence of pressure solution and cementation effects. These changes involve a decrease in porosity and an increase in the continuous character of the material towards the fault plane. For two regions these experiments establish a rather similar texture evolution, due to a normal fault associated with extensional system:

-a fault plane acted as a dissolution plane: faulted material
-a compact, continuous and less porous zone: strained material
-a more porous, less compact and continuous zone: unstrained material

These variations are clearly accentued in the Lixhe chalk than in the Mons white Chalk. They are probably explained by the Liege area geodynamics framework connected to the dynamics of the Rhine Graben that modifies the driving actions of the pressure solution and cementation due to mechanical action and fluids circulation. In spite of these differences, chalk presents same major transformation mechanisms: pressure solution and cementation, and same transformation stage : -compressive condition: vertical stress

-grains moves and possibility of dilatancy against fault plane
-matrix consolidation and fluids circulation caused by a disorganisation of the pore system
-start of dissolution-crystallisation phenomena following stress increase due to fault slip and drainage

AN 18,000-YEAR MULTIPROXY LACUSTRINE RECORD OF CLIMATE VARIABILITY IN SOUTH-CENTRAL CHILE (40°S): LAGO PUYEHUE, CHILEAN LAKE DISTRICT

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An 11-m-long sediment core was collected in Lago Puyehue (40ºS, Lake District, Chile). The coring site had been selected on basis of a seismic-stratigraphic analysis that highlighted it as an area of relatively condensed, continuous and undisturbed sedimentation in this otherwise highly dynamic post-glacial lake. The 11-m core extends back to 17,915 cal yr BP. An age-depth model was established by 9 AMS ^{14}C dates, constrained by ^{210}Pb, ^{237}Cs, ^{241}Am measurements, by the identification of event-deposits related to earthquakes and/or volcanic eruptions, and by varve-counting for the past 600 yr. The core was submitted to a multi-proxy analysis, including sedimentology, mineralogy, grain-size, major geochemistry and organic geochemistry (C/N ratio, $\delta^{13}C$), loss-on-ignition, magnetic susceptibility, diatom analysis and palynology.

Along-core variations in sediment composition reveal that the area of Lago Puyehue was characterised since the Last Glacial Maximum (LGM) by a series of rapid climate fluctuations superimposed on a long-term warming trend. These rapid climate changes are: (1) an abrupt warming at the end of the LGM at 17,300 cal yr BP, (2) a short, relatively cold interval between 13,100-12,300 cal yr BP, roughly coeval with the Huelmo-Mascardi Cold Reversal that was recently defined in the region and is thought to represent the South-American counterpart of the northern-hemisphere Younger Dryas Cold Reversal, (3) a second abrupt warming, possibly with increased precipitation, at about 12,300 cal yr BP, and (4) an increase in climate variability in the late Holocene at 5000-6000 cal yr BP.

Spectral analysis of varve-thickness variations over the past 600 yr reveal periods that display sub-decadal periodicities similar to those associated with the El Niño Southern Oscillation and the Pacific Decadal Oscillation.

THE "CLATHRATE GUN" DID NOT FIRE BUBBLES…

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The "clathrate-gun" theory has been invoked to explain several sudden and drastic atmospheric-warming events in the geological history of the Earth, which were also characterised by increased levels of atmospheric methane. The model assumes that this methane originated from a massive and catastrophic release at the sea floor caused by the dissociation of continental-margin gas hydrates (clathrates) in response to changes in ocean bottom-water temperatures or sea level. The released methane is then thought to be transferred directly to the atmosphere, where it acts as a greenhouse gas causing global warming, but how exactly the transfer of methane through the water column takes place is not discussed.

In the EC-funded CRIMEA project, we investigate the transport of methane that is released as gas bubbles from the sea floor at different types of high-intensity gas seeps in the Black Sea. A first type can be found at the NW Black Sea shelf, where echosounder mapping revealed a dense field of "acoustic flares" at 92 m water depth. The observed acoustic flares, which are caused by the backscatter of acoustic energy at gas bubbles in the water column, often reach the sea surface at this water depth. A second type of high-intensity seep environment can be found at the "active" Dvurechenskiy and Vodyanitskiy mud volcanoes, at 2065 m water depth in the Sorokin Trough, above which echosounding data revealed the presence of a > 1300 m high acoustic flare. This monster flare was observed repeatedly during several return visits over nearly 2 years. Both types of high-intensity seeps represent massive releases of methane from the sea floor and as such they can be regarded as something similar to a single "clathrate-gun shot".

Our investigations have traced the released of methane by a multidisciplinary approach involving 1) the analysis of chemical and isotopic composition of the free and dissolved gas, 2) the study of the water-bubble gas-exchange processes, 3) the measurement of bubble sizes and rising speeds, dissolution rates, (microbiologically mediated) oxidation rates, etc., and 4) supported by bubble transport and bubble-plume modeling. At present, all our data indicate that the methane released from the sea floor dissolves and gets oxidised very rapidly, and that even in the shallow-water high-intensity seep area, where the acoustic flares are seen to extend up to the sea surface, only negligible amounts of methane are actually transmitted into the atmosphere. These findings illustrate the tremendous –and tremendously fast– buffering capacity of the oceans to methane input from the sea floor, and put into question the concept of direct methane input into the atmosphere by dissociation of continental-margin gas hydrates, as proposed in the original "clathrate-gun" hypothesis. So, if the clathrate gun does indeed exist, it probably does not fire methane bubbles directly from the sea floor into the atmosphere…

THE IDJILL GROUP (WEST AFRICAN CRATON, MAURITANIA): GEOCHEMISTRY, AND FE, SR, ND ISOTOPES OF A PALAEOPROTEROZOIC IRON FORMATION, WITNESS OF THE "GREAT OXIDATION EVENT" (GOE)

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In the Western Reguibat Rise (West African craton, WAC), the Palaeoproterozoic Idjill Group ("Kédia d'Idjill", Zouerate area, Mauritania) unconformably overlies the Archaean basement of the Tiris Group. The Idjill Group comprises the ferriferous Tazadit Formation, 1,000 to 1,200 meters thick, overlain by a shale unit, the Achouil Formation (Bronner and Chauvel, 1979). The Idjill Group was affected, soon after its deposition, by the Eburnian orogeny (~2 Ga) that resulted in (1) the thrusting of the 250 km^2-wide Kédia d'Idjill over the Archaean basement of the WAC; (2) an intense deformation and (3) a low-grade metamorphism episode (greenschist facies). This tectonic event would be coeval to noticeable Si migration/recrystallization, resulting in the formation of a typical red jasper facies. After a long quiescence period of 2 Gyrs, the Tazadit ferriferous Formation underwent a late meteoric weathering (lateritization) episode, in the Cenozoic period.

The Tazadit Formation is made of stacked alternations of tens of meters of ferriferous quartzites (*Banded Haematite Quartzite*, BHQ) and of thick stratiform pockets or lenses of haematitic ore, with over 68% Fe (>95% Fe_2O_3, "Minerai Riche Naturel", MRN). The origin of the MRN is debatable: it could result from (1) progressive iron enrichment of an initial BHQ, either by Fe migration/reconcentration and/or silica migration/removal, or (2) from an iron-rich sedimentation *ab initio*. Several field and sedimentological arguments – geometry, bedding, fine laminations and sedimentary structures – would support the second hypothesis. The initially iron-rich MRN would have subsequently undergone discrete enrichment phases when fluids were able to percolate throughout the series, during the Eburnian orogeny and the Cenozoic lateritization (De Putter and Decrée, 2005). Several mineralogical, geochemical (major and traces elements, REE patterns) and isotopic (stable: Fe and radiogenic: Nd, Sr) data of the BHQ, the associated MRN and shales will be presented and discussed. Iron isotopes will specifically provide constraints on Fe cycling within the studied system.

The ferriferous quartzites of the Tazadit Formation have been dated at 2.05 ±0.15 Ga (Nd model ages; Henry, 1995). Overall, they are then sub-contemporaneous to the global event known as the "*Great Oxidation Event*" (GOE), in which the atmospheric pO_2 increased from ≤0.002 atm (1% of present-day fugacity) to ≥0.02 atm (10% of present-day value), in about 200 Myrs, from 2.3 to 2.1 Ga (Holland, 2002). The link between the GOE and sediments highly enriched in Fe such as those of the Tazadit Formation has to be tightly envisaged. Indeed, a major and rapid precipitation of Fe is likely if iron passes from the reduced state (Fe^{2+}, typical of Archaean times) to the oxidized state (Fe^{3+}, typical of Proterozoic times). However, the mixed Archaean / Palaeoproterozoic signature of the Tazadit Formation (Henry, 1995) points to a more complex origin. The latter would only be tackled if the geodynamical environment is taken into account and in particular the metacratonic evolution of the Tiris Archaean craton during the Eburnian orogeny in the course of which the Idjill Group was accreted towards the craton. The combination of such a geodynamical context and the GOE is probably the cause of the generation of this exceptional and huge Fe deposit.

PRE-ANTHROPOGENIC GEOCHEMICAL FLUCTUATIONS IN A BELGIAN PEAT BOG

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Almost three percents of the Earth is covered by peat deposits. Among peat bogs ombrotrophic types are only fed by atmospheric fallout, being highly sensitive to external inputs (e.g. atmospheric pollution, dust storms, *etc*.). For more than 30 years environmental geochemists have been studied peat material to provide an archive of anthropogenic pollution. Few geochemical studies are actually focused on palaeoclimate records in peat cores. Here we present a geochemical survey from the Misten bog (Hautes Fagnes, SE-Belgium), with a particular focus on the beginning of peat accumulation during Atlantic times. Several workers have recorded fluctuations in pollen spectra characterized by a sharp increase of hazel tree together with a decrease of alder tree. These changes, also found in other sites of the Hautes Fagnes, were tentatively linked to a sudden climatic change, possibly linked to North Atlantic deep oceanic circulation. Using palynology, elemental and Pb-isotopic content, together with ^{14}C dating, our results from the Misten bog show a strong perturbation around 8.0 ka cal B.P. The origin and time span of this disturbance will be discussed as part of this presentation.

HIGH RESOLUTION PETROGRAPHY OF IMPREGNATED PEAT COLUMNS CONTAINING TEPHRAS. PRINCIPLE, APPLICATIONS AND PERSPECTIVES

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Here we present a resin-impregnation technique which can be used to provide high-resolution analysis of tephra and cryptotephra in peat samples. Impregnated blocks and thin sections of peat can provide a continuous archive of tephra succession that can be further investigated through a wide range of non-destructive techniques. We present several examples which illustrate the potential applications and limitations of impregnated peat which contain tephra from Germany, Iceland and New-Zealand. A broad range of field encompassing polarizing microscopy, scanning electron microscopy with and/or without elemental analysis, and XRF core scanning have been tested. We compare the findings from this technique with conventional systematic sampling, ashing, and microscopy to detect and quantify cryptotephra content in peat.

PRE-DEVONIAN, BRABANTIAN (?) DEFORMATION WITHIN THE SOUTHERN CONDROZ INLIER (RUISSEAU DES CHEVREUILS, DAVE, BELGIUM)

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The Condroz Inlier is a narrow belt of Lower Palaeozoic rocks, flanked to the south by the Lower Devonian of the Dinant Synclinorium, and to the north by the Middle Devonian of the Namur Synclinorium. Whereas the former experienced a significant brittle-ductile Variscan deformation, in the latter compressive deformation appears to have been restricted to the local development of thin-skinned reverse faults. Because of this particular position of the Condroz Inlier - approximately coinciding with the Variscan front zone -, and its poor degree of exposure, the presence of compressive deformation features, the structural architecture and the age of deformation have been widely debated. Despite its narrowness, some authors distinguish three, rather ill-constrained, zones within the Condroz Inlier: a) a northern part, at Ombret (E), with cleavage, b) a central and main part, without cleavage, and c) a southern part, at Puagne (W) and the Fond d'Oxhe (E), again with cleavage. Because of the relative position of these three zones, the cleavage in the northern part is sometimes considered as a result of the pre-Devonian, Brabantian (?) deformation event, whereas the cleavage in the southern part is often attributed to the Variscan deformation.

The present study focuses on the Ruisseau des Chevreuils, situated in the SW-part of the Condroz Inlier, directly to the SE of Dave. The Lower Palaeozoic (upper Llanvirn to lower Caradoc) outcrops along this brook can be combined to a discontinuous, ~300 m long NNW-SSE-trending outcrop section, whereas, to the southeast, the section continues for at least another 100 m across the Lower Devonian of the Dinant Synclinorium. Most of the Lower Palaeozoic is only poorly deformed: the rocks generally have gentle to moderate dips, with quite variable strikes, and, although locally reflecting gentle, dm- to m-scale fold structures, do not show any macroscopically recognisable fold-related cleavage. In fact, the only pervasive fabric is a bedding-parallel compaction fabric, and much, if not all, of the internal deformation of the rocks appears to be due to the abundant bioturbations and, in certain levels, to (non-biogenic) soft-sediment deformation (e.g. slump folds). However, between 75 and 125 m to the NNW of the (fault?) limit with the Devonian, the Lower Palaeozoic is affected by a poorly to well-developed, gently to moderately NE-dipping cleavage. In several outcrops, asymmetric, S-verging folds are observed (including a folded quartz vein), to which the cleavage shows an axial planar relationship. Apart from their mere presence, also the NW-SE-trend of the cleavage and the S-verging folds is unexpected, as it is markedly oblique to the overlying Devonian and to the general trend of the Condroz Inlier (E-W). Towards the north and towards the south, cleavage becomes less obvious or disappears altogether.

Taken together, a) the irregular distribution and intensity of the cleavage fabric, b) the comparably irregular distribution of the S-verging, syn-cleavage folds and c) the unexpected predominantly NW-SE-trends of the cleavage, fold hinge lines and cleavage/bedding intersection seemingly reflect a "higher-strain zone" in otherwise almost undeformed Lower Palaeozoic rocks. The N-dipping cleavage, the associated S-verging folds and the suggested "higher-strain zone" are attributed to the pre-Devonian, Brabantian (?) deformation event. This NW-SE-trending Brabantian fabric is not necessarily reflected by the shape of the inlier.

GEOPHYSICAL STUDY ON AN ARCHAEOLOGICAL GALLO-ROMAN SITE AT MATAGNE-LA-PETITE, BELGIUM

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The use of non-invasive techniques for the investigation of sites of potential archaeological interest has grown over recent years. The primary motivation for using such methods is to identify "key" areas for detailed investigation and/or as follow up to conventional archaeological dig. Among the available methods, surface geophysical investigations, such as magnetic methods, ground penetrating radar (GPR) and electrical resistivity measurements, hold great promise as low cost and minimally-invasive sensors of the subsurface. These methods allow to point out anomalies due to local variations of physical properties in the subsurface, for instance the magnetic susceptibility, the dielectric permittivity or the electric resistivity. These variations could be linked to various archaeological features (i.e. buried walls, ditches, burial mounds, graves, ancient water courses...).

The study site is situated in Matagne-La-Petite near Vierves-Sur-Viroin in the region of Couvin, Belgium. Geophysical field experiments were conducted on this site in order to assess the efficiency of geophysical methods to delineate two formerly recognized "fana" (Gallo-Roman temples). Measures of the vertical gradient of the magnetic field and ground penetrating radar profiles were carried out.

The investigated area is a 50 x 45 m rectangle located near a metallic wind mill which is situated over an ancient well. The footprint of these "fana" foundations appear as two centered squares with a small one inside a larger one. The first "fanum" is adjacent to the well and the side of the larger square is about 13 meters long. The second "fanum" is located next to the first one and the side of the larger square is about 18 meters long. Magnetic and GPR measurements were conducted along parallel profiles acquired meandering. The profiles were separated 50 cm from each other. Magnetic measurements were acquired with a G-858 gradiometer at a 1Hz sampling frequency. Two antennas of respectively 250 and 500 MHz central frequency were used for the ground penetrating radar. Measures were taken every 2 cm in order to fully recover the foundations structures.

Measurements of the vertical gradient of the magnetic field showed a large influence of the metallic wind mill which partly hides the response of the smallest "fanum". Several processings were needed to remove the stripping pattern due to the meandering. However, the vestiges of the bigger "fanum" were delineated accurately on the vertical gradient map.

GPR measurements present the advantage to be less influenced by surface features. The complete structure of the two temples was clearly pointed out. Moreover, an old access path was also detected.

In conclusion, these two geophysical methods showed useful tools to accurately point out the foundations of the known "fana". They should therefore be able to delineate "key" areas were archeological dig should be conducted in similar contexts.

THE GENESIS OF THE NEFZA PB-ZN ORE DEPOSIT (NORTHERN TUNISIA): COMPARISON WITH CENTRAL TUNISIA DEPOSITS AND EVALUATION OF THE GEODYNAMICAL CONTROL

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Pb-Zn mineralizations are abundant in Tunisia from the "Zone des nappes", characterized by stacked Eocene and Oligocene thrust sheets in Northern Tunisia, to the "Zone des dômes", characterized by important diapiric structures, in Central Tunisia. Main regional structures are oriented NE-SW and are linked to the convergence between the African and European plates. In the course of this complex collision, there were successive episodes of extensional and compressional phases. An extensional context prevailed during the Oligo-Miocene; it was responsible for the reactivation of preexisting superficial NE-SW faults which has favoured i) the re-ascent of Triassic salt diapirs, notably in the Northern part of the country; ii) the emplacement of Serravallian-Tortonian subvolcanic plutons, in Northern Tunisia (e.g. in the Nefza district) and iii) the formation of a shear zone in Northern Tunisia, which facilitated the emplacement of late Miocene shallow stratiform intrusive bodies in the Nefza area ("Zone des Nappes").

In Central Tunisia, well-known Pb-Zn mineralizations are classically related to the Mississippi Valley Type (MVT) ore deposits and are closely associated to Tortonian mineralising fluids rising along the diapir structures.

In the focused Nefza area, the Pb-Zn mineralizations of Sidi Driss and Douahria were less studied than the southern larger deposits. The Nefza ore deposits occur within limestone/evaporite lenses, in two small basins in the immediate vicinity of the above-mentioned subvolcanic plutons. These Pb-Zn mineralizations consist mainly of galena and sphalerite, associated with pyrite, celestite and barite, that i) replace Late Miocene algal carbonates and/or evaporites and ii) fill open cavities and veins. The epigenetic character of the mineralizations, compared to the initial carbonate/evaporite sediments, suggests also a MVT-type emplacement of the Northern Tunisia ores, with mineralising fluids younger than the host sediment (i.e. late Messinian or younger). However, in this area, fluid circulations leading the emplacement of these ore deposits are likely to have been influenced/reinforced by the shallow intrusive magmatic bodies. Moreover, these fluids possibly took advantage of the presence of alternative circulation ways provided by the discontinuities at/near thrust sheet boundaries. These specific conditions, combining a structural control and a magmatic influence in the mineralization process, make the Northern deposits different from the Southern ones, in which a close relationship between salt diapirs, fluid circulation and mineralizations is classically invoked. Consequently, the Sidi Driss and Douahria Pb-Zn ore deposits could be described as *"hybrid"* MVT ore deposits, in comparison with the "classic" MVT deposits in Central Tunisia.

GEOLOGICAL STRUCTURE OF THE EASTERN BORDER OF THE CAMBRIAN GIVONNE-MASSIF AND ITS DEVONIAN COVER (MUNO, BELGIUM)

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The Belgian Ardennes, in their major part, are (siluro-)devono-carboniferous metasedimentary rocks deformed and affected by an epizonal metamorphic event during the hercynian orogenesis. The hercynian deformation resulted in a series of first order-folds having East-West axes. In the heart of the regional anticlinoria, cambro(-silurian) massifs are brought over to outcrop. These ancient massifs have been structured twice, first during the Caledonian orogenesis, before being retaken during the hercynian one. The southernmost of them is the Givonne-Massif. Questions concerning its stratigraphy and metamorphism interest scientists since 1910. Ductile and brittle structures were described by early pioneers, but had to wait for the investigations of Beugnies (1960, 1976) to be interpreted and integrated in a regional context.

This work aims to describe and interpret the structure of the eastern periclinal closure of the Givonne-Massif in the light of more recent advances in structural geology. It allies field observations and descriptions of thin sections and so-doing permits a re-evaluation of previous studies. Essentially the ductile structures imposed on the metasedimentary detritic terrigeneous rocks are detailed.

The general structure of the Massif is an anticlinal, slightly plunging to the ESE and rejected to the North. The major structure stands out as minor folds, scaling down to the field-sample, which attest its existence.

The measurements of foliations and lineations in the field combined with specific observations in thin sections allow to retrace a geological history similar to the one known for the more intensively studied Rocroi-Massif (e.g. Belanger, 1998). Three deformative events marked Givonne's geological history. The Caledonian deformation D_1 gave rise to folds plunging to the SSE and an axial plane-schistosity S_1. The second folding D_2 did not have an associated schistogenesis, but could be traced back due to the particular upright North-South directed attitude conferred to certain cambro-(ordovician) strata. The hercynian orogenesis was the only one affecting the (siluro-)devonian cover, but it restructured also the Cambrian basement. ESE-dipping folds P_3 and axial plane-schistosity S_3 were developed and are well-expressed in the cover. Depending on the attitude of the Massif's core strata, S_3 simply superposed itself to S_1 or crenulated this first schistosity. The presence, in core and cover, of microkinks, markedly visible in the field, imposes the existence of a late tectonic event to explain these little brittle structures.

Posterior to the D_1-phase, but anterior or contemporary to the hercynian D_3-deformation, recrystallization and mineral neoformation took place during a metamorphic event. The relationship between schistosities and porphyroblasts (chloritoid, chlorite, chiastolite) highlights the chronology between tectonic phases and metamorphism.

A NEW ALKALINE AND CARBONATITE PROVINCE IN NE POLAND.

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Carbonatites and the associated alkaline rocks are generally emplaced in rift zones in continental cratonic blocks (oceanic carbonatites are extremely rare). On the East European craton (EEC), more specifically on the Fennoscandia crustal segment, carbonatites are known in the Kola alkaline province (KAP) of Late Devonian age (380 – 360 Ma) and in the small Fen (S. Norway; 565 Ma) and Alnö (Sweden; 540 Ma) intrusions. The Kola province consists of more than 20 intrusions, including the famous agpaitic nepheline syenite massifs of Khibina and Lovozero. These complex intrusions, called UACC, are characterized by the typical trilogy: ultramafic cumulates (mainly clinopyroxenites), alkaline silicate rocks (nepheline syenites and/or rocks of the ijolite series) and carbonatites (with associated phoscorites). Dyke swarms (ultramafic lamprophyres, melanephelinites, melamelilitites and less commonly kimberlites) are spatially and temporally associated with the UACC; they possibly correspond to primitive, high MgO (>12 wt %), strongly silica-undersaturated (20 – 40 wt % SiO_2) liquids. Locally, these intrusions have given rise to ore deposits (apatite, magnetite, loparite, Nb, Ta, REE,…)

The Proterozoic crystalline basement of NE Poland (NE of the Trans-European suture zone) belongs to the EEC. It is covered by a thick Phanerozoic sedimentary pile. Geophysical prospecting and drilling operations have lead to the discovery of 3 massifs intruding the basement: the small (~5km^2) Tajno massif and the much bigger (100 – 400 km^2) Elk and Pisz bodies.

Preliminary petrographical, geochemical and isotopic data have shown that Tajno is a differentiated pluto-volcanic carbonatite complex in which the UAC trilogy has been found. Nevertheless the Tajno rocks have some mineralogical and geochemical peculiarities when compared to their Kola equivalents: (i) foids are much less abundant in Tajno roks; (ii) perovskite is absent while titanite is a cumulate phase in the clinopyroxenites; (iii) the typical accessory mineral association of carbonatites (pyrochlore, perovskite, baddeleyite,..) is not well represented at Tajno. By contrast, fluorite and sulfides are abundant as cement of the carbonatite breccia. Elk intrusion appears as a ring-structure essentially made of various syenites (mostly foid-bearing) that are quite similar to those of Khibina and Lovozero. Pisz is a gabbro-syenite intrusion.

Preliminary unpublished U-Pb zircon SIMS and SHRIMP ages for the 3 intrusions yield the same age, close to 360 Ma, which suggests that the emplacement was contemporaneous with KAP. Initial Sr (0.7037-0.7040) and Nd (εNd: + 0.7 to +3.5) isotopic ratios point to a slightly-depleted time-integrated mantle source comparable to that of the KAP parental magma.

Our data suggest that these 3 intrusions constitute a new occurrence of the widespread Late Devonian alkaline and carbonatite magmatism related to rifting of the East European Platform.

FLUID FLOW HISTORY IN THE SICILIAN FOLD-AND-THRUST BELT: IMPLICATIONS FOR HYDROCARBON EXPLORATION

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Foreland fold-thrust-belts (FFTB's) around the Mediterranean (e.g. in Sicily) are interesting oil and gas exploration regions. Source rocks occur in both Mesozoic carbonate intraplatform basins and siliciclastic foreland deposits. Rapid burial and maturation is provoked by thrusting and foreland sedimentation and anticlines form good trapping conditions. However, exploration in FFTB's is risky and special attention goes to the structural complexity of FFTB's and the complicated geodynamic and fluid flow history.

Five study areas were selected in Sicily to study fluid flow in Mesozoic carbonates throughout the geological history. Preliminary results from 2 areas are available now while three others are under investigation. The chosen areas are key locations with complex deformation structures, representing two or more important episodes in the geodynamic evolution of the Sicilian FFTB (i.e. around thrusts, strike slip faults and normal faults). Moreover, most of these areas show limited oil seeps along fractures or thrusts. Within the chosen study areas, early and late diagenesis is considered because both affect the petrophysical properties of the potential reservoir rocks. A PVTXt-model is set up for each study location (P = pressure, V = volume, T = temperature, X = composition and t = time), using an integrated structural, petrographic, geochemical and microthermometric approach.

The first study area is located in the front of the accretionary wedge. Here, décollement levels have brought Triassic to Eocene basinal limestone and marl deposits on top of Oligocene to Pliocene deposits. Stable isotope and microthermometric data indicate that aqueous fluids and hydrocarbons migrated from deeper supracrustal or subthrust levels through the décollement (T_h of calcite veins: Between 100 and 180°C). Study of veins within the décollement and in overlying units show no geochemical and petrographic similarities. Either a strong host-rock buffering effect of the basinal limestones and marls can be postulated or two separate hydrogeological systems were active during deformation. During tectonic relaxation and rotational movements in the Pliocene, NS oriented faults were formed. Positive $\delta^{18}O$ signatures suggest that circulating fluids within these faults interacted with overlying Messinian evaporites.

The second study area is located in the north of Sicily, were the fold-and-thrust belt is subject to strong normal fault activity. Presence/absence of calcite twins in vein calcite cements allow to subdivide veins that originated before or during tectonic compressive deformation from those formed under the extensive tectonic regime during tectonic relaxation. The latter cements have low iron content and occur throughout the rocks, both in veins and interparticle and vuggy porosity within Triassic dolomites. The stable isotope data clearly suggest a dominant meteoric component of fluids responsible for these calcite cements. Hence, fluids that migrated through the normal faults are probably meteoric in origin and an open hydrogeological system was present from the late Miocene-Pliocene onwards.

Our results are in line with other studies where several authors mention the presence of more closed system conditions during deformation while during tectonic relaxation; an open hydrogeological system is installed with meteoric fluids. Ghisetti *et al*. (2001) have come to identical conclusions concerning the fluid flow history in the Apennines.

THE CRETACEOUS OF THE HINNISDAEL UNDERGROUND QUARRIES IN VECHMAAL (COMMUNE HEERS, BELGIAN LIMBOURG)

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The Hinnisdael underground quarries form the westernmost, still accessible extraction site of Maastrichtian limestone in the 'Mergelland' of southern Limbourg, exploited for building stone and soil conditioner by room and pillar mining. The Maastricht Limestone in Vechmaal possesses the same facies as in the type area and definitely belongs to the same depositional basin. Two members of the Maastricht Formation are exposed and consist of slightly different rock types, hence leading to different exploitation methods and cave morphologies. The older Nekum Limestone is exposed over 8 m and consists of cream-yellow coloured, fine-grained calcarenites with frequent fossil debris beds. Macrofossils are mostly composed of echinoids, serpulids and oysters. The Kanne Horizon constitutes a persistent fossil bed, rich in serpulids near the top of the unit. Two levels with complete large echinoids (*Hemipneustes* beds) occur above and below the Kanne Horizon. Flint and tauw (silicified fossil beds) also occur in two distinct horizons towards the base of the Nekum Member and around the Kanne Horizon. The younger Meerssen Limestone is exposed over 4 m and consists of orange-yellow coloured, coarser-grained calcarenites and several hardgrounds. The intensely bored and reworked Caster Hardground forms the boundary between the Nekum and Caster Members and the sediment overlying this hardground is enriched in foraminifers, bryozoans and algal clasts.

Only the upper part of the Nekum Limestone was suitable as building stone. Galleries in this stratigraphic level show sawed walls and rectangular sections, becoming parabolic where lithostatic pressure approximated the mechanical strength of the roof. The base of the Caster Hardground, occasionally the Kanne Horizon, form the sufficiently solid roof for the excavations. The building stone was dispatched to the southern part of the County of Looz, as could be derived from the occurrences of the typical tauw facies among the building stones recorded in monuments. From this same origin, but corroborated by historical documents, most quarrying for building stone must have taken place in the late 13th to 16th centuries. The coarser-grained and irregularly lithified Meerssen Limestone and the lower, flint-bearing part of the Nekum Limestone served as soil conditioner and fertiliser. Galleries carved out in these levels present an arched form.

The stratigraphic level (or rock quality) thus determines the type of exploitation. The location of the artificial caves is controlled by the necessity to have access to a minimum thickness of 7 m for the Cretaceous strata, between the groundwater table and the overburden, consisting of low-permeable Oligocene clayey sands and loam. Tectonics decide where which stratigraphic level occurs within this narrow interval. The Cretaceous strata slightly dip to the northeast but are cut by one normal fault with a throw of 4 m. The fracture network responded to the stresses created by the bending termination of the Brabant Massif, not to the opening of the Roer Valley Graben. Weathering and paleokarst (both exokarst with dolines and solution pipes and endokarst with cylindrical natural caves and dissolution pockets made up of alveoli) occurred at different periods of uplift and erosion during the Tertiary and have strongly affected the extent and colouration of the remaining carbonates. Current hazards to the preservation of the artificial caves are more related, however, to mudflows from collapse sinkholes and to potential roof collapse in zones with weak pillars.

THE STRATIFORM COPPER MINERALISATION AT LUFUKWE, LUFILIAN FORELAND, DEMOCRATIC REPUBLIC CONGO

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The sediment-hosted stratiform copper deposits form a large, diverse class of deposits that include some of the richest and largest copper deposits in the world. They are defined as stratiform disseminations of native copper and copper sulphides in a variety of sedimentary rocks, including black shale, sandstone and limestone. The genetic models for the stratiform copper deposits can range from early to late diagenetic, syn-orogenic and post-orogenic. The aim of this research is to characterise the stratiform copper deposits in the Lufilian foreland, to define the relative time period of ore formation and to compare the different types of the stratiform copper deposits in the Lufilian orogen. The data obtained from these analyses will be integrated to propose a preliminary metallogenic model. This study focuses on copper deposits in the Lufukwe anticline in the eastern part of the Lufilian foreland, DRC.

The rocks investigated in the Lufukwe anticline are of Neoproterozoic age and belong to the Roan, Nguba and Kundelungu Groups. The core of the anticline consists of Mwashya sediments (Roan Group), which are overlain by the Grand Conglomerate of the Nguba Group. The Monwezi sandstone conformably overlies the Grand Conglomerate. This sandstone unit hosts numerous stratiform copper prospects in the Lufilian foreland, including the Kinkumbi prospect at Lufukwe. At Kinkumbi, the Monwezi sandstone is approximately 30-40 m thick, with disseminated and interstitial copper-silver mineralisation concentrated in the basal 10 m. It grades conformably into the Petit Conglomerate at the base of the Kundelungu group.

The coarse-grained Monwezi sandstone has been subjected to intense compaction and silica cementation. After compaction and deep burial, the feldspars underwent kaolinitisation and sericitisation, associated with intense dissolution, which finally resulted in a well-developed secondary porosity. The copper mineralisation is mainly concentrated in the cavities and partly replaces the detrital grains. Sulphide mineralisation started with the precipitation of pyrite followed by chalcopyrite, bornite, chalcocite and minor sphalerite. Supergene enrichment caused the precipitation of digenite, covellite, hematite and minor cuprite and native copper. Based on satellite image interpretation, the Lufukwe anticline is crosscut by a large set of structural lineaments. These lineaments could have played an important role in the circulation of the leaching and mineralising fluids in the highly compacted Monwezi sandstones.

The stratiform copper mineralisation in the Lufukwe anticline in the Lufilian foreland displays different features than the stratiform copper-cobalt mineralisation in the Lufilian arc, i.e. the Copperbelt in the DRC. Copper mineralisation in the Lufilian arc is usually associated with cobalt, especially concentrated in Roan sediments and interpreted to be of syn-sedimentary to late-diagenetic origin. Copper mineralisation in the foreland is, however, often associated with silver, occurs in Nguba and Kundelungu rocks (Mwatipile area) and has likely a late-diagenetic to post-orogenic origin.

Cancelled

GLACIAL/INTERGLACIAL INSTABILITIES OF THE WESTERN BOUNDARY UNDERCURRENT DURING THE LAST 360 KYR FROM SM/ND RATIOS OF THE CLAY-SIZE FRACTIONS IN SOUTHERN GREENLAND CORES

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We present 40 Sm-Nd isotope measurements of the clay-size (< 2 □m) fractions of sediments from the Southern Greenland rise (ODP-646) that span the last 360 ka. These data track changes in the relative supply of fine particles carried into the deep Labrador Sea by the Western Boundary UnderCurrent (WBUC) during the last four glacial-interglacial cycles. Earlier studies revealed three general sources of particles to the core site: i) Precambrian crustal material from Canada, Greenland, and/or Scandinavia (*North American Shield* - NAS), ii) Palaeozoic or younger crustal material from East Greenland, NW Europe, and/or western Scandinavia (*Young Crust* - YC) and, iii) volcanic material from Iceland and the Mid-Atlantic Ridge (MAR). Clay-size fractions from glacial sediments have the lowest Nd isotopic ratios. During glacial stages of oxygen isotope stages (OIS) 2, 6, and 10, supplies of young crustal particles were similar, whereas mean volcanic contributions decreased relative to old craton material, from OIS 10 to OIS 6 and from OIS 6 to OIS 2. The glacial OIS 8 interval displays a mean Sm/Nd ratio similar to those of interglacials OIS 1, 5, and 9. Compared with other interglacials, OIS 7 was marked by a higher YC contribution but a similar ~30% MAR supply. The overall NAS contribution dropped by a factor of 2 during each glacial/interglacial transition, with the MAR contribution broadly replacing it during interglacials. To decipher between higher supplies and/or dilution, particle fluxes from each end member were estimated. Glacial NAS fluxes were systematically higher than interglacial fluxes. During the time interval examined, fine particle supplies to the Labrador Sea were strongly controlled by proximal ice-margin erosion and thus responded to glacial stage intensity. In contrast, the WBUC-carried MAR supplies from the eastern basins did not change significantly throughout the last 360 kyr, except for a marked increase in surface-sediments that suggests unique modern conditions. Over glacial/interglacial it is concluded that whereas Sm-Nd ratios in clay-size fraction provide useful information on relative sedimentary supplies from proximal sources, thus on glacial erosion rates, distal WBUC-controlled inputs from the Northern and NE North Atlantic seem to have been less variable. In addition short-term changes within Holocene are discussed with complementary analyses in other sediments cores (MD99-2227, HU90-13-013) recoverd in nearby location in Labrador Sea.

DEFORMATION AND GEOCHEMICAL EVOLUTION OF PRE-OROGENIC GRANITOIDS DURING DEEP CRUSTAL THRUSTING (YEU ISLAND, FRENCH VARISCAN BELT)

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Yeu Island is situated at the southernmost extremity of the Southern Brittany Variscan Belt of France. In this area, this belt results from the stacking of numerous tectono-metamorphic units (composed of para- and ortho-derived crystalline materials) thrust upon an unknown Aquitanian platform in late Devonian to Carboniferous times. This specific geographic setting of Yeu Island allows us to observe 1) the deepest nappe level of the regional crustal stacking and 2) preserved early-Variscan structures. In the other, mainly continental, zones of the belt (i.e. Les Sables d'Olonne) these structures have almost all been transposed during the late-orogenic events.

Recent structural (including AMS data), petrological and geochemical surveys of the island have been performed during geological mapping. More or less deformed Pre-Variscan peraluminous granitoids ranging from tonalite to monzogranite (some of them containing tonalitic and granodioritic enclaves) constitute the major part of the island. Amphibolitized mafic dykes and/or sills cut the granitoid unit. Locally, at the southern edge of the island, the "Yeu orthogneiss" nappe sole and the para-autochtonous metasedimentary basement units crop out inside a tightened anticline. The nappe sole is a tectonic complex composed, among other things, of granitoid-derived "ortho-schist" just below strongly metasomatised (sometimes almost undeformed) granitoids. These high-strain tectonic structures have been observed inside the "orthogneiss unit" itself. Each horizon of high strain blasto-mylonitization is also characterised by anastomosed but highly localised deformation and by a fluid-control chemical exchange between mylonite and adjacent granitoids along these tectonic joint. Shearing planes are coherent with the main foliation. Yeu Island has preserved the memory of the North-South convergence of Variscan stacking (North-South lineation on flat lying foliation).

The mylonitic rocks are characterised by enrichment in MgO, K_2O, LILE and fluid-related elements (H_2O, P) and depletion in CaO and Na_2O, whereas adjacent granitoids display inverse characteristics. Mylonite and adjacent rock are thus geochemically complementary; they both result from the progressive metasomatic change of the granitoid protolith: 1) in the mylonite, K-feldspar is replaced by muscovite, plagioclase disappears and induces a strong local enrichment in Al_2O_3 allowing the crystallisation of kyanite (showing the prograde character of the shearing); 2) in the adjacent undeformed rock, alkali feldspar is albitised, biotite is chloritised. In the most metasomatically transformed rocks, garnet, cordierite, gedrite, staurolite and tourmaline have been observed in association with a green hornblende and albite.

All these mineralogical transformations, especially the feldspar → muscovite replacement are directly responsible of the highly flatten strain attained in these localised zones.

OCCURRENCE OF SURSASSITE, MN2AL3(SIO4)(SI2O7)(OH)3, IN THE LIENNE VALLEY, STAVELOT MASSIF

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In quartz veinlets crosscutting the red purple schists of the Ottré Formation (Salm Group) in the core of the Lienne syncline, sursassite occurs as orange red needles associated with manganese oxide masses mostly constituted by cryptomelane. Detailed petrographic observations coupled with electron microprobe analytical work reveal sursassite in close association with spessartine, manganoan clinochlore, fluorapatite, and hematite.

The chemical composition of sursassite shows the presence of about 2 wt % MgO, and up to 4 wt % CaO, whereas FeO does not exceed 1 wt %. These substitutions are interpreted in comparison with pumpellyite-(Mg), $Ca_2MgAl_2(SiO_4)[Si_2O_6(OH)](OH)_3$. Heterogeneities have also been detected in the distribution of V and As. From a chemical point of view, these zones rich in V and As correspond to ardennite s.l., $Mn_4\,(Al_5Mg)\,(SiO_4)_2\,(Si_3O_{10})\,[(V,As)O_4]\,(OH)_6$, previously identified in Bierleux.

The unit-cell parameters of sursassite are given and its infrared spectrum is briefly discussed. Sursassite constitutes a new additional phase among the minerals characteristic of the low-grade metamorphism known in the Lienne valley, in the western part of the Stavelot Massif, i.e. about 300°C and 1.5kb. As for the occurrence of the manganoan clinochlore, it is reasonable to envisage the formation of sursassite in the quartz veins during the retrogarde process at the beginning of the temperature decline.

FIELDS APPLICATIONS FOR THE SCRATCHING TEST

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Several papers have already been presented in the litterature to describe the methology to assess strength of geomaterials with "partially-destructive" scratching tests. Experiments on several geomaterials have shown that the intrinsic specific energy is well correlated to the strength of the rock. Furthermore the friction coefficient mobilized along the wear flat of a blunt cutter has been found to be well correlated to the internal friction coefficient of rock materials.

The paper gives an overview of the scartching method principles and presents some particular field applications where the scratching test has been applied to characterized materials strength:

1. In petroleum engineering, the scratching test has been considered to detect weak reservoir sections with high potential for sanding production or to calibrate log derived mechanical properties.
2. In mining engineering, the test has been used to compare the behavior of rocks while cutting or to characterize carboniferous schists properties nearly impossible to assess with standard uniaxial compressive tests.
3. In civil engineering, the scratching test has been conducted for material characterization of historical building materials like mortars or jet grouting in the projet for the foundation stabilization of Our Lady Cathedral in Tournai.
4. The scratching test has also been used for the detection and the measure of mechanical damage due to coring, pollution, fluid invasion, heat, …

The description of those different applications points out the high efficiency of the scratching test to characterize materials strength even if samples are poor quality, too small to perform standard tests or if the sample may not be damaged.

METALLOGENESIS OF THE DIKULUSHI CU-AG ORE DEPOSIT IN THE LUFILIAN FORELAND (DEMOCRATIC REPUBLIC CONGO)

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The Katanga province is located in the south-eastern part of the Democratic Republic of Congo (DRC). The southern part of Katanga can be divided in two regions: (a) the Lufilian fold-and-thrust belt on the border with Zambia, which developed in the Neoproterozoic and early Cambrian during the Pan-African orogeny and (b) its Kundelungu foreland to the north. The current research mainly focuses on the Cu-Ag-deposit at Dikulushi, located in the Kundelungu foreland.

Two mineralising phases can be distinguished in the deposit at Dikulushi. The first mineralising phase appeared in the footwall of a reverse fault that broke through the forelimb of a periclinal detachment anticline. This anticline developed on top of a mobilised mélange. Small arsenopyrite and pyrite crystals precipitated first, followed by massive sphalerite, chalcopyrite and tenantite. Galena, sphalerite, chalcopyrite and bornite precipitated during a second stage of the first mineralising phase. At the end of this phase chalcocite and digenite developed. The ore minerals are partially associated with a medium-grained dolomite and exhibit a transition from a reducing to a more oxidizing environment. The medium-grained dolomite pre-dating the first mineralising phase has oxygen and carbon isotopic values of -2.7‰ and +1.1‰ respectively. Its oxygen and carbon isotopic composition changes at the start of the precipitation of the ore minerals to -2.6 and -7.7‰ respectively. The oxygen isotopic values of all medium-grained dolomites and the carbon isotopic values of the medium-grained dolomites pre-dating the first mineralising phase point to a seawater origin of the brines precipitating these dolomites. A very coarse-grained dolomite, post-dating the metal sequence and a sphalerite, precipitated at a minimum temperature (homogenisation temperature of primary fluid inclusions) of ~150°C from a high-salinity Ca-Na-Cl-rich brine. The $\delta^{34}S_{CDT}$ values of the sphalerite, chalcopyrite, galena, bornite, chalcocite and digenite range between 11.3 and 14.5‰. These values show that the sulphur is originally derived from seawater sulphate by thermogenic reduction ($\delta^{34}S_{CDT}$ of Proterozoic seawater = 17.5+/-3‰). The lower $\delta^{13}C_{PDB}$ of the medium-grained dolomite, precipitating during the first mineralising phase, should be explained by the oxidation of organic matter, associated with the reduction of sulphate. The very coarse-grained dolomites post-dating the first mineralising phase have $\delta^{13}C_{PDB}$ values ranging between -1.3 and 0.2‰. These values coincide closely with the $\delta^{13}C_{PDB}$ isotopic composition of the medium-grained dolomites pre-dating the first mineralising phase and are probably the consequence of buffering of the mineralising fluid by this medium-grained dolomite. The $\delta^{18}O_{PDB}$ values of the very coarse-grained dolomites (-6.5 and -12.6‰) are depleted in comparison with the medium-grained dolomites, likely due to a higher precipitation temperature.

The second mineralising phase occurred in the hinge zones of steeply plunging, third order perclinal antiforms, where they are crosscut by NE-SW trending fractures. The second mineralising phase is initiated with the precipitation of barite. After this barite, the fractures were filled with a massive chalcocite –with a high Ag content– that partially recrystallised into digenite. Quartz and Fe-rich calcites pre- and post-date barite and chalcosite formation. Precipitation of barite, Fe-rich calcite and quartz took place from a moderate-salinity H_2O-NaCl fluid at a minimum temperature of ~75°C (barites) that lowered gradually to ~40°C (calcites post-dating the sulphide and barite mineralisation). The barites have $\delta^{34}S_{CDT}$ values that range between 11.2 and 13.1‰, similar to the $\delta^{34}S_{CDT}$-isotopic values of the sulphides from the first mineralising phase. These $\delta^{34}S_{CDT}$ values show that the sulphur is likely derived from seawater sulphate by thermogenic reduction, and was oxidised during the precipitation of barite. The chalcocite of the second mineralising phase has lower $\delta^{34}S_{CDT}$ values (10.3 and 10.4‰) that could be the consequence of precipitation from a fluid more enriched in ^{32}S that was present after barite precipitation. The lower $\delta^{34}S_{CDT}$ values of these chalcocites could also reflect more

oxidising conditions of the mineralising fluid. Measurement of the carbon and oxygen isotopic composition of the Fe-rich calcites that precipitated throughout the second mineralising phase show a large range in stable isotopic values ($\delta^{18}O_{PDB}$= -12.8 to +0.6 and $\delta^{13}C_{PDB}$= -3.4 to -1.5) that could be interpreted to be due to different water-rock interaction, precipitation temperature and even original fluid chemistry. The Fe-rich calcites that formed after the second sulphide mineralisation show a depletion in $\delta^{13}C_{PDB}$ (-4.1 and -8.7), which is the result of the oxidation of organic matter.

Remote sensing and geophysical data allowed us to obtain good insight in the geology of the region of Dikulushi. Dikulushi itself is located in the culmination zone of a first-order detachment anticline running from the Kiaka anticline in the south to the Kabangu anticline in the north. These anticlines developed during Neoproterozoic tectonics. The first mineralising phase is situated in the forelimb of a second-order pericline and is interpreted to have developed together with the pericline during this Neoproterozoic folding event. The second mineralising phase developed along NE-SW trending fractures, which belong to a larger fracture system along this direction. This fracture system is parallel to the border faults of the incipient Mweru-Tschangalele rift zone and is believed to lie in the tip zone of one of these bordering faults. Following this hypothesis, the second mineralising phase likely developed during Phanerozoic tectonics, closely related to the rifting in southern Africa. However, the location of the mineralisation is strongly controlled by the pre-existing structural architecture that resulted from the Neoproterozoic Katanga orogeny.

TRANSFORMATION SEQUENCES OF COPPER SULFIDES AT VIELSALM, STAVELOT MASSIF, BELGIUM

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Located in the southeastern portion of the Stavelot Massif, the Salm syncline shows, between Vielsalm and Salmchâteau, a geological section containing schists of the Salm Group, of Lower Ordovician age. This area was first affected by a very low-grade metamorphism during the Caledonian orogeny (0.8-3 kbar / 280-380°C), and then by a low-grade metamorphism during the Hercynian orogeny (2 kbar / 360-420°C), which is responsible for the crystallization of the metamorphic minerals observed in the quartz veins and in the schists.

The quartz veins crystallized at the end of the Hercynian metamorphic phase. Fluid circulations through the rock fractures, coupled with metasomatic processes, resulted in concentration of numerous chemical elements, such as Cu, Mn, Te, or Mo, within the quartz veins. This explains the diversity of minerals discovered in this area: copper sulfides, which constitute the main topic of the present study, Mn-bearing aluminosilicates, such as davreuxite and ottrelite, and manganese oxides, such as lithiophorite, cryptomelane, nsutite, and hollandite-strontiomelane. The sulfides-bearing quartz veins investigated herein cross-cut the green to violet chloritoid-bearing schists of the Colanhan Member (Middle Salm Group, Sm 2c).

The sulfides bornite, chalcopyrite, idaite, covellite, yarrowite, spionkopite, anilite, digenite, djurleite, and chalcocite have been identified by ore microscopy, and their identification is confirmed by electron microprobe analyses. The chemical composition of idaite is significantly enriched in Cu, when compared with the ideal formula Cu_3FeS_4, and a progressive compositional evolution from bornite to idaite has been observed. The X-ray powder diffraction pattern of idaite is indexed in the space group *I*-42*m*, similar to that of stannite, and gives the unit-cell parameters a = 5.279(4) and c = 10.47(2) Å.

The association of primary sulfides indicates that the bornite-bearing quartz veins have crystallized above 300-350°C, whereas the chalcocite-bearing quartz veins have crystallized below 200°C. Relations among sulfides indicate the occurrence of two sequences of transformation, responsible of the formation of secondary sulfides: chalcocite-*H* → chalcocite-*M* → djurleite → low digenite or (anilite + djurleite) → yarrowite + spionkopite → covellite + oxidation minerals, and bornite → idaite + chalcopyrite → covellite + oxidation minerals. The crystallization of chalcocite-*M*, djurleite, and low digenite or (anilite + djurleite) took place between 103.5 and 72°C. The associations idaite + chalcopyrite, yarrowite + spionkopite, and covellite + oxidation minerals, were produced under meteoric conditions.

THE STRATIGRAPHIC POSITION OF THE CAMBRIAN JODOIGNE FORMATION REDEFINED (BRABANT MASSIF, BELGIUM)

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The age of the Jodoigne Formation is debated. It was never dated, and its stratigraphic position is mainly based on its relative position with respect to the other lithostratigraphic units within the Brabant Massif. Going from the south towards the more internal parts of the Cambrian core, the following formations are encountered: 1) the Upper Cambrian Mousty Formation (acritarchs), 2) the Lower Cambrian to basal Middle Cambrian Oisquercq Formation (acritarchs), 3) the Lower Cambrian Tubize Formation (Oldhamia), 4) the probably lowermost Cambrian Blanmont Formation (Oldhamia) and 5) the Jodoigne Formation. Because of its more central position, some authors placed the Jodoigne Formation below the Blanmont Formation (e.g. Verniers et al., 2001 and references therein). Other authors, however, considered this formation as Upper or Middle Cambrian (e.g. De Vos et al., 1993 and references in Verniers et al., 2001). However, in the latter case, no adequate explanation could be given for the close position in outcrop to the Blanmont Formation (Gette valley).

On the basis of an analysis of pre-existing data and new data from various sources we favour the latter hypothesis and suggest a Middle to Upper Cambrian age for the Jodoigne Formation. These data are: 1) the resemblance between the black mudstone-dominated parts of the Jodoigne Formation and the rocks of the Mousty Formation; 2) the similar anomaly in terms of temperature-dependent variation of magnetic susceptibility for the Jodoigne Formation and the Mousty Formation; 3) the apparent stratigraphic hiatus, yet unexplained, between the basal Middle Cambrian (Oisquercq Fm.) and the Upper Cambrian (Mousty Fm.) in Verniers et al. (2001); 4) the overall E-ward younging direction within the Jodoigne Formation in its type area (Gette valley), away from the seemingly adjacent lowermost Cambrian Blanmont Formation; 5) the seemingly anomalous position of several boreholes said to contain the Jodoigne Formation, in between the Lower Cambrian to the north and lower Tremadoc to the south (Piessens et al., 2005); 6) the enigmatic age-range (acritarchs by Vanguestaine, 1992) of boreholes said to belong to the Mousty Formation, from Upper Cambrian at Cortil-Noirmont (40W539), Eine (84E1372) and Vollezele (100E010) to lower Middle Cambrian at Heverlee (Leuven, 89E01), the latter reflecting a turbiditic sedimentology, thus far only encountered within the Jodoigne Formation at Jodoigne.

The close proximity in the eastern part of the Brabant Massif between the Jodoigne Formation and the Blanmont Formation can be explained by means of the Asquempont detachment system. In the Senne-Sennette valley, this detachment system places Lower Ordovician on top of the Oisquercq Formation, in boreholes to the west Upper Ordovician on top of the Oisquercq Formation and in the Dyle-Thyle valley the Mousty Formation on top of the Tubize and Blanmont formations (Debacker et al., 2004, 2005 and Piessens et al., 2005). Extrapolating this apparent trend towards the east (Gette valley), one indeed arrives at rocks of Middle or Upper Cambrian on top of the Blanmont Formation (Piessens et al., 2005).

Cancelled

POST-PALEOCENE GHOST SHRIMPS, LOBSTERS AND CRABS FROM BELGIUM: AN UPDATE

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In central and northwest Belgium, ghost shrimps, lobsters and crabs are locally common in post-Paleocene Cenozoic strata, and in recent years new material has been collected on a regular basis. Van Straelen's 1921 list of all species then known naturally is out of date now, and although there has been some subsequent work on certain crabs and lobsters, culminating in several systematic papers, there currently is no exhaustive listing. We know of some 35 species, in no fewer than 31 genera, comprising two macruran lobsters and seven thalassinoid ghost shrimps, the remainder being crabs. Although data in the 1921 list generally are accurate, only occurrences verified by ourselves are included here.

Ypresian (lower Eocene) strata at Forest (Brussels area) have furnished the calappid *Silvacarcinus laurae* Collins and Smith, 1993, and the raninid *Raninoides glabra* (Woodward, 1871); a second, coeval assemblage, still undescribed, is from Marke (Kortrijk area), including the crab *Zanthopsis* cf. *leachii* (Desmarest, 1822) in abundance, and an associated spear lobster, *Linuparus scyllariformis* (Bell, 1857). Correlative, yet richer, faunas are known from Egem, where *L. scyllariformis*, the crab *Glyphithyreus wetherelli* (Bell, 1858) and new species of the thalassinoid *Upogebia* and the crab *Retropluma* have been collected, as well as a single carapace of the crab *Goniochele*, possibly conspecific with *G. angulata* Bell, 1858. 'Ledian' (mid-Eocene) levels exposed at Balegem have furnished new species of the hermit crab *Pagurus* and the crab *Stevea*, and from Lutetian-age strata temporarily exposed at Zaventem the crab *Harpactocarcinus punctulatus* (Desmarest, 1822) is known. All occurrences of *Zanthopsis* are here lumped by us in a single species; earlier listings also refer to *Z. bispinosa* M'Coy, 1849 and *Z. unispinosa* M'Coy, 1849. Still other species, such as the lobster *Hoploparia gammaroides* M'Coy, 1849, and the crabs *Xanthilites bowerbanki* Bell, 1858 and *Portunites incerta* Bell, 1858, may be expected at Egem. In addition, there are still unnamed species of callianassid, calappid, *Palaeocarpilius* and *Etisus*, from 'Bruxellian' levels in the Brussels area, as well as the lobster *Hoploparia corneti* van Straelen, 1920 and the crab *Cancer burtini* Galeotti, 1837.

Oligocene material is known from the Boom area, where numerous well-preserved *Coeloma (Paracoeloma) rupeliense* Stainier, 1887 have been collected from concretions, associated with claws of a huge lobster, *Homarus percyi* van Beneden, 1872. Claws of a hermit crab with stridulatory apparatus, *Ciliopagurus obesus* van Bakel, Jagt and Fraaije, 2003 have been recorded from Rupelian levels at Sint-Niklaas, and a single diminutive dromiid, apparently closely related to *Dromia eotvoesi* Müller, 1976 from the Miocene of Hungary, currently is under study.

Miocene assemblages are dominated by the crab *Tasadia carniolica* (Bittner, 1884, associated with much rarer *Mursia lienharti* (Bachmayer, 1962), near Ramsel and Berlaar. Road works at Borgerhout have produced a cancroid, possibly *Glebocarcinus*, characterised by distinctly swollen protogastric regions.

Pliocene (Piacenzian) material is well known from the Kallo area, where dock works have been supplying good collecting conditions. Small-sized species have been collected from gastropod sediment fill, and include pagurids (*Pagurus bernhardus* Linné, 1758), galatheids (*Galathea dispersa* Bate, 1859), the leucosiids *Ebalia cranchii* Leach, 1817, *E. jacqueshermani* van Bakel, Jagt, Fraaije and Wille, 2004 and *E. tumefacta* (Montagu, 1808). Larger forms, collected from wind-blown faces in the actual dock works, comprise the cancroids *Cancer* cf. *pagurus* Linné, 1758 and *Metacarcinus*

tenax van Bakel, Jagt, Fraaije and Wille, 2004, the spider crab *Maja squinado* (Herbst, 1788) and the corystid *Corystes holsaticus* (Noetling, 1881). Concretions of comparable age, collected at a temporary outcrop near Oelegem, have produced the cancroid, *Cancer vancalsteri* van Bakel, Jagt and Fraaije, 2003, while from canal works near Emblem (Antwerpen area) a new species of the axiid *Axius* is now known, based on claws and a single, reasonably preserved carapace.

In our current studies, the assistance of non-professional palaeontologists has proved indispensable; we wish to thank in particular L. Anthonis, Y. Christiaens, L. De Coninck, A. Iserbyt, T. Lambrechts, R. Meuris, F. Mollen, F. Smet, F. Van Calster and E. Wille.

HYDROGEOLOGY OF THE AQUIFER OF THE DEVONO-CARBONIFEROUS LIMESTONES OF HAINAUT : A KARSTIFIED MEDIUM, A NON-KARSTIC BEHAVIOUR – RESOURCES AND GENERAL KIND OF FLOW

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The aquifer of the Devono-Carboniferous Limestones of Hainaut is mainly calcareous and dolomitic, and is bounded by the Devonian shales on the northern side and by the Namurian shales on the South. The superficial formations include Cenozoïc sands, clays and silts. These formations belong to the aquifer coverage, which has variable effectiveness depending on the proportion of clays.

The reservoir permeability comes from numerous fractures, joints and faults affecting the limestones. The joints, particularly, are preferential drainage ways. Some of them are altered and enlarged by karstification, causing the global transmissivity to increase in mean as well as in heterogeneity.

The former conceptions described a global East-West flow. One of the aims of this study was to draw up a new piezometric map, based on a complete inventory of wells, piezometres and any other way to get information about the water table of the Devono-Carboniferous Limestones aquifer. This map allowed to characterize several hydrogeological basins, organized around a natural discharge. These basins seem to work as individual hydrogeological entities, with rather stable limits (sometimes affected by pumping activities). These results bring new management options about the water resource in this aquifer.

The new map doesn't show any drainage zones. The flow seems to stay a classic sheet flow (in agreement with the Darcy law), unless in regions where pumping activities strongly affect the natural water level.

LOWER EDIACARAN AGE (630-610 MA) FOR THE SARHRO GROUP: AN OROGENIC TRANSPRESSIVE BASIN DEVELOPMENT DURING THE METACRATONIC EVOLUTION OF THE ANTI-ATLAS (MOROCCO)

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The Anti-Atlas region is classically subdivided in a northern Pan-African island arc and in a southern Eburnian domain (the West African Craton, WAC) whose boundary is the Anti-Atlas Major Fault (AAMF), delineated by several ophiolitic remnants (e.g. Saquaque et al., 1989). This "island arc" series comprise a volcano-sedimentary series (the Sarhro Group) which are intruded by granitoids. Both were considered as subcontemporaneous with the ophiolites, c. 700 Ma old. The Sarhro Group is even considered as the oldest term of this Pan-African domain. The present study shows that this interpretation is not anymore viable.

Recent U-Pb zircon dates indicate that the Saghro granitoids, mainly high-K calc-alkaline in composition (Errami et al., 2002), are actually in the range of 615-575 Ma (e.g. Thomas et al., 2001; Levresse et al., 2001). The island arc status of the Sarhro Group is debated. A challenging interpretation is to consider this series as resulting from a Pre-Pan-African extension related to an unknown northern continent (e.g. Lécolle et al., 1991; Fekkak et al., 1999, 2003) or to the WAC itself (Ennih and Liégeois, 2001). In all cases, the Sarhro Group was always considered to be older than the c. 700 Ma ophiolitic sequence. However, T_{DM} Nd model ages of basaltic pillows located towards the base of the Sarhro Group are in the range of 640-580 Ma (this study) which threw serious doubts on this Cryogenian attribution. It must be stressed that the contacts between the Sarhro Group and the ophiolitic sequences are of tectonic nature.

We present here U-Pb ages acquired by laser ICP-MS on detrital zircons separated from the base to the top of the Sarhro Group. There is a mixing of Palaeoproterozoic and Neoproterozoic zircons, with a progressive increase of the proportion of the Neoproterozoic zircons from the base (10%) to the top (67%). Most of the Palaeoproterozoic zircons are in the range 2000-2050 Ma, which corresponds to the ages known in the Eburnian Anti-Atlas (e.g. Thomas et al., 2001), indicating a West African Craton provenance. The Neoproterozoic zircon ages correspond to: (1) the Ifzwane doleritic suite (c. 880 Ma) from the WAC passive margin; (2) the ophiolitic sequence (750-660 Ma) and (3) a group of zircons more and more younger and more and more abundant towards the top of the Sarhro sequence, with ages between 630 and 612 Ma. It must be noted that the Sarhro Group is covered by the Bou Salda Group, which includes rhyolitic dykes dated at c. 605 Ma (Thomas et al., 2001, 2004).

The abundance of zircons from the Palaeoproterozoic basement and pre-Sarhro units implies the uplift and the erosion of the WAC and its superstructures, i.e. the passive margin and the ophiolitic sequences, with the consequent deposition of the Sarhro group during the onset and growing of a volcanism from which the younger zircons came from. Including structural constraints, we interpret the Sarhro Group as a post-collisional transpressive basin developed during the metacratonic evolution of the northern boundary of the WAC (the Anti-Atlas). This period evolved progressively to a transtensive episode, marked by the huge volume of magmas belonging to the Ouarzazate Supergroup (580-550 Ma). This metacratonic evolution of the northern boundary of the WAC occurred during the convergence with the Pan-African Avalonian terranes, which moved elsewhere during the Phanerozoic.

SEDIMENTOLOGY AND MAGNETIC SUSCEPTIBILITY OF THE COUVIN FORMATION (EIFELIAN, SOUTH WESTERN BELGIUM): CARBONATE PLATFORM INITIATION IN A HOSTILE WORLD

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The Eifelian is mainly characterized in Belgium by a detrital ramp related sedimentation. The Couvin Formation is the more important and remarkable exception. It represents a carbonate platform initiation in a siliciclastic environment.

This work is mainly based on two stratigraphic sections located in Couvin: the Eau Noire and Falaise de l'Abîme sections corresponding the Couvin Formation stratotype (southern flank of the Dinant Synclinorium). However, these two sections are discontinuous. To allow a better understanding of the sedimentary dynamic, the data are completed by a shorter but continuous section located in Villers – la – Tour (3,5 km West of Chimay).

Petrographic study leads to the definition of 14 microfacies. MF1: Wackestone and packstone with abundant detrital fraction; MF2: Algal wackestone and packstone; MF3: Crinoidal packstone in a microsparitic matrix; MF4: Coverstone with in situ stromatoporoids in a microsparitic matrix; MF5: Crinoidal grainstone and packstone; MF6: Poorly-sorted peloidal microsparitic packstone and grainstone; MF7: Crinoidal rudstones; MF8: Rudstone with stromatoporoids and tabulate corals; MF9: Poorly-sorted peloidal and crinoidal grainstone; MF10: Bioclastic wackestone (floatstone) and packstone with branching and fasciculate organisms; MF11: Floatstone with branching and fasciculate organisms; MF12: Wackestone and packstone with gastropods; MF13: Wackestone and mudstone with fenestrae; MF14: well-sorted peloidal grainstone.

These microfacies are integrated in a palaeogeographical model and a curve showing microfacies evolution is interpreted in terms of changing bathymetry. This interpretation is complemented by results obtained by magnetic susceptibility, providing a better understanding of the sedimentary dynamic.

ACTIVE FAULTS AND FAULT SEGMENTATION IN THE UFIPA PLATEAU, SW-TANZANIA

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The Ufipa Plateau is located in SW-Tanzania and lies within the NW-SE trending Ubendian Paleoproterozoic tectonic domain. It has undergone a long and complex structural evolution and the dominant NW-SE trend, which has been used to structurally identify the belt, results from a late Paleoproterozoic deformational event associated with shearing.

The Ufipa plateau is cut longitudinally by three main fault systems: (1) the > 70 km long Kalambo-Mwimbi fault to the west, near lake Tanganyika, (2) the > 160 km long Kanda fault (25-30 km east of the former), and (3) the > 300 km long Rukwa border fault to the east. All of these faults are normal faults dipping in the same direction (NE). This study is concerned with the first two faults.

The mean scarp slope value of the Kalambo-Mwimbi fault is less by nearly half of that of the Kanda fault. To the contrary, comparison of the differences between vertical offset and free scarp heights of both faults show that the Kalambo-Mwimbi fault has lost its free scarp by nearly 50 % more than the latter. This could serve to explain for the fact that the Kalambo-Mwimbi fault, whose vertical offset values are of comparable magnitudes to that of the Kanda fault, is or has experienced relatively more prolonged erosion than the Kanda fault and that this fault is probably no longer active. Furthermore, the incision of river(s) against the Kalambo-Mwimbi fault scarp (footwall) near Kalambo ranch, is an additional evidence in support of this argument.

The Kanda fault is characterized by 4 fault segments: the Sumbawanga, Mpui, Kitete and Mlenje segments. They are respectively > 35 km, about 60 km, 50 km and > 15 km long. The highest scarp height is in the Mpui segment and has the highest values (of the order of 50m) at Ilembo, most likely indicating results of fault segment growth and interactions.

Field investigations conducted in the years 2004 and 2005 have revealed a number of < 2 m up to almost 15 m high fault scarps as relatively smaller segments along the Kanda fault within the main segment and also within the Kitete and Mlenje fault segments. There is no evidence for smaller fault segments in the Sumbawanga fault segment.

Studies by Ambraseys (1991) and Vittori et al. (1997) show that in the year 1910 the Ufipa plateau area was struck by a M7.4 earthquake, the strongest instrumentally recorded earthquake in Africa ever, since the last century.

These data and results thereof show that, unlike the Kalambo-Mwimbi fault, the Kanda fault seems to have growing fault segments, more especially towards its southern part. This could serve to explain the potentiality of this area for future earthquakes. However, more work needs to be done in this area to constrain the age relationship between various geologic events such as Holocene fault displacement (if any) and slip rate(s), maximum recorder seismogenic slip and average recurrence time for strong earthquakes.

STUDY OF THE NATURAL ZEOLITE DEPOSITS OF COASTAL ECUADOR

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The occurrence of zeolite deposits in Coastal Ecuador has been demonstrated at the end of the last decade. The zeolites are found in the Cayo formation, a rock unit of Cretaceous age consisting of volcaniclastic and sedimentary rocks. Previous studies, concentrated in the region of Guayaquil, have demonstrated the presence of zeolite minerals of the clinoptilolite-heulandite solid solution series. The minerals are used locally for several applications in agriculture, waste-water treatment and the cement industry. This study is the first detailed investigation of the mineralogy, geology and genesis of the deposit over its entire outcrop area, a region of approximately 1000 km^2. Three cross-sections were sampled through the Cayo formation and neighbouring rock units. In the Coastal area the Cayo formation crops out west of the Puerto Cayo – Canande fault zone. In an east-west section along the Rio Ayampe the dominant lithology is a green silicic fall-out tuff consisting of mordenite, clinoptilolite-heulandite, quartz, celadonite and smectite. Pelagic sedimentary rocks contain calcite and quartz and some minor mordenite. Wairakite is present near fault zones. A second cross-section was sampled in the central part of the area, near Isidro Ayura. The basal part of the Cayo formation consists mainly of green silicic fall-out tuffs consisting of mordenite and quartz. The upper part is dominated by decametric ignimbritic sequences consisting of clinoptilolite-heulandite, quartz and smectite. Laumontite occurs as vein fillings. The type locality of the Cayo formation, the Via Perimetral near Guayaquil, was studied in detail. At this location a continuous north-south section can be observed through the 2700 metres thick rock unit. Decametre size sequences of coarse grained lapilli-tuffs, tuffs, reworked volcanics and pelagic sedimentary rocks were interpreted as submarine ignimbrites, associated fall-out tuffs, surges and pelagic sediments. Locally decametre size strata of rhyolitic fall-out tuffs are intercalated with this sequences. Next to clinoptilolite-heulandite, three other zeolite minerals, mordenite, laumontite and analcime have been identified. A clear zonation of diagenetical minerals is present through the rock unit, as observed by X-ray diffractometry and optical microscopy. The basal part, locally named Calentura formation or Calentura unit, is dominated by quartz, albite and calcite and locally laumontite. The central part is dominated by clinoptilolite-heulandite, quartz and minor laumontite. These minerals occur in ignimbritic sequences and associated tuffs and in sedimentary rocks. Analcime occurs locally in the lapilli-tuffs, while mordenite and quartz dominate the rhyolitic tuffs. Clinoptilolite-heulandite occurs in all rocks, laumontite is found in the matrix of coarse grained lapilli-tuffs and as vein fillings, where it is dehydrated to leonhardite. The upper part of the sequence is dominated by clinoptilolite-heulandite and quartz. Smectite or a mixed layer of smectite is present through the whole section, and this mineral is dominant in the upper part of the section. Celadonite is present in the upper and central part of the section and causes the intense green colour of some rocks. Opal-CT was not identified in the sequence, but it is present in small amounts in the overlying Guayaquil cherts. A burial diagenetic to low-grade metamorphic model is proposed to explain the mineral zonation along the Via Perimetral. The evolution of a low-grade heulandite-quartz to a higher grade laumontite-albite-quartz zeolite facies is gradual due to large differences in rock composition and rock permeability. In the central part of the section this can be observed as intercalation of clinoptilolite-heulandite, mordenite and laumontite bearing strata. Mordenite occurs in fine-grained rhyolitic tuffs, clinoptilolite-heulandite in ignimbritic sequences, laumontite replaces heulandite in permeable coarse-grained beds. Only the rhyolitic mordenite tuffs are exploited actually. This model can be useful for indicating future exploitation areas for clinoptilolite-heulandite and mordenite.

THE QUATERNARY GEOLOGICAL EVOLUTION OF THE BELGIAN CONTINENTAL SHELF: A SNEAK PREVIEW

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With respect to the Quaternary deposits, the Belgian Continental Shelf (BCS) is one of the last unmapped and unknown areas of Belgium. Notwithstanding the amount of information available (more than 16.000 km of high-resolution seismic profiles and almost 500 core descriptions), and apart from some punctual detailed studies of isolated sandbanks, the available data were never brought together in an integrated and coherent way.

It is generally assumed that most of the offshore Quaternary deposits are of Holocene age due to fluvial erosion during Pleistocene sea-level lowstands and transgressive reworking during the Holocene sea-level rise. The objective of this study is to archive, integrate and (re-)interpret all existing data sets (seismic and cores) in order to develop a genetic model for the Quaternary geological evolution of the BCS.

On the seismic data, the Quaternary deposits on the BCS can be sub-divided in seven seismic-stratigraphic units, in agreement with former studies on the Middelkerke Bank: three basal units were recognised as channel-fill structures, possibly deposited in an estuarine environment; a fourth sheet-like unit is assumed to be deposited in a tidal flat setting; a fifth and sixth unit are lens-shaped and interpreted as coastal sandbank deposits and the seventh unit represents recent tidal sandbank and swale deposits.

Thanks to the integration of all the available sedimentological core data with the seismic stratigraphy, it also became evident that this 7-unit seismic-stratigraphic sub-division of the Quaternary cover has indeed a regional validity. Based on seismic-stratigraphic evidence, it is assumed that these units were initially deposited across the entire BCS and subsequently affected by incision, after which the recent sandbanks formed on that morphology.

The exact age and environment of the older (first three) units is not easy to determine because of the lack of suitably located cores and, in particular, of datable material. Possibly, the formation and infilling of a palaeo-valley with scour hollows offshore Oostende is the result of a combination of erosive phases during successive glacial sea-level lowstands and tidal scouring and infilling during the last interglacial highstand and early Holocene.

The younger units are deposited in a straightforward vertical facies succession reflecting an overall transgressive context: first a tidal environment was established, followed by the formation of coastal, wave-dominated sandbanks, after which offshore tidal sandbanks formed under the current macro-tidal regime, and the continuing –but slowing- rise of the sea level. However, the exact triggering mechanism and hydrodynamic processes responsible for the initiation of the swale and sandbank morphology are still not very clear.

THE CHANXHE SECTION (EASTERN BELGIUM), A REFERENCE FOR THE NERITIC LATE TO LATEST FAMENNIAN TRANSITION (UPPER DEVONIAN)

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The international Subcommission on Devonian Stratigraphy (SDS) has decided to subdivide the Famennian Stage into four substages, which do not require GSSP definitions, but need reference sections in continental, neritic and pelagic facies. We present here a candidate section for a base of the Latest Famennian in neritic facies.

In addition to several macrofossils (algae, brachiopods, crinoids, corals, stromatoporoids, etc), the faunal and floral microfossils at Chanxhe, in eastern Belgium, are represented by miospores, acritarchs, conodonts; foraminifers, and ostracods, which allow accurate correlation with other well known sections in northern France and western Germany. The base of the Latest Famennian (Strunian in neritic facies) has already been proposed at the base of the conodont Upper expansa Zone.

In this work, we mainly discuss the sedimentological context of the Chanxhe section which was previously studied by different authors on limy sediments only and sometimes reaching contradictory conclusions. Although the transgressive character of the Late Famennian part of the section, starting with the so-called “Epinette transgression”, is generally accepted, the Latest Famennian part is alternatively interpreted either as a mixed-carbonate-siliciclastic ramp deepening upwards or as a very shallow environment with a decreasing depth upwards where it became slightly semi-restricted. Although abundant shales are present throughout the section containing tens of thousands of palynomorphs (acritarchs, miospores, palynodebris, etc) per gram of sediment, they have been largely ignored by these authors. We present arguments which interfere with the conclusions based only on the limy sediments of this section.

THE SUBENG MAMMAL SITE (LATE PALEOCENE, CHINA): EVIDENCE FOR A UNIQUE WOODLAND ON THE DRY MONGOLIAN PLATEAU

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In the understanding of the global turnover of the mammal faunas during the Paleocene-Eocene transition, an important role has been attributed to the Asian continent, although the Asian fossil record for this period is still very incomplete. Here we present a multidisciplinary study of the Late Paleocene Subeng mammal site (Inner Mongolia, P.R. China). We integrate sedimentological and diverse paleontological data, trying to reconstruct the paleo-environment and to enhance the understanding of the late Paleocene communities that once thrived on the Mongolian Plateau.

At Subeng, a rich fossil assemblage of pollen, ostracods, charophytes, molluscs, mammals and other vertebrates was discovered in the Nomogen Formation. The basal unit of this formation consists of typical lacustrine deposits, while the upper unit has a fluvio-lacustrine character. Both types of deposits provided a rich ostracod and charophyte assemblage, closely related to that of the Naran Member of the Naran Bulak Formation of Mongolia. The mammal fauna, occurring in the fluviatile deposits, is closest to that from the Bayan Ulan and Nomogen sites in China and from Gashato and Naran Bulak in Mongolia. These four faunas are the typical faunas of the Gashatan Asian Land Mammal Age, classically considered and recently shown to be Late Paleocene in age.

Typically, the Late Paleocene Mongolian Plateau is considered to be an arid or semiarid savanna region with only small, dispersed woodlots. The presence of reworked pedogenic carbonate nodules and mud aggregates agrees with an at least seasonally dry regional climate. Contrastingly however, molluscs suggest a warm and humid climate, similar to present-day southern China and Vietnam. Palynomorphs from Subeng suggest a closed and woody local flora. Combined sedimentological and paleontological data suggest that on the dry Mongolian Plateau, the Late Paleocene Subeng area was an isolated, but locally extensive woodland with a relatively humid, warm to subtropical, local climate. The mammal fauna reflects these differences from the other typical Gashatan faunas, and shows a number of relatives to mammals from the more humid northeastern Chinese biotic province as well as some North American immigrants.

COMPARING DIFFERENT GEOPHYSICAL METHODS IN THE VERDRONKEN LAND VAN SAEFTINGE

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Morphodynamic and process-based modelling of active sedimentary environments such as deltas and estuaries enable us to trace back the history of past morphodynamic changes in the stratigraphy of modern sedimentary environments, and to enhance the predictive value of process-based models on geological time scales. In order to validate existing models of sedimentation in estuaries stratigraphic information from both the land and the sea is indispensable. In the framework of the "Westerschelde" project different geophysical data acquisition techniques are developed and tested in an active estuarine sedimentary environment, thereby combining land-based and sea-based techniques. The land-sea-boundary is often a blank spot, as shallow water areas (<3 m) present serious technological challenges, whereas active coastal processes in the surf zone render high-precision geodesy difficult.

A first test site was chosen in the Verdronken land van Saeftinghe, situated at the southern rim of the Westerschelde estuary, at the Dutch-Belgian border. It consists of approx. 3000 ha of intertidal flats and salt marshes cut by numerous subtidal creeks and gullies. The high tidal amplitudes (up to 5.5 m) enable the application of different techniques at different water levels. During high tide marine-based geophysical data could be obtained from the major creeks, whereas during low tide land-based shallow geophysical data could be obtained from the exposed salt marshes and minor creeks. This should allow the same sedimentary bodies to be imaged both from the land and the sea.

Data acquisition focussed on the top 10 m of the active sediment bodies, with a resolution preferably on decimetre scale. The different techniques applied included very-high-resolution marine seismics (2D and pseudo-3D), geo-electrical methods (both on land and marine), electromagnetic (on land), ground penetrating radar (on land), high-resolution land seismics, CPT, and shallow coring. The geophysical data were correlated with existing historical data, detailed aerial photographs and maps of past coastline and vegetation development since 1930, as well as existing borehole data from the DINO data-base of NITG.

In general the acoustic techniques allowed a better interpretation of the sedimentary structures (lateral accretion, shifting gullies) than the electric and electromagnetic methods. The latter suffered from the effect of tidal action and salt-water intrusion, making it difficult to distinguish lithological variations from background signatures related to hydrogeological features; furthermore the application of these techniques on land proved very strenuous. The results clearly show that not one single technique can provide all the answers. Only an integrated use of complementary geophysical methods may allow us to get a better grip on sedimentation rates and preservation potential in active estuarine sedimentary environments, a prerequisite to start validating numerical morphodynamic and stratigraphic models.

VERY HIGH RESOLUTION SEISMIC INVESTIGATIONS OVER A BURIED WOODEN SHIP WRECK

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The application of marine reflection seismic profiling for the detection of buried wooden artefacts was long restricted by poor resolution and the difficulties to image the seabed and shallow subsurface in shallow water depths. The recent advances in very high resolution subbottom imaging in shallow water environments, however, make this technique an ideal tool for rapid site assessment and site delineation prior to more detailed in-situ surveys.

The ability to image wooden objects largely depends upon the acoustic impedance contrast between the object and the surrounding sediment, which in turn will determine the reflection strength. Theoretical and experimental studies have indicated that both oak and pine can generally be detected when buried in a variety of unconsolidated marine sediments. The reflection coefficient of degraded wood become more negative. In some cases however, e.g. moderately degraded oak in clay, the reflection coefficient may be too close to zero to detect the impedance contrast. Also the size of the object may play a role. Acoustic reflections from a shipwreck will mainly be caused by long boards, and to allow detection the wavelength of the seismic signal should not be much bigger than the thickness of the boards, i.e. of the order of decimeters. Working with main frequencies >2-3 kHz this will most likely not be a problem.

In October 2004 a seismic survey was carried out on the river Schelde near Antwerpen. Target of the survey was a small wooden shipwreck (presumably 17th c.). The wreck was damaged by dredging operations in the past and most likely broken up in pieces. Multibeam maps of the area seem to suggest that the wreck is now completely buried. The seismic measurements were carried out using a Seistec boomer/receiver system (frequency bandwidth 1-6 kHz) and Delph Elics recorder (20 kHz sampling frequency). Together with the seismic profiling side-scan sonar data were acquired using a GeoAcoustic dual-channel side-scan sonar (410 kHz) and multibeam data were recorded using the EM3000 system. In total 31 seismic profiles were recorded at the wreck site. Average profile interval was 5-10 m; due to the high current and low vessel speed regular profile spacing could not always be achieved.

The seismic profiles indicate a thin top layer of soft sediments, most likely silty or sandy mud, marked by internal reflectors suggesting thin layers of sandy or silty material. Below this soft layer the internal stratification becomes less clear; this is most likely due to the presence of biogenic gas in the shallow sediments. On several seismic profiles a number of short, strong reflectors can be observed that do not follow the seafloor morphology. The reflectors are marked by phase reversion. This phase inversion (i.e. negative reflection coefficient) is typical for wooden objects buried in sandy-muddy sediments. The strong reflections seem to indicate that the wood is heavily degraded. The (supposed) wreck pieces are completely buried under a thin (>0.5 m) sediment layer. Side-scan and multibeam data do not show any objects exposed on the seafloor in the wreck site area.

HIGH RESOLUTION GEOPHYSICAL INVESTIGATIONS OF AN OLD WW1 MUNITION DUMP SITE

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In recent years several studies have been carried out on the "Paardenmarkt", a shallow sand flat offshore Heist where a considerable amount of war material was dumped after the first World War. Accurate knowledge of the total volume of dumped material is unknown, but most estimates converge to a total waste of at least 35.000 tons, of which most likely about one third consists of chemical warfare. The dumping site extends over 3 km^2, ranging in water depth between 1.5 and 5.5 m. The munition has been sagging and is largely covered under accumulating fine-grained sediments.

At this moment there are no strong indications for acute danger and the best option seems to be to leave the dump site untouched. Regular sampling of the sediments and water column is carried out, and sea-bed monitoring allows to map the erosion/accumulation processes. Ongoing research focuses on integrated 3D geophysical modelling of the dump site, both regarding the natural settings and the recent geological evolution as well as the location of dumped warfare. This integrated approach will yield an improved insight in the setting and the structure of the dump site, its ecosystem and its potential risks for the shoreline population and the users of the sea.

In July 2005 an integrated very-high-resolution seismic and geo-electric survey was carried out in a small test-area of the dump site. Additional magnetometric data were acquired one month later. The main goal of this test study was (1) to evaluate the potential of the seismo-electric method for the qualification of the shallow sediments; (2) to determine the exact thickness of the protecting sediment cover, and (3) to further delineate the exact location of the different dumping zones. During the measurements a seismic source and an array of dual-channel streamers were towed on the surface. A 60 m long resistivity cable (10 electrodes) was towed over the sea floor. A network of 17 profiles was acquired with an average line spacing of 5-10 m.

Although the presence of biogenic gas in the shallow sediments limited the penetration depth of the seismic data, some clear internal stratification can still be observed, likely due to thin sandy and/or silty layers. The shallow sediments are furthermore marked by a thin (~1 m) wedge of recent deposits. The high resistivity values indicate that this wedge consists of sandy material. Numerous nests of diffraction hyperbolae are observed, probably due to the presence of dumped material. The resistivity data show a horizontal stratification; the raw resistivity data are furthermore marked by a number of anomalies that can be linked to dumped war material, as confirmed by the magnetic data. The results clearly show that the high complementarity of the different geophysical methods proved to be an important plus-point in this integrated study.

HOLOCENE EARTHQUAKE-TRIGGERED MASS-WASTING EVENTS RECORDED IN THE SEDIMENTS OF LAKE PUYEHUE (SOUTH-CENTRAL CHILE)

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Despite South-Central Chile's high seismicity and the occurrence of earth's largest instrumentally recorded earthquake (AD 1960; M_w: 9.5), paleoseismic data is still scarce for this region. In this study, very high-resolution reflection seismic profiles (3.5 kHz) in Lake Puyehue (41˚S) were utilized to trace giant seismic events back into time. The seismic profiles show repeated occurrences of multiple mass-wasting deposits (slumps, debris flows, homogenites) occurring at a same seismic-stratigraphic horizon, indicating that they are coeval and caused by a single mass-wasting event of basin-wide importance. An age-depth model, based on 9 AMS radiocarbon datings and varve-counting on an 11 m-long sediment core, has been used to develop a "seismic chronostratigraphy". It allows dating of the mass-wasting events by interpolation between dated seismic horizons to the distal parts of the mass-wasting deposits.

The mass-wasting events are assumed to be earthquake-triggered because:
A) The recentmost mass-wasting events correlate with the devastating historical earthquakes of AD 1575 and AD 1960.
B) Synchronicity of multiple slope failures (mass-wasting events) requires a strong regional trigger, such as an earthquake. Consequently, local slope oversteepening at delta fronts or local fluid expulsion could not initiate such widespread events.
C) South-Central Chile has been historically subjected to several strong (M > 8) subduction earthquakes and subduction processes have been constantly active since Mesozoic times.
D) Multiple slope failures occur at water depths > 70 m, which rules out shallow instability triggers, such as storm wave action and lake-level fluctuations.

This study reveals nine paleoseismic events during the Holocene with a mean recurrence rate of about 1000 yr, but with an overall relatively aperiodic occurrence (ranging between 400-2000 yrs.). The most prominent event took place around 1660 cal. yr. BP, evidenced by at least 29 simultaneous mass-movements and a homogenite deposit. Quantitative comparison of mass-wasting events related to the historical earthquakes of AD 1960 and AD 1575 showed significant differences (respectively 17 and 4 observed mass-wasting deposits) although these earthquakes are assumed to have had a comparable strength. This can be attributed to a lowered sedimentation rate on the potentially unstable slopes in the period 3000 cal. yr. BP – 500 cal. yr. BP, which would have made lacustrine earthquake recording less likely in AD 1575. The absence of mass-wasting deposits associated with other historical earthquakes (e.g.: AD 1737 (M_s: 7.5) and AD 1837 (M_s: 8)) indicates that only mega-earthquakes (M_w > 8.5) within a range of about 300 km are recorded in the sedimentary sequence of Lake Puyehue.

Reflection seismic profiles also show vertical fluidisation structures with large-scale sediment injections, which disturb the upper sedimentary sequences. The top of these fluidisation structures and diverse deformation levels could be spatially linked to seismically induced mass-wasting deposits and consequently indicate an additional method for lacustrine paleo-earthquake tracing.

Several reconaissance seismic surveys on other glacigenic lakes in the Chilean Lake District also show promising paleoseismic records, which will offer the opportunity to correlate lacustrine records to reveal South-Central Chile's paleoseismic history in detail and the earthquake registration capacities of its glacigenic lakes.

TI AND AL SUBSTITUTIONS IN PHLOGOPITES FROM THE SUWALKI MASSIF-TYPE ANORTHOSITE, NE POLAND

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Intercumulus titanium-phlogopites occur in leuco- and gabbro-noritic cumulates from the Suwalki anorthosite massif, NE Poland. The degree of Ti-enrichment in the micas is variable and ranges from 2.59 to 9.48 wt.%. The variation of composition also concerns FeO (6.85-19.63 wt.%), MgO (9.79- 20.09 wt.%), with a Mg/(Fe+Mg) ratio ranging from 0.471 to 0.839, Al_2O_3 (13.17-16.75 wt.%) and K_2O (7.88-10.78 wt.%).

Substitution mechanisms for Ti and octahedral Al have been determined and suggest the presence of exchange vectors involving octahedral and tetrahedral cations. In samples characterized by the lower Ti-content (Ti: 0.144-0.213 *p.f.u*), the Ti-incorporation mechanism is:

$^{[6]}Ti^{4+} + {}^{[6]}\square = 2(^{[6]}Mg^{2+}, {}^{[6]}Fe^{2+})$,

where $^{[6]}\square$ corresponds to a vacancy in octahedral coordination. In the two groups with intermediate (Ti: 0.160-0.367 *p.f.u*) and high Ti-content (Ti: 0.489-0.557 *p.f.u*)., the Ti-substitution mechanism is different from the first group and can be represented by the substitution mechanism:

$^{[6]}Ti^{4+} + 2{}^{[4]}Al^{3+} = (^{[6]}Mg^{2+} + {}^{[6]}Fe^{2+}) + 2{}^{[4]}Si^{4+}$.

A variation of the octahedral aluminium content is only present in the two groups with the lower and intermediate Ti-content. This cation is incorporated in the phlogopite structure by the following substitution mechanism:

$(^{[6]}Mg^{2+} + {}^{[6]}Fe^{2+}) + {}^{[4]}Si^{4+} = {}^{[6]}Al^{3+} + {}^{[4]}Al^{3+}$. In the group with the higher Ti-content, the absence of $^{[6]}Al^{3+}$-substitution is related to the high K content of the samples. Indeed, this substitution is responsible for a contraction of the interlayer crystallographic site and is thus very limited in highly potassic micas.

In the twenty past years, several authors have proposed that deprotonation can be the most important Ti-substitution mechanism in high grade metamorphic and magmatic phlogopites. Deprotonation mechanism can be represented by the following reaction:

$(Mg, Fe)^{2+} + 2OH^- = Ti^{4+} + 2O^{2-+}$. In order to verify the importance of deprotonation in the phlogopites from Suwalki, an infrared spectroscopic study was carried out on the micas. The relative area of the Mg_3-OH^- absorption band is compared with the Ti-content for 8 samples. The lack of correlation between the two parameters permits us to consider the total absence of deprotonation in phlogopites from Suwalki.

THE MARGINAL GABBRO OF THE SEPT ILES INTRUSIVE SUITE (QUEBEC): CONSTRAINTS ON THE PARENT MAGMA COMPOSITION OF THE MAFIC LAYERED INTRUSION

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The composite Sept Iles Intrusive Suite (540 Ma: U/Pb on zircon; Higgins & van Breemen, 1998) is made of 4 distinct intrusions, the largest component being a mafic layered intrusion (Higgins, 2005).

An important question in any discussion of the differentiation of layered intrusions is the identification of possible parent magma composition. One way of resolving this question is to look for appropriate chilled samples from the marginal groups. A series of samples have thus been collected in the marginal gabbros outcropping at the northern contact of the Sept Iles Mafic Layered Intrusion with grenvillian gneisses. Petrographic and geochemical data were used to screen these samples for possible crystal accumulation, alteration and metamorphic origin (fine-grained mafic grenvillian gneisses). Several samples appear as good candidates for parent magma composition. They are very fine-grained gabbros (< 0.5mm) made of plagioclase, Ca-rich clinopyroxene with minor amounts of olivine and orthopyroxene. These gabbros are rich in FeO_t (14.19-16.06 wt.%), TiO_2 (2.91-4.52 wt.%) and have moderate contents of P_2O_5 (0.34-0.42 wt.%). Their REE patterns display slight LREE fractionation ($(La/Yb)_N$ = 2.46-6.40) and no Eu anomalies. These ferrogabbros are very close in composition to chilled and dyke samples from the Skaergaard and the Newark Island Intrusions which have been experimentally studied by Toplis & Carroll (1995 and 1996) for Skaergaard and by Snyder *et al.* (1993) for Newark Island.

The composition of experimentally obtained olivine and plagioclase (Snyder *et al.*, 1993; Toplis & Carroll, 1995) closely reproduces mineral compositions observed in the Sept Iles Mafic Layered Intrusion (Cimon, 1998). Also, the experimental crystallization sequence is identical to the Stratigraphic succession of the Sept Iles Mafic Layered Intrusion, indicating that these gabbros represent plausible parent magmas compositions. Liquidus mineral compositions obtained with the PELE Software (Boudreau, 1999) also support this conclusion.

THE USE OF ACOUSTIC SEAFLOOR BACKSCATTER MEASUREMENTS FOR QUANTITATIVE AND QUALITATIVE CHARACTERIZATION OF METHANE SEEP AREAS

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During the 2003 and 2004 cruises of the EC project CRIMEA almost 3000 active methane seeps were detected with an adapted scientific split-beam echosounder in the Dnepr paleo-delta area in the NW Black Sea. The seeps are widely, but not randomly, distributed over the transition zone between the continental shelf and slope, in water depths of 66 to 825 m. The highest concentration of seeps occurs on the shelf, in water depths of 80 to 95 m. Here, the location of the seeps is controlled by the underlying geology (filled channels) and seepage is characterised by the presence of pockmarks and high acoustic seafloor backscatter, visible on both multibeam and side-scan sonar data.

Since seep detection during the CRIMEA cruises was performed independently but simultaneously with the multibeam and side-scan sonar recordings, these datasets possess a great potential for quantitative and qualitative analyses of acoustic seafloor backscatter in relation to the seep locations. Our analyses are further sustained by visual observations, high-resolution 5 kHz seismic data and sediment samples from gravity and multi-coring.

For this study we selected an area of 37 km^2 on the shelf. Within this area the normalized multibeam backscatter values ranges from -28.32 dB to 20.42 dB. After eliminating high-backscatter values caused by high topographic gradients, all seep positions within this area correspond to backscatter values of more than -2.89 dB and have a standard normal distribution. Furthermore, no seeps occur at locations characterised by the highest backscatter values. Within the area, 99.3 % of the seeps correspond to backscatter values ranging between -1.39 and 4.60 dB.

These data indicate that actively bubbling seeps do not necessarily correspond to the highest backscatter values as would be expected; they rather surround the high-backscatter areas. This is also clear from visual observations in which bubbles are seen to emanate at the perimeter of white *Beggiatoa* mats. Since *Beggiatoa* mats are commonly associated with the precipitation of authigenic carbonates formed via AOM, these carbonates are very likely to be the cause of the higher backscatter values. Sediment samples and visual observation also indicated that areas corresponding to higher backscatter values are characterised by more shell material in the first 5-10 cm of the seabed.

Also pockmarks are characterised by typical backscatter patterns. Better evolved, deeper, pockmarks are characterised by higher backscatter values and the seep activity is lower than at shallow pockmarks, which are often active bubbling. This could be explained by some sort of self-sealing of these seeps, as postulated by Hovland (2002).

All these observations at the seafloor are clearly a result of the underlying geology where fluid migration is focussed to the sides of filled paleo-channels. The seismic data show the presence of a distinct “gas front” that locally domes up to the seafloor. These areas of gas front updoming on the shelf are characterised by seeps, higher backscatter values, *Beggiatoa* mats and pockmarks.

GEOLOGICAL AND MORPHOLOGICAL SETTING OF 2778 METHANE SEEPS IN THE DNEPR PALEO-DELTA, NORTHWESTERN BLACK SEA

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Gas seeps or expulsions of gas bubbles at the sea floor are widespread in the world oceans and can be found on active and passive continental margins ('cold seeps') and at the ocean spreading centers ('hot vents'). Gas seeps have engendered a substantial research effort worldwide because of their impact on the geosphere, the biosphere, the hydrosphere and the atmosphere. They can support unique endemic ecosystems of marine organisms (bacteria, tubeworms, clams, etc.) associated with authigenic carbonate or barite precipitation. Seeps also have an important economical value because they can be indications for shallow or deep hydrocarbon reservoirs.

Lately, several international research efforts have focused on how gas seeps, methane seeps in particular, can influence atmospheric methane concentrations and how they can play an important role in the global warming scenario. The EU-funded CRIMEA project focuses on this transfer of methane from the sea floor through the water column and into the atmosphere from submarine high-intensity methane seeps in the Black Sea. Our study area on the continental margin of the northwestern Black Sea is well known for the abundant presence of shallow gas and gas seeps. We studied the relation between the spatial distribution of methane seeps, sea-floor morphology and subsurface structures based on detailed multibeam, seismic and hydroacoustic water-column investigations.

During the CRIMEA expeditions 2778 new methane seeps were detected on echosounding records in an area of 1540 km^2. All seeps are located in the transition zone between the continental shelf and slope, in water depths of 66 to 825 m. The integration of the hydroacoustic and geophysical datasets clearly indicates that methane seeps are not randomly distributed in this area, but that they are concentrated in specific locations.

The depth limit for the vast majority of the detected seeps coincides with the phase boundary of pure methane hydrate at 725 m water depth. This suggests that gas hydrates, where stable, can act as a buffer for the upward migration of methane gas and prevent seepage of methane bubbles into the water column.

Higher up on the margin, gas seeps occur preferentially in particular morphological and geological contexts. On the shelf, high seep concentrations can be found in elongated depressions or pockmarks. On the continental slope, seeps are concentrated on crests of sedimentary ridges, in the vicinity of canyons or in relation with submarine landslides.

The seismic data show the presence of a distinct "gas front" within the sea-floor sediments, which is characterised by acoustic blanking and enhanced reflections. The depth of this gas front is variable and locally it domes up to the sea floor. These areas of gas front updoming coincide with areas where seeps were detected in the water column. A regional map of the subsurface depth of the gas front emphasises this "gas front – seep" relationship.

The integration of all data sets allows us to suggest that the spatial distribution of methane seeps in our study area is controlled by several factors (stratigraphic/sedimentary/structural), but mainly stratigraphic and sedimentary. The stratigraphic and sedimentary control on the distribution of methane seeps is demonstrated by the absence of seeps above parallel stratified deposits (low-permeable stratigraphic horizons). The possible seal or buffer made up by gas hydrates or sediment covers gets emphasized by the behavior of a distinct gas front that domes up to the sea floor where seeps where detected in the water column and were the possible seals or buffers are absent or negligible. The general absence of faults at the seep areas corresponds to earlier observations in Monterey Bay and it also doesn't support the hypothesis that seepage is primarily associated with tectonically driven flow through regional faults in the Dnepr paleo-delta.

GAS HYDRATES, MUD VOLCANOES AND GAS SEEPS IN LAKE BAIKAL

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Lake Baikal, a large continental rift lake in South-Central Siberia, is the only fresh-water lake with gas hydrates in its sedimentary fill. The hydrates have been sampled, both in deep boreholes and in short cores, and consist of nearly-pure methane hydrate of biogenic origin. The extent of the deep hydrates was mapped by tracing the BSR ("Bottom-Simulating Reflector") on seismic profiles: they are present in the area around the Selenga River delta, in the southern and central Baikal basins, at water depths of > 580 m.

In recent years, a series of mud volcanoes was discovered in this hydrate province: the first report involved a cluster of mud volcanoes near Posolsky Bank, and more recently two additional groups of mud volcanoes were found. They all occur in water depths of > 1000 m, within the GHSZ ("Gas-Hydrate Stability Zone") and in areas of abnormally shallow BSR, and they are closely associated to large, active faults. Methane release is not continuous and most mud volcanoes are dormant at present. The methane and associated fluids are believed to originate from destabilising gas hydrates at 200-300 m subbottom depth under the influence of a tectonically controlled geothermal fluid pulse along adjacent faults. The lake-floor sediments at these mud volcanoes often contain near-bottom hydrates.

In addition, a whole series of methane vents (i.e. without distinct morphological expression) were recently discovered in shallower areas. These venting sites occur mostly in deltaic environments (e.g. Babyshkin), but some are also associated with faults (e.g. Posolsky Bank), and they are always located outside the GHSZ. Methane release appears to be more continuous (many are now active) and the source of the methane is probably shallow subsurface methane formed by the decomposition of organic matter, although deeper sources can not be excluded.

INTAS Project 01-2309 has investigated the chemical, physical and ecological consequences of this methane expulsion from mud volcanoes or shallow seeps for the waters of Lake Baikal, and has been monitoring mud volcano and seep activity over a period of 2 years.

DIFFERENTIATION PROCESSES IN THE ALKALINE LAVA SERIES FROM BIOKO ISLAND (CAMEROON LINE)

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The Bioko Island (Gulf of Guinea) is situated in the southern part of the Cameroon Line (CL) at the ocean-continent transition zone. The CL is a major SW-NE-trending geological feature of the African plate that extends over more than 2000 km from the Gulf of Guinea to Lake Tchad. Bioko is the largest island of the oceanic part of CL, it consists of tree amalgamated strato-volcanoes. Recent volcanic activity is marked by fresh cinder cones.

All the Bioko lavas are alkaline to strongly alkaline and less differentiated than those of the other volcanic centers of CL. They consist of basanites, picrobasalts, alkali basalts and potassic trachybasalts with subsidiary shoshonite and tephrite. Many types of lava have porphyritic textures with euhedral to subhedral (1 to 5 mm) phenocrysts. The main phenocrysts are clinopyroxenes (diopside to titanian augites; $0.83 > Mg^{\#} > 0.62$) in the picrobasalts and basanites, and plagioclase (An_{62-67} Ab_{30-35} Or_{1-3}) in alkaline basalts and potassic trachybasalts. Olivine phenocrysts ($0.87 > Mg^{\#} > 0.83$) are less abundant and partially resorbed. The micro- to cryptocrystalline matrix is composed of olivine, plagioclase, clinopyroxene and magnetite.

Detailed petrographical, mineralogical and textural investigations have allowed us to subdivide the lava series in two groups:

Group 1 corresponds to the differentiated series picrobasalt -basanite - alkali basalt - potassic trachybasalt - shoshonite. The texture is essentially macroporphyritic with cpx ± pl euhedral phenocrysts (>5 mm). Resorbed olivine phenocrysts are ubiquitous.

Group 2 defines a short basanite-tephrite sequence. Texture is vesicular and microcrystalline. Cpx and pl phenocrysts are less abundant; olivine phenocrysts are absent. Amphibole microphenocrysts are found in the tephrites.

Group 1 lavas display a continuous geochemical evolution trend illustrated by the increase of incompatible elements and the decrease of MgO and compatible elements (Ni, Cr, Co) contents that can be interpreted as a liquid line of descent, from primitive basanites (10% MgO; 300 ppm Ni) to evolved potassic trachybasalts (4% MgO; 65 ppm Ni). The trend can qualitatively be explained by fractional crystallization of cpx±ol. Picrobasalts are significantly enriched in MgO (15%) and Ni (600ppm) and probably represent phenocryst-laden liquid. The chemical composition of the bulk-fractionated solid (cpx+ol+pl) is slightly enriched in SiO_2 (49 % SiO_2) when compared to the host lava (44 % SiO_2). Differentiation vectors show that group 2 lavas can be interpreted as evolved liquids derived from group 1 lavas by a two step fractionation process: 1) a high P step, at 0.3 – 0.5 GPa (clinopyroxene barometry), probably occurred in a deep magma chamber (close to Moho?); it involved olivine and diopside; 2) a low P step (in a subsurface magma chamber) that occurred during decompression (uprise of magma) and involved the fractionation of Ti-augite (a low pressure phase with high growth rate) and plagioclase. Olivine phenocrysts from the first step are resorbed during this second step. Eruptive mechanisms could have brought simultaneously and together magma batches from types 1 and 2 lavas.

EVALUATION AND MAPPING OF LOCAL SITE EFFECTS AND SEISMIC HAZARD: CASE STUDIES IN MONS BASIN AND BRUSSELS REGION

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The studies of numerous large earthquakes in the world indicate that unconsolidated surface sediments often amplify ground shaking in specific frequency bands. It results important spatial variation of damages in urban areas as most of them are built on such recent deposits. Evidences of those effects have been also identified at different sites in cities of Belgium. Since a decade, specifics studies have been initiated to investigate local seismic hazard. The main objective of those studies are to provide with a methodology and tools to estimate the spatial variation of ground shaking for future major earthquakes and then identify zones where the expected damages would be the highest. Collaborative works between geologists, seismologists, engineers and architects are in progress in the urban areas of Mons and Brussels.

FIRST STEPS TOWARDS CU AND ZN ISOTOPE GEOCHEMISTRY IN ESTAURINE ENVIRONMENTS

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The knowledge of Cu and Zn isotope systematics in low temperature environment, either natural or condition-controlled systems, has benefited of recent insights for a tenth of years. So far, it has been demonstrated that naturally occurring low temperature physicochemical processes (redox and adsorption/desorption reactions) as well as biological uptake fractionate the isotopic composition of both Cu and Zn. Moreover, application of Zn isotopes to the study of aquatic ecosystems has already validated their potential use as biogeochemical tracers in deep ocean carbonates or Fe-Mn nodules. However there are no reliable studies on heavy stable isotopes in estuarine environments that are important pathways for hydrological and geochemical cycling of metals. Moreover, in many regards, trace metals geochemistry in estuarine and coastal systems is influenced by anthropic activities. Compared to open ocean water, stronger hydrodynamic and physico-chemical gradients (in pH, dissolved oxygen,…) are commonly developed in estuaries. In response, modification in Cu and Zn partitioning between the particulate and the dissolved phase is more intense and may fractionate their isotopic composition to a greater extent as well. In order to evaluate the possibility to trace estuarine physicochemistry and decipher the relative contribution of natural processes and anthropogenic components to the Cu and Zn isotopic composition of the particulate phase, Cu and Zn elemental and isotope geochemistry has been studied in surface sediments (first top centimeters) and in suspended particulate matter (SPM). Samples were collected along a 100 km transect in the Scheldt estuary (Belgium and the Netherlands) from November 2002 to February 2006, with the systematic monitoring of environmental parameters of the water-column. Following HF/HNO3 wet acid digestion of 100 mg of sample, Cu and Zn are separated and purified by two-step ion-exchange resin chromatography on AG-MP1. Cu and Zn isotopic ratios are measured with a “Nu-Plasma” MC-ICP-MS (ULB). Instrumental mass bias is corrected by simultaneous standard-sample bracketing and external normalisation, assuming an exponential law of mass fractionation. Long term accuracy and reproducibility of in-house standards, characterized against international reference material Cu NIST and Zn JMC, are 0,00 ± 0,07 ‰ for both δ^{65}Cu and δ^{66}Zn. The analytical protocol and resin chromatography have been validated for contrasted matrix type. Spectral and non-spectral interferences (involving relevant major (Ca, Mg, Na, Fe Ba and Si) and trace (Ti, Co, Cr) elements) on Cu and Zn masses have been assessed, as well as concentration related effects on mass discrimination, for both dry and wet plasma conditions. Our very first results highlight important variations in Cu and Zn isotopic composition, of 1.80 and 0.99 for δ^{65}Cu and δ^{66}Zn, respectively, that encompass the natural range of variation for low temperature environment. Particulate Cu and Zn show sediment-SPM as well as upstream-downstream contrasts in isotopic composition. Data presently available suggest that Cu and Zn isotope compositions are dependent upon granulometry of the sample with a heavy isotopic signature associated with marine sands and a light isotopic signature associated with upstream maximum turbidity zone sediments as well as SPM of the whole estuary. Zn isotopic signatures fit a qualitative model of particulate materials dynamics of the Scheldt estuary (Baeyens et al., 1998). New results on Cu and Zn isotopic compositions will be presented.

SULPHIDES AND SELENIDES FROM THRUST-SLICE 2400, MUSONOI MINE, KATANGA, D.R.CONGO

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Mineralogical studies on the Cu-U-Se mineralization of the '*écaille 2400*' (thrust-slice 2400) of Musonoï Extension mine has permitted to better characterize sulphides and selenides minerals from this Cu-Co kolwezian deposit.

Copper-bearing phases such as chalcocite Cu_2S, digenite Cu_9S_5, covellite CuS, or berzelianite $Cu_{2-x}Se$, and cobaltiferous species as carrollite $Cu(Co,Ni)_2S_4$, and trogtalite $CoSe_2$, have been identified in the Roan.2 dolomitic sandstones. The identification of the minerals are confirmed by optical studies, X-ray powder diffraction data and electron-microprobe analyses. The sulphides and selenides occur as a cement between of quartz grains or sometimes as carbonate-sulphides veins going through host rocks. The samples are frequently deeply altered in malachite but some mineralogical and petrographical features can still be investigated.

Sulphides generally show a sulphur-selenium replacement giving interesting mineralogical and crystallographical properties. Se-digenite seems to show optical properties between those of digenite and berzelianite, with a blue-shift of its hue, as well as a noticeable increasing of the unit-cell parameter with the selenium content, according to Vegard's law. Se-blaubleibender covellite, $Cu_{1+x}(S,Se)$,has also characteristic features under ore microscope with a typical yellowish colour.

Paragenetic relations between those minerals show three different stages for the crystallization of these metallic phases. An early precipitation of sulphides without selenium would occur with chalcocite, digenite and carrollite probably related to a complete replacement of pyrite as it has been observed at Kamoto Principal. Then, a metasomatic stage has enriched the deposit in numerous elements (U, Se, V, Mo, Pb, Cr) creating notably the selenium-bearing phases Se-digenite, berzelianite, trogtalite and PGE-selenides. This association seems to crystallize at temperature around 200°C. Later on, hydrothermal and meteoric alteration deeply oxidized the deposit due to its intense fracturation and karstic features. Fluids running through these conducts have leached the copper out of the sulphides forming Se-covellites lamellae along the cleavages of digenite as well as some released gold which precipitates as minute grains in malachite.

THERMAL SIGNALS IN GAS HYDRATE SEEPS AND MUD VOLCANOES: NEW INSIGHTS IN A HIGHLY DYNAMIC SYSTEM

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Fluid seeps, gas seeps, mud volcanoes and mud mound are global phenomena known for over 200 years, but only recently the submarine occurrences are mapped and investigated in detail and it has become evident that they are the unique sites of near-surface gas hydrate occurrence. Seeps, mud volcano and mounds are local seafloor venting structures resulting from focused upward migration of warm fluids, sometimes along with ascending mud diapirs or extrusions. The thermal field at these structures is heavily affected by transient effects and mass convection, and by the presence of a dynamic hydrate system. By studying the thermal signals we can learn more about the complex dynamic systems of fluid flow, mud extrusion and hydrate formation and dissociation.

Detailed thermal studies in seeps and mud volcanoes exist in Lake Baikal (seeps), in the Gulf of Mexico (Bush Hill seep), in the Okhotsk Sea (Chaos seep), Black Sea (Dvurechenski mud volcano), on the Barbados accretionary wedge (mud volcano), in the Norwegian Sea (Hakon Mosby mud volcano), on the Costa Rica forearc (Mound Culebra) and on the Cascadia accretionary wedge (Hydrate Ridge). These studies have revealed that all structures are associated with enhanced heat flow (often around 150-200 mW/m2, but up to 15000 mW/m^2) and elevated temperatures (up to 20ºC). Heat flow anomalies generally peak at one or more sites near the center and concentrically decrease away from it. At 1-2 km away from the structure most thermal anomalies completely disappear. Within the seep centers and mud volcano craters non-linear temperature profiles and thermal gradients varying over short distance are typical. Most thermal conductivity measurements of mud volcano sediments returned increased values of 1.1-1.2 W/m/K compared to 0.7-1.0 W/m/K for surrounding sediments.

Heat-fluid modeling suggest that the anomalous thermal signatures at seeps and mud volcanoes often result from the advective heat transport by upflowing warm fluids and by the conductive lateral heat loss. In these cases, the thermal constraints can also be used to estimates for fluid migration velocities and source depth of fluids. However, other processes can also contribute to anomalous thermal signals in seeps and mud volcanoes: topographic effects (e.g. Mound Culebra), surface mud flows (e.g. Hakon Mosby), and the formation and dissociation of gas hydrate near the sediment surface.

The presence of gas hydrates in seeps and mud volcanoes at sufficient water depths (>300 m, mostly >1000 m) appears to be very common. As the stability of hydrates is depending on parameters that can be strongly variable in a seep and mud volcano environment (temperature, pressure, salinity, gas and fluid supply), the hydrate system is believed to be a highly dynamic system. Formation of hydrates will be associated with heat production and dissociation of hydrates with heat absorption. Thermal modeling shows that near a hydrate layer heat flow anomalies of more than 2-10 W/m^2 can result during hydrate formation. Thermal signals related to the presence of near-surface hydrates have been interpreted in both thermal conductivity measurements and temperature measurements (Baikal seeps, Dvurechenski mud volcano, Bonjardin mud volcano).

The lower limit of gas hydrate occurrence within the sediments is often recognized as a bottom simulating reflection (BSR) on seismic data. BSR have been traced in many areas, also near and around seeps and mud volcanoes. Within these seeping structures, however, they are generally disrupted with only uplifted enhanced reflections remaining. Recently, the first continuous BSR reflector has been traced throughout the mud conduit of the Al Idrissi mud volcano (Gulf of Cadiz). The presence of this BSR gave the opportunity to estimate the thermal gradient within the seep structure at sub-bottom depth of 10s to several 100s of meters. Calculations resulted in gradients up to 1000 mW/m^2 in the crater of the mud volcano.

Seeps, mud volcanoes and mounds are highly dynamic flux systems and sites of near-surface hydrate occurrences. In order to better understand these structures of economical and ecological

interest, detailed investigations of thermal parameters are important as they can help to constrain and quantify the hydrate and gas-fluid-mud flow systems.

A QUADRUPLE BSR IN THE BLACK SEA: A POTENTIAL PROXY OF PAST CLIMATE CONDITIONS ?

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A previously unknown pattern of double, triple and quadruple Bottom-Simulating Reflections (BSRs) occurs on high-resolution reflection seismic data in the Danube deep-sea fan, associated with acoustic features indicating free gas. Our study provides evidence that this pattern is developed in relation with the architecture of distinct channel-levee systems of the Danube fan. Channel-levee systems hosting multiple BSRs act as relatively well-sealed gas-bearing systems the top of which is situated above the base of the gas hydrate stability zone (BGHSZ). Inside these systems, free gas accumulates below the BGHSZ under a combined lithological, structural and stratigraphical control.The uppermost BSR marks the current equilibrium BGHSZ, for a gas composition of more than 99 % methane. Model-derived depths of the BGHSZ for different gas compositions and pressure-temperature conditions show that multiple BSRs would correspond to the BGHSZ either for (1) layers of gas hydrates with high contents of heavy hydrocarbons or hydrogen sulphide, or (2) stable climatic episodes with temperatures between glacial values and the present-day conditions. As the gas hydrate compositions required by hypothesis (1) are in sharp contradiction with the general background of the gas composition in the study area, we suggest that multiple BSRs are most probably relics of former positions of the BGHSZ, corresponding to successive steps of climate warming. In this case, they can provide sea-bottom paleotemperature values for these episodes, and hence they are potential new proxies for deciphering past climate conditions.

U/TH DATING OF A NEAR WATER-TABLE SPELEOTHEM IN THE CAVE OF HAN-SUR-LESSE – IMPLICATIONS ON GEODYNAMICS EVOLUTION OF ARDENNE

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Close to the resurgence of the Lesse River from the hill of Boine (Han-sur-Lesse), the gallery of "Grandes Fontaines" ends by a little lake of a quiet water. In this lake, there is a speleothem. The upper part (approximately 60 cm) is above the water surface, more of 50 cm is under this surface, which represents the local water table because the altitude of the lake surface fluctuates like the level of the Lesse River. The development of this speleothem began when there was no water in this area. The altitude of the water table was lower then now. Thus, the chronological study of this speleothem can give some data about the past fluctuation of the water table and thus about the evolution of the basis level.

We have drilled the speleothem and obtained a core of 1.10 meter long. The lithostratigraphy shows a horizontal stratification along 70 cm. Lower, the drilling cut the side of the speleothem with oblique strata. We have made 6 U/Th datings along the core. The summit is 10.5 ky old and the lower sample (70 cm deep) is 25.0 ky old. There is a good correlation between the lithostratigraphy and the radiochronology.

There are two important conclusions. First, from paleoclimate point of view, the speleothem grew during a cold period (around 20.0 ky). It is possible that more detailed datings will show a irregular development in agreement with the Dansgaard-Oeschger oscillations. We have yet had some speleothems which grew during some interstadial periods with an opened cover of Betula. Second, during some time in the isotopic stage 2, the altitude of the water table was at least between 0.7 to 1 m lower than its present level. In the future, we shall must integrate those data in the sedimentary evolution of the cave like we have reconstructed from other caves deposits.

CONTRIBUTION OF ELEMENTAL AND LEAD ISOTOPES GEOCHEMISTRY TO ARCHEOLOGY IN A BELGIAN PEAT BOG (HAUTES FAGNES)

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A recent archaeological excavation in a Hautes Fagnes peat bog allowed to exibit a new part of an ancient paved road buried in the peat. In spite of the numerous studies concerning this road, its age and purpose are still discussed. Elemental geochemistry and lead isotopes analysis were achieved on two peat columns taken on each side of the road. Six samples have been radiocarbon-dated. Two pollen profiles and slides made from impregnated peat complete the study. Depth profiles of element concentrations display parallel zinc and lead enrichment peaks. Silicium profile displays sharp increase related to small quartzite fragments and clay dropped in the peat during the construction and use of the road. Lead isotopic ratios of peat with high lead concentrations are similar to lead isotopic ratios of Verviers synclinorium Pb-Zn ores. These results suggest that the road could have been used for the transport of Pb-Zn ores during the late Roman and/or Merovingian times.

PLEISTOCENE COASTAL EVOLUTION AND SEA-LEVEL CHANGE OF THE LOWLANDS OF WESTERN BELGIUM: THE RECORD FROM THE WOUMEN BOREHOLE, NEAR DIKSMUIDE

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Woumen is located at the eastern margin of the western coastal plain of Belgium. The plain got its current configuration along the river IJzer during the Holocene and extends about 20 km inland. Pleistocene deposits of marine origin occur locally across the plain beneath a wedge of Holocene transgressive sediments and overlying stiff clays of Eocene age. Until recently, these deposits were hardly known, except in a few localities where they were correlated with the Herzeele Formation (Holsteinian Stage) of northern France. However, deep cores undertaken as part of the geological mapping programme have revealed that Pleistocene deposits occur extensively in the region (except where eroded during the late Holocene) and their sediment succession shows considerable diversity. Lithological characteristics, sedimentology and morphological and stratigraphical position show that they represent a complex infill of a major valley in which the vertical sequence consists of alternating fluvial and estuarine deposits of Middle and Upper Pleistocene age. In contrast to the eastern coastal plain, Weichselian coversand is absent. The Pleistocene deposits are laterally discontinuous, representing successive phases of erosion and accumulation during low and high sea-level stands, respectively. Erosion was not general, but restricted laterally and the margins of the valley remained intact. This major valley, which trends in a SE-NW direction is also present in the top of the Eocene strata and shows a striking resemblance with the morphology of the top of the Pleistocene deposits. This valley was later invaded by the sea and filled during the Holocene.

This paper presents new biostratigraphical data from a deep (12 m) sediment core from Woumen near Diksmuide, on the margin of the present-day IJzer valley. The core is located in a part of the valley that escaped erosion. Uniquely for this region, the Woumen core includes two well developed organic units, interbedded with fine-grained clastic sediments of fluvial and estuarine origin. The lower organic unit (depth 4.5 – 7.3 m) has yielded a temperate pollen assemblage dating from the early temperate substage of an interglacial, a time when oak and other thermophilous taxa were expanding in the regional forest. Dominant pollen taxa include *Corylus, Quercus* and *Ulmus*. The presence of low frequencies of salt-marsh pollen and the associated occurrence of low numbers of foraminifera confirm that this deposit accumulated in a marginal marine or estuarine environment. The upper organic deposit (depth 1.5 – 1.9 m), which is thinner, but more peaty in character, has yielded temperate pollen dominated by *Tilia*, *Alnus* and *Quercus* pollen. The sporadic occurrence of brackish and marine diatoms in the upper part of this unit confirm a distal marine origin. Palynomorphs of intertidal orgin also occur intermittantly lower down in the Woumen succession (depth 10.60 – 11.10 m). The absolute age of the three fossiliferous deposits and the associated implications for regional coastal evolution and sea-level change during the Pleistocene are discussed.

THE STUDY OF PUSHTE-JANGAL ANTICLINE IN NORTHEAST OF KUHDASHT

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The northeast of Kuhdasht in Zagros folded zone are formed from different structural and geomorphologic phenomenon .The purpose of this paper is study of Pushte-Jangal anticline and search about existence of hydrocarbons in it. The method of study include preparation of base map, field geology and laboratory activities. Amiran and Gurpi formations are the most exposed in Pushte-Jangal anticline. The conclusions show that these folds are parallel folds and I used from Busk (1929) and Higgins (1962) methods to draw structural cross sections. In this anticline Asmari hydrocarbon has been destroyed by erosion in Gachsaran formation and fractures of Asmari formation. Khami and Dehram formations are store rocks, Gotnia and Kangan formations are covering rocks.

Key words: Kuhdasht, anticline, base map, structural cross section, parallel fold.

Cancelled

NEW DATA ON BIRD REMAINS FROM THE TYPE MAASTRICHTIAN (LATE CRETACEOUS, SE NETHERLANDS AND NE BELGIUM)

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The medium- to coarse-grained biocalcarenitic deposits that constitute the upper Gulpen Formation and overlying Maastricht Formation in the type area of the Maastrichtian Stage (SE Netherlands, NE Belgium), are extremely poor in remains of birds (i.e., avian dinosaurs), even more so than skeletal elements of non-avian dinosaurs (Weishampel *et al.*, *Geologie en Mijnbouw* 78, pp. 357-365, 1999; Jagt *et al.*, *Compte Rendu Palevol* 2, pp. 67-76, 2003).

So far, a single fragmentary individual (Natuurhistorisch Museum Maastricht collections, NHMM RD 271) of an ornithurine bird has been described from the basal Valkenburg Member (Maastricht Formation) at the CBR-Romontbos quarry, Eben Emael (Liège), dated at c. 65.8 Ma. This specimen (Dyke *et al.*, *Naturwissenschaften* 89, pp. 408-411, 2002) comprises thoracic vertebrae, dentaries, an incomplete right humerus, the distal end of the right ulna, the scapular blade, a proximal tarsometatarsus and a piece of the right coracoid, plus a single tooth. It is of note in demonstrating that archaic members of Ornithurae persisted until the end of the Cretaceous, at least in mainland Europe. NHMM RD 271 is closely similar to the North American *Ichthyornis*, but is about twice the size of the largest specimen known of that genus. Current work on NHMM RD 271 includes further preparation of additional bones from the matrix block, so that all available material of this individual can be viewed three dimensionally.

Subsequent to this find, new material has come to light from the same area (Ankerpoort-Marnebel and CBR-Romontbos quarries), and this includes a forelimb bone (the proximal end of a radius; NHMM K 4101), a hindlimb bone (the distal end of a tarsometatarsus; NHMM K 4925) as well as a single tooth (M. van Es Colln., no. 3), different in many respect from the one associated with NHMM RD 271. The radius at least suggests the presence of the diverse Cretaceous clade Enantiornithes in the Maastrichtian type area.

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ABOUT BOUDINS AND MULLIONS IN THE HIGH-ARDENNE SLATE BELT

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In 1908 the terms boudin and boudinage have been coined by M. Lohest, X. Stainier and P. Fourmarier in the Bastogne area to describe sausage-like structures occurring in the psammite layers of the Lower-Devonian series of the High-Ardenne slate belt. These sausage-like segments, lying side by side, were, moreover, bounded by a remarkably parallel array of quartz veins. From the beginning, a discussion on the mechanisms forming these structures unfolded, wondering whether or not quartz veining and the development of the cuspate-lobate morphology of the psammite-pelite interfaces occurred simultaneously.

In the current manuals on structural geology the term boudinage is used to define the process of the disruption of layers, bodies or foliation planes within a rock mass in response to bulk extension along the enveloping surface. This kinematic definition stirred the ongoing controversy, primarily because the Ardenne structures did not comply with the modeled geometrical constraints of structures resulting from the process of boudinage. In an attempt to reconcile the process-oriented definition of boudinage with the geometrically atypical Ardenne structures, the idea of 'shortened boudins' has been postulated.

Extensive research efforts, focusing on the geometrical and physico-chemical vein-quartz characteristics, the microfabrics and the modeling of the particular cuspate-lobate interface-morphology, have recently allowed to put forward a consistent and satisfying model to explain the kinematics of these structures, eventually solving the 'boudinage question'. It has been demonstrated that the Ardenne structures are the expression of a polyphase deformation history in brittle-ductile deformation conditions at the onset of the Variscan orogeny. Hydraulic fracturing caused the formation of the quartz-vein arrays, while layer-parallel shortening is responsible for the cuspate-lobate morphology of both the upper and lower interfaces of the psammite layers. Taking into account the currently acknowledged geological nomenclature, the sausage-like structures as we observe them now in the High-Ardenne slate belt, should be described as mullions, or even as double-sided mullions, referring exactly to the process of layer-parallel shortening leading to the cuspate-lobate morphology of folded interfaces. In this respect, it should be noted that the textbook example of mullions is indeed also found in the High-Ardenne slate belt, i.e. at Dedenborn. The geometrical characteristics of the cuspate-lobate interface-morphology even turned out to be a palaeorheological gauge, indicating Newtonian behaviour of the middle crust during Variscan deformation.

Notwithstanding the fact that the kinematics giving rise to the particular structures in the High-Ardenne slate belt are not related to the process of boudinage, it should be strived for to create – as is the case at Dedenborn for mullions – a heritage site at Bastogne, still the locality where the terms boudin and boudinage have been used for the fist time. Moreover, the High-Ardenne slate belt should be promoted as an unique natural laboratory to study the brittle-ductile deformation behaviour in the middle crust as exemplified by these exceptional structures.

LITHOLOGICAL DESCRIPTION AND GRANULOMETRIC STUDY OF THE EALDEN FACIES IN TWO BOREHOLE CORE DRILLED IN THE « CRAN AUX IGUANODONS DE BERNISSART » (N-W OF THE MONS BASIN, BELGIUM)

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In 1878-1881, a very rich and well-preserved Cretaceous fauna and flora was discovered in the Wealden facies "trapped" in a natural pit at Bernissart. It includes the world-famous 30 complete *Iguanodon* skeletons, which led to a new view on the anatomy of those dinosaurs. Nowadays, several new researches document the paleoenvironments, the paleoecology and the precise age of those Wealden strata.

The aim of this poster is to provide a complete lithological canvas of the Wealden strata of Bernissart, still poorly know. The studied material comes from two boreholes called BER2 and BER3 drilled in 2003 in the "cran aux iguanodons de Bernissart". A first correlation between them is proposed, according to the granulometric profiles of the Wealden facies.

The Wealden strata crossed by the two boreholes are quite homogeneous. They are composed of a succession of laminated sediments, containing brown to black clays, including variable quantities of silts. The organic matter is often present in rich proportions, colouring the lamina in black. Former studies showed the presence of a mix of fern spores and pollen grains of both gymnosperms and angiosperms in it.

Granulometric study has been performed on the Wealden facies of the two boreholes. The results allow us to define three different zones within the Wealden strata, based on the mean of their D(v,0.9) parameter. This parameter can also be used to correlate the BER2 and BER3 boreholes, since it presents a similar evolution in both of them. The fact that the BER2, drilled on the external part of the natural pit, contains coarser grains that those of the BER3 documents us about the paleoenvironment of the *Iguanodons*.

HYDRAULIC AND BRITTLE EXTENSIONAL FAULTING IN THE WEALDEN FACIES OF HAUTRAGE (MONS BASIN, BELGIUM)

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In Belgium, the Wealden facies are mainly localised on the north edge of the Mons Basin, where they appear in pluri-kilometric sized "pockets". The Hautrage Clay Formation (Middle Barremian to Earliest Aptian in age) is composed of continental clays, silts and sands. It is nowadays interpreted as a flooding plain environment crossed by many channels. The interest of this study lie in the fact that the observed deformations affect the more ancient sediments of the Mons Basin, the Wealden facies. And up to now, little was known about the tectonic history of these sediments, mainly because of the lack of detailed outcrops.

Due to recent excavating campaigns in the Hautrage clay pit, an interesting outcrop composed of a multi-faulted channel complex has been revealed. Its complete lithological profile has been described, and different sections have been done to constrain the channel's geometry. The channel appears as a succession of white sands (containing a variable quantity of lignite remains and pyrite) alternating with brown to black clay beds, rich in organic matter.

Different types of faulting are observed on the studied outcrop. It includes hydroplastic faults with various clay injections along the fault planes, associated with complex features of plastic deformations. In addition, brittle faults organised in grabens are observed, inducing a plurimetric displacement of the channel basal bed. A preferential orientation of these faults is measured around N100°E. This tectonic event can be related with the major regional movements occurring elsewhere at this particular period, coinciding with the beginning of the tectonic subsidence of the Mons Basin. Some organised systems of joints are also found, mostly oriented NW-SE, mainly related to younger dynamic, widely recognized in the region. In consequence, the understanding of the tectonic mechanisms affecting the Wealden facies document the original processes giving birth to the basin itself, during the continental period.

Moreover, some textural analyses are realised on the clay matrix localised along both sides of the faults, in order to establish the different faulting process, and their influence on the clay texture. It includes petrophysical analysis such as sonic and MEB observations, and mineralogical analysis.

NO IMPORTANT HIATUS IN THE LATE WESTPHALIAN C AND EARLY WESTPHALIAN D STRATA OF THE CAMPINE BASIN (NORTH EASTERN BELGIUM).

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A contribution by van Amerom & van Tongeren (2002), based on plant macrofossils, claims that a large hiatus is present in the Westphalian of well KB 146 in the Campine Basin. Both the upper part of the Late Westphalian C as well as all the Early Westphalian D should be missing. These conclusions are in contradiction with former data (Dusar 1989) allowing this well to be correlated, coal beds by coal beds, with all other wells traversing the same stratigraphical intervals in the Campine Basin. However van Amerom & van Tongeren (2002) did not take into consideration the detailed palynological work which has been carried out in this basin since many years and which would have invalidated their conclusions. Having analysed the respective arguments, we reject the presence of a large hiatus in well KB 146 in the Campine Basin and the Westphalian D plant macrofossil based dates proposed by van Ameron and van Tongeren (2002).

STABLE LEAD ISOTOPES RATIOS IN A MULTI-SOURCE POLLUTED ENVIRONMENT : THE SCHELDT ESTUARY

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Pb isotopes are now well-known to be used, in environmental studies, as a powerful tool for tracing Pb origins. A large variety of materials (atmospheric aerosols, lake sediments, peat, ice cores, ...) have already been investigated, but riverine and estuarine systems remain significantly less documented. However, estuaries constitute key areas, located at the interface between continental freshwaters and marine waters, and characterized by very dynamic biogeochemical and physical properties (contrasting with the state of quasi-equilibrium of oceans and lakes). Estuarine problematic can be summarized by two major characteristics: (i) the long residence time of both waters and particles and (ii) the multiplicity of the particulate matter sources. This is particularly true for the macrotidal estuaries such as the Scheldt estuary that shows the additional specificity to be one of the more polluted estuary in particulate trace metals of western Europe.

The principal objective is to evaluate how Pb isotopes can be used as reliable tracer of estuarine physico-chemical processes and multiple particle sources in a polluted environment.
Surface sediments and suspended particulate matter (SPM) were collected in the Scheldt estuary along a salinity gradient and in the Belgian coastal zone. After a classical digestion of the samples using sub-boiled HF-HNO3-HCl in Savilex teflon beakers, Pb fractions were obtained by a one step-chromatographic separation. Pb isotopic compositions were analysed on a Nu Plasma MC-ICP-MS at ULB. Pb/Tl ratios for the samples equalled ~5, reproducing the Pb/Tl value of the standards. The total Pb ion beam intensities varied from 20 to 40 V/ppm. During the analysis sessions, 44 analyses of the NBS981 Pb standard gave mean values of $^{208}Pb/^{204}Pb$ = 36.7151 ± 0.0027 (2SD), $^{207}Pb/^{204}Pb$ = 15.4967 ± 0.0010 and $^{206}Pb/^{204}Pb$ = 16.9401 ± 0.0011.

As a whole, $^{206}Pb/^{207}Pb$ data (1.15407-1.18290 ± 0.00002 (2SD)) are strongly correlated with $^{208}Pb/^{207}Pb$ and salinity values. This reflects a main control of variations in Pb isotopic composition, and Pb concentration, by the relative contributions of marine ('natural' component) and fluvial (anthropogenic component) inputs. In the middle-estuary, Pb isotopic compositions of the SPM are comparable to those of the underlying sediments, suggesting a long residence time of particles and recurrent sedimentation-resuspension cycles. In contrast, at the marine stations, considerable isotopic differences are observed between the sediments and the SPM signatures (dominated by the fluvial/anthropogenic component) which may reflect a low SPM deposition. Both the $^{208}Pb/^{207}Pb$ vs. salinity profile and the mixing plot (inverse of Pb concentration vs. the $^{208}Pb/^{207}Pb$) put the stress on two areas, particularly under the influence of anthropogenic inputs: the estuarine turbidity maximum ($^{208}Pb/^{207}Pb$ = 2.4569 and 2.4543) and the mouth ($^{208}Pb/^{207}Pb$ = 2.4487 and 2.4506). The sources of these contaminations are probably related, respectively, to waste waters outputs of the Antwerp city (km 80) and either the Ghent city outputs via the Ghent-Terneuzen Canal (km 20), or the input in the Scheldt estuary of polluted coastal water masses flowing from the Rhine/Meuse estuary. Further investigations will be performed to better constrain the origin and relative contribution of those Pb pollution sources.

KINEMATIC SIGNIFICANCE OF AN ANGULAR UNCONFORMITY DURING PROGRESSIVE SHEAR DEFORMATION: EVIDENCES FROM THE SOUTHERN BORDER OF THE LOWER PALAEOZOIC ROCROI INLIER (NAUX, FRANCE)

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A detailed structural analysis at the southern border of the Lower Palaeozoic Rocroi inlier (Gire and Semoy valley, Naux, France) revealed that the structural heterogeneity, inherent to an angular unconformity may result in a completely different deformation style in both cover and basement. These new insights contribute to the ongoing discussion whether or not a penetrative Early Palaeozoic tectonometamorphic event – called the Ardennian orogeny - affected the Lower Palaeozoic Ardenne basement inliers, outcropping in the culmination zone of the High-Ardenne slate belt. The main argument in favour of an Early Palaeozoic event is the certain presence of an angular unconformity. Moreover, the occurrence of complex structures within the basement, suggesting a polyphase deformation history, in contrast tot the cover sequence on top of the unconformity, lacking any complex deformation, is considered to be conclusive with respect to an early deformation event. Although the structures in the basement are co-genetic with the cleavage development, only one pervasive cleavage can be recognized at the unconformity, affecting both the basement and the cover. These contradicting observations have given rise to the ongoing discussion about the importance of the Early Palaeozoic tectonometamorphic event.

In order to contribute to this ongoing discussion we focused on some outcrops at the southern border of the Rocroi inlier, were the basement-cover interface is locally well-exposed. This particular strategy allowed a clear identification of the deformation history in both the basement and the cover.

At the basement-cover interface only one cleavage could be observed, representing a shortening of ~50% in both the cover and the basement. This shortening is, however, only present in the incompetent layers and is less intense in the competent layers as expressed by the cleavage refraction pattern, clearly perceptible above the unconformity. This cleavage refraction pattern in the cover sequence implies that during the onset of the Variscan deformation, the shortening was more or less parallel to the bedding and formed an incipient cleavage perpendicular to bedding. During the subsequent progressive shear deformation, the deformation, however, mainly occurred in the pelitic horizons, resulting in a decrease of the cleavage-bedding angle in these layers (30-35° in the slates), while the cleavage planes in the competent layers only underwent passive rotation and remained relatively steep (>60° in the sandstones). This top-to-the-north shear deformation had a completely different effect on the strata in the basement underneath the angular unconformity. After the development of a vertical incipient cleavage in both basement and cover, further shortening of the pelitic horizons in the tilted basement forced the competent layers, which were badly oriented to the imposed shortening, to buckle or to be boudinaged, depending on their orientation with respect to the finite strain ellipsoid. In the sandstones, this buckling caused the passive rotation of the incipient 'frozen' cleavage, while cleavage further developed in the pelites, giving rise to a slaty cleavage that is identical to that developed in the pelitic horizons in the cover sequence.

The contrasting deformation style on both sides of the angular unconformity can thus be explained entirely by a contrasting behaviour with respect to one single progressive shear event. Both are linked by a common structural feature, the – Variscan – penetrative cleavage. The contrasting deformation style can therefore not be used as a conclusive argument in favour of an Early Palaeozoic tectonometamorphic event.

HYDROLOGY AND GRAVITY AT THE MEMBACH STATION, BELGIUM

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We investigate the hydrological processes and their influence on gravity at the underground Membach station (eastern Belgium), where absolute (AG) and superconducting (SG) gravity measurements have been performed since 1996. The gravity station was excavated in low-porosity argillaceous sandstone. Geophysical prospecting showed that the thickness of the weathered zone covering this bedrock can be highly variable between zero and 10 meters. To quantify the gravity effect induced by the hydrological variation above the Membach station, we use the time series from the soil moisture probes that were installed in 2004 in the shallow upper 60 cm partially saturated zone, 48 m above the SG. Using the inferred gravimetric water content, a digital elevation model and a spatial discretization of the weathered zone in rectangular prisms, the gravitational effect of the prisms on SG data was calculated and compared with the gravity effect inferred from a regional water storage model.

With an improved understanding of the hydrological effects, we were able to remove successfully the seasonal variation as well as short decreases in gravity due to rainfall. By its ability to remove the seasonal effects, this study will help to monitor long term gravity change induced by tectonics and post-glacial rebound. This work can also be essential for hydrologists in closing water balance or to correct local effects that can mask time variation of regional or continental gravity field such as changes in continental water storage. For example, local hydrological effects could prevent the combination of satellite data (e.g. GRACE) with ground-based gravity measurements.

QUARTZ VEINING IN THE HIGH-ARDENNE SLATE BELT. NEW EVIDENCES FROM THE RURSEE AREA, NORTH EIFEL, GERMANY

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The outcrops studied along the shores of the Rursee are located in the North Eifel (Germany), forming the north-eastern peripheral, anchizonal part of the High-Ardenne slate belt (France, Belgium, Germany), situated in the front zone of the Central European Variscides. The outcrops expose thick Pragian-Emsian pelite-siltstone-psammite sequences. Detailed structural field work shows that the area consists of closed, cylindrical, NW verging, slightly overturned folds with fold hinges that plunge to the northeast. In this respect they differ from the open, cylindrical, N-verging, upright folds within the central, epizonal part of the High-Ardenne slate belt (Bastogne area).

The good quality of outcrops allows us to classify different pervasive quartz vein sets throughout the area. *(1)* A conjugated vein set developed perpendicular to bedding and *parallel* to the fold hinge lines. The majority of these veins are restricted to the competent psammite layers. Their shape varies from hairline veins up to lensoid, blocky quartz veins and sometimes show a curved curvature, caused by flexural drag. Similar bedding-perpendicular veins are present in the central part of the High-Ardenne slate belt, where they form a parallel vein set. It has been demonstrated that these bedding-perpendicular veins are the result of a hydrofracturing event at the onset of the Variscan orogeny. *(2)* Bedding-perpendicular veins, (*sub)perpendicular* to the fold hinge lines, are disposed in an en-échelon arragement, indicating shear during vein formation. The latter veins are mostly observed on the bedding plane of the inverted limbs and crosscut the former group. Internal deformation affecting both vein sets (e.g. vein buckling) suggests ongoing layer-perpendicular compaction after vein development. It is therefore fair to assume that the formation of both bedding-perpendicular vein sets occurred during the burial stages in the Ardenne-Eifel basin.

Contrary to the central part of the High-Ardenne slate belt, where the bedding-perpendicular veins acted as rigid bodies during the subsequent layer-parallel compression, eventually leading to the buckling of the pelite-sandstone interface in between the veins and the development of mullions, layer-parallel deformation is expressed differently in the peripheral part of the belt. *Bedding-parallel (3)* veins occur and have an complex internal structure, consisting of different generations of quartz laminae intercalated with pelitic (host rock) brecciated fragments. Each lamina is marked by slickensides. Slickenlines are uniform in trend on individual lamina but slightly differ from orientation from lamina to lamina. Mostly, these slickenlines reflect flexural-slip related to folding. Some slickenlines, however, are oriented parallel to fold hinge lines, indicating a bedding-parallel movement prior to folding.

All vein sets are considered to have developed early in the deformation history, because they are all overprinted by the progressive folding and development of a slaty cleavage within the pelitic layers. The cleavage refracts through the bedding-perpendicular veins and fan out against the bedding-parallel veins due to the competence contrast at time of the cleavage development.

Further research efforts will concentrate on a microstructural fabric analysis of all vein sets and microthermometry of the primary fluid inclusions of vein quartz in order to determine deformation mechanisms and deformation conditions (temperature, confining pressure, fluid pressure, fluid chemistry, …) at time of the veining respectively.

OFFSHORE RECORD OF BRITISH-IRISH ICE SHEET FLUCTUATIONS DURING THE LAST GLACIAL CYCLE: IMPLICATIONS FOR DEEP-WATER SEDIMENTATION

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During the late Pleistocene, cold-warm fluctuations (Heinrich and Dansgaard-Oeschger events) have been detected in the polar ice sheet of Greenland and correspond in deep-sea cores to the input of ice-rafted debris (IRD). During these HE and DOE major freshwater input, detected in the isotopic composition of foraminifera and led to major circulation configurations. The formation of North Atlantic Deep Water (NADW) was significantly weakened, with the reduction of bottom current flow. Such effects have been documented in many sediment drifts in the North Atlantic basins. Each ice sheet, however, has its own dynamic behavior, which obviously becomes more pronounced closer to the margins. Such effects have been clearly documented close to the British-Irish Ice Sheet (BIIS) where the North Atlantic Heinrich layers (HL) are "sandwiched" between layers of local IRD.
Here, we present data of long cores located on the eastern slope of the Porcupine Seabight, SW of Ireland. These cores have been taken within the framework of the IMAGES programme and the past EC FP5 GEOMOUND project in order to better understand the palaeoceanography of this area.

On several locations along the slope, large cold-water coral banks are clustered in different provinces such as the Belgica mound province on the eastern slope. Their presence is thought to be closely related with local environmental factors such as topography and the hydrodynamic regime). Cores MD99-2327 and MD01-2449, respectively located at 651 m in the Belgica mound province and at 435 m south of this province document the influence of the destabilization of the BIIS on the local sedimentary regime. Although the glacial period is dominated by a high frequency of local ice-rafting events, several distinct "Heinrich"-like events can be inferred. However, cores located more to the north of the basin do not longer show the dominant BIIS signature and clearly show the presence of typical HL.
Both cores MD99-2327 and MD01-2449 also demonstrate that a slight change of environment, combined with changing palaeoceanographic conditions might lead to a different sedimentary facies. In core MD99-2327 located close to the cold-water coral banks, cold (glacial-stadial) and warm (interglacial-interstadial) periods are characterized by the presence of respectively muddy/silty and sandy contourites. This effect is less pronounced in core MD01-2449, which is located further from the cold-water coral banks.

ORIGIN, CONTROL AND EVOLUTION OF CONTOURITE DRIFTS ASSOCIATED WITH COLD-WATER CORAL BANKS, OFFSHORE IRELAND

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Numerous investigations on contourite drift systems have demonstrated they are dependent on a close interaction of topography, oceanography, sediment supply and climate. Most of these contourites have been reported from areas along the ocean margins directly influenced by thermo-haline deep-water currents. Yet similar deposits can be found along the ocean margin in areas where bottom currents are formed under different circumstances like internal tides, cascading water, etc. Disregarding their often smaller size, they contribute to the understanding of the contourite paradigm, documenting its wide variety of appearance, under different, sometimes very peculiar settings. Here, we report on such a small contourite drift from the Porcupine Seabight, SW of Ireland.

The Porcupine Seabight is a relatively shallow embayment along the Irish North Atlantic margin. Its location is well above the depth range of the large deep-water currents. It is characterized by the presence of cold-water coral banks which seem to be related to strong bottom currents. Within the Belgica mound province, located on the eastern slope, various observations demonstrate the presence of an overall northward flowing bottom current. This current seems to be created by a complex interaction of the water mass characteristics, tidal influences, and seafloor topography. Therefore, the present-day seafloor around these coral banks is covered with a thin contourite sand sheet with sand ripples, barchan dunes and sand ribbons.

Over the past 8 years, this site has been surveyed with very-high resolution seismics, multibeam bathymetry, side-scan sonar, ROV observations, and cores, and it was recently drilled during IODP Expedition 307. These studies demonstrate that the coral banks are seated on a complex topographic surface, created by a probable Intra-Pliocene erosion event. The resulting (early Quaternary) seabed morphology features a wide variety of obstacles which could foster a topographic steering of bottom currents, affecting the geometry of the sediment body deposited within this area. Several sediment mounds can be observed within the vicinity of the coral banks.

A 26 m long Calypso core taken in such a drift mound shows the variability of the bottom currents throughout the last glacial period. The glacial part of the core (Marine Isotope Stage 4-2) is a muddy contourite with a high content of ice-rafted debris. Grainsize data show several periods of bottom current enhancement which might be linked with warmer (interstadial) periods and an inferred influx of Mediterranean Outflow Water. The lower part of the core is a sandy foraminiferal deposit resembling the present-day seafloor sediments. Stable isotope and micropaleontological data confirm these are interglacial deposits (Marine Isotope Stage 5), demonstrating high benthic currents under a hydrodynamic environment similar to present-day conditions.

UPPER ORDOVICIAN GLOBAL STRATOTYPE SECTION & POINTS AND THE BRITISH HISTORICAL TYPE AREA: A CHITINOZOAN POINT OF VIEW

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Recent developments in chronostratigraphic procedure and new biostratigraphical insights necessitated the ongoing drastic revision of the Ordovician System's chronostratigraphy. A new global subdivision of the Ordovician is being established at the expense of the British chronostratigraphical framework, which has long been used as an informal 'global' standard. Carefully evaluated graptolite and conodont index species have already been selected to define the intra-systemic boundaries in their new Global Stratotype Sections and Points, or GSSP's for short. Although historically less well studied, the chitinozoans are a fossil group with a similar biostratigraphical potential as the two aforementioned groups. However, up to the present, they remained virtually unstudied in several of the newly proposed GSSP's for the Ordovician System. The project's main objective consists of the study of the chitinozoan assemblages in those newly proposed, or already ratified Global Stratotype Sections and Points. Because the Ordovician is a long period, the present study has necessarily been restricted to its three uppermost stages, grouped into the Upper Ordovician Series. Chitinozoan abundances and preservation permitting, a biozonation is established and a proxy is selected for each of the investigated boundary levels. This approach was particularly successful in the Swedish Fågelsång section, the new GSSP for the base of the Upper Ordovician Series. Attempts to recover biostratigraphically equally significant assemblages from the Hartfell Score (Scotland) and Wangjiawan (China) sections, respectively proposed as GSSP's for the bases of the second and third stage of the Upper Ordovician Series, proved somewhat less rewarding.

In the second part of the study, these new Upper Ordovician GSSP's are compared to the historical type areas of the British equivalent Caradoc and Ashgill Series and their subdivisions in the UK. Concomitantly, the first Upper Ordovician chitinozoan biozonation for British Avalonia is established. The historical Caradoc and Ashgill type sections in the Anglo-Welsh basin yield an important chitinozoan fauna; these data are supplemented with information from other British key sections which are famous for their accurate graptolite control. The latter include several Shelve Inlier sections, the Whitland road cutting, the Cardigan area and the Wye Valley around Rhayader. As a result, the established chitinozoan biozonation for British Avalonia is nicely tied to both the British chronostratigraphical framework and the graptolite biostratigraphy. It consists of thirteen chitinozoan biozones and subzones and is of importance as Avalonia lacks a formal biozonal scheme for the Ordovician, in contrast with the well-established biozonations in the other prominent palaeocontinents of that period in time. Interestingly, the newly drawn British biozonation scheme has a predominantly Baltoscandic signature, supplemented with endemic Avalonian and northern Gondwanan influences which fits Avalonia's migratory pattern during the Ordovician, away from Gondwana and approaching Baltica. The Baltoscandic *Fungochitina spinifera* Biozone brackets the base of the Ashgill Series in its type area. The base of the Ashgill therefore corresponds to a level in the Baltoscandic upper Oandu or in the Rakavere Stage; previously the base of the Ashgill was thought to fall in the overlying Vormsi Stage.

Conclusions drawn in this study are based on the observation of 40 860 chitinozoan specimens in total, handpicked from 295 samples which have been collected in *c.* twenty sections, inliers or areas in Great Britain, China and Sweden.

TWO DISTINCT FERROPOTASSIC A-TYPE MAGMATIC SUITES WERE EMPLACED AT THE END OF THE SVECONORWEGIAN OROGENY

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The postcollisional magmatism of the Sveconorwegian (Grenvillian) orogen is abundant and comprises two distinct ferropotassic A-type magmatic suites : the Anorthosite-Mangerite-Charnockite (AMC) and Hornblende Biotite Granitoids (HBG) suites (Vander Auwera et al., 2003). The former, characterized by opx-bearing lithologies (the Rogaland anorthosite Complex), is located on the western side of southern Norway whereas the latter intruded the eastern part of the orogeny. The AMC suite has been dated at 930 Ma whereas ages for the HBG suite ranges from 960 to 930 Ma. In major and trace elements variation diagrams, the two facies display similar trends but there are significant differences. Mainly FeOt/MgO, MnO, Na_2O are higher whereas Rb and Pb are lower in the opx-bearing facies. Also, the amphibole from the opx-bearing facies has a higher Fe# (0.60-0.82) than that of the other facies (0.59-0.65) reflecting the higher FeO_t content of the magma. Most importantly, the isotopic composition of Sr and Nd unequivocally identifies the two magmatic suites. Experimental data indicate that the two suites differentiated under contrasting conditions : anhydrous and reduced for the AMC suite, hydrous and oxidized for the HBG suite. It has been shown that the differentiation from a jotunite to a charnockite within the AMC suite can be taken into account by a fractional crystallization process and that the parent jotunitic magma was produced by partial melting of a lower crustal ultramafic source. Differentiation from a gabbronoritic composition to granite within the HBG suite is currently quantitatively tested. Several intrusions located along the contact zone between the two series display opx-bearing and hornblende-bearing lithologies. In the case of the Farsund intrusion, it has been shown that this results from a large scale mingling process. This further implies that magma emplacement was fast, probably through dyking.

REVIEW OF THE STRATIGRAPHY AND CHITINOZOAN BIOZONATION OF THE MIDDLE AND UPPER ORDOVICIAN OF THE CONDROZ INLIER (BELGIUM): EVIDENCE FOR LATERAL OR ONLY INTRA-BIOZONAL FACIES CHANGES?

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The Condroz Inlier (Bande de Sambre-et-Meuse or Bande condrusienne) is a narrow strip of ~65 km long and ~0.5 to 4 km wide, composed of Ordovician and Silurian rocks. To the north, it is bordered by Middle Devonian rocks of the Namur Synclinorium and to the south by Lower Devonian rocks of the Dinant Synclinorium. Given its position within the Variscan front zone and its poor degree of exposure, the stratigraphy of the Condroz Inlier is difficult to establish. The first stratigraphical scheme was presented by Malaise (1909, 1910), and was emended by Maillieux in 1926 and 1939. The important fieldwork of Michot (1928, 1934, 1944) resulted in a new stratigraphical scheme (Michot, 1954, 1980), which, in turn, was refined by the acritarch research of Martin (1969). On the basis of a literature review, Verniers *et al*. (2001) proposed a new stratigraphical scheme for the Condroz Inlier. The latter scheme, however, shows that many stratigraphical uncertainties still exist.

New fieldwork and the study of ~250 chitinozoan samples resulted in a revised stratigraphical scheme for the Condroz Inlier. In addition, a chitinozoan biozonation for the Middle and Upper Ordovician of the Condroz Inlier is proposed, thus contributing to the establishment of an Ordovician chitinozoan biozonation for the whole of Avalonia.

New fieldwork confirms the differentiation of the black shales of the Huy Formation and the siltstones of the Sart-Bernard Formation, as proposed by Maillieux (1939) and later supported by Servais & Maletz (1992) and Owens & Servais (in press). Chitinozoan data confirm the early Llanvirn age of the Huy Formation and the middle Caradoc age of the Sart-Bernard Formation. The Ombret and the Oxhe Formation, situated respectively in the Ombret and Oxhe Inliers, in the eastern part of the Condroz Inlier, are also dated as middle Caradoc (Dean, 1991; Vanmeirhaeghe & Verniers, 2002). The newly defined Ruisseau des Chevreuils Formation, consisting of bioturbated shales and sandstones, contains upper Llanvirn to lower Caradoc chitinozoans. The Vitrival-Bruyère Formation, formerly assigned to the middle Caradoc, is shown to be latest Llanvirn – early Caradoc in at least a part of its type section, whereas its contact with the overlying Fosses Formation is shown to be latest Caradoc in age. In the Puagne Inlier, the southwestern allochtonous part of the Condroz Inlier, the top of the Basse-aux-Canes Formation is shown to have a latest Caradoc age as well. The above results indicate intra-biozonal facies changes, possibly reflecting lateral facies changes within the Condroz Inlier.

The limit between the Vitrival-Bruyère Formation and the Fosses Formation was formerly believed to contain a large time gap (Michot, 1980). According to Michot (1980) this reflects the uplift of the Ardennes by the supposed Ardennes deformation phase. The previously supposed transgressional conglomerate at the base of the Fosses Formation is shown to consist of possibly reworked phosphate nodules in a dominant Fosses Formation matrix. The Fosses Formation itself is dated as latest Caradoc to late Rawtheyan (late Ashgill; Vanmeirhaeghe, in press). The overlying Génicot Formation has probably a Hirnantian (latest Ashgill) age and likely records the sea-level drops associated with the end-Ordovician glaciation (Herbosch *et al*., 2002; Vanmeirhaeghe & Verniers, 2004).

CD ISOTOPE FRACTIONATION IN THE SCHELDT ESTUARY: PRELIMINARY RESULTS FROM MC-ICP-MS ON REFERENCE MATERIAL, SUSPENDED PARTICULATE MATTER AND SEDIMENTS - IMPLICATIONS FOR TRACING OF POLLUTION

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Our study aims to analyse the Cd isotopic composition of sediment and suspended particulate matter from the Scheldt estuary (The Netherlands – Belgium) to investigate the capacity of Cd isotopes to trace fractionation effects related to anthropogenic activities.

Cadmium is a transition metal composed of eight stable isotopes ranging from mass 106 to 116. Until now, large Cd fractionations of up to 8‰/amu have been found for meteorites and lunar soils. In contrast, terrestrial materials display isotopic variations of only 0.3‰/amu, with the largest variations observed in anthropogenic samples from smelters or metal-rich soils. These observations suggest that Cd isotopes can be useful in tracing the source of anthropogenic Cd pollution in the environment.

Our chemical procedure includes a wet dissolution of the sample and separation of the Cd fraction on AG-MP1 resin and TruSpec resin, based on Zn and Cu chemical procedures realized in routine in our laboratory and on the procedure as described in Wombacher et al. (2003). The isotopic analyses were performed on a Nu Plasma MC-ICP-MS at ULB.

To validate our methodology, a first series of measurements was done on a Cd solution of the Johnson-Matthey Company (Specpure solution n° 181270710) hereafter JMC-B (in-house standard). Isotope analyses were also realized on several reference materials (Münster Cd, Münster JMC and BAM 1012) combining external normalisation by Ag doping method and sample-standard bracketing method for mass bias corrections (cf. Wombacher et al., 2003).

Variations in Cd isotopic compositions are preferentially reported as δ^{114}Cd/amu, calculated based on ^{114}Cd/^{110}Cd ratios. The δ^{114}Cd/amu obtained for the reference solution JMC-B is 0.01 ±0.03‰, based on measurements during several days. Solutions used in other laboratories were measured against our Cd JMC-B standard and gave $\delta^{114/110}$Cd/amu values of -0.08 ±0.1 ‰/amu for Münster JMC, +1.04 ±0.07 ‰/amu for Münster Cd and -0.4 ±0.14 ‰/amu for BAM 1012 solution. The measured fractionation between Münster Cd and Münster JMC is consistent with the conclusions of Cloquet et al. (2005).

Sediments from the Scheldt estuary sampled between November 2002 and July 2005, contained between 0.006 and 3 ppm Cd, while suspended particulate matter shows Cd contents up to 5 ppm. Recently, the heavy metal load in the Scheldt river has decreased considerably compared to 1978 and 1981. These Cd riverine inputs are still due, however, to anthropogenic activity and isotopic characterization of the Cd could give information about the sources of pollution. Isotopic measurements on sediments from the Scheldt estuary are in progress and will be discussed.

FRACTURING AND FLUID FLOW IN THE UPPER CRETACEOUS TO PALEOCENE STRATA OF THE IONIAN ZONE (ALBANIA)

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The Upper Cretaceous to Paleocene deep water carbonates of the Ionian Basin in the Saranda anticline can be considered as a reservoir analogue of the nearby Delvina oil field. These carbonates consist mainly of pelagic mudstones, with subordinate turbidites and debris flows, which belong to the frontal unit of the thrust system and are unconformably covered by the Oligocene flysh deposits. During the Albanides foreland fold-and-thrust belts evolution, a fault-propagation fold (i.e. Saranda anticline) was created during the propagation of the thrusts and moved towards the southwest on the Triassic evaporites decollement. The Saranda anticline was transported nearly 45 kilometers to the west. It is an asymmetric structure with a subvertical and partly overthrusted eastern flank.

The study area has been subjected to several fracturing events, associated with stages of fluid migration during the Neogene Alpine deformation. The highest density of fractures occurs at the top of the anticline and shows a clear relationship with the lithology: in the fine-grained white mudstones (i.e. Lower Cretaceous) the fracture density is lower than in the turbidites (i.e. Upper Cretaceous-Eocene), and many are cemented by calcite. On the other hand, the debris flows contain less fractures, and are all cemented.

In this study, results from cathodoluminescence, trace element and stable isotope geochemical analyses will allow to replace the evolution of the fluid flow into its kinematics framework as well as into the burial evolution of the anticlinal structure.

During the pre-deformational stage, complex textures such as crack-and-seal features most likely reflect expulsion of overpressured fluids. The depleted $\delta^{18}O$ values (-10,2‰ to -13,3‰ V-PDB) are interpreted in terms of precipitation at elevated temperatures, which reflect different fluid pulses and/or differences in non-equilibrium precipitation temperature between host-rock and marine fluids.

Afterwards, during the prefolding compressional stage, an earlier forebulge is created. This period is characterized by the migration of meteoric fluids, which caused cementation and development of a karst network during a period of emergence. In fact, these calcites displays a $\delta^{18}O$ around -5,5‰ and a $\delta^{13}C$ ranging mostly from 0,5‰ to -12,5‰.

Within the post-deformational stage, a meteoric fluid occurred. These calcites are characterized by an intensely zoned luminescence pattern, with bright yellow and non-luminescent zones. $\delta^{18}O$ and $\delta^{13}C$ values of the paleofluid plot from -6,2‰ to -8,1‰ V-PDB and -0,3 to -2,2‰ V-PDB respectively. According to the microscopic observations (e.g. cathodoluminescence), this trend can be explained by complex diagenetic processes (i.e. dissolution, brecciation and recrystallization

DATING OF THE WEATHERING PROCESSES IN THE ARDENNE AREA (BELGIUM)

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Dating the paleoweathering processes is essential to integrate the paleosurfaces and the geomorphology into their paleoclimatic, eustatic and geodynamical framework. This work deals with the dating of the saprolitisation in the Haute-Lesse area (Ardenne, Belgium).

In this area, the weathered mantle can reach 65 meters of depth, and is preserved in the highest plateaus only. The alternations of Lochkovian shales and sandstones experienced the Hercynian tectonic activity and were later affected by saprolitisation processes. The saprolitisation mainly resulted in (1) the oxidation of pyrite, (2) the destruction of local carbonates, chlorite, illite-smectite mixed-layers, part of illitic material, and (3) the correlative neoformation of kaolinite, iron oxy-hydroxides and manganese oxides. Due to the relative maturity of the primary sediments (rare ion-rich minerals), the reactions were nevertheless limited: a main part of the primary minerals (quartz, muscovite, heavy minerals) were unaffected (or poorly affected) by the weathering.

In the Transinne profile (Haute-Lesse area, Belgian Lambert coordinates: X=209.150, Y=78.290, Z=455), the neoformed parageneses are the result of three phases of saprolitisation, probably in relation with both carbonic and sulphuric acid fluids. The various dating methods we used, such as K-Ar, Ar-Ar on hollandites, paleomagnetism on iron oxy-hydroxides and isotopic geochemistry on kaolinite and oxy-hydroxides, give consistent results. The upper part of the profile is early Early Cretaceous (~ 130 My) in age, the middle part early Late Cretaceous (~ 93 My), and the lowest part Early Miocene (~ 21 My). Another weathering process during the Late Permian-Early Triassic is also deciphered by using the Pb-Pb dating method on uranium-bearing phosphates located in fractures just below the transition between the weathered and the fresh rocks; these fractures were probably closed (and remained closed) after the neoformation of the phosphates. When dating the saprolitisation processes, careful must therefore be paid to the detailed mineralogical and geochemical context of the dated samples, as well to their precise nature and position in the studied profile.

This study highlights the geodynamic relative stability of the studied area since the Late Permian-Early Triassic. Basically, weathering is only possible when rocks are in/near the atmosphere-lithosphere interface: this was the case during the Late Permian-Early Triassic, the early Early Cretaceous, the early Late Cretaceous and the Early Miocene, as deduced by the dating methods. Today also, these thick weathered mantles are still in the contact atmosphere-lithosphere. This study also indicates that the saprolitic landscapes in the Haute-Lesse area are relict and thus not in relation with the current climatic conditions. The results finally allow us to integrate the Haute-Lesse saprolite within the global context of paleoweathering processes in Northwestern Europe where four major saprolitisation periods are identified: Late Permian/Triassic, Early Cretaceous, Paleocene/Eocene interval and Early Miocene.