GB2016 Mother Earth

Geologica Belgica

Proceedings

of the

5th International Geologica Belgica Congress

GB2016

University of Mons, Mons, Belgium

26-29 January 2016

POLYTECH MONS

UMONS Université de Mons

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FOREWORD

Welcome address

Ladies and Gentlemen, Dear Colleagues, Monsieur le Doyen,

On behalf of the scientific association Geologica Belgica, I have the honour to open the 5th International Geologica Belgica meeting in Mons. This beautiful university city is the fifth in row to organise the Geologica Belgica Congress, after Leuven in 2002, Liège in 2006, Gent in 2009 and Brussels in 2012.

The Geologica Belgica Congress, is the largest gathering of earth scientists in Belgium, uniting all geoscience research centers from the north and south of the country and open to our neighbours, for some days of intensive exchange. These congresses and a journal with impact factor, equally named Geologica Belgica, form the flagships of our scientific association.

Geologica Belgica is a rather young organisation, founded in 1999 as a result from the merger of two older geological societies whose history goes back 140 years. The purpose of this merger was to abandon the divisions of the past and to unite forces to represent geoscience at the national level. This is no easy task, which can only be realised through the continued and benevolent support of its members. I thank all of you in the audience who as members of our society make this happen. I ask those who are not yet members to consider joining as well.

The theme of the present meeting, Mother Earth, sounds more compassionate than the theme of the previous meeting in Brussels, Moving plates and melting icecaps, and also less utilitarian than the theme in Gent, Challenges for the Planet. Mother Earth makes clear that humanity is united in its relation to the Planet Earth and that we all depend on the proper functioning of the intricate ecosystems and material cycles that keep the Earth a living planet. Care for the present and concern for the future start with good understanding of where we stand now and where we are heading to, after 4 and a half billion years of Earth history. This understanding advances continuously and so must be the exchange between scientists.

We have gathered here to learn from each other and increase cooperation. This has been made possible through the preparatory work of the organising committee, who ensure that the congress runs smoothly. It all looks very promising and I look forward to a very rewarding meeting.

Michiel Dusar

President Geologica Belgica

Reflection on the 5th International Geologica Belgica Congress (GB2016)

The Geologica Belgica Congress is the largest gathering of earth scientists in Belgium, uniting all geoscience research centres from the north and south of the country and open to our neighbours, for some days of intensive exchange. The host city for the fifth congress - Mons - is a hidden pearl among the historical cities of Belgium but is also a centre for earth science research and learning, the fifth to host such a meeting after Leuven, Liège, Gent and Brussels. The location was charming in the venerable building of the Faculté Polytechnique, the preparation and technical support was well organised by the staff of its Geology and Applied Geology Unit, the cultural – culinary service including a trip to PASS at La Malogne underground quarry, was outstanding. This lustrum congress fulfilled the expectations with 180 presentations, 2/3 of which were oral and 1/3 posters. Besides general themes such as hydrogeology, climate change, ore geology, teledetection, reservoirs, geohazards, geoheritage, African and Belgian regional geology and marine geology, special sessions were held around Bas-Congo, Cretaceous – Paleocene climate events, chalk from petrography to engineering, Upper Devonian life, Proterozoic life, terrestrialisation and return to the sea, all fitting well to the theme of 'Mother Earth'. As a result both organisers and participants can look back at a successful meeting.

What factors make these Geologica Belgica Congresses so unique and contribute to their success?

Most scientific meetings today are highly specialised. The Geologica Belgica congresses are among the rare generalist meetings, which offer a wide scope of scientific disciplines. There is, however, the modest scale of Belgium, allowing easier contacts and exchange than the huge events such as the International Geological Congress or EGU.

The Geological Belgica congresses succeed in uniting all geoscience research institutes and universities in Belgium, which in this complicated country is a unique achievement. The focus remains on research, not on R&D.

Contributions to the congress are dominated by young researchers, highlighting current lines of research, balanced by world top keynotes. This combination could guarantee a durable future but logistics and time-constraints become compelling factors for both organisers and participants.

The support of the hosting institute is a must. The organising committee unites an enthousiastic and untiring team, devoted to manage a smooth congress in a friendly atmosphere, with all documents ready and all events running on time.

The GB2016 congress forms a showcase for the hosting institute and is also a flagship for the scientific association Geologica Belgica. It was the appropriate location for awarding the André Dumont medal in the field of astrobiology to Frances Westall, from Centre de Biophysique moléculaire-CNRS in Orléans. Her keynote lecture entitled 'Early Life: its hydothermal starting point and evolution' was a most remarkable conference.

In order to encourage young participants and upgrade the poster contribution (supported by daily dedicated poster sessions during the congress) a price for the best student poster was awarded. The laureates are:

1. Antoine Triantafyllou (Mons University) for 'GeoLog Toolkit 0.9: a new open source and cross-platform for geological data visualization in Google earth environment'

2. Kris Welkenhuysen (KULeuven & Geological Survey of Belgium) for 'CO2-enhanced oil recovery in the North Sea region and its importance for Belgium'

3. Paul Picavet (Lille University) for 'The Arkose of Macquenoise: a suitable Lochkovian raw material for ancient millstone: quarries, properties, manufacture and distribution (France – Belgium)'.

We now look forward to the edition of the Proceedings volume and present our sincerest thanks to the organising committee for this achievement.

Michiel Dusar

President Geologica Belgica

GENERAL PROGRAM

MONDAY January 25th

Monday January 25th	19:00	**Ice breaker party** (meeting point : entrance hall)

TUESDAY January 26th

Tuesday January 26th	08:30 09:00	**Welcome participants**		
		Auditoire 12		
	09:00 09:20	**Opening ceremony**		
	09:20 10:00	**Keynote 1 : MORTIMORE R. et al.** "Stonehenge : new phosphatic chalk deposits in the Upper Cretaceous Chalk of England and implications for tunneling"		
		Auditoire 12	Auditoire 11	Auditoire 03
	10:00 11:00	**Session 1 : Cretaceous - Paleocene Strata**	**Session 2 : Bas-Congo I**	**Session 3 : Hydrogeology I**
	11:00 11:30	**Coffee break**		
		Auditoire 12	Auditoire 11	Auditoire 03
	11:30 12:30	**Session 4 : Devonian Strata**	**Session 5 : Bas-Congo II**	**Session 6 : Hydrogeology II**
	12:30 13:20	**Lunch**		
		Auditoire 12	Auditoire 11	Auditoire 03
	13:20 15:00	**Session 7 : Chalk - From Geology to Engineering**	**Session 8 : Ore & Ressource Geology**	**Session 9 : Reservoir I - Hydraulic and thermal properties of rocks**
	15:00 15:30	**Coffee break**		
		Auditoire 12	Auditoire 11	Auditoire 23
	15:30 16:30	**Session 10 : Upper Devonian Life**	**Session 11 : African Ore Geology**	**Session 12 : Poster session**
		Auditoire 12		
	16:30	**DUMONT Medal ceremony**		
	16:35 17:30	**Talk by the laureate**		
	17:30	**Closing the day**		

WEDNESDAY January 27th

Wednesday January 27th

08:30 09:00	Welcome participants		
	Auditoire 12		
09:00 09:40	**Keynote 2 : WESTALL F. et al.** "Early life: its hydrothermal starting point and early evolution"		
	Auditoire 12	Auditoire 11	Auditoire 23
09:40 10:40	**Session 13 : Proterozoic Life I**	**Session 14 : Central Africa during the Cenozoic**	**Session 15 : Poster session**
10:40 11:10	Coffee break		
	Auditoire 12	Auditoire 11	Auditoire 23
11:10 12:30	**Session 16 : Proterozoic Life II**	**Session 17 : Geoheritage & Geoarcheology I**	**Session 18 : Poster session**
12:30 13:20	Lunch		Geologica Belgica General Assembly
	Auditoire 12		
13:20	VANDENBROECK MEDAL ceremony		
13:25 14:20	Talk by the laureate		
	Auditoire 12	Auditoire 11	Auditoire 03
14:20 15:20	**Session 19 : Environmental Change**	**Session 20 : Geoheritage & Geoarcheology II**	**Session 21 : Late Cenozoic I**
15:20 15:50	Coffee break		
	Auditoire 12	Auditoire 11	Auditoire 03
15:50 17:30	**Session 22 : Geological Risks**	**Session 23 : Regional Geology I - Paleozoic**	**Session 24 : Late Cenozoic II**
17:30	Closing the day		

THURSDAY January 28th

Thursday January 28th

08:30 09:00	Welcome participants		
	Auditoire 12		
09:00 09:40	**Keynote 3 : GUTZMER J. et al.** "The Paleoproterozoic Manganese Bonanza in Africa"		
	Auditoire 12	Auditoire 11	Auditoire 23
09:40 10:40	**Session 25 : Geomaterials**	**Session 26 : Teledetection**	**Session 27 : Poster session**
10:40 11:10	Coffee break		
	Auditoire 12	Auditoire 11	Auditoire 03
11:10 12:30	**Session 28 : Structural Geology**	**Session 29 : Marine Geology**	**Session 30 : Cretaceous - Eocene Climates**
12:30 14:30	Gala Dinner (PASS, Frameries)		
14:30 17:00	Field trip (Malogne underground quarry)		
17:00 17:30	Return to Mons - Closing the day		

FRIDAY January 29th

Friday January 29th

08:30 09:00	**Welcome participants**		
	Auditoire 12		
09:00 09:40	**Keynote 4 : HOUSSAYE A.** "Physiological and morpho-functional (secondary) adaptations of Amniotes to an aquatic life"		
	Auditoire 12	Auditoire 11	Auditoire 23
09:40 11:00	**Session 31 : Terrestrialization and return to the sea I - Mesozoic Mammals**	**Session 32 : Reservoirs II**	**Session 33 : Poster session**
11:00 11:20	**Coffee break**		
	Auditoire 12		
11:30 12:10	**Keynote 5 : MELLES M. et al.** "Continuous 2.8 million year record of Arctic climate change from lake El'gygytgyn (NE Russia)"		
12:10 12:30	**Special issue : VERSCHUREN D. et al.** "Research opportunities for Belgian earth scientists through the International Continental Scientific Drilling Programme (ICDP)"		
12:30 13:30	**Lunch**		
	Auditoire 12	Auditoire 11	Auditoire 03
13:30 15:10	**Session 34 : Terrestrialization and return to the sea II - Mesozoic Reptiles**	**Session 35 : Regional Geology II**	**Session 36 : Holocene Climates and Environments**
	Auditoire 12		
15:10 17:00	**Closing of the conference and drink**		

SESSION PROGRAM

Tuesday January 26th

08:30 – 10:00 Plenary session (Room 12)

08:30 – 09:00 Arrival and registration

09:00 – 09:20 Introducing the conference

09:20 – 10:00 **Keynote:** MORTIMORE R., GELDER J., MOORE I., BROOKS R., GALLAGHER L., FARRANT A.
Stonehenge: new phosphatic chalk deposits in the Upper Cretaceous Chalk of England and implications for tunneling

10:00 – 11:00 Thematic sessions

SESSION 1: CRETACEOUS – PALEOCENE STRATA (ROOM 12)

10:00 – 10:20 SINNESAEL M., MONTANARI A., CLAEYS P.
New XRF data for the upper Maastrichtian in Gubbio, Bottaccionne section, central Italy

10:20 – 10:40 NOIRET C., DUPUIS C., STEURBAUT E., DAWANS Q., YANS J.
Did the PETM occur before or after the Claret Conglomerate (CC) at Campo (Spain)? New perspectives from high-resolution chemostratigraphy ($\delta^{13}C_{org}$, $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$)

10:40 – 11:00 BAELE J.-M., QUESNEL F., DUPUIS C.
Silcrete in northern France and Belgium: a terrestrial record of surface environments under the influence of pyroclastic ash-falls

SESSION 2: BAS-CONGO I (ROOM 11)

10:00 – 10:20 KANT-KABALU F., KADJA-WONGUDI G., MUJINGA-MULEMBA E., NSEKA-MBEMBA P., PHAMBU-LANDU J., KANDA-NKULA V., BAUDET D., DEWAELE S., EEKELERS K., FERNANDEZ M., LAGHMOUCH M., THEUNISSEN K., TACK L.
New 1/500.000 scale GIS-based geological and mineral resources maps for Bas-Congo province (DRC) with an updated lithostratigraphy of the Neoproterozoic West Congo Supergroup

10:20 – 10:40 PEDROSA-SOARES A., DUSSIN I., NSEKA P., BAUDET D., FERNANDEZ-ALONSO M., TACK L.
Tonian rifting events on the Congo-São Francisco palaeocontinent: New evidence from U-Pb and Lu-Hf data from the Shinkakasa plutonic complex (Boma region, West Congo Belt, Democratic Republic of Congo)

10:40 – 11:00 GLORIE S., ARCHIBALD D. B., VAN DEN HAUTE P., DE GRAVE J., EECKHOUT S., BEHIELS M., FERNANDEZ-ALONSO M., TACK L., BAUDET D.
The Noqui peralkaline granite body (Matadi - Bas-Congo - DRC): a marker of 1.0 Ga lithospheric-scale triple junction updoming during long-lived Columbia breakup

SESSION 3: HYDROGEOLOGY I (ROOM 03)

10:00 – 10:20 ALFARRAH N., WALRAEVENS K.
Hydrogeological and Hydrogeochemical Investigation of the Coastal Area of Jifarah Plain, NW Libya

10:20 – 10:40 DEVRIESE G.-J., CLAUS J., LEBBE L.
Enhanced salinization of the Nieuw-Arenbergpolder for the creation of salt meadows on the left bank of the river Scheldt, Belgium

10:40 – 11:00 KAUFMANN O., WATLET A.
Electrical Resistivity Tomography Monitoring to Assess Water Distribution in the Vadose Zone

11:00 – 11:30 Coffee break

11:30 – 12:30 Thematic sessions

SESSION 4: DEVONIAN STRATA (ROOM 12)

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Unravelling orbital climatic cycles from Devonian magnetic susceptibility signal – the quest for a better age model for the Lochkovian and Pragian stages (Czech Republic)

11:50 – 12:10 DJOUDER H., BOULVAIN F., DA SILVA A.-C., CORNET P., LÜNING S., MUSIAL G.
The Siluro – Devonian sedimentary record of the Tassili n'Ajjer (SE Algeria): new insights from sedimentology and stratigraphy

12:10 – 12:30 LAGROU D., LAENEN B.
Introduction of the Booischot Formation, a new formal lithostratigraphic unit for the Devonian in the Campine Basin (N. Belgium)

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The Lower Diamictite Formation of the Cataractes Group, West Congo Supergroup (Bas-Congo, DRC): a 700 Ma marker of extensional episodic activity during breakup of Columbia

12:10 – 12:30 TACK L., THEUNISSEN K., DELVAUX D., EVERAERTS M., FERNANDEZ M., BAUDET D.
The West Congo Belt of Bas-Congo (DRC) revisited: a patchwork of individual tectono-metamorphic domains as a result of South Atlantic ocean opening

SESSION 6: HYDROGEOLOGY II (ROOM 03)

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11:50 – 12:10 POULAIN A., GODERNIAUX P.
Study of groundwater-quarry interactions in the framework of energy storage systems

12:10 – 12:30 BODEUX S., PUJADES E., ORBAN P., DASSARGUES A.
Hydrogeological conditions required for Underground Pumping Storage Hydroelectricity (UPSH) in old mines

12:30 – 13:20 Lunch

13:20 – 15:00 Thematic sessions

SESSION 7: CHALK – FROM GEOLOGY TO ENGINEERING (ROOM 12)

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Relations between lithology and geomechanical properties of chalks from NW Europe

13:40 – 14:00 FAŸ-GOMORD O., SOETE J., KATIKA K., GALAUP S., CALINE B., DESCAMPS F., LASSEUR E., FABRICIUS I. L., SAÏAG J., SWENNEN R., VANDYCKE S.
New insight into the microtexture of chalks from NMR analysis

14:00 – 14:20 BROUX A., SCHROEDER C., VERBRUGGE J.-C.
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14:20 – 14:40 SAÏAG J., COLLIN P.-Y., SIZUN J.-P., LASSEUR E., FAŸ-GOMORD O., CALINE B.
Heterogeneity of petrophysical properties in the chalk: depositional versus diagenetic origin

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Foraminifera and the sea grass communities of the Maastricht Chalk

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Quantifying marine aggregate resources of the Belgian part of the North Sea, first results using a layered voxel modelling approach

14:20 – 14:40 KINT L., VAN HETEREN S., LAGRING R., VAN LANCKER V.
Building a transnationally harmonised marine geological database

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14:20 – 14:40 WATLET A., POULAIN A., FRANCIS O., HALLET V., KAUFMANN O., ROCHEZ G., VAN CAMP M.
Gravity changes in a karst system highlight its vadose zone hydrodynamics

15:00 – 15:30 Coffee break

15:30 – 16:30 Thematic sessions

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An extraordinary new site to study upper Frasnian cephalopods during the onset of anoxia in the Dinant basin

15:50 – 16:10 OLIVE S., CLEMENT G., DENAYER J., DERYCKE C., DUPRET V., GERRIENNE P., GUERIAU P., MARION J.-M., MOTTEQUIN B., PERNEGRE V., PRESTIANNI C.
A new Famennian (Upper Devonian) locality at Becco: geological and paleontological insights

16:10– 16:30 PRESTIANNI C., GESS R.
The latest Famennian spermatophytes from South Africa

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Re-appraisal of the world-class Paleoproterozoic manganese deposit of Kisenge (Katanga, DRC)

15:50 – 16:10 CHARLIER B., YUAN Q., FISCHER L.A., NAMUR O.
Fe-Ti-V-P ore-forming processes in the Upper Zone of the Bushveld Complex, South Africa

16:10 – 16:30 LAURENT O., ZEH A., DELMELLE N., VANDER AUWERA J., WILSON A., D'ABZAC F.-X.
The role of Archean tectonics in shaping Paleoproterozoic intraplate magmatism and ore deposits in the Kaapvaal craton (southern Africa): a case study from the 2.05 Ga Schiel complex

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15:30 – 16:30 **Geomaterials**

BAELE J.-M., GOEMAERE E., MORTIER T.
Firing effects on quartzite materials revealed by cathodoluminescence

VANDENBERGHE D., DE GRAVE J.
Understanding rocks: introducing MINPET's geo-analytical toolkit

15:30 – 16:30 **Geological modelling**

KAUFMANN O., MARTIN T.
Building 3D geological model from geological records

TRIANTAFYLLOU A., WATLET A.
GeoLog Toolkit 0.9: a new open source and cross-platform for geological data visualization in Google Earth environment

VAN NOTEN K.
Visualizing (geological) cross-sections vertically in Google Earth

15:30 – 16:30 **Geoenergy and Reservoirs**

BOUMAN M., BERTIER P., SWENNEN R., GOOVAERTS T., VANBRABANT Y., PIESSENS K.
Beyond the current limits of Raman Spectroscopy: controlling fluorescence in solid bitumen with low thermal maturity

PETITCLERC E., MAES D., BUYSSE J., VERSPECHT A., PIESSENS K.
ALPI: impact of policy instruments on the development of the geothermal energy sector

SALIH N., MARTIRE L., BARALE L., AL-AASM I., MUCHEZ P., KOLO K., MANSURBERG H., PREAT A.
Multiple hydrothermal-Cretaceous dolomitization in different diagenetic settings, Provençal Domain, NW Italy

VANDEWIJNGAERDE W., PIESSENS K., BERTIER P., SWENNEN R.
Example of natural fracture patterns in Westphalian deposits: Occurrence and Controls

VERBIEST M., FAŸ-GOMORD O., ALLANIC C., GAUTHIER B., VANDYCKE S., LASSEUR E., SWENNEN R.
Mechanical stratigraphy of the Cenomanian chalk of Cap Blanc Nez (France)

WELKENHUYSEN K., BRÜSTLE A.-K., PIESSENS K., RAMÍREZ A., SWENNEN R.
Reservoir capacity assessment and ranking of potential targets for geological storage of CO_2 in Austria

WELKENHUYSEN K., PIESSENS K., RAMÍREZ A., SWENNEN R.
CO_2-enhanced oil recovery in the North Sea region and its importance for Belgium

16:30 – 17:30 Plenary session (Room 12)

16:30 – 16:35	DUMONT Medal ceremony
16:35 – 17:30	Talk by the laureate
17:30	Closing the day

Wednesday January 27th

09:00 – 09:40 Plenary session (Room 12)

09:00 – 09:40 **Keynote:** WESTALL F., CAMPBELL K. A., BREHERET J.-G., FOUCHER F., GAUTRET P., HUBERT A., SORIEUL S., GRASSINEAU N., GUIDO D. M.
Major transitions in Early Life evolution

09:40 – 10:40 Thematic sessions

SESSION 13: PROTEROZOIC LIFE I (ROOM 12)

9:40 – 10:00 CORNET Y., STORME J.-Y., COMPERE P., BUTTERFIELD N.J., JAVAUX E.J.
Ultrastructural and chemical characterization of the Cryogenian acritarch Cerebrosphaera

10:00 – 10:20 CORNET L., WILMOTTE A., JAVAUX E., BAURAIN D.
Dating the origin of plastids

10:20 – 10:40 GOUY R., BAURAIN D., PHILIPPE H.
What 20 years of phylogenetics teach us: the Last Universal Common Ancestor (LUCA) is not the origin of Life and might have been more complex than we used to believe

SESSION 14: CENTRAL AFRICA DURING THE CENOZOIC (ROOM 11)

9:40 – 10:00 GANZA G., DELVAUX D.
First paleostress tensors from the Kivu – North Tanganyika rift region, Central Africa (D.R.Congo, Burundi): Insight its Phanerozoic brittle tectonic evolution

10:00 – 10:20 GUILLOCHEAU F., SIMON B.
Relief and topographic evolution of Central Africa during Cenozoic times

10:20 – 10:40 STEEMAN T., NOIRET C., SOLE F., DESMARES D., MEES F., DE PUTTER T., SMITH T., YANS J., LOUWYE S.
The Landana section (Cabinda, Angola): a unique Paleocene-Eocene biotic and sedimentary record in the Congo Basin

SESSION 15: POSTERS (ROOM 23)

9:40 – 10:40 **Geoenvironment, Geohazards, Hydrogeology**

ALFARRAH N., HWEESH A., VAN CAMP M., WALRAEVENS K.
Groundwater flow and chemistry of the oases of Al Wahat, NE-Libya

BEERTEN K., LETERME B., LALOY E., GEDEON M., ROGIERS B., VANDERSTEEN K., JACQUES D.
Towards an innovative modelling framework to assess environmental change impact on the water cycle at the catchment scale

BOES E., FUJIWARA O., GARRETT E., LAMAIR L., DE BATIST M., HEYVAERT V. M.A., YOKOYAMA Y., MIYAIRI Y., IRIZUKI T., RIEDESEL S., BRÜCKNER H., HUBERT-FERRARI A., QuakeRecNankai Team
Exploring the potential of Lake Hamana to hold a long and reliable sedimentary record of paleotsunamis along the Nankai-Suruga Trough

CLAUS J., DE TOLLENAERE J., ELOBAID E. A., LEBBE L.
Numerical groundwater model of the dessication and dissipation of an unlined treated sewage effluent pond in Doha, Qatar

DE BATIST M., NAUDTS L., CASIER R., KHLYSTOV O., KHABUEV A., MINAMI H., GRACHEV M., SHOJI H.
An Inventory of Underwater Landslides in Lake Baikal Suggests a Strong Link with Gas Hydrates

DECLERCQ P.-Y., WALSTRA J., HAYEN R., SHIMONI M., BARBIER C., DERAUW D., VAN BALEN K., VERSTRYNGE E., BEJARANO URREGO L. E.
Cartography of the Belgian monuments at risk via PSI analysis of the ground movements, the GEPATAR project

DUBOIS C., GODERNIAUX P., DECEUSTER J., POULAIN A., KAUFMANN O.
Hydrogeology of weathered limestones

GOVAERTS J., BEERTEN K., TEN VEEN J.
Numerical simulation of Weichselian permafrost depth in the Netherlands

JURADO A., VÁZQUEZ-SUÑÉ E., CARRERA J., TUBAU I., PUJADES E.
Using mixing ratios to quantify chemical reactions in groundwater

KAUFMANN O., BASTIN C., BARCELLA C., WATLET A., VAN RUYMBEKE M.
Design and Calibration of a System for Monitoring Highly Variable Dripwater Flows in Caves

KEREK B., HALUPKA G., MARSI I., OROSZ L.
A new soil map approach in the frame of the NAGiS Project

LAMAIR L., HUBERT-FERRARI A., BOES E., YAMAMOTO S., GARRETT E., HEYVAERT V. M.A., NAKAMURA A., MIYAIRI Y., YOKOYAMA Y., DE BATIST M., QuakeRecNankai Team
A history of mass transport complexes related to earthquake shaking: the case of Lake Motosu (Japan)

MAKAREWICZ M., WELKENHUYSEN K., DHAERENS D., PIESSENS K.
Measuring the amount of CO_2 in oversaturated waters by mass balance: an overview of trials and errors

PRAET N., MOERNAUT J., VAN DAELE M., BOES E., VANDEKERKHOVE E., STRUPLER M., HAEUSSLER P., DE BATIST M.
Sublacustrine landslides in several Alaskan lakes reveal a long history of strong earthquake shaking

PUJADES E., DE SIMONE S., CARRERA J., VÁZQUEZ-SUÑÉ E., JURADO A.
Settlements around pumping wells: distribution, relation with the storage coefficient and role of surrounding layers

RONCHI B., DREVET J.-P., FRIPPIAT C., VESCHKENS M.
Risk assessment in an abandoned coal field: ten years of hydrological monitoring in Liège (Belgium)

VAN HETEREN S., MOSES C., Van DE VEN T.
Coastal erosion and accretion: translating incomplete data and information into vulnerability assessments

WALSTRA J., DE CLERCQ P.-Y.
Time-series analysis of SAR images for detecting ground subsidence in the Scheldt estuary

WATLET A., POULAIN A., FRANCIS O., HALLET V., KAUFMANN O., ROCHEZ G., VAN CAMP M.
Hydrogeological and hydrogeophysical monitoring of vadose and saturated zones at the Rochefort Cave Laboratory

10:40 – 11:10 Coffee break

11:10 – 12:30 Thematic sessions

SESSION 16: PROTEROZOIC LIFE II (ROOM 12)

11:10 – 11:30 BEGHIN J., POULTON S. W., GUILBAUD R., GUENELI N., BROCKS J. J., STORME J.-Y., BLANPIED C., JAVAUX E. J.
Palaeoecological model of the Mesoproterozoic Taoudeni Basin and implications for early eukaryotes evolution

11:30 – 11:50 FRANCOIS C., KABAMBA BALUDIKAY B., STORME J.-Y., BAUDET D., JAVAUX E. J.
Proterozoic time constraints on the deposit of the Mbuji-Mayi Supergroup, Democratic Republic of Congo (DRC)

11:50 – 12:10 KABAMBA BALUDIKAY B., STORME J.-Y., BAUDET D., FRANCOIS C., JAVAUX E. J.
Organic-walled microfossil assemblage and Chemostratigraphy of the Mbuji-Mayi Supergroup (Democratic Republic of Congo): Evidence for a Late Mesoproterozoic-Early Neoproterozoic age

SESSION 17: GEOHERITAGE AND GEOARCHEOLOGY I (ROOM 11)

11:10 – 11:30 MISSIAEN T., EVAGELINOS D., PIETERS M., DEMERRE I., CLAERHOUT C.
Geo-archaeological prospection of the intertidal area: case study of Ostend-Raversijde

11:30 – 11:50 PLEUGER E., ABICHOU H., GADHOUM A., GOIRAN J.-P., QUINN J., FENTRESS E., WILSON A., BEN JERBANIA I., FAGEL N.
Evolution of the palaeoenvironment of the Medjerda delta (Tunisia) and geoarchaeology of the ancient city of Utica

11:50 – 12:10 PIRSON S., ABRAMS G., BONJEAN D., COURT-PICON M., DAMBLON F., TOUSSAINT M., DI MODICA K.
Deciphering sedimentary dynamics in cave entrances. Implications for archaeology and palaeoenvironmental reconstructions

12:10 – 12:30 VERHEYDEN S., JAUBERT J., GENTY D., CHENG H., BLAMART D., SOULIER M., BURLET C., REGNIER E., CAMUS H., DELABY S., EDWARDS L. R., MAKSUD F., MORA P., SANTOS F.
Geo-archaeological study of a broken stalagmite structure in the Bruniquel Cave, Tarn-et-Garonne, France

SESSION 18: POSTERS (ROOM 23)

11:10 – 12:30 **Paleoclimatology and Quaternary geology**

BEERTEN K., VANACKER V.
Surface exposure dating of the Campine Plateau, NE Belgium: first results

BOES E., VAN DAELE M., MOERNAUT J., SCHMIDT S., STRUPLER M., FORTIN D., DE BATIST M., KAUFMAN D., HAEUSSLER P., LOSO M.
Using varve thickness records from three proglacial lakes in south-central Alaska as proxies for climate variations on multidecadal and interannual timescales

DEPREZ A., TESSEUR S., STASSEN P., D'HAENENS S., STEURBAUT E., KING C., CLAEYS P., SPEIJER R. P.
Benthic foraminiferal and isotopic patterns during the Early Eocene Climatic Optimum (Aktulagay section, Kazakhstan)

FAGEL N., ALLAN M., VERHEYDEN S., CRUCIFIX M.
Holocene paleoenvironmental reconstructions from speleothem and peat bog archives

JUAN C., ERCILLA G., HERNÁNDEZ-MOLINA J., ESTRADA F., ALONSO B., CASAS D., GARCÍA M., FARRAN M. L., LLAVE E., PALOMINO D., VAZQUEZ J. T., MEDIALDEA T., GORINI C., D'ACREMONT E., EL MOUMNI B., AMMAR A.
Palaeoceanographic implications of current-controlled sedimentation in the Alboran Sea after the opening of the Strait of Gibraltar

STASSEN P., STEURBAUT E.
Towards an improved holostratigraphy of the Ypresian Clays

11:10 – 12:30 **Early and Past Life**

BISCONTI M., LAMBERT O., BOSSELAERS M.
New description and phylogenetic relationships of 'Balaena' belgica, a large right whale from the Pliocene of Belgium

DENAYER J., MOTTEQUIN B., POTY E.
Early Carboniferous marine ecosystem recovery after the Hangenberg Crise, insight from the Tournaisian brachiopod-coral fauna from South Belgium

DENAYER J., PRESTIANNI C., GUERIAU P., OLIVE S., CLEMENT G.
Late Devonian arthropods and tetrapods palaeoenvironments: the example of the Late Famennian of Strud and Becco

MARTIN T., KAUFMANN O., PAPIER S., BAELE J.-M.
Bernissart: Back to the crime scene

MORTIER J., VERNIERS J.
The evolution of the Upper Ordovician to Silurian basin in the Condroz Inlier: litho- and biostratigraphy with chitinozoans

PAPIER S., BAELE J.-M., DEBOUGE W., DE JONG. J., MATTIELLI N., GILLAN D.
Iron isotope fractionation in a Modern iron-oxidizing bacterial mat

STORME J.-Y., GOLUBIC S., WILMOTTE A., KLEINTEICH J., VELAZQUEZ D., JAVAUX E. J.
Raman characterization of the UV-protective pigment gloeocapsin- potential biosignatures of early Earth records

11:10 – 12:30 **Sedimentary rocks and stratigraphy**

LANCKACKER T., MENKOVIC A., WALSTRA J., DECKERS J., WITMANS N., MEYVIS B., DUSAR M., BOGEMANS F., VERNES R., VAN DER MEULEN M., DE KONINCK R., VERHAERT G., SLENTER C., HESKES E., HEYVAERT V.
H3O – a better understanding of Campine cross-border Cenozoic stratigraphy

VAN RANST G., DE SCHEPPER S., LOUWYE S.
The Miocene – Pliocene boundary in the eastern North Atlantic: dinoflagellate cyst biostratigraphy

12:30 – 13:20 Lunch Geologica Belgica General Assembly

13:20 – 14:20 Plenary session (Room 12)

13:20 – 13:25 VANDENBROECK Medal ceremony

13:25 – 14:20 Talk by the laureate

14:20 – 15:20 Thematic sessions

SESSION 19: ENVIRONMENTAL CHANGE (ROOM 12)

14:20 – 14:40 MESTDAGH T., DE BATIST M.
Evaluation and modelling of the response of gas hydrate reservoirs to changing environmental conditions across a high-latitude continental margin

14:40 – 15:00 SAMYN D., UETAKE J., KERVYN F.
RIDEC – Rwenzori Ice dynamics and Environmental Changes

SESSION 20: GEOHERITAGE AND GEOARCHEOLOGY II (ROOM 11)

14:20 – 14:40 DREESEN R., DUSAR M.
Stony immigrants in the Bruges area (West Flanders, Belgium) traced back to their geological origin: Jurassic building stones from the Boulonnais area (Nord-Pas-de-Calais, northern-France)

14:40 – 15:00 NIKIS N., DE PUTTER T.
A geological context for ancient copper production in the Niari basin (Republic of Congo)

15:00 – 15:20 EVERS C., DE PUTTER T.
Multidisciplinary study of prestige ornamental stones or 'marbles' in the Roman city of Alba Fucens (Abruzzo, Italy)

SESSION 21: LATE CENOZOIC I (ROOM 03)

14:20 – 14:40 BOURDON H., XAVIER R., DEMOULIN A.
Timing and distribution of Plio-Quaternary uplift in the NW European Alpine foreland

14:40 – 15:00 JUAN C., ERCILLA G., ALONSO B., ESTRADA F., VAZQUEZ J. T., CASAS D., HERNÁNDEZ-MOLINA F. J., EL MOUMNI B., D'ACREMONT E., GORINI C.
Detailed analysis of the interaction between alongslope and downslope sedimentary processes in the Alboran Sea during the Pliocene and Quaternary

15:00 – 15:20 NEHME C., VERHEYDEN S., NOBLE S., FARRANT A., DELANNOY J.-J., CLAEYS P.
Paleoclimate reconstruction in the Levant region from the petrography and the geochemistry of a MIS 5 stalagmite from the Kanaan Cave, Lebanon

15:20 – 15:50 Coffee break

15:50 – 17:30 Thematic sessions

SESSION 22: GEOLOGICAL RISKS (ROOM 12)

15:50 – 16:10 ANDRE L., DELVAUX C., MONIN L.
Lake Kivu biogeochemistry: complex interactions between hydrothermal recycling, bathtub ring oxic-anoxic reactions and hydrodynamic mixing

16:10 – 16:30 DRAIDIA S., EL OUAHABI M., DEWITTE O., FAGEL N., HAVENITH H. B.
Landslides' mechanism and evolution in the west Rwanda

16:30 – 16:50 GARRETT E., HEYVAERT V. M.A., FUJIWARA O., DE BATIST M., GARRETT P., SHISHIKURA M., HUBERT-FERRARI A., BRÜCKNER H., NAKAMURA A., YOKOYAMA Y., the QuakeRecNankai team
Nankai Trough (Japan) palaeoseismology: progress since the 2011 Tōhoku earthquake

16:50 – 17:10 KEMPF P., MOERNAUT J., VAN DAELE M., VANDOORNE W., MESSENS F., VANDENBERGHE D., PINO M., URRUTIA R., DE BATIST M.
Bimodal recurrence pattern of tsunamis in south central Chile

17:10 – 17:30 VAN NOTEN K., LECOCQ T., HINZEN K., CAMELBEECK T.
Macroseismic analysis of online "Did You Feel" responses to M_L > 3 earthquakes felt/heard in and around Belgium

SESSION 23: REGIONAL GEOLOGY I – PALEOZOIC (ROOM 11)

15:50 – 16:10 CUSTINE E.
Field evidence of turbidite deposit in the lower Member of the Quatre Fils Aymon Formation (QFA) of the Deville Group (Rocroi Inlier) and revision of the paleoenvironmental deposit conditions of these rocks

16:10 – 16:30 LICOUR L., DUPONT N., SWENNEN R., STEEMANS P., BOULVAIN F., PETITCLERC E., HENNEBERT M., BAELE J.-M., RORIVE A., GODERNIAUX P.
Reappraisal of the deep Devonian strata under the Mons Basin

16:30 – 16:50 COBERT C., BAELE J.-M., BOULVAIS P., POUJOL M., BEYSSAC O., DECREE S.
Upper Silurian magmatism in the Rocroi Massif, Ardennes: new constraints from geochronology and geochemistry of microgranite dyke at Mairupt

16:50 – 17:10 DUPONT N., KAUFMANN O.
Exploration of the geothermal reservoirs of Hainaut (Belgium): preliminary results of the 2DMons2012 seismic survey. New deep structures revealed in the Brabant Parautochton

17:10 – 17:30 PIESSENS K.
The map of the Brabant Massif for off-shore Belgium

SESSION 24: LATE CENOZOIC II (ROOM 03)

15:50 – 16:10 BEERTEN K., VANDENBERGHE D., BUROW C., VANACKER V., VERBEECK K., DEFORCE K., DE GRAVE J., WOUTERS L.
Age constraints for the Pliocene Mol Sands as observed in the 2014 palaeoseismological trench near Mol (NE, Belgium): a combined ESR-OSL-CRN dating study

16:10 – 16:30 BOULVAIN F., JADOT H., NEUFCOURT G.
Sedimentology and magnetic susceptibility of recent littoral sediments from New Caledonia, France and Belgium

16:30 – 16:50 DE CLERCQ M., MISSIAEN T., BUSSCHERS F. S., VAN HETEREN S., BUNNIK F. P.M.
A First Assessment of Belgian Continental Shelf Prehistory

16:50 – 17:10 VAN DE VEN T. J.M., MENKOVIC A., WESTERHOFF W. E.
Mapping the marine Miocene sediments of the southern Netherland

17:10 – 17:30 WESTERHOFF W.
The Meinweg site and the Pretiglian: onset of the Quaternary?

Thursday January 28th

09:00 – 09:40 Plenary session (Room 12)

09:00 – 09:40 **Keynote:** GUTZMER J., BEUKES N. J.
The Paleoproterozoic Manganese Bonanza in Africa

09:40 – 10:40 Thematic sessions

SESSION 25: GEOMATERIALS (ROOM 12)

09:40 – 10:00 DE BOEVER W., CNUDDE V.
Multi-scale imaging of stones: getting the inside-story

10:00 – 10:20 DE KOCK T., BOONE M. A., DE SCHRYVER T., DE BOEVER W., DELEPIERRE J., VAN STAPPEN J., DERLUYN H., CNUDDE V.
Freezing Rocks: a pore scale study

10:20 – 10:40 VAN DAELE M., CNUDDE V., BOONE M., DEPREZ M., DE BATIST M.
X-ray (micro) computed tomography to study turbidite structures and fabrics: state-of-the-art and future challenges

SESSION 26: TELEDETECTION (ROOM 11)

09:40 – 10:00 VANBRABANT Y., BURLET C.
Aerial imagery from an high-altitude drifting balloon platform: applications in geohazards monitoring (Sierra Arana, Spain and Mons Province, Belgium)

10:00 – 10:20 TONG S.S., DEROIN J.-P.
Tidal flats, characteristic and change in North of Vietnam

10:20 – 10:40 DECLERCQ P.-Y., DEVLEESCHOUWER X., WALSTRA J., GERARD P., PIRARD E., PETITCLERC E., GOEMAERE E., DUSAR M., VANBRABANT Y.
Overview of the ground mouvements highlighted by the Persistent Scatterer Technique (PSI) in Belgium

SESSION 27: POSTERS (ROOM 23)

09:40 – 10:40 **African Geology**

DE PUTTER T., NIKIS N.
The Mindouli (Republic of the Congo) mining district revisited (1): geological context and preliminary results on the formation of complex, multiphase, Cu-Pb-Zn deposits

DEWAELE S., MEES F., MUCHEZ P., DE PUTTER T.
Cu-Pb-Zn mineralization in the West-Congo belt: Bas-Congo (DRCongo) and the Niari Basin (Rep. of the Congo)

DEWAELE S., HULSBOSCH N., MUCHEZ P.

Geology of the Sn, Nb-Ta and W mineralization in the Karagwe-Ankole belt, Central Africa: current state of knowledge

EVERAERTS M., NIMPAGARITSE G., DE PUTTER T.
Structural trends in the geology of Burundi as emphasized from geophysical datasets

09:40 – 10:40 **Marine Geology**

COLLART T., VERREYDT W., STEWART H., HOWELL K., BOURILLET J.-F., LLAVE E., BLAMART D., VAN ROOIJ D.
Cold-water coral mini-mounds on the Ferrol Canyon (Cantabrian Margin): initiation and controlling factors

DE CLERCQ M., CHADEMENOS V., MISSIAEN T., VAN LANCKER V.
A high-resolution DEM for the Top-Paleogene surface of the Belgian Continental Shelf

DELIVET S., VANDORPE T., WIENBERG C., BLAMART D., BASSINOT F., MIENIS F., STUUT J.-B. W., VAN ROOIJ D.
Cold-water coral occurrence and critical bottom current conditions in the Pen Duick Escarpment (Gulf of Cadiz, Moroccan margin)

GARCIA M., HERNANDEZ-MOLINA F. J., ALONSO B., VAZQUEZ J. T., ERCILLA G., LLAVE E., CASAS D., JUAN C.
Origin of morphological depressions on the Guadalquivir Bank uplifted area (Gulf of Cadiz middle slope)

VAN ROOIJ D., VANDORPE T., VANDENBERGHE M., HEBBELN D., WIENBERG C.
Buried cold-water coral mounds along the Moroccan Atlantic Margin: new insights in cold-water coral mound growth processes?

WEI A., LIN C., JIANG J., YAO Q.
Faults System Evolution in the Baiyun Sag of the Pearl River Mouth Basin, Northern South China Sea

10:40 – 11:10 Coffee break

11:10 – 12:30 Thematic sessions

SESSION 28: STRUCTURAL GEOLOGY (ROOM 12)

11:10 – 11:30 CHENG F., JOLIVET M., GUO Z.
Eastward extrusion of the North Tibetan plateau: insight from the Altyn Tagh fault offset and a 3D crustal budget in North Tibet

11:30 – 11:50 HUBERT-FERRARI A., DRAB L., BENEDETTI L., VAN DER WOERD J.
The Central North Anatolian Fault Segment: insights from cosmogenic nuclide dating of the Kizilirmak River terraces and from ^{10}Be erosion rate data

11:50 – 12:10 DEBAILLE V., O'NEILL C., BRANDON A. D.
Stagnant-lid tectonics in the early Earth history revealed by ^{142}Nd variations in late Archean rocks

12:10 – 12:30 TRIANTAFYLLOU A., BERGER J., BAELE J.-M., DIOT H., ENNIH N., MONNIER C., VANDYCKE S.
Neoproterozoic oceanic arc complexes in the Moroccan Anti-Atlas: tracking its genesis, accretion and collision

SESSION 29: MARINE GEOLOGY (ROOM 11)

11:10 – 11:30 COLLART T., STEWART H., HOWELL K., BOURILLET J.-F., LLAVE E., BLAMART D., MIENIS F., VAN ROOIJ D.
Using cold-water coral mini-mounds as analogue for giant mound growth: assessment of environmental drivers and anthropogenic impact

11:30 – 11:50 DUSAR M., PIETERS M., VAN HAELST S., DE CLERCQ M., GOETHALS H., DE CEUKELAIRE M., HEYVAERT V. M.A.
Pleistocene gravels on the Belgian offshore investigated for composition and provenance, towards a reassessment of the transport models

11:50 – 12:10 VAN ROOIJ D., REBESCO M., HERNÁNDEZ-MOLINA F. J., HEBBELN D., WIENBERG C., WAHLIN A.
The significance of contourites in marine palaeoenvironmental studies

12:10 – 12:30 VANDORPE T., MARTIN I., VITORINO J., HEBBELN D., GARCIA M., VAN ROOIJ D.
Contourite deposits in the El Arraiche area, southern Gulf of Cadiz

SESSION 30: CRETACEOUS - EOCENE CLIMATES (ROOM 03)

11:10 – 11:30 DE WINTER N., CLAEYS P.
Isotopes and elements from Mollusk shells: Tracing Cretaceous seasonality

11:30 – 11:50 DEPREZ A., JEHLE S., BORNEMANN A., SPEIJER R. P.
Deep-sea benthic foraminiferal faunal and isotopic records of the Latest Danian Event from Walvis Ridge (ODP Site 1262), Southern Atlantic Ocean

11:50 – 12:10 DEVLEESCHOUWER X., WOUTERS S., RIQUIER L., YANS J., STORME J.-Y., STEURBAUT E.
A climatic change at the Danian/Selandian boundary: increasing weathering fluxes

12:10 – 12:30 STASSEN P., SPEIJER R. P., DEVLEESCHOUWER X., ABELS H. A., KING C., WILLEMS W., STEURBAUT E.
Early Eocene climate changes in the North Sea Basin: a Belgian perspective

12:30 – 14:00 Lunch in PASS (Frameries)

14:00 – 17:00 Field trip (Malogne underground quarry)

17:00 – 17:30 Closing the day and return trip to Mons

Friday January 29th

09:00 – 09:40 Plenary session (Room 12)

09:00 – 09:40 **Keynote:** HOUSSAYE A.
Physiological and morpho-functional (secondary) adaptations of Amniotes to an aquatic life

09:40 – 11:00 Thematic sessions

SESSION 31: TERRESTRIALIZATION AND RETURN TO THE SEA I – MESOZOIC MAMMALS (ROOM 12)

09:40 – 10:00 BOSSELAERS M.
(Sub-)Fossil whale barnacles (Coronulidae) provide indirect evidence about the presence of baleen whale populations in the southern North Sea and about the routes followed towards their subtropical breeding grounds

10:00 – 10:20 DEWAELE L., AMSON E., LAMBERT O., LOUWYE S.
Reappraisal of the fossil seal Phoca vitulinoides from the Neogene of the North Sea Basin, with bearing on the geological age, phylogenetic affinities, and locomotion of a diminutive Miocene phocine species

10:20 – 10:40 LAMBERT O.
The fossil record as a tool for studying the convergent evolution of deep diving abilities in beaked whales and sperm whales

10:40 – 11:00 RITSCHE I., FAHLKE J. M., HAMPE O.
Phylogenetic signal or functional analogy in cochlear shape of Mysticeti

SESSION 32: RESERVOIR PROPERTIES (ROOM 11)

09:40 – 10:00 VANDEWIJNGAERDE W., PIESSENS K., BERTIER P., KROOSS B., SWENNEN R.
The behaviour of Westphalian mudstones both as source and reservoir rock (Campine Basin, NE Belgium)

10:00 – 10:20 HONLET R., GASPARRINI M., JOHN C., SWENNEN R.
Burial dolomite in the Variscan foreland fold-and-thrust belt of N-Spain: examples from the Bodón Unit

10:20 – 10:40 SALIH N., MUCHEZ P., PROUST J.-N., KOLO K., OTHMAN R., MANSURBERG H., PREAT A.
Hydrothermal diagenetic evolution of Upper Cretaceous Bekhme Formation, NE Kurdistan, Iraq

10:40 – 11:00 LIU S., WANG J.
Seismic of a shallow-lacustrine Delta in the Southern Huanghua Depression, Eastern China

SESSION 33: POSTERS (ROOM 23)

09:40 – 11:00 **Regional Geology**

BAELE J.-M., PAPIER S., SPAGNA P., TSHIBANGU J.-P., MARTIN T., KAUFMANN O.
Karst subsidence in the Iguanodon Sinkhole, Bernissart, Belgium. Evidence for active collapse processes during the Lower Cretaceous

CUSTINE E.
The importance of the pseudonodules in sedimentology: a review and some conclusions based on the study of the pseudonodules of the Roc de la Tour (Rocroi Inlier)

DUPONT N., KAUFMANN O.
Reinterpretation of a Mons Basin geological cross-section based on ERT survey: the Hainin-Hautrage pumping station site

DUPONT N., QUINIF Y., DUBOIS C., KAUFMANN O.
Speleogenesis by alterite erosion within ghost-rock features in the Ardenne Allochton (Sprimont syncline, East Belgium)

GONZE N., PINPIN G., BAELE J.-M.
Upper Silurian-Lower Devonian SEDEX mineralization as a primary source for alluvial gold in the Rocroi Massif, Belgium

HERBOSCH A.
A new synthetic subcrop map of the Brabant Massif, SE area

MATTHIJS J., DECKERS J., BROOTHAERS M., DE KONINCK R.
A new lithostratigraphic and seismostratigraphic interpretation of the Cenozoic strata for the Molenbeersel well (049W0226) in the Roer Valley Graben, NE Belgium

QUINIF Y., BLOCKMANS S., VERHEYDEN S.
The underground sedimentary series of the upper gallery in cave of "Pont d'Arcole", Hastière, Belgium

09:40 – 11:00 **Geoarcheology, Geoheritage, Geoeducation**

DREESEN R., DE CLERCQ W., TRACHET J., DEBONNE V.
Bedrock ballast stones in Flanders: first evidence for the presence of Baltic glacial erratic boulders and their historical re-use in Belgium

DUPONT N., PACYNA D., MORTIER T., BAELE J.-M.
The Colfontaine forest: vestiges of multi-secular an multi-ressources extractive activities in the Mons Basin Geopark

GOEMAERE E., DREESEN R., FRONTEAU G., PEROZ M., DATH J., ZARLENGA I.
Geology and legends in the Ardenne(s): another form of Geoheritage

MISSIAEN T., HEIRMAN K., JONGPIER I., GELORINI V., CROMBE P.
Holocene landscape evolution of the Waasland Scheldt polders in relation to human occupation and exploitation

MISSIAEN T., HEIRMAN K., VERHEGGE J.
Cone Penetrating Testing to map deeply buried palaeolandscapes for geo-archaeological prospection of polder areas

PICAVET P., RENIERE S., CNUDDE V., DE CLERCQ W., DERU X., DREESEN R., FRONTEAU G., GOEMAERE E., HARTOCH E.
The "Arkose of Macquenoise": a suitable Lochkovian raw material for ancient millstones: quarries, properties, manufacture and distribution (France-Belgium)

WILLEMSE S., PIESSENS K., WELKENHUYSEN K.
Board games as scientific communication tools for black-box methodologies: the principles of the geo-techno-economic PSS III simulator translated into an interactive educational game

11:00 – 11:30 Coffee break

11:30 – 12:30 Plenary session (Room 12)

11:30 – 12:10 **Keynote:** MELLES M., BRIGHAM-GRETTE J., MINYUK P., and the El'gygytgyn Scientific Party
Continuous 2.8 million year record of Arctic climate change from lake El'gygytgyn (NE Russia)

12:10 – 12:30 **Special issue:** VERSCHUREN D., DE BATIST M., CLAEYS P., SWENNEN R.
Research opportunities for Belgian earth scientists through the International Continental Scientific Drilling Programme (ICDP)

12:30 – 13:30 Lunch

13:30 – 15:10 Thematic sessions

SESSION 34: TERRESTRIALIZATION AND RETURN TO THE SEA II – MESOZOIC REPTILES (ROOM 12)

13:30 – 13:50 FISCHER V., BENSON R. B.J., ARKHANGELSKY M. S., ZVERKOV N. G., FRIEDMAN M. S.
Peculiar macropredatory convergences in Cretaceous marine reptiles

13:50 – 14:10 KLEIN N., SANDER P. M., SCHEYER T. M., KRAHL A., HOUSSAYE A.
Complex variability in microanatomical specializations in marine reptiles (Sauropterygia) from the Middle Triassic

14:10 – 14:30 SANDER P. M., HAYASHI S., HOUSSAYE A., NAKAJIMA Y., SATO T., WINTRICH T.
The evolution of plesiosaur bone histology: evidence from long bones and vertebrae

14:30 – 14:50 STEIN K., PRONDVAI E., HUANG T., REISZ R., SANDER P. M.
Flexible eggshell in Lower Jurassic prosauropod dinosaurs and the origin of the dinosaurian egg

14:50 – 15:10 WINTRICH T., SANDER P. M.
The first Triassic plesiosaur: a skeleton from the Rhaetian of Germany and its implications for the evolution of plesiosaur locomotion

SESSION 35: REGIONAL GEOLOGY II (ROOM 11)

13:30 – 13:50 VANDENBERGHE N., DE CEUKELAIRE M., GOEMAERE E.
Stratigraphy and Commissions. Do we need stratigraphic commissions?

13:50 – 14:10 DE NIL K., VAN DAMME M., VERHAERT G.
Flanders Soil and Subsoil Database (DOV) – The web portal to the geological information of Flanders

14:10 – 14:30 DECKERS J.
Recent insights in the Cenozoic tectonic evolution of the Roer Valley Graben

14:30 – 14:50 WALSTRA J., VERNES R. W., DECKERS J., HEYVAERT V. M.A., BOGEMANS F., DABEKAUSSEN W., DE CEUKELAIRE M., DEN DULK M., DOORNENBAL H. C., DUSAR M., HUMMELMAN J., LANCKACKER T., MATTHIJS J., MENKOVIC A., MEYVIS B., REINDERSMA R. N., WESTERHOFF W. E., WITMANS N.
H3O: Crossing borders in 3D geological modelling

14:50 – 15:10 QUINIF Y., CAMELBEECK T., KNUTS E., VERHEYDEN S.
Endokarstic breakdown and earthquakes: The relation between the "dome" room collapse (Han-sur-Lesse cave) and the 1828 earthquakes in Belgium

SESSION 36: HOLOCENE CLIMATES AND ENVIRONMENTS (ROOM 03)

13:30 – 13:50 ALLAN M., VERHEYDEN S., LE ROUX G., JAVAUX E. J., PIOTROWSKA N., MATTIELLI N., FAGEL N.
Holocene paleoenvironmental reconstructions from Belgian peatbog

13:50 – 14:10 DE CORT G., BARAO L., CONLEY D., HAUG G., BLAAUW M., ENGSTROM D., VERSCHUREN D.
Holocene hydroclimate shifts in tropical East Africa and their link to the African Humid Period termination: the multi-proxy sediment record from Lake Rutundu, Kenya

14:10 – 14:30 GURDEBEKE P. R., POSPELOVA V., MERTENS K. N., CHANA J., DALLIMORE A., LOUWYE S.
Holocene dinoflagellate cysts from fjords of western Vancouver Island (British Columbia, Canada)

14:30 – 14:50 MEYER I., VAN DAELE M., FIERS G., VERLEYEN E., DE BATIST M., VERSCHUREN D.
Color reflectance spectroscopy of profundal lake sediments: a novel moisture-balance proxy for tropical East Africa

14:50 – 15:10 VANDERSTRAETEN A., BONNEVILLE S., FLAMENT P., DEBOUDT K., DEVLEESCHOUWER F., LE ROUX G., GIERE R., TISON J.-L., DEBAILLE V., MATTIELLI N.
Physico-chemical characterisation of dust deposition in snow from NE Antarctica

15:10 – 17:00 Closing the conference and drink

ABSTRACTS

TUESDAY January 26th

KEYNOTE

Stonehenge: new phosphatic chalk deposits in the Upper Cretaceous Chalk of England and implications for tunneling

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Keywords: Phosphatic-chalk, engineering, environment, keyword, keyword

Abstract

Ground investigations for the A303 Stonehenge Tunnels revealed a unique and complex Chalk geology including the presence of the thickest, and previously unknown, phosphatic chalks in England, partly filling fault controlled erosional channels. The use of natural gamma-ray borehole logs to determine the presence and thickness of the phosphatic deposits is of particular value and combined with the lithostratigraphy and biostratigraphy from cores has, for the first time, accurately constrained the Coniacian to Santonian age and the lenticular geometry of such deposits. Four phosphatic chalk events between 88.5-86.5 Ma are recognised associated with synsedimentary faulting.
The risks associated with this geology include: (i) predicting the material behaviour in open face or machine tunnelling in coarse, firm to loose calacarenitic chalk; (ii) the ability of the material to support temporary arch support; (iii) the environmental impact of phosphatic chalk material in terms of nutrient to ground and surface water drainage, in lansdscaping and in terms of radon production (iv) and the differences in rock mass character of the various chalk deposits.

SESSION 1
CRETACEOUS – PALEOCENE STRATA

New XRF data for the upper Maastrichtian in Gubbio, Bottaccionne section, central Italy

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Keywords: XRF, Palaeoclimatology, Maastrichtian, Cretaceous-Palaeogene Boundary, Gubbio

Abstract

The Gubbio sections from the Umbria-Marche basin in central Italy form the basis of numerous stratigraphic studies spanning the Jurrasic to the Miocene. The Bottaccione gorge is renowned for its pioneer work on the Cretaceous-Paleogene boundary. A multiproxy ($\delta^{18}O$, $\delta^{13}C$, MS, $CaCO_3$) study at high-resolution (5 cm) sampled the uppermost 7.2 m from the Maastrichtian Bottaccionne Gorge is now completed with new XRF data. These were carried out both with the new portable and micro X-Ray Fluorescence scanners at the AMGC department of the VUB.

A close covariation between the $\delta^{18}O$ and Sr concentration is observed. The largest shift in these covariant proxies coincides with a change in characteristics of the variation of other elements (e.g. Ti). Interestingly the stratigraphical interval of this transition corresponds with a drop in Os-isotope values, which is classically explained as caused by the Deccan volcanism. Surface XRF mapping reveals heterogeneities in the sampled material as concentrated areas show elevated concentrations of elements (e.g. K) related to the presence of clays. Furthermore, periodic relative variations in elemental concentrations allow an evaluation of the existing cyclostratigraphic framework and accompanying palaeoclimatological interpretations.

Did the PETM occur before or after the Claret Conglomerate (CC) at Campo (Spain)? New perspectives from high-resolution chemostratigraphy ($\delta^{13}C_{org}$, $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$)

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Keywords: Campo, PETM, Spain, Isotopes, Nannofossils

Abstract

The Tremp-Graus and Basque-Cantabrian basins in northern Spain, expose several sections from continental to marine setting, encompassing the PETM (Paleocene-Eocene Thermal Maximum). The Campo section has remained a reference section because of 1) its transitional position, marine during the late Paleocene and early Eocene and continental across the Paleocene-Eocene boundary (PEB) and 2) the presence of two late Paleocene mammal levels, cropping out below the Claret Conglomerate (CC), at Tendruy and Claret respectively. The position of the PETM is still a matter of debate: previous studies on both organic material and bulk carbonate suggest that this event is located prior to the CC. We here present a high-resolution $\delta^{13}C_{org}$ study for the Campo section, spanning 14m of continental/proximal marine deposits, across the PEB. Through comparison of the carbon isotope profiles of organic matter ($\delta^{13}C_{org}$), bulk carbonate carbon and oxygen ($\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$), we were able to identify a typical CIE (Carbon Isotope Excursion) triangular profile: (1) the onset starts at ~1m (unit c; -24.4‰) or at 3.05m (unit c; -25.8‰), above the last limestone bed (unit a); (2) rapid CIE decrease to minimum value at 4.15m (unit c; -29.5‰); (3) continuation of the minimum values up to 5.60m, representing the core of the CIE (unit d; -29.3‰) and finally 4) the recovery phase up to 8.70m (unit e; -24.8‰). The magnitude of the CIE recorded for $\delta^{13}C_{org}$ is about 3.5 to 4.9‰, which is similar to previous studies at Campo (2.1-4.8‰). The CIE onset starts below the lateral equivalent of the Claret Conglomerate (between 5.90m and 8.80m). The upper section shows perturbations in the $\delta^{13}C_{org}$ that could be explained by incorporation of marine organic matter. The lower part of the section (below 3.05m) shows two successive negative shifts of the $\delta^{13}C_{org}$ record, respectively at 0.45m (unit b; -27.8‰) and 2.30m (unit c; -28.7‰). At least one of these small excursions, below the core of the CIE, is observed in numerous other PETM sections and is here highlighted for the first time in the Campo section. Carbonate and oxygen isotope values seem to be perturbed by carbonate diagenetic overprint resulting in anomalous $\delta^{13}C$ shifts. A high-resolution calcareous nannofossil investigation has been carried out, but the preliminary results are rather discouraging, because of the nearly complete absence of *in situ* specimens. Additionally, palynofacies and Rock-Eval data have also been performed to quantify the marine organic matter input in the sequence.

Silcrete in northern France and Belgium: a terrestrial record of surface environments under the influence of pyroclastic ash-falls

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Keywords: silcrete, titanium oxides, ash-falls, PETM

Abstract

Silcretes are common in uppermost Palaeocene to lowermost Eocene sediments from northern France and Belgium. Most silcretes are traditionally classified into "pedogenic" and "groundwater" types (Milnes and Thiry, 1992; Thiry, 1999). Pedogenic silcretes exhibit geopetal features at macro- and microscopic scale along with other soil-like structures and show enrichment in TiO_2, while groundwater silcretes are defined as nearly pure quartzitic lenses lacking both geopetal organization and Ti-enrichment. Many silcretes we have examined share characteristics of these two ideal end-members and necessitate a re-examination of their significance in terms of formation environment and processes. Ti-oxide grains, coatings and illuviations occur in quartzitic silcretes. The Ti-rich grains dominate the heavy mineral assemblage and many are weathered ilmenite. The observed Ti-oxides cannot result from a relative accumulation by soil processes as it is reported for pedogenic silcretes. Some are concentrated in caps which formed in porosity and were silicified in a distinct phase predating the silicification of the main silcrete mass. TiO_2 in silcrete is here interpreted as being sourced from pyroclastic ash falls of mafic composition. This interpretation is furthermore supported by the occurrence of Ti-rich ash beds at Sinceny, in a unit deposited during the PETM (Quesnel et al., 2011). Ti-rich bentonites were also reported from the Tienen Fm, earliest Eocene in age, at Goudberg, Belgium (Zeelmaekers et al., 2012). It is known for a long time that mafic volcanic activity in the North Atlantic Igneous Province (NAIP) was intense during the Late Paleocene and Early Eocene (e.g. Roberts et al., 1984) and represents the most likely source of airborne volcanic products. In this scheme, ash material could also have provided highly-soluble silica which promoted silcrete formation either on the very surface and/or in the underground. Silcrete may thus represent a terrestrial counterpart of marine bentonites and other related volcanogenic sediments, which are abundant in the Late Paleocene-Early Eocene of the North Sea (Huggett and Knox, 2006).

References:

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SESSION 2
BAS-CONGO

New 1/500.000 scale GIS-based geological and mineral resources maps for Bas-Congo province (DRC) with an updated lithostratigraphy of the Neoproterozoic West Congo Supergroup

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Keywords: Bas-Congo - DRC, geological map, mineral resources, West Congo Belt, geodynamics, metallogeny

This work is the result of a collaboration programme between the Royal Museum for Central Africa (RMCA, Belgium) and the Centre de Recherches Géologiques et Minières (CRGM, D.R.Congo) with the financial support of the Belgian Cooperation Agency.

Abstract

The Bas Congo province covers 3 full square-degrees and 6 partial ones. In the 1960-ies a geological mapping and prospection programme which built on earlier work was carried out (BAMOCO consortium), but only half of the coverage was published (sheets Kinshasa, Inkisi, Luozi, Ngungu; 1/200.000).

The biggest part of the province consists of Neoproterozoic rocks from the Panafrican West-Congo Belt. These are the easternmost third of the Araçuai – West Congo Orogen (AWCO) which runs North to South from SW Gabon to NW Angola and extends in width from Brazil to Congo. In Bas-Congo province, the structural direction of AWCO belt changes from N to NW, while another NE direction shows the presence of the Sangha aulacogen.

A model of dextral trans-tensional rifting and associated magmatic events during the Columbia break-up was proposed for its history (Tack et al 2001). Peralkaline magmatism (1.0 Ga, Noqui granite) represents an initial phase followed by a major phase with a bimodal magmatism (920-910 Ma, Gangila mafic lavas and Inga felsic magmatism). A final mafic volcanic event (700 Ma) precedes ocean opening (660 Ma) evidenced at the Brazilian side of the belt.

The new GIS-based cartographic compilation produces the complete geological coverage of the Bas–Congo province. 1/500.000 maps (geology, mineral resources) were produced, together with the 3 missing 1/200.000 geological sheets of Matadi, Kai-Mbaku and Tshela-Moanda.

The 2001 geodynamic model required a major update of the 1960-ies regional Proterozoic lithostratigraphy, which was formalized in order to match current lithostratigraphic rules. The lithostratigraphy was also adapted to reflect published works since 1970 and results from recent field work.

The new 2013 pre-Karoo lithostratigraphy is as follows (top to bottom):

Lithotratigraphy

This work (2013)	*Tack et al (2001)*	*Lepersonne (1974)*
	Phanerozoic	
Inkisi Supergroup	Inkisi Subgroup	
	Neoproterozoic	
Ouest-Congo Supergroup	Ouest-Congo Supergroup	Ouest-Congolien
Cataractes Group	Ouest-Congolien Group	
		Inkisi
Mpioka Subgroup	Mpioka Subgroup	Mpioka
Lukala Subgroup	Schisto-calcaireSbgp	Schisto-calcaire
Haut-Shiloango Subgroup	Mixtite supérieure Fm	Tillite supérieure
	Haut-Shiloango Sbgp	Haut-Shiloango
Sansikwa Subgroup	Mixtite inférieure Fm	Tillite inférieure
	Sansikwa Subgproup	Sansikwa
Tshela / Seke-Banza Group	Mayumbien Group	
Matadi Group	Zadinien Group	
	Mesoproterozoic	
		Mayumbien
	Paleoproterozoic	
Kiméza Supergroup	Kimézien Supergroup	Zadinien
	Archean	
		Mpozo-Tombagadio Complex

The new mineral resources map reports 1068 metal indices for 800 sites. The main mineralisations, like Bamba-Kilenda, Toni and Kussu Senge, are epigenetic sulphide concentrations that occur along major Panafrican (EW and NE) fault systems.

Tonian rifting events on the Congo-São Francisco palaeocontinent: New evidence from U-Pb and Lu-Hf data from the Shinkakasa plutonic complex (Boma region, West Congo Belt, Democratic Republic of Congo)

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Keywords: U-Pb, Lu-Hf, A-type granite, Tonian, West Congo Belt

Abstract

The West Congo Belt (WCB) together with its counterpart located in Brazil, the Araçuaí orogen, represents a Pan African-Brasiliano orogenic system developed within an embayment shaped into the Congo-São Francisco palaeocontinent. At Bas-Congo, the ENE-verging WCB segment was thrust onto the Sangha aulacogen, making up a prominent salient into the Congo Craton foreland. This salient is rich in anorogenic igneous rocks hosted by the Kimezian basement. Our study, based on U-Pb (SHRIMP) and Lu-Hf (LA-ICP-MS) analysis on zircon crystals, focuses on the Boma sector at the westernmost Bas-Congo region, where the Shinkakasa plutonic complex (SPC) has been mapped (see Baudet and coauthors, this meeting). SPC mostly includes weakly to non-metamorphosed, A-type, granitic to syenitic and gabbroic rocks, displaying magma mixing features. The studied samples and respective analytical results (MCA, magmatism U-Pb age in Ma; TDM, Lu-Hf model age in Ga; eHf, epsilon $Hf_{(t)}$) are: **#166103**, granodioritic orthogneiss (MCA, 2069±17; TDM, 2.47–2.59; eHf, -0.71 to -4.06), representing the SPC host rocks; **#166104**, foliated syenogranite rich in pink K-feldspar (MCA, 869±14; TDM, 1.94–2.29; eHf, -8.31 to -18.10); and rocks from a SPC zone rich in magma mixing features, like **#166101**, gray syenogranite (MCA, 911±13; TDM, 1.90–2.01; eHf, -7.10 to -11.02); **#166102**, monzogranite poor in mafic minerals (MCA, 909±25; TDM, 1.89–2.36; eHf, -7.98 to -19.89); and **#117590**, porphyritic quartz syenite (MCA, 880±13; TDM, 1.89–2.06; eHf, -7.64 to -10.98); both 166101 and 117590 are rich in brown biotite and bluish green amphibole, displaying igneous flow. Quite juvenile zircon grains together with an Archaean inheritance suggest a magmatic arc setting for the Kimezian basement. Lu-Hf isotopic signatures from SPC rocks suggest distinct magma evolutions in space and time. Samples 166101 and 117590 record relatively less evolved magmas, mostly derived from the Kimezian basement. Samples 166102 and 166104 represent more evolved magmas, including an older crustal component. This also suggest two magmatic phases for the rifting event: the first, around 910 Ma, correlates to the bimodal Seke-Banza magmatism; the second phase, around 880-870 Ma, is equivalent of A-type magmatic rocks found in other WCB regions (Mayumba complex, Gabon), as well as in the Araçuaí orogen (Salto da Divisa suite), in Brazil. Our data also reinforces the assumption that more than one Neoproterozoic rifting event preceded the Araçuaí-West Congo orogen: the Noqui (ca. 1000 Ma), Boma-Mayumba-Salto da Divisa (930–860 Ma), and the Lower Diamictite-South Bahia Alkaline Province (735-670 Ma) events.

The Noqui peralkaline granite body (Matadi - Bas-Congo - DRC): a marker of 1.0 Ga lithospheric-scale triple junction updoming during long-lived Columbia breakup

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Keywords: single-zircon geochronology, West Congo Belt,; magmatism, Columbia breakup, Bas-Congo of DRC

Abstract

The Panafrican West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO), which formed during Gondwana amalgamation (550 Ma). The AWCO is underlain by a 2.1 Ga Eburnean-aged orogenic system, whose migmatitic gneisses belong in the WCB to the Palaeoproterozoic Kimeza Supergroup. The WCB extends from SW Gabon to NW Angola along the Atlantic ocean. Its central part displays an ENE-verging fold-and-thrust belt with eastward decreasing deformation and regional metamorphism. In the DRC, the belt is separated by a thrust front from the Sangha aulacogen (foreland domain). The Neoproterozoic West Congo (WC) Supergroup comprises – from old to young - the Matadi, Seke-Banza and Cataractes Groups (Baudet et al 2013 and this meeting).

In the N and NW Matadi region, the Noqui peralkaline granite intrudes the Matadi Group (silicoclastic Matadi and underlying Palabala Formations) showing thermal metamorphism. It is composed of mesoperhite, quartz, aegyrine ± lepidomelane ± opaques ± riebeckite and has a A1-type geochemical composition. It originated from a deep-seated OIB-type source affected by crustal contamination resulting into evolved liquids. New LA-ICPMS emplacement ages (1018±19 and 1043±25 Ma) for the Noqui granite and its related hypabyssal equivalents confirm the earlier SHRIMP age (999±6 Ma).

In the SE Matadi region, the Noqui granite is separated by a NW-SE trending fault from the Mpozo syenomonzonite.Two new ages for the Mpozo syenomonzonite (1948±10 Ma and 1947±30 Ma) show that despite of the cartographic and compositional similarities, this body is unrelated to the Noqui granite and is a part of the nearby Kimeza basement.

During the 550 Ma AWCO, the Kimeza basement and the WCB units were thrust partly upon each other and all rocks were affected by tectonic overprinting of variable intensity under greenschist facies conditions (retrograde for Noqui, Mpozo and Kimeza rocks and prograde for Matadi and Seke-Banza rocks). Late Pan-African N-S trending shear zones and corridors formed under brittle conditions. The Noqui granite, and other comparable poorly studied intrusions, occur only in the central part of the WCB, i.e. in the fold belt – aulacogen triple junction. They mark a 1.0 Ga subregional lithospheric-scale updoming event, which corresponds to one of the successive extensional events occurring during the long-lived Columbia breakup history preceding the AWCO and Gondwana amalgamation.

SESSION 3
HYDROGEOLOGY I

Hydrogeological and Hydrogeochemical Investigation of the Coastal Area of Jifarah Plain, NW Libya

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Keywords: Seawater intrusion, overexploitation, upper aquifer, Jifarah Plain, Tripoli, Libya

Abstract

Large increases in water demand with very little recharge have strained Libya's groundwater resources resulting in serious declines in water levels and quality, especially along the Mediterranean coast where most of the domestic, industrial and agricultural activities are concentrated. The rapid economic expansion, coupled with sharp population growth, in the Jifarah Plain comprising Tripoli, NW-Libya, has created an immediate need for proper groundwater reserves, not only to meet the increasing population's demands, but also to secure a contingency plan. The main problem is salinization of freshwater. Based on the available hydrogeological and hydrochemical information, the sources of salinization are identified. The overpumping for groundwater contributed to the deterioration of the water quality by seawater intrusion and exposing the deep saline water. Groundwater level is mostly low especially near to the coast, where zero and negative heads are recorded for the majority of wells. Depression cones in various places have dropped from 20 to 33 m below sea level, which testifies the inversion of the hydraulic gradient and the intrusion of seawater.

Cl^- is the major pollutant of the aquifer. Water samples were collected from 134 sampling wells in the study area and analyzed for the major cations and anions. The chemical results for the groundwater samples in the plain are classified according to the Stuyfzand groundwater classification system. The water type is mostly CaCl, NaCl and Ca/MgMix. These water types indicate that groundwater chemistry is changed by cation exchange reactions during the mixing process between freshwater and seawater. The majority of groundwater samples (80%) show a composition that is indicative of seawater intrusion.

The groundwater flow model of the upper aquifer was successfully constructed and developed. The steady state simulation has indicated that groundwater flow direction is from higher topography in the south to the north, towards the Mediterranean Sea in the north and sebkha drains in the northwest of the plain. The non-steady state simulation has indicated that groundwater levels in the upper aquifer are most sensitive to discharge from wells. Groundwater flow direction is from south to north, towards the depression cones and reduced heads on the coast.

Enhanced salinization of the Nieuw-Arenbergpolder for the creation of salt meadows on the left bank of the river Scheldt, Belgium

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Keywords: enhanced salinization, salt meadows, polders, groundwater modelling, artesian wells

Abstract

One of the conditions for the expansion of the port of Antwerp on the left bank of the river Scheldt is the development of several nature reserves north of the harbour. One of the areas that is chosen for this is the Nieuw-Arenbergpolder in which salt meadows have to be developed. Earlier research (Devriese & Lebbe, 2014) showed that the natural development of salt meadows in this area will be slower than desired with the proposed development plan. Therefore, an additional study was ordered to explore the ways in which the salinization process could be enhanced (both accelerated and facilitated). The first step of this additional investigation was the collection of field data in a test plot in the Nieuw-Arenbergpolder. The field work comprised the installation of additional monitoring wells, the continuous monitoring of hydraulic heads, the performance of geophysical measurements and the execution of a step pumping test. The monitored water heads and the hydraulic resistance of the peat layer allowed us to evaluate the present velocity fluctuation through the peat. From the beginning of November till the end of March the hydraulic head below the peat is higher than the desired surface level. By perforating the peat layer, artesian wells can be created through which salt water can flow to the surface. At the surface, the salt water will spread principally horizontally from the irrigation to the parallel drainage canals. To quantify the acceleration of the salinization by the artesian well canal system a detailed groundwater model as well as a larger scale groundwater model of the Nieuw-Arenbergpolder and its vicinity have been constructed. The results of the detailed groundwater model showed that the artesian wells are a valid option for the enhancement of the salinization of the area. During winter, the salt content in the irrigation canals around the artesian wells rises quickly, while during summer the salinized canals create a brackish groundwater flow towards the drainage canals through the uppermost pervious layer. The results of the large scale groundwater model confirmed these results. By comparing the results from the natural salinization with the results of the enhanced salinization, a clear increase in salinization speed could be noted. The modelling at both scales showed that the combination of (closable) artesian wells with drainage canals in the Nieuw-Arenbergpolder is a valid option for the acceleration of the salinization to meet the required nature development goals.

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Electrical Resistivity Tomography Monitoring to Assess Water Distribution in the Vadose Zone

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Keywords: ERT, monitoring, vadose zone

Abstract

Water distribution in the subsurface is subject to variations not only in space but also in time. These variations result from the combined effect of different phenomena such as precipitation, run-off, evapotranspiration, water storage in soils or weathered rocks and infiltration to deeper horizons leading to groundwater recharge. Imaging those variations might reveal specific behaviours in the storage and infiltration process linked to local patterns in the subsoil hydraulic properties. However direct in-situ observation of the water distribution is not possible.

As soil and rock electrical properties are strongly dependent on the presence (and salinity) of water in their porosity, DC electrical resistivity geophysical methods has long been applied to groundwater exploration. Electrical Resistivity Tomography (ERT) is a geophysical inversion technique allowing to reconstruct a model of subsurface resistivity. In order to detect and track spatial and temporal variations in water distribution, ERT monitoring methods, that incorporate the temporal dimension, are actively developed. Here we focus on the challenges associated with the monitoring of groundwater distribution based on such methods.

Taking reliable electrical resistance measurements is a necessary precondition to ERT monitoring. We present our approach to achieve this, by examining several key points: (1) definition and qualification of the monitoring system and procedures, (2) automation of measurement and reporting, (3) assessment of measure repeatability and measurement error and (4) (semi-)automated verification of the system integrity and derive.

ERT monitoring quickly produce large datasets. Handling such datasets for pre-processing requires efficient storage and retrieval structures as well as semi-automated (or fully automated) processing workflows. Several strategies that we developed for storing, selecting, filtering, filling gaps associated to instrumental maintenance or breakdowns, including external time series of additionally monitored environmental parameters (e.g. effective rainfall, soil humidity, temperature), formatting data prior inversion and correcting for external factors (e.g. temperature) and inverting datasets are discussed.

Python routines have been developed to integrate all the steps prior inversion: data acquisition, append of the hierarchically formatted file, standard filtering and time series pre-processing. Datasets are then generated for inversion program such as BERT. After inversion, models are appended in the hierarchically formatted file for further processing and interpretation. First results obtained with this approach show its added value not only for subsurface imaging and data management but also for designing improved acquisition and processing workflows.

SESSION 4
DEVONIAN STRATA

Unravelling orbital climatic cycles from Devonian magnetic susceptibility signal – the quest for a better age model for the Lochkovian and Pragian stages (Czech Republic)

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Keywords: Devonian, Lochkovian, Pragian, cyclostratigraphy, Magnetic

Abstract

The uncertainties on the Devonian stage boundaries are currently in the order of several millions of years. When shown to reflect a detrital signal, which is influenced by climatic variations, Magnetic Susceptibility (MS) has been proven as a useful tool for identifying climatic cycles; which can subsequently be used to improve the time scale.

Here, we focus on two sections from the Prague Synform (Czech Republic) cutting through the Lochkovian, Pragian and the lower part of the Emsian. Sedimentation is rhythmic, dominated by slightly clayey offshore limestones, being mostly calciturbidites and hemipelagites. We provide hysteresis analysis in order to get insight into the nature and the origin of the magnetic minerals driving the variation in the MS signal. The results point to a MS signal mostly carried by clay minerals.

Subsequently, to improve estimation of the duration of the stages, we apply different spectral analysis techniques on this MS signal. From the Continuous Wavelet Transform (CWT), Evolutive Harmonic Analysis (EHA) and field observations, we subdivide the section into portions with a steady sedimentation rate (a first estimate of this rate is also delivered by these analyzes). Then, we apply Multitaper Method (MTM) and Multitaper harmonic Analysis (F-test) and extract the frequencies reaching 95% Confidence Level. These frequencies are then implemented into the Average Spectral Misfit procedures (ASM) which enables comparison with orbital targets. By combining these different techniques, 405 kyr cyclicty is identifed, a powerful duration paleochronometer. These new results indicate a duration of 7.7 ± 2 Myr for the Lochkovian stage and of 1.7 Myr ± 1.4 for the Pragian stage, compared to respectively 8.4 ± 6 Myr and 3.2 ± 5.4 Myr in the 2012 Geological Time Scale.

The Siluro – Devonian sedimentary record of the Tassili n'Ajjer (SE Algeria): new insights from sedimentology and stratigraphy

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Keywords: Silurian – Devonian, Tassili n'Ajjer, Berkine Basin, Black shales, Sahara

Abstract

The Silurian and the Devonian are two periods of interest throughout North Africa basins and Middle East, because sediments and organic-rich shales deposited in many places and formed important hydrocarbon reservoirs and source rocks (Beuf et al., 1971; Boot et al., 1998 & Lüning et al., 2000).

The study areas during this project are the Illizi-Berkine basins and Tassili n'Ajjer outcrops.

In the prolific Illizi-Berkine basins (Western Ghadames, Algeria) a basin-wide approach is needed, especially with the new "shale gas and shale oil" frontier in the upcoming years, in order to capture regional trends and re-assessment the Siluro-Devonian successions.

Wireline-logs from more than 146 (Berkine – Illizi Basin) Algerian petroleum exploration wells have been studied. Furthermore, a complete logging of spectacular large-scale and well exposed outcrops of the Siluro-Devonian sediments was carried out at the south margin (SE, Tassili n'Ajjer) of the Illizi-Berkine basins. The following analysis incorporates biostratigraphic, ichnological, sedimentological, magnetic susceptibility and high resolution stratigraphic data.

We present here a reference section for the Siluro-Devonian successions with an update on sedimentology and stratigraphy interpretation.

Silurian Facies from subsurface and outcrops, are ranging from offshore to deltaic deposits. The Silurian sequences can be subdivided into 6 main sequences, which are in stratigraphic order: (Si-1) Black 'Hot' Shale of Oued Imihrou Formation, organic-rich shales with nodular cabonates; (Si-2) Atafaïtafa Formation 500 to 650 m thick in subsurface with HCS, gutter casts and *Cruziana* Ichnofacies; (Si-3) and (Si-4) corresponds to 'Zone de passage' or 'M units' in the subsurface, which shows respectively increasing content of silts and sands then overlaid by clays of the M2 unit The M units with Storm-wave dominated interpreted to reflect deltaic origin, and environment framework prograding from prodelta to mouth bar; (Si-5) 'Barre inférieur' is coarsening-shallowing-upward unit, with large braided channels, conformably overlies the 'M unis' but with an erosional surface; Finally the (Si-6) corresponding to "Talus à Tigillites" or B units is mostly characterized by *Skolithos*, well developed on the delta-plain, and the topmost part of this sequence (B2) is truncated by the Caledonian unconformity.

Devonian Facies from subsurface and outcrops, are ranging from fluvial to normal-marine depositional conditions, and much more complex.

The Devonian sequences are under investigations, and some preliminary results on biostratigraphy are already obtained. *Eodevonaria* brachiopod fauna have been find in the Soutar section (identifications by D. Brice), marking the boundary between the Givetian and Frasnian Stage.

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Introduction of the Booischot Formation, a new formal lithostratigraphic unit for the Devonian in the Campine Basin (N. Belgium)

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Keywords: Booischot Formation, Campine Basin, Devonian, lithostratigraphy

Abstract

During systematic lithostratigraphic description of the deep subsurface of the Campine Basin (Northern Belgium) it was found that certain stratigraphic intervals in deep boreholes, already identified and described as separated units by different authors (Laenen, 2003; Lagrou, 2012), are not yet formally named. As one of the goals of the detailed stratigraphic study was to put all data in the Flemish web-based 'Databank Ondergrond Vlaanderen' (DOV), codes for the different lithostratigraphic units were needed. To have an accordance between DOV and the Belgium official stratigraphy, the newly proposed lithostratigraphic units are submitted to the Belgian National Commission on Stratigraphy. For the Devonian lithostratigraphy the Booischot Formation is submitted.

The Booischot Formation is composed of red, green and mottled conglomerates interbedded with gray sandstones and shales. Locally paleosoils are present. In borehole Booischot (GeoDoc 59E146, DOV no. kb24d59e-B160) the 400 m thick sequence can be subdivided in two units: an upper unit of mottled conglomerates, sandstones and quartzites and few thin shale beds in which several paleosoils are developed; and a lower unit dominated by red conglomerates with occasional paleosoils. In the Campine Basin the thickness and presence of the proposed formation are very variable as evidenced by its absence in borehole 007E178 (Heibaart 1/1bis). This is due to the deposition in a half-graben system along the northern boundary of the Brabant Massif (Muchez & Langenaeker, 1993).

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SESSION 5
BAS-CONGO II

Detrital zircon geochronology and provenance analysis of the Matadi metaquartzites and Yelala metaconglomerates: lithostratigraphic implications for the Matadi Group of the West Congo Supergroup (Bas-Congo, DRC)

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Keywords: detrital zircon geochronology, lithostratigraphy, West Congo Supergroup, Meso-Neoproterozoic, Bas-Congo of DRC

Abstract

The West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO), formed during Gondwana amalgamation. It is underlain by 2.1 Ga migmatitic gneisses of the Palaeoproterozoic Kimeza Supergroup. It extends from SW Gabon to NW Angola and displays eastward decreasing deformation and regional metamorphism. During AWCO, the Kimeza basement and WC groups were partly thrust upon each other. The Neoproterozoic West Congo Supergroup (WC) comprises – from old to young - the Matadi, Seke-Banza, Cataractes Groups (Baudet et al, 2013 and see this meeting, in particular for the correspondences with the previous lithostratigraphy). In the Matadi region, the Matadi Group comprises three Formations (from bottom to top): 1) Palabala (phyllites), 2) Matadi (metaquartzites), 3) Yelala, (metaconglomerates). New field evidence and sample data indicate that the Palabala Formation is composed of mylonitic rocks, described as "phyllites", derived from various protoliths outcropping in the region: Kimeza gneiss, Mpozo syenomonzonite and Matadi metaquartzite. Because this “formation” is a tectono-structural unit it must be deleted from the Matadi Group lithostratigraphy; due to mylonitization the unconformity between the Matadi Group and underlying Kimeza Supergroup is undiscovered. Detailed mapping shows that the 1.0 Ga Noqui granite intrudes the Matadi Formation (see this meeting), constraining it as pre-Neoproterozoic. Maximum ages of detrital zircons of two samples give respectively 1.3, 1.5 Ga, indicating that deposition occurred during the Mesoproterozoic. The bulk of the zircons have Palaeoproterozoic ages, with only few zircons older than 2.5 Ga, in line with a derivation from the nearby Kimeza basement source. Because of its Mesoproterozoic age, the Matadi Formation must be excluded from the Neoproterozoic West Congo Supergroup and is here redefined as the Mesoproterozoic “Matadi Group”. It marks, in Bas-Congo a relatively early arenaceous sedimentation during the Mesoproterozoic breakup of Columbia similar to the Brazilian Espinhaço Supergroup which witnessed three successive Mesoproterozoic extensional events at 1.70, 1.57 and 1.18 Ga. The bulk of the zircons of one sample from the Yelala Formation duplicates the results of the Matadi Formation, except for three zircons with a maximum age of 970-960 Ma The meaning of these early Neoproterozoic ages, of the depositional relationships with the other formations and the overall age of the base of the West Congo Supergroup is still under investigation.

The Lower Diamictite Formation of the Cataractes Group, West Congo Supergroup (Bas-Congo, DRC): a 700 Ma marker of extensional episodic activity during breakup of Columbia

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Keywords: detrital zircon geochronology, diamictite, West Congo Supergroup, Neoproterozoic, Bas-Congo of DRC

Abstract

The Panafrican West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO), formed during Gondwana amalgamation. It extends from SW Gabon to NW Angola and displays eastward decreasing deformation and regional metamorphism. In Bas-Congo, the Neoproterozoic West Congo Supergroup comprises – from old to young - the Matadi, Seke-Banza, Cataractes Groups (Baudet et al 2013 and see this meeting). The latter consists of Sansikwa, Haut-Shiloango, Lukala and Mpioka Subgroups. The Sansikwa Subgroup is composed of 3 Formations, the Lower and the Middle Sansikwa and on the top, the Lower Diamictite Formation (LDF). The lithological composition of the LDF is not uniform but includes true diamictites with an interlayered politic sequence with subordinate arenites; sedimentological observations do not show a glaciogenic origin but indicate gravity mass deposit characteristics. The LDF also contains lenticular subaqueous and subaerial tholeiitic basalts whose doleritic/gabbroic feeder system has given an U-Pb baddeleyite emplacement age of 694±4 Ma (Straathof, 2011). New detrital zircon geochronology and provenance analysis of the LDF gives a maximum depositional age of 700 Ma. The matching results between the two ages, for the basalts interbedded and for the LDF provenance analysis younger population, give a good accuracy for the LDF deposition age. In SW Gabon (Thiéblemont et al., 2011), the 700 Ma emplacement age of the Bas-Congo LDF is confirmed by an unprecise SHRIMP age (≤ 71349 Ma) on a tuffaceous rock, ascribed to the base of the Louila Formation (equivalent of the Bas-Congo Haut-Shiloango Subgroup). However, both macroscopic and microscopic re-examination of the dated rock indicates that it is similar to pelitic rocks interlayered in the LDF of Bas-Congo (Tack, personal communication). It is in agreement with the results of detrital zircon provenance analysis populations of the younger Lukala (707 Ma) and Mpioka (721 Ma) Subgroups of the West Congo Supergroup and of the Phanerozoïc Inkisi Supergroup (719 Ma) in Bas-Congo (Straathof 2011). The 700 Ma emplacement age of the LDF is in line with Neoproterozoic episodic extensional activity of Columbia, recorded by specific lithologies marking both exogenic (LDF) and endogenic (tholeiitic mafic magmatism) geodynamic processes as proposed in the "Zipper Rift Model". Finally, our 700 Ma age in the WCB constrains the loosely bracketed 735-670 Ma age for the same extensional tectonic episode ("E6"), as reported from the Brazilian side of the AWCO (Pedrosa-Soares and Alkmin, 2011). Finally, in the absence of glaciogenic sedimentological features and because of the extensional tectonic setting, a Sturtian glaciogenic origin due to exogenic processes for the LDF can be excluded.

The West Congo Belt of Bas-Congo (DRC) revisited: a patchwork of individual tectono-metamorphic domains as a result of South Atlantic ocean opening

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Keywords: West Congo Belt, Neoproterozoic, Bas-Congo of DRC, Reactivation, South Atlantic ocean opening

Abstract

The Panafrican West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO) formed during Gondwana amalgamation (550 Ma). The AWCO is underlain by a 2.1 Ga Eburnean-aged basement, whose migmatites and gneisses in the WCB belong to the Palaeoproterozoic Kimeza Supergroup. The Neoproterozoic West Congo Supergroup comprises – from old to young - the Matadi, Seke-Banza / Tshela and Cataractes Groups. The WCB extends from SW Gabon to NW Angola along the Atlantic Ocean. In its central part – including Bas-Congo – the belt displays a triple junction setting. Two segments of the fold-and-thrust belt (parallel to the Ocean) merge with the Sangha aulacogen (in the foreland). Both NNW-SSE striking segments show eastward decreasing deformation and regional metamorphism from SW to NE. During AWCO, the Kimeza basement was involved in East verging thrust of the WC groups. The recently published GIS-based geological map of Bas-Congo (Baudet et al., 2013; see this meeting) in fact is based on more than forty years old field mapping. Reappraisal of 1) scattered published and unpublished structural data of Bas-Congo, 2) thirty years old off-shore and on-shore geophysical data from adjacent Congo-Brazzaville and Angola and 3) new Bas-Congo data (field, geochronology, petrochemistry; five abstracts, this meeting) gives new insight in the structural complexity of the WCB. The latter is controlled by reactivation under brittle regime of two systems of inherited structures: 1) NE-SW to E-W trending basement structures and "weakness zones" of assumed/inferred Palaeoproterozoic age (parallel to trend of the aulacogen) and 2) NW-SE to N-S trending thrust fronts of Panafrican age (parallel to trend of WCB segments). Simultaneous reactivation of both structural systems resulted in blockfaulting and transcurrent movement. In Bas-Congo, two such blockfaulted units of first order are exposed, separated by an E-W trending left lateral shear zone. Due to uplift, the southern unit reveals - from E to W - a deeper, more complex crustal section of the WCB (amphibolite facies to unmetamorphosed rocks) with three successive thrust fronts of first order. The northern downfaulted unit shows a more superficial crustal section. Repeated post-Pan African reactivation, in particular as a result of Cretaceous breakup of Pangaea and South Atlantic Ocean opening, has led to a patchwork of individual tectono-metamorphic domains separated by structural discontinuities. Within each domain only a limited part of the Bas-Congo geology and virtual lithostratigraphy can be observed. It is essential to take into account this challenging structural setting during revision of geological mapping and lithostratigraphy, as currently in progress.

SESSION 6
HYDROGEOLOGY II

Double-peaked breakthrough curves: from field data to modelling. A study case in the Dinant area (South of Belgium)

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Keywords: karst, tracer-tests, scale model, numerical modelling, double restitution

Abstract

Carbonifereous carbonates outcropping in the Dinant area (South of Belgium) are intensely karstified. In particular, in Furfooz (6 kms SE of Dinant), an interesting karstic system is developed along the Lesse river. The Lesse is partially infiltrating through a sinkhole (*Trou des Nutons*) and is re-emerging 1200 m downstream at a resurgence called the *Trou de La Loutre*. The specificity of this underground system is that the existence of an important volume of standing water (the *Puits des Vaux* lake) on the flow path.

In order to understand and to characterize the hydrogeology of the active system, tracer-tests were performed in various flow conditions. Breakthrough curves (BTC) obtained via the different tests show similarities, particularly in the existence of a double restitution peak downstream the underground lake. Interpretation of the BTCs, along with field observations and monitoring of various parameters, suggests that the dual peak is due to the presence of the lake on the tracer route.

The understanding of the origin of these dual peaked BTCs is of major importance in the building of a conceptual model of the investigated system. In this aim, a scale model was build and several scenarios could be tested. The analog BTCs were then matched to the field BTCs and helped us to rethink our conceptualization of the field reality. Moreover, thanks to the establishment of a conceptual model, modelling based on the field BTCs could be performed. The modelization tool used is the OTIS program (One-dimensional Transport with Inflow and Storage) that supposes a main dynamic flow in mobile zone in which solute is transported by advection and affected by dispersion and, possibly, adsorption and decay. Next to the main channel, immobile zones acting as transient storage zones are equally distributed. To permit storage in stagnant zones, an exchange between mobile and immobile water zones has to take place. The major advantage in OTIS is the possibility of discretization of the system which is a very interesting feature in heterogeneous environments such as the studied system. OTIS is an adequate tool to model solute transport in karst conduits and allows to dimension karst conduits and to estimate the main transport parameters.

Study of groundwater-quarry interactions in the framework of energy storage systems

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Keywords: Oscillatory pumping, Groundwater, Unconfined aquifer, Quarries, Modflow

Abstract

Pump storage hydroelectricity is an efficient way to temporarily store energy. This technique requires to store temporarily a large volume of water in an upper reservoir, and to release it through turbines to the lower reservoir, to produce electricity. Recently, the idea of using old flooded quarries as a lower reservoir has been discussed. However, these flooded quarries are generally in relation with an unconfined aquifer. Consequently, pumping or injecting large volumes of water, within short time intervals, will have an impact on the adjacent water table. The objectives of this study is to understand this impact of oscillatory pumping in flooded quarries, using numerical simulations. Sinusoidal pumping is imposed to a generic quarry modelled with a 3D finite difference simulator. We observe and study the propagation of this stress in the adjacent porous media and the amplitude of water level variations in the quarry, as a function of the hydraulic parameters. Two different configurations have been considered: homogeneous hydraulic parameters in the porous media and the influence of a fractured zone in the vicinity of the quarry. The amplitude of water level fluctuations in the quarry, depend mostly on the volume of water pumping/injecting and on the quarry dimension. The influence of the quarry – aquifer interactions remains low whatever the hydraulic parameters. The attenuation of the groundwater head fluctuations in the porous media logically increases with the distance of the quarry. In the homogeneous case, we have an equal propagation of the stress in all point of the environment. The maximal distance of propagation increases with the hydraulic conductivity and the porosity values. The presence of a fractured zone induces preferential flow paths, which deform significantly the zone impacted by the sinusoidal pumping in the quarry. In the fracture, the distance of influence may increase by more than one order of magnitude, depending on the fracture and matrix hydraulic properties. In this study, we have focused on the impact assessment of pump/storage operations on aquifers. However, the actual field monitoring of groundwater levels fluctuations around a pump/storage system would also allow constitute an efficient characterization tool, by numerical inversion of collected data.

Hydrogeological conditions required for Underground Pumping Storage Hydroelectricity (UPSH) in old mines

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Keywords: UPSH, Hydroelectricity, Energy storage, Old mines, Hydrogeological characteristics, Groundwater leakage

Abstract

Renewable energy sources, because of their intermittence, could not afford a stable production and an adequate variability according to the energy demand. Underground Pumped Storage Hydroelectricity (UPSH) using abandoned mine works is an interesting alternative, in flat regions, to store energy during low demand periods by pumping water from an underground mine to an upper reservoir.

From the hydrogeological point of view, two considerations can arise for studying the feasibility before constructing an UPSH plant: 1) the alteration of the natural conditions of surrounding aquifers, and (2) the efficiency of the plant depending on possible leakage in the cavities from the hydrogeological environment.

A potential old slate mine was selected through a multi-criterion method and its geometrical and hydrogeological characteristics are used to build a simple but typical model. With the help of the HFEMC approach implemented in the code SUFT3D (HEG-ULg), the groundwater flows are modelled for a representative cavity.

Simulations of groundwater flow induced by a UPSH system are performed and the main variables are identified. Piezometric heads around the reservoir oscillate, the magnitude of the oscillations and the time to achieve a pseudo-steady state (magnitude and head reached during oscillations not varying anymore with time) depend on the boundaries, the parameters of the aquifer and the characteristics of the underground reservoir.

The required hydrogeological conditions are deduced and a screening methodology can be proposed to assess the main impacts caused in aquifers by UPSH plants. Their efficiency regarding the water level evolution inside the reservoir is also considered accommodating the cyclic pumped storage schemes.

Acknowledgments

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SESSION 7
CHALK – FROM GEOLOGY TO ENGINEERING

Relations between lithology and geomechanical properties of chalks from NW Europe

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Keywords: chalk, uniaxial compressive strength, Young's modulus, diagenesis index, porosity.

Abstract

High porosity pure white chalks have been extensively studied for more than forty years in relation with oil and gas production. Recently, there has been an increasing interest for unconventional reservoirs, among which other chalk formations, leading to the need for investigating a wider range of sedimentary systems.
For a better understanding of their mechanical behaviour, a relation can be made with the diagenesis of chalk formations. Several classification systems exist for carbonates, based on their mineralogical content and their granulometry. Faÿ-Gomord (2014) developed a diagenesis index based on the evaluation of textural and diagenetic parameters: the micritic matrix texture, grains contact, coccolithe disintegration, cemented zone, automorphous cement crystals, coccolithe grain overgrowth and intraparticle cementation. This tool, especially developed for chalk, aims to quantify the global porosity reducing diagenesis affecting chalk microtexture.
In this study, a wide variety of chalk samples from NW Europe have been investigated: classical high porosity chalk, clayey chalk, cemented chalk, coarse white chalk… On the one hand, a petrographical and petrophysical study has been performed to determine their petrography, density, porosity, permeability and sonic velocity. On the other hand, uniaxial compression experiments have been performed. The dataset gathered on more than 30 samples covers a wide range of values for the determined properties: porosities range between 15 and 45%, strength between 3 and 50 MPa, just to give two examples. Additional data from literature are also considered in the study.
The relations between petrographic and mechanical properties are investigated. The porosity-permeability relationship is found to be non-linear. Porosity is linked to P-wave velocity, strength and Young's modulus: high porosity chalks have lower P-wave velocities and lower strength. In addition, the pore size shows an interesting relationship with the Young's modulus. Finally, when assessing those relationships, chalk families based on their lithology can also be emphasized.

New insight into the microtexture of chalks from NMR analysis

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Keywords: chalk, petrography, petrophysics, SEM, marl-seams, porecasts, transverse relaxation

Abstract

An integrated petrographical and petrophysical study was carried out on a set of 35 outcrop chalk samples, covering a wide range of lithologies and textures. In this study various chalk rock-types have been characterized, in terms of microtextures and porous network, by integrating both geological, sedimentpetrological and petrophysical data, including porosity, permeability, low-field NMR (Nuclear Magnetic Resonance), MICP and specific surface area (BET) measurements. The data allow an in depth understanding of the NMR signal of chalks, with a focus on tight chalks, including all low reservoir quality chalks independently of their sedimentological and/or diagenetic history. The study aims to develop a NMR-based approach to characterize a broad range of chalk samples. The provided laboratory low-field NMR chalk classification can be used as a guide to interpret NMR logging data.
Based on the petrographical and petrophysical analysis, 6 groups of samples were identified, each of them characterized by a unique NMR signature. They are: (1) Micritic chalks, (2) Grainy chalks, (3) Cemented chalks, (4) Marl-seam chalks, (5) Argillaceous chalks and (6) Silicified chalk. NMR T_2 distributions were linked to pore body size. It is apparent that tight chalks, whether their characteristics are sedimentological (e.g. argillaceous chalks) or diagenetic (e.g. cemented or silicified chalks), yield smaller pore body sizes (T_2lm < 20 ms), as well as narrower pore throats (average radius < 150 nm) and lower permeability values (typically below 0.2 mD). Grainy chalks, with a packstone microfacies, possess T_2 distributions reflecting larger pore sizes (T_2 lm > 60 ms) as well as pore throats (average radius > 290 nm) and higher permeabilities (up to 13 mD). The marl-seam chalk samples yield bimodal T_2 distributions, with a first peak related to the micritic matrix porosity and a second peak related to intraparticle porosity.

Influence of waters parameters of rocks on seismic waves velocities

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Keywords: chalk, sonic measurements, saturation ratio, porosity , Gassmann, Biot critical frequency

Abstract

It is known since no more than 30 years that the mechanical behaviour of chalk is directly governed by its water content. The saturation ratio in the porous structure induces the "suction" phenomenon and all its consequences (a.o. constitutive law and related parameters). Besides the strict mechanical properties such as the strength and the stiffness, the seismic waves velocities also depend on the saturation degree of chalk.

This paper aims to present the so far unpublished results obtained in the framework of a Master Thesis supported at the Université Libre de Bruxelles. It presents the experimental methods and results and the resulting model of the variation of wave velocity as a function of fluid content.

The model is derived from the Gassmann theory, taking into account the "Biot-Gardner-White" effect. It consists of a generalization of the Gassmann model, using a theoretical fluid with weighted average water/air. The model reconciles two idealistic saturation processes, the perfect homogenous saturation with a harmonic average theoretical fluid and the perfect heterogeneous saturation with an arithmetic average fluid. A critical saturation ratio who marks the limit between the two saturation behaviours can be defined for each rock. This parameter is directly linked to the shape of the rock porosity distribution.

For some rocks, the waves velocities measurements in the range of the intermediate saturation ratios are greatly lower than those predicted with the generalized Gassmann model. In the Biot theory for saturated media, an inertial coupling between the solid and the fluid phases is introduced and explains the waves velocities decreases for a specific frequencies range. This phenomenon is characterized by the tortuosity of the rock. By analogy with the Biot theory, a loss of kinetic energy due to an inertial coupling between the water and air phases is introduced. This coupling is characterized by a new parameter, λ, depending presumably also on the geometry of the rock porous network.

Some questions are still to be answered or at least discussed, mainly:

i) What is the relation between the porosity distribution and the critical saturation ratio?
ii) What is the relation between tortuosity and the λ parameter?
iii) What is the influence of frequency on the coupling?

Heterogeneity of petrophysical properties in the chalk: depositional versus diagenetic origin

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Keywords: Chalk, sedimentology, nanostructure, diagenesis, petrophysics.

Abstract

Chalk is defined as a microporous reservoir rock. This formation is a prolific hydrocarbon-bearing reservoir in the North Sea and is one of the main aquifers in the Paris Basin.The heterogeneity of the chalk in terms of petrophysical properties (both surface and subsurface) is illustrated by porosity ranging from 4 to 52 %, permeability from 0.01 to 100 mD, and P-wave velocity on water-saturated samples from 2.4 to 4.4 km/s.

In the study area (Haute-Normandie, France), taken as an outcrop analogue, 99 samples (Cenomanian – Santonian) were collected. As in the North Sea fields, these samples show large petrophysical heterogeneity: total porosity (ϕ) from 6 to 46.5 %, very low permeability (K; 0.002 mD) to atypical high permeability (470 mD; without fracture), and P-wave velocity on water-saturated samples ranging from 1.8 to 5.5 km/s. However, the origin(s) of this large variation in petrophysical parameters is poorly understood. Four sedimentary models are defined here for the chalk:

- Argillaceous ramp model, with porosity from 36.3 to 46.5 %, and permeability from 0.02 to 1.5 mD,
- Carbonate ramp model (mudstone to packstone), with porosity from 26.1 to 46.5 %, and permeability from 0.04 to 6 mD, along a trend,
- Contourite model (mudstone to packstone and micro-packstone), with porosity from 8.3 to 45.5 %, and permeability from 0.05 to 470 mD, along two trends,
- *Softground* to *Hardground* model, with porosity from 6 to 32.6 %, and permeability 0.02 to 13.2 mD, along a well-correlated trend (R^2=0.85).

A nanostructure classification of the chalk is for the contourite and carbonate ramp models is proposed, based on SEM observation of several parameters, including grain morphology and grain contact. This classification reflects the intensity of chalk modification during diagenesis (rate of diagenesis, whether early stage or not). An increase in the diagenetic rate induces a decrease in porosity and an increase in P-wave velocity. Diagenetic transformation induces a decrease in pore space size, with better grain contact, explaining the decrease in porosity and the improved propagation of acoustic P-wave velocity.

The complex relationships between depositional inheritance and diagenetic transformation, lead to variability in chalk petrophysical parameters. Spatial distribution of depositional facies and associated diagenetic transformation is not random, particularly in the Coniacian-Santonian contourite model. Extrapolation of the combined facies and diagenesis characterisation will allow to distribute the petrophysical properties on several cliff sections and therefore to illustrate the resulting reservoir architecture of the chalk.

Foraminifera and the sea grass communities of the Maastricht Chalk

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Keywords: Foraminifera, sea grass, Cretaceous, Maastricht, palaeoecology

Abstract

Sea grasses are marine angiosperms (plants) that, in the Late Cretaceous, migrated from the land into shallow-water marine environments. They represent a distinct, but fragile, marine habitat and sea grass meadows are often regarded as biodiversity hot-spots with a range of species (including fish, sea horses and cuttlefish) using them as nurseries for their young. Foraminifera are often found associated with sea grass meadows, with the associated taxa reflecting both the environment and palaeolatitude. In the tropics and sub-tropics, miliolid foraminifera dominate (e.g., *Peneroplis* spp.) as do large discoidal taxa such as *Marginopora* and *Calcarina*. In temperate to cool latitudes the assemblage changes to one dominated by smaller benthic taxa, including *Elphidium* spp. One taxon, *Elphidium crispum*, is geotropic and is often found – in the summer months – to crowd the fronds of the sea grass.

In the Gulpen and Maastricht formations of the Maastricht area (The Netherlands and Belgium) sea grass fossils (both fronds and rhizomes) have been recorded in association with assemblages of both larger and smaller benthic foraminifera. Some of the large discoidal forms (e.g., *Omphalocyclus* and *Orbitoides*/*Lepidorbitoides*) and the distinctive *Siderolites* are associated with these sea grass fossils and are suggestive of the modern sea grass communities of sub-tropical areas. The presence of sea grass fossils and their associated benthic foraminifera is indicative of a clear, shallow-water seaway, with a maximum depth of 15–20 m. The reported variations in sea level during the latest Cretaceous cannot, therefore, have been very large as such a change in water depth would have been disastrous to such a fragile ecosystem. The fossil record of sea grasses in the Cenozoic is relatively limited, though there are some assemblages of benthic foraminifera that are suggestive of their presence, despite the lack of plant fossils.

SESSION 8
ORE & RESOURCE GEOLOGY

Manganese layered oxides (asbolane, lithipophorite and intermediates) identification and characterization by Raman and infrared spectroscopy

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Keywords: manganese, layered oxides, Raman spectroscopy, infrared spectroscopy

Abstract

In this study, Raman and infrared spectroscopy is applied to investigate two manganese oxide phases: lithiophorite [(Al, Li)$Mn^{4+}O_2(OH)_2$] and asbolane [$(Ni,Co)_xMn^{4+}(O,OH)_4.nH_2O$], along with their intermediates ("Asbolane-Lithiophorite Intermediates": ALI). These oxides typically incorporate variable concentrations of Co, Ni, Cu and Li. They represent a group of economically interesting phases that are difficult to identify and characterize with classical X-ray diffraction techniques. They were described in many places around the world, including the oxidized horizon of large ore deposits in New-Caledonia, Australia, the Democratic Republic of the Congo (DRC) amongst others. They also represents phases encountered as Ni-Co enriched manganese nodules of the deep ocean floors.

Our results show that Lithium-bearing manganese oxides with typical X-ray diffraction lines of lithiophorite can exhibit two different Raman responses, namely the one of a typical lithiophorite and the one of ALI. This difference of reaction between X-ray and Raman methods strengthen the model developed in literature [2] that the X-ray diffraction lines of these oxides result primarily from one component of the structure, the MnO6 octahedra layers. In the same way, the reflectors associated with the unstructured Ni-Co oxide layers in asbolane are too weak to be visible on X-ray diffraction patterns. By contrast, the Raman responses are also driven by the chemical composition of the samples, allowing a more precise characterization.

We propose reference Raman spectroscopic signatures for lithiophorite, asbolane and ALI phases. These spectra are mainly composed of two spectral domains, the first one is located between 370-630 cm^{-1} and the second one between 900-1300 cm^{-1}. We then assess the impact of their highly variable chemistry on their Raman peak positions, intensities and FWHM using a semi-systematic curve-fitting method profiled for these phases. The strong affinities observed between the Raman spectral content of asbolane, lithiophorite and their intermediates, combined with the progressive trend observed for some peak parameters indicate that the studied phases represent probably a solid solution.

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Genesis of Mn-W(-As)-rich hydrothermal veins in the Haut-Poirot deposit (Central Vosges, France)

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Keywords: Manganese deposit, Tungsten, Hydrothermal, Haut-Poirot, Vosges

Abstract

Between 1890 and the end of the Second World War, the Haut-Poirot deposit has provided 60 valuable tons of manganese ores. Now, the manganese and related tungsten content of this area had no more economic significance. The veins are located in the Haut-Poirot and Lyris woods in the Central Vosges Mountain, 7 km westward of Gérardmer (France). The mineralized veins are mainly hosted in a biotite-granite but also, in two-mica granite to the North, part of the Central Vosges Granites (CVG), formed 330 to 320 Ma ago during the Hercynian cycle (Tabaud *et al.* 2014). The orebodies form two subparallel veins oriented N90° to N120° in a well-fractured zone. The vein 1 is ~600 m long with a thickness ranges from 1 to 0.4 m and a dip angle of 80°N. The second vein is subdivided in two segments with a thickness of about 0.4 m (Bonhomme 1958, Lougnon 1984). By combining field observations, XRD, SEM and geochemistry, we propose refined parageneses of the ore and its relation to the geodynamic context of the Vosges Mountain and Black Forest.

The ore forms a tectonic breccia filled by pyrolusite, braunite, barite and quartz. Scheelite and hollandite *s.s.* are associated to the ore, as well as U-minerals (francevillite, chalcolite and autunite, Jurain 1956, Weil *et al.* 1960, Lougnon 1984) that have been described in the ore and host-rock granite. Three paragenetic sequences have been defined to constrain the ore deposition. (1) The main hydrothermal event enables the formation of quartz veins followed by massive braunite and pyrolusite, and then scheelite, after the CVG formation. (2) Ba-rich fluids concentrate barite in the gangue, and interact with Mn-rich minerals, leading to the formation of hollandite *s.s.* that partly replaces pyrolusite. (3) Brecciation of the ores enables the formation of a Mn-oxide (undefined) associated to Mn-calcite veins, concurrently to Ca-F-Arsenate (undefined) that replaces braunite. The hydrothermal brecciation of the host-rock might be linked to the vicinity of the N-S Straiture-Cellet overthrust zone, 500 meters westward from the Haut-Poirot deposit. Despite a lack of datable materials in the ore, the age of such Mn-deposit might be related to the post-Hercynian mineralization period (260-280 Ma), as already mentioned in the Eisenbach Mn-deposit located in the Black Forest (Segev *et al.* 1991).

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Quantifying marine aggregate resources of the Belgian part of the North Sea, first results using a layered voxel modelling approach

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Keywords: North Sea, sand extraction, resource estimation, 3D voxel model, geostatistics

Abstract

With increasing exploitation of marine aggregates, the need for dedicated resource estimations becomes urgent. This is also the case for the North Sea, where sand extraction already takes place for more than 30 years. To enable long-term predictions of the availability of the main resource qualities in the Belgian and southern Netherlands part of the North Sea, a 3D voxel modelling approach was followed. Focus is on the unconsolidated sediments of the Quaternary of which only the most modern deposits are suitable for exploitation. Therefore, Holocene and Pleistocene stratigraphic units were defined, based on bathymetric, borehole and 2D seismic data. The resulting 2 layers were then used in a geostatistical interpolation, for which a voxel resolution of 200 m x 200 m x 1 m was chosen. First results will be presented starting with a high-resolution model of the Top Paleogene (De Clercq et al., in review). Next, for both Holocene and Pleistocene units, the distribution of up to 7 lithological classes (clay to gravel) will be shown, as also their probabilities of occurrence based on 100 renditions of the interpolation. Additionally, first volume calculations were made providing insight into expected resource quantities. The presentation contributes to the BELSPO Brain-be project TILES (Transnational and Integrated Long-term Marine Exploitation Strategies; www.odnature.be/tiles).

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Building a transnationally harmonised marine geological database

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Keywords: resources, marine aggregates, data management, seabed mapping, North Sea

Abstract

Within the framework of marine resource management, a common knowledge base is being developed on the distribution, composition and dynamics of various geological resources. Focus is on data from the Belgian part of the North Sea, being representative of a typical sandbank sedimentary system. To ensure harmonised seabed mapping over large, supraregional areas and to facilitate the exchange of information, special attention was paid to compatibility with marine geodatabases from the adjacent Netherlands territory.

With reference to the seabed and its subsurface, two main databases are being compiled: one comprising all available lithological descriptions and one with all numerical grain-size information. To enable standardisation of the data and make them easily query-able, non-numerical descriptions are being coded to an international standard (EU FP7 Geo-Seas; www.geoseas.eu), of which the Udden-Wentworth scale is the main classifier. Several other parameters were derived, such as percentages mud, sand, gravel, shells and organic material. For the sediment database, cumulative grain-size-distribution curves were compiled, enabling calculations of any desired granulometry parameter, such as percentages of the grain-size fractions (fine, medium, coarse sand) and percentiles that are relevant in seabed-habitat mapping or sediment-transport modelling (D35, D50, D84). For both databases, the completeness and accuracy of the metadata were considered highly important. Information about sampling and coring techniques, analytical methods, horizontal and vertical positioning accuracy, and the exact timing of data acquisition is pivotal in uncertainty analyses, which are an increasingly important element of seabed mapping. The time of seabed mapping is critical to convert measured water depths to a common datum such as TAW in Belgium, facilitating integration of sample data in bathymetry data and thus their incorporation in 4D-modelling studies on morphodynamic change.

For Belgium, the geological databases will be imbedded in the data infrastructure of the Belgian Marine Data Centre (www.bmdc.be), ensuring compatibility with international standards and providing easy access to a wide user community. Following processing to generate data products such as resource-related subsurface models, visualisation is foreseen through Subsurface Viewer (GmbH INSIGHT). Applied maps and models thus disseminated are crucial in decision making, and invaluable for outreach and educational purposes. The newly developed database and its associated data products will contribute to the objectives of the projects TILES (Belspo Brain-be), EMODnet-Geology (EU DG MARE), and ZAGRI (private revenues from the marine-aggregate industry).

A voxel model for loess deposits in Flanders

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Keywords: Loess, Quaternary, voxel model, mineral resources, extraction, land use planning

Abstract

INTRODUCTION

Loess deposits in Belgium are still of great importance for the ceramic industry. Therefore the Flemish Government ordered VITO to set up a voxel model containing these deposits. Voxel modelling of mineral resources is VITO's next step following the geological layer model of the Flanders and Brussels Capital Region (G3D). The aim of the voxel model is to schematise loess deposits in voxels that represent lithological information on a grid in three-dimensional space (25x25x0.5m).

METHODOLOGY

A new methodology has been developed using software programs Voxler, Surfer, ArcGIS and AutoCAD. Firstly the model boundaries were extracted from the geological layer model G3Dv2 (Matthijs et al., 2013) and the latest Quaternary Geological map of Flanders (Bogemans F., 2005). Then 8,000 boreholes were, prior to interpolation, encoded and classified in simplified lithological classes. These classified intervals were also converted into data points serving interpolation. Finally the interpolation process combined 2D and 3D interpolation which handles modelling issues like landscape relief and varying data availability.

A VOXEL MODEL OPEN TO EXTERNAL USERS: THE 'MINERAL RESOURCE EXPLORER'

For presenting voxel model information to the public the Flemish government has set up a special online viewer called the 'mineral resource explorer'. The loess deposits are the first modelled mineral resources and will be available at the end of 2015. In 2016 the sand and gravel deposits from Meuse and Rhine are the following modelled mineral resources to be available online.The 'Mineral resource explorer' is an instrument to provide model information to external users without needing any complicating software. It allows users to view 3D data, to do calculations and to combine it with other models and geographical information. Within a scale of 1/50.000 a first indication of extractable mineral resources can be determined based on certain preconditions such as: maximum depth and minimum thickness of the mineral resource, maximum thickness of cover and maximum thickness of other sediments. Furthermore specific interactions make it possible to see the voxel model on an XY-location, in cross section and even to calculate the volumes of mineral resources of a polygon, such as a future extraction area.

CONCLUSIONS

Commissioned by the Flemish Government, VITO has built the first voxel model for loess deposits in Flanders. VITO developed a new methodology for creating a voxel model specific on loess deposits as mineral resources. The 'Mineral resource explorer' makes it possible to expose model information to external users

SESSION 9
RESERVOIR I – HYDRAULIC AND THERMAL PROPERTIES OF ROCKS

Permeability simulations on natural and virtual rock samples. Can multiple point geostatistics generate rock models that overcome spatial scale dependency?

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Keywords: *Permeability, Continental carbonate, Multiple point geostatistics, Representative elementary volume, Resolution problem*

Abstract

Geological systems, especially carbonate rocks are characterized by petrophysical variability at nearly every spatial scale. The Representative Elementary Volume is a concept, which allows describing complex systems and focusing on the specific features under investigation. A correct assessment of the REV is primordial because it allows to describe petrophysical properties in a representative way and to treat the studied medium as a continuum. Hence by the use of the effective medium approximation, a hypothetical homogeneous property replaces a heterogeneous parameter. This allows to describe reservoir rocks in a computational efficient manner.

In this study two different methods for calculating the REV were used. The first method is based on the original definition of Bear (1972) and uses the chi-square statistical test to objectify the method. The second method uses applications of geostatistical techniques based on variogram models to assess the size of the REV.

Both methods have a different approach and generate complementary information. The statistical method is more general and allows to deduce 95 % confidence intervals of the size of the REV. The second method provides more information about the spatial distribution of the studied parameter and the critical direction (anisotropy) of the REV. Hence the combination of both methods allows to thoroughly analyse the size of the REV.

In order to fully characterize the studied samples petrophysically, Lattice-Boltzmann method simulations were applied to study and illustrate fluid flow in their complex pore networks. Large volume renderings of the pore network at high spatial resolution based on Computed Tomography were introduced to single-phase gas flow simulations in Palabos. The obtained simulated permeability is lithofacies and pore type dependent. The simulation results show a similar spread as the laboratory porosity and permeability measurements.

Connected porosity and tortuosity control permeability and are needed to understand the fluid-flow through complex porous networks. The simulations demonstrate the effect of spatial resolution and REV of the porosity parameter on the simulated permeabilities.

Multiple Point geo-Statistics (MPS) bridges the gap of the volume - resolution problem. The MPS workflow generates large volume rock models at better resolutions and yields realistic permeability values. The fluid flow in artificial rock models demonstrates the same facies and pore type dependency as observed for natural rock samples. Facies and pore type characteristics are preserved in the MPS workflow. Moreover this workflow allows to link results from LIDAR, medical CT, micro-CT and thin-sections and to accurately predict adequate REV sizes.

How heterogeneity of the K-field influences a heat plume in a shallow alluvial aquifer: responses from a heat tracer test

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Keywords: shallow geothermal system, heat tracer test, inverse modelling, pilot points

Abstract

Simultaneous solute and heat tracer test provides essential information for a reliable assessment of low temperature geothermal systems. The actual efficiency of 'open systems', including heat storage projects, is strongly affected by the heterogeneity of the hydraulic conductivity field (*K*-field). It could be also useful for assessing the cumulative impacts of numerous projects in urban areas on the groundwater resources.

Using field data from a solute and heat tracer test conducted in the alluvial aquifer of the Meuse River (Belgium), an inverse problem of parameter estimation is solved. The tracing experiment consisted in simultaneously injecting heated water and a dye tracer in a piezometer and monitoring the evolution of groundwater temperature and tracer concentration in the recovery well and in monitoring wells. To get insights in the 3D characteristics of the heat plume, an arrangement of three transects of observation wells was used.

The breakthrough curves measured in the recovery well showed that heat transfer in the alluvial aquifer is slower and more dispersive than solute transport. Recovery is very low for heat while in the same time it is measured as relatively high for the solute tracer. This is due to the fact that heat transport is a thermal diffusion dominated process. For conditions corresponding to high Peclet numbers, the hydraulic conductivity is the primary calibration parameter for predicting heat plume distribution. Heat diffusion is larger than molecular diffusion, implying that exchange between groundwater and the porous medium matrix is far more significant for heat than for solute tracers.

Acknowledgments:

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Thermal characterisation of the Brabant Massif for shallow geothermal applications (BeTemper and BruGeoTherMap projects)

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Keywords: Shallow geothermal energy, thermal conductivity, geothermal potential, Brussels region

Abstract

The BeTemper project (2 years at RBINS-GSB) aims to assess the shallow geothermal potential in Belgium through analysis of rock thermal properties from the surface to a depth of 150 m, which covers the standard depth for a vertical loop system currently installed in Belgium (75% of the Ground Source Heat Pumps market). A detailed study focused on the basement rocks of the Brabant massif (Cambrian-Silurian-Ordovician) through laboratory thermal properties analyses (thermal conductivity (λ in W/m.K) and diffusivity (m^2/s)) of about 50 rock samples corresponding to four main lithologies (quartzite, sandstone, phyllade and siltstone). The influence of water content, porosity, mineralogical composition and mineralogical texture on these thermal parameters was studied. Thermal parameters measurements were performed with the high-resolution Thermal Conductivity Scanning (TCS) method for both saturated and dry conditions. The mineralogical and petrological analyses were conducted with different analytical equipment of the mineralogical and petrological laboratory at RBINS-GSB. The proportion of different mineralogical phases was evaluated with the new Panalytical X-ray Diffraction equipment, while the EDS (Energy-Dispersive X-ray Spectroscopy) and EBSD (Electron BackScattered Diffraction) modules were applied to evaluate the chemical and micro-textural content.
The BruGeoTherMap project (EU-FEDER funding) will be launched in January 2016 and will aim at enhancing the value of the geothermal potential in Brussels (both open and closed systems). The consortium brings together all the major actors in the field of geothermal energy in Brussels (ULB, VUB, IBGE, CSTC, SGB) with the support of EGEC. Thanks to BeTemper, the thermal parameters (thermal conductivity and diffusivity) will be integrated in the database as valuable information on the technical geothermal potential of Brussels. The realisation of geothermal potential maps will combine geoscientific and administrative layers of information (e.g. thermal parameters of rocks, hydrogeology, extractable heat from the ground, environmental risks, legal constraints…) that will be managed through a WebGIS. BruGeoTherMap will start with an exploration phase (piezometers, boreholes, cores sampling) to increase the quality and the amount of available data on the subsoil. Finally, an important communication phase is scheduled (including seminars, conferences, formation days, website). The project is intended for the Brussels citizens, the public administration and the professionals of the field (design offices, installers, etc.) to provide them more detailed information and usable data about the local shallow geothermal conditions as well as to promote this technology.

Gravity changes in a karst system highlight its vadose zone hydrodynamics

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Keywords: Gravimetry, Hydrogeology, Hydrogeophysics, Karst

Abstract

Monitoring gravity continuously is an integrating technique that has already proved its efficiency to provide valuable hydrogeological information in different contexts. Most of the time, the aim of such a method consists in the monitoring of aquifer recharge. Applying it to follow groundwater variations within unsaturated zones has also been successfully tested, even in karst environments. The particularity of such areas concerns temporary perched aquifers that can occur in the subsurface due to changes of weather conditions, reduced evapotranspiration and the vertical gradients of porosity and permeability. Thus, vadose zones in karst systems may show higher and more noticeable variations in their gravity signal.
We present a microgravimetric monitoring installed at the Rochefort Cave Laboratory (RCL), located in the Variscan fold-and-thrust belt (Belgium), a region that has many karstic networks within Givetian limestone units. Our investigations cover two years of hydrogeophysical monitoring. It involves a superconducting gravimeter continuously measuring at the surface of the RCL. Early in 2015, a second relative gravimeter was installed in the underlying cave system located 35 meters below the surface. These relative measurements are calibrated using data of an absolute gravimeter measuring approximately every month at RCL.
While measuring only from the surface already give useful information on the groundwater variations within the vadose zone, it also record changes in the saturated zone. Typically, flash floods events in the cave are highly noticed by the gravimeter. When adding a gravimeter permanently measuring in the cave, it allows removing most of the saturated zone gravity signal by subtracting surface gravimetric data to those recorded at depth. Gravity changes within the vadose zone are therefore highlighted, bringing information on the seasonal recharge of potential groundwater reservoir.
We also investigated the spatial gravity variations within the studied area using a spring gravimeter. It involves 12 additional stations (7 at the surface, 5 in the cave) monitored on a monthly basis. Such measurements are useful but tricky in such a small area (1 ha). The influence zone of the gravimeter comprises a cone below (and above) the gravimeter with a diameter that varies as 20 times its depth. This allows investigating only variations in the 2-3 first meters of below each of these temporary stations; such depths are comprised in the epikarstic layer, where most changes are expected though.
Direct measurments are also used to calibrate both gravity signals coming from the vadose and the saturated zone. Level monitoring and tracer tests performed in the saturated zone are used as well as dripwater monitoring in the cave, informing on the vadose zone discharge and response to rainfall events.

SESSION 10
UPPER DEVONIAN LIFE

An extraordinary new site to study upper Frasnian cephalopods during the onset of anoxia in the Dinant basin

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Keywords: Lompret, Goniatites, Conodonts, Matagne Formation, Kellwasser events

Abstract

From the summer of 2013 on, an interesting succession of upper Frasnian sediments of the Neuville and Matagne Formations became progressively more exposed at the Lompret quarry, 10 km west of Frasnes, Belgium. Regular visits to the quarry allowed to constitute a large collection of fossils from various levels within the sequence, in particular of ammonoid cephalopods (goniatites) belonging to the superfamilies Gephuroceratoidea and Tornoceratoidea. The most common goniatite at Lompret, and by extension in the entire Belgian upper Frasnian, *Manticoceras*, belongs to the Gephuroceratoidea.
The most intriguing part of the Lompret succession is found near the base and within the lower part of the Matagne Formation, where within a sequence of cephalopod rich limestone beds, an abrupt change to darker colored shales and limestones coincides with a drop in benthic diversity. This change seems to situate near the base of the upper *rhenana* conodont zone (preliminary data).
At this point in time, the true nature and context of the observed changes in cephalopod and other invertebrate faunas are far from being well understood. However, the combined reduction in benthic diversity and the darkening of the sediment seems to evidence the installation of reduced oxygen conditions at the seafloor within the late Frasnian in this part of the Dinant basin. Also, the observed short-term re-colonizations of the seafloor by brachiopods, as well as the changes from dominant Gephuroceratoid to dominant Tornoceratoid and then back to dominant Gephuroceratoid within the goniatites faunas, seem to indicate that the installation of anoxia was complex and occurred in several pulses. Whether or not this truly correlates with the Lower Kellwasser Event (LKW) is a yet unanswered question, partly caused by the fact that recent studies of the upper Devonian mass-extinctions have revealed that the true nature, causation, duration and timing of the LKW is far from being well-understood.
The abundance of cephalopods in the section, the possibility to collect bed-by-bed at large scale and to observe the same stratigraphic interval in several corners of the quarry make from the Lompret quarry one of the most extraordinary and richest upper Frasnian cephalopod sites in the Dinant basin.

A new Famennian (Upper Devonian) locality at Becco: geological and paleontological insights

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Keywords: acanthodians, actinopterygians, early seed plants, fluvial facies, Namur-Dinant Basin, placoderms, sarcopterygians, tetrapods

Abstract

The Becco locality (Liège Province) is a road-cut exposure, which belongs to the Theux tectonic window. It represents a proximal, probably fluvial, environment corresponding to a channel infill. We present here a preliminary report of the fossil assemblage discovered at the locality in 2013 and 2014. The Becco site has yielded a diverse flora of early seed plants including *Moresnetia zalesskyi*, *Dorinnotheca streeli* and *Condrusia* sp. This assemblage, characteristic of the Belgian Famennian, highlights the diversity of early spermatophytes in the country. Becco has also delivered a rich vertebrate fauna with antiarch, groenlandaspid and phyllolepid placoderms, diplacanthiform acanthodians, as well as actinopterygians and various sarcopterygians. The fossiliferous assemblage of Becco resembles those of several Devonian tetrapod-bearing localities, including that of Strud in Belgium, and could therefore provide a favourable palaeoecological setting in the search for early tetrapods. In this context, and as the road-cut exposure displays a reduced fossiliferous surface, which is moreover damaged, it has been decided to expand the excavation area to the neighbouring agricultural field. The results of those future investigations will be communicate during the Geologica Belgica Meeting held in Mons in January, 2016.

The latest Famennian spermatophytes from South Africa

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Keywords: seeds, spermatophytes, South Africa, Devonian, Famennian

Abstract

The terrestrialization of living forms is by far one of the most important process that took place during the Palaeozoic. It deeply modified all ecosystems, both marine and continental. The evolution of the seed habit is often interpreted in the framework of this process as allowing the colonization of new habitats. It is one of the most important steps in the evolution of plants. However, the lack of fossils documenting an intermediate transformational sequence has precluded a clear understanding of their origin. New plants collected by R.G. in the latest Famennian in age Waterloo Farm locality (South Africa) shed new light on the evolution of spermatophytes. The Waterloo Farm locality represents a lagoonal system partially separated from the Agulhas Sea by a barrier island complex. Fine black anaerobic muds deposited in still portions of the lagoon accumulated a huge mixed assemblage representing the life of marine and fresh water influenced parts of the lagoonal system, as well as that of adjacent terrestrial environments. Terrestrial remains largely consist of plant material comprising a minimum of fifteen taxa. The newly discovered plants are here interpreted and new evolutionary hypotheses are proposed.

SESSION 11
AFRICAN ORE GEOLOGY

Re-appraisal of the world-class Paleoproterozoic manganese deposit of Kisenge (Katanga, DRC)

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Keywords: chemical sediments, Katanga, Kisenge, manganese, Paleoproterozoic

Abstract

The Kisenge area, in the southwestern part of the Katanga province (Democratic Republic of the Congo), hosts a poorly documented world-class Paleoproterozoic manganese deposit, occurring in outcrops along an East-West trending 6 km-long series of small hills. The area belongs to the southern part of the Congo Craton, represented mainly by schists, gneiss, migmatites and amphibolites. The Mn ore deposits of the region have an assumed Late Paleoproterozoic age, based on geological context (youngest age of the underlying basement is ~2 Ga: pers. comm. A. Boven), on similarities with equivalent deposits in western and southern Africa, and on a single radiogenic age for a cross-cutting pegmatite body (1,853±89 Ma; Ledent et al., 1962).

The primary Mn ores are rhodochrosite-dominated limestones or marbles, with varying abundance of Mn-rich garnet (spessartine), grading to non-calcareous garnetite. Within limestones/marbles, garnets often contain abundant rhodochrosite micrite inclusions, hence suggesting a relatively early formation, in a non-lithified sediment. Sterile intercalations consists of graphitic shales and mudstones. The deposits are Mn-rich (c. 50%) and contain significant quantities of accessory metals (up to 0.1% Co, Ni, Zn). The deposits are intensely folded and dip steeply to the south (70°) in the outcrop area. They are crossed by veins representing a complex hydrothermal paragenesis, with predominantly pyroxmangite ($MnSiO_3$), tephroite (Mn_2SiO_4), and secondary rhodochrosite.

The rhodochrosite marble displays relatively flat (La_n/Yb_n~1) or hump-shaped (La_N/Yb_N~0.4) REY patterns, with low light-to-heavy REE ratios (Pr_N/Yb_N~0.8) and positive Ce anomalies ($1.3 < Ce/Ce^* < 2.3$). This is compatible with sediment deposition in a stratified basin with a redoxcline, and hence of late Paleoproterozoic age (typically from c. 1.9 Ga onward).

Along the surface, the deposits have undergone intense weathering, transforming the carbonate ore into supergene Mn oxide deposits, composed of cryptomelane and relatively minor lithiophorite, manganite and pyrolusite. Ar-Ar age determination of K-bearing Mn oxides (cryptomelane) has identified several stages of supergene ore development, including major episodes around 10.5 Ma, 3.6 Ma and 2.6 Ma, providing a record of Cenozoic geodynamic evolution of the region.

The c. 2 Ga Kisenge Mn deposit is comparable to roughly contemporaneous (c. 1.9 to 2.2 Ga) deposits located elsewhere in Africa (Burkina Faso, Ghana, Gabon, South Africa), as well as in Brazil. Some of these deposits, including Kisenge, are located along the margins of the proto-Congo Craton, which included the Gabon and São Francisco blocks.

Fe-Ti-V-P ore-forming processes in the Upper Zone of the Bushveld Complex, South Africa

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Keywords: magnetite, vanadium, layered intrusion, magma chamber, cumulate

Abstract

The Bushveld Complex (South Africa) is the largest layered intrusions on Earth and plays a considerable role in our understanding of magmatic differentiation and ore-forming processes. The Upper and Upper Main Zones (ca. 2 km-thick), located above the Pyroxenite Marker, are commonly considered as the last pulse of magma injected into the magma chamber. They represent the largest known sheet of basaltic magma that produced world-class deposits of V, Ti, and P in Ti-magnetite and apatite. In this study, we present data for major and trace elements in whole-rocks and silicate minerals combined with the study of apatite-hosted multiphase inclusions in gabbroic cumulates sampled in the Bierkraal drill cores of the western limb. Our closely-spaced sampling (average sampling interval less than 10 meters) allows us to define subtle compositional variations used to discuss the closed vs. open solidification of the magma chamber and the ore-forming processes for layers enriched in magnetite ± apatite. Bulk major and trace element data are used to obtain the best estimate of the Upper and Upper Main Zones parent magma composition and to discuss how much liquid is likely to have erupted during the late-stage crystallization of the Bushveld Complex. Inclusions in apatite are interpreted to represent equilibrium melts trapped during the growth of their host minerals. These inclusions re-homogenized at high-temperature (1060-1100°C) display a range of compositions in a single rock sample, from iron-rich (35 wt.% FeO_{tot}; 28 wt.% SiO_2) to silica-rich (5 wt.% FeO_{tot}; 65 wt.% SiO_2) in similar proportions. This trend is best explained by immiscible melts trapped in apatite during progressive cooling along the binodal of the two-liquid field. The coexistence of Si-rich and Fe-rich immiscible melts in single apatite grains is used to discuss the ability of immiscible melts to segregate from each other, and the implications for mineral and bulk cumulate compositions. Segregation in the crystal mush and the production of contrasting phase proportions from the Fe-rich and the Si-rich melts can be responsible for the formation of melanocratic (Fe-Ti-P-rich) and leucocratic (plagioclase-rich) gabbroic layers in the Upper Zone.

The role of Archean tectonics in shaping Paleoproterozoic intraplate magmatism and ore deposits in the Kaapvaal craton (southern Africa): a case study from the 2.05 Ga Schiel complex

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Keywords: Kaapvaal craton, alkali complexes, geochemistry, Archean tectonics, ore deposits

Abstract

The Paleoproterozoic, intraplate Phalaborwa and Schiel alkaline/carbonatitic complexes (Kaapvaal craton, South Africa) represent world-class phosphorus, Cu, K, Zr and REE deposits. Moreover, they belong to the same magmatic event as the 2055 Ma-old Bushveld complex, the largest layered intrusion on Earth, representing giant reserves of PGE, Cr and Ni. This study focuses on the Schiel complex, which is by far the less studied, and aims at constraining its age, petrogenesis and their significance for the geodynamic framework of this major magmatic event and associated ore deposits. The Schiel complex was built up during several magmatic pulses, corresponding to the successive emplacement of (i) pyroxenites, phoscorites; (ii) phlogopite-bearing alkali gabbros; (iii) aegirine-bearing syenites and (iii) hypersthene-bearing syenogranites. However, new U-Pb zircon dating reveal that the ages of four samples from each phase are undistinguishable within error and range from 2055 ± 3 Ma to 2051 ± 6 Ma. This confirms that the Schiel complex was coeval with the Bushveld and Phalaborwa complexes. Whole-rock geochemistry suggests that most rocks of the Schiel complex derive from melting of variously enriched, lithospheric mantle sources, including LREE-rich domains, carbonated peridotite, carbonatite-metasomatized mantle or a combination thereof. Results of Hf isotope analyses on zircon reveal that those sources have distinct signatures, yet all characterized by highly non-radiogenic Hf isotope composition with $\varepsilon Hf_{2.05\ Ga}$ ranging from –12 to –17. We interpret this signature as reflecting the presence in the lithospheric mantle source of crustal components with low time-integrated $^{176}Lu/^{177}Hf$ ratios, corresponding to the local, 3.0- to 2.7 Ga-old Archean felsic crust. Comparison with data from the Phalaborwa and Bushveld complexes reveal that they may also derive from mantle sources enriched by various Archean crustal components. We therefore propose a general model in which the lithospheric mantle of the Kaapvaal craton is contaminated by mafic to felsic crustal material owing to Meso- and Neoarchean subduction (2.97-2.75 Ga), in agreement with constraints on the evolution of the local Archean crust. Thereby, the most enriched mantle domains were located along a fossil Archean suture zone that was then tectonically and magmatically reworked during the Paleoproterozoic, presumably by an impinging plume at 2.06–2.05 Ga. This model also accounts for the wealth of ore deposits associated with the Bushveld, Phalaborwa and Schiel complexes, since melting of re-fertilized (highly enriched) mantle domains represents a favourable "distillation" process able to efficiently concentrate economically important elements in magmas.

SESSION 12
POSTERS

GEOMATERIALS
GEOLOGICAL MODELLING
GEOENERGY AND RESERVOIRS

Session 12 Posters

GEOMATERIALS

Firing effects on quartzite materials revealed by cathodoluminescence

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Keywords: Firing, quartzite, quartz, cathodoluminescence

Abstract

Quartz grains in sandstone occasionally exhibit bright red cathodoluminescence (CL), especially in their outer rim. To date, the origin of this particular CL emission has never received attention. The observation of abundant red CL in a sandstone collected just beneath a Tertiary lava flow in Germany (Rockeskyll volcano, Eifel) strongly suggests it may be related to firing effects. Preliminary experiments were setup to assess the influence of heat on the CL of quartzite materials.

Samples of the "Bray Sandstone" (Upper Thanetian quartz-arenite of Mont-saint-Eloi, Douaisis) were subjected to a 4h heating in a furnace with a maximum temperature of 300, 600 and 900°C. The reference sample (unheated) and the samples heated up to 300 and 600°C remained unchanged under CL. The sample heated up to 900°C exhibited a pattern with bright-red CL veins and patches between the quartz grains. This pattern is similar to that observed in the naturally-heated sandstone. In addition, in the the Bray Sandstone, the CL of the microcrystalline cement was increased to a bright milky emission.

The cause of the red CL induced by heat in quartzite materials is obscure. Trace-element analysis with the EPMA was complicated because of the very small size of the luminescent zones and their location on the edges of the grains. However, there is a slight but noticeable increase in K, Al and, to a lesser extent, Fe, in the red-CL zones. This could relate to the influence of intergranular clay and/or oxide minerals. The question then arises whether the induced red CL is activated in a quartz or a glass phase produced by the melting of silica in contact with other minerals. K, Fe and Al are indeed known as efficient fluxes (melting) agents of silica in the refractory industry and bright colorful CL has been observed in the resulting glass phases. The enhanced milky-white CL in the microcrystalline cement is possibly due to the influence of titanium.

While the red CL in quartz still needs further investigation, it is clearly induced by heating processes at up to 600-900°C in the investigated quartzite. Therefore it has a significant potential to indicate past heating events due to anthropic or natural causes such as fire places in archaeology, lava flow, lightning strikes, wildfires, etc.

Understanding rocks: introducing MINPET's geo-analytical toolkit

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Keywords: *geo-analytical techniques, geomaterials, mineralogy, petrology, geochronology, thermometry*

Abstract

Analytical techniques are increasingly used in a wide variety of fundamental and applied geoscientific studies. The UGent Laboratory of Mineralogy and Petrology (MINPET) has been active in this area for several decades. Its present research activities range from material characterisation, to proxy analysis, geochronology and thermometry.

We present an overview of the techniques that are currently available, including optical microscopy using thin sections, scanning electron microscopy, X-ray diffraction and fluorescence spectrometry, physical and chemical analyses of sediment and water, and thermometry and chronometry of consolidated and unconsolidated rocks. In terms of methodology, we highlight the potential of innovative luminescence techniques to unravel the Young Quaternary thermal and light-exposure histories of consolidated rocks. The integrated use of these techniques is illustrated through case studies in paleoclimatology and Quaternary geology, geothermy, geohazards, geomaterials, regional geology, plate tectonic and structural geology, geoheritage and geoarcheology, and sedimentary rocks and stratigraphy.

This poster aims at making Belgian researchers aware of the fundamental scientific expertise that is available at MINPET. The configuration of the laboratory is unique. It seeks to combine methods, materials and research questions that are of common interest to members of various disciplines. MINPET is keen to support and undertake collaborative research and provides its scientific services at request.

Session 12 Posters

GEOLOGICAL MODELLING

Building 3D geological model from geological records

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Keywords: 3D geology, modelling, geocanvas

Abstract

Nowadays, private and public sectors seem to be more interested in the usefulness of 3D geological modelling in various domains to understand what is going on under our feet.
Since the early 2000s, the Mons University is developing a methodology to build 3D geological models of geological bodies. This methodology includes several steps: collect information, structure information, insert and manage it in a database, validate data and interpret geological descriptions.
The great challenge is to manage geological data of various types, some of them including geographical objects, originating from very heterogeneous source of information and recorded at different periods. Our methodology takes into account both outcrop and borehole descriptions which is the major source of original geological information. Borehole descriptions consist in intervals (samples) along a curve. By contrast, outcrop describe 2D or 3D features observed on a flat or irregular surface. Structure data from boreholes with their geometry is rather straightforward. Dealing with outcrop description may however be more challenging and need to develop a specific approach.
A geodatabase have been developed in order to also integrate the geographical information. The third dimension (elevation), critical for 3D modelling, is managed separately. Elevation values are either encoded in the database as objects or are extracted from a DEM. Geographic layers associated with elevation values allow to represent the spatial position and shape of each geological object in an informal 3D spatial reference system.
In order to build a 3D geological model, descriptions are interpreted according to a geocanvas and an interpretative scheme. Geocanvas specify which kind of geological bodies are considered and the relationships between them. Interpretative scheme try to clarify different criteria to associate observations to a geological unit *s.l.* Geological observations previously interpreted according to at least one geocanvas can be reinterpreted in another canvas. This work is done by the interpreter and may be assisted by a pre-processing step consisting of translation queries.
Several steps of validation are performed to check geological data. The first step is to qualify the data in terms of fidelity to the original information and completeness of the records. Then, there is a selection and validation process to keep accurate and reliable data and reject questionable or imprecise data for the project.
Once the geological observations with their localisation and interpretation are validated in a project, various models can be built to evaluate hypothesis.

GeoLog Toolkit 0.9: a new open source and cross-platform for geological data visualization in Google Earth environment

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Keywords: GIS, Google Earth, 3D vizualization, structural geology

Abstract

GIS solutions are today's essential tools for geological purposes. A wide range of GIS software and suppliers are active on the market with either commercial (e.g. ArcGis, Global Mapper, Surfer) or freeware licenses (Quantum GIS).The main strength of such types of software stands in their broad range of tools that they offer from basics to highly specific ones. This generally meets the needs of a large panel of specializations in geoscience (e.g. environmental research, geomorphology, mining exploration, geological mapping). Such a large diversity makes simple tools hard to find and may become a brake on productivity when needing to visualize 'simple' fieldwork geological data. Moreover, basemaps are usually crucial in the process of visualization but webmap services are often 'heavy' (specifically for satellite high-resolution imagery). This slows down the display cadence and thus, slows data visualization. These are the main reasons why we developed the *GeoLog Toolkit v0.9*, an open-source and freeware, written in Python (a high-level, cross-platform programming language) accessible through a graphical user interface. The punchline of the *GeoLog Toolkit* could be: making GIS environment as user friendly as Google Earth to visualize geological data sensu lato.Practically, the *GeoLog Toolkit v0.9* software allows users to import their raw data in headers-table format, e.g. directly transcribed from field investigations. Using multiple tools, users are invited to represent and plot their data in Google Earth via an automatic generation of.*kml* files. This workflow requires no need of any third party software, except Google Earth itself. Broadly speaking, the *GeoLog Toolkit v0.9* allows you to display directly in Google Earth and with a large kind of labels, symbols, colours and placemarks:

(i) multi-points data ;
(ii) interpolated contours between discrete data ;
(iii) discrete planar and linear structural data in 2D or 3D, supporting all types of structures input format (plane: right-hand rule, strike-dip-sense, dip-direction ; and line: pitch, rake, trend on plane, trend-plunge formats) ;
(iv) stereonets and rose diagram ;
(v) drawn cross-sections as vertical sections ;
(vi) georeferenced maps (.geotiff) ;
(vii) field pictures using either localization metadata from a camera built-in GPS module, or the same-day track of an external GPS module.

We are looking for you to discover all the functionalities of the *GeoLog Toolkit v0.9* during the poster session. As this project is under development, we are definitely looking to discussions, contributions and shares of ideas to integrate in the software.

Visualizing (geological) cross-sections vertically in Google Earth

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Keywords: Tutorial, Google Earth, SketchUp, Research Visibility

Abstract

Visualizing research results properly during scientific presentations already does half the job of informing the audience on the geographical framework of your research. Many scientists use Google Earth™ as it is a great interactive mapping tool in which individual observations are georeferenced and can be shown in 3D. Although many people use Google Earth to localize their research area or to drape maps of results on the Earth's surface, visualizing cross-sections vertically through these maps is often not shown dynamically although the workflow how to do so is rather simple. The only programs necessary to display results are SketchUp Make, which allows the creation of your 2D and 3D models, and Google Earth™. The usefulness of the proposed workflow lies in its simplicity as no external programming codes linked to any specific programming language are needed.

The workflow is as follows:

1. Import your figure in the program Sketchup under File/Import;
2. Scale your figure to the proper dimensions;
3. Select the region where the figure needs to be geolocated;
4. Export to Google Earth;
5. Move/Rotate the figure to the exact profile location by modifying the properties of the model in Google Earth.
6. Save it as a kmz file.

In this presentation the easy workflow to plot cross-sections vertically in Google Earth is demonstrated. Some tips will be given and the endless applications of the method are shortly discussed by showing several examples. The scale dimensions of this workflow are endless as meter-scale profiles as well as profiles as large as the diameter of the Earth can be shown.

Once your model is exported to Google Earth, you can fly around it, export the various views or make a fly-through movie and impress the audience during your next conference presentation.

Reference:

Van Noten, K. 2016. Visualizing cross-sectional data in a real-world context. EOS 97.
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Session 12 Posters

GEOENERGY AND RESERVOIRS

Beyond the current limits of Raman Spectroscopy: controlling fluorescence in solid bitumen with low thermal maturity

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Keywords: Raman spectroscopy, Peak parameter, Fluorescence, Solid bitumen, Low thermal maturity

Abstract

Raman spectroscopy is an interesting tool to assess the thermal maturity of solid organic matter. For carbonaceous material with moderate to high maturities, several studies have found good correlations between Raman spectral parameters and thermal maturity, expressed as vitrinite reflectance (VR) or bitumen reflectance (BR). However, at low maturities a large part of the Raman peaks is lost under an intense background radiation, caused by fluorescence. This fluorescence problem mainly occurs at 0.4-1.0% VR (the oil window), and makes it difficult to recognize the original spectrum.

In this study, Raman parameters that have been put forward in literature were tested on a low maturity, solid bitumen sample of approximately 0.61% BR. The investigated parameters include the peak's full width at half maximum FWHM, peak position W, peak area A, area ratio A_D/A_G and intensity ratio I_D/I_G. Fluorescence in this sample is very high and covers Raman peaks.

It was found that during consecutive measurements at a single location (i.e. irradiation with the Raman laser), fluorescence decreases with time and Raman peaks appear. This is in line with Quirico et al. (2005), who observed the same effect at coal measurements.

An interesting observation is the behaviour of Raman parameters during ongoing irradiation. The full widths at half maximum do not change at all for every investigated peak in our spectra. Also peak positions remain the same. The peak areas do change with irradiation, and show a decrease with decreasing fluorescence. Comparison of areas under individual peaks and total spectrum area however suggests that A and fluorescence decrease at equal speeds. This is the case for most important Raman peaks at 1370 (D-band), 1600 (G-band) and 3200 cm^{-1}, with correlation coefficients of 0.66, 0.97 and 0.92 respectively. Lastly, the area ratio A_D/A_G and intensity ratio I_D/I_G (approximation) show no trend with fluorescence, indicating that the shape of the spectrum remains the same with irradiation. This is a promising result, because it suggests that fluorescence can be controlled without changing spectral parameters.

Although not all peak parameters in this study (FWHM and A_D/A_G) correspond to parameters from literature regarding maturity, the behaviour of the Raman peak parameters in combination with the decreasing fluorescence is an exciting outcome.

If further research proves that the original parameters are not altered by irradiation, this will provide an answer to the problem of fluorescence at low maturity samples.

ALPI: impact of policy instruments on the development of the geothermal energy sector

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Keywords: Geothermal energy, policy instruments, renewable energy, low-carbon society

Abstract

The ALPI project focuses on fiscal policies to finance the transition towards a low-carbon and resource-efficient society. The project concentrates on promoting relevant instruments to accelerate the transition towards a low carbon society by demonstrating the performance and impact of policy instruments on economic, government budget and environmental aspects. Five case studies were set-up to cover different economic sectors, type of instruments, and various investments in energy-efficiency and renewable energy. A common methodology is followed in each ALPI work packages. Each investigation starts with a broad stakeholder consultation. A techno-economic evaluation then is realized. Finally, different fiscal measures are designed in collaboration with stakeholders, and their effectiveness to stimulate the transition to a low carbon society is evaluated.

As a showcase of emerging technologies in Belgium, the Hasselt University and the Geological Survey of Belgium are investigating the potential for geothermal electricity production. Such a geothermal pioneer project has a long development trajectory. Deep geothermal energy appears to be currently on the edge of a take-off. But the actual emergence of this technology is subject to developments in legislation and incentives from regional governments. Different risk/return expectations across stages of the investment continuum exist and the financial structures that are employed at each stage may require different types of public support. As the development of deep geothermal energy is a complex process, a detailed stochastic calculation is made of a project decision tree. This approach allows to investigate measures, such as insurances or government guaranteed, to reduce project risk, in order to increase the interest of investors in this sector. Secondly, this approach is combined with an evolutionary step development to analyse the potential growth of the sector over the coming decades. Giving the high geological uncertainty, this combined geological-economic analysis is arguably the most realistic way to calculate project performance.

Multiple hydrothermal-Cretaceous dolomitization in different diagenetic settings, Provençal Domain, NW Italy

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Keywords: Hydrothermal saddle dolomites, Mesogenesis, Telogenesis, Mesozoic, Provençal

Abstract

Triassic and Jurassic carbonate rocks of the Provençal Domain (NW-Italy), locally display several generations of saddle dolomites associated with fractures and breccias. We investigated the petrography and the geochemical signatures of these carbonates to provide constraints on the timing and on the precipitation conditions. Three dolomite types have been distinguished. Type I is an epigenetic replacive matrix dolomite; type II consists of small-sized, non-zoned saddle dolomites and type III consists of larger-sized, curved, saddle dolomites. The latest carbonate phase identified in the fractures and breccia is sparry calcite which contains microbial filaments encrusted by silica. The type II dolomite is associated with early, low amplitude stylolites and type III with late, high amplitude, gash-tension stylolites. Breccia and fractures are commonly observed and filled with types II and III saddle dolomites.

$\delta^{18}O$ values exhibit a clear shift from type II (up to -8.3‰) to more depleted values in type III (up to -11.6‰) indicating saddle dolomite precipitation at elevated temperature. Subsequent fractures are filled by calcite cement, which sometimes replaced former saddle dolomites. This late cement has depleted $\delta^{18}O$ values (up to -14.1‰) and slightly negative $\delta^{13}C$ values (up to -0.6‰). Fluid inclusions from the Provençal area show that saddle dolomites (types II and III) precipitated at minimum temperatures ranging from 120°C to 280°C, while late calcite stage formed at lower temperatures (between 45°C and 60°C).

Most Triassic dolomites show depleted $^{87}Sr/^{86}Sr$ ratios (0.707735-0.711628) in contrast with the radiogenic values of the Jurassic dolomites (0.708757-0.711203) relative to their seawater signatures. The Triassic dolomites where therefore probably influenced at least by local tectonic events.

Finally, trace elements in the dolomite (mean: Fe= 575 ppm; Mn=121 ppm) and calcite (mean: Fe=116 ppm; Mn=80 ppm) suggest a change in the redox conditions, i.e. towards a more oxidizing environment, from deep burial (mesogenesis) to near the surface (telogenesis).

Our petrographic and geochemical study suggests that the fluids responsible for the precipitation of the saddle dolomites (types II and III) migrated through the subsurface during multiple tectonic events. This fluid migration could have been linked to extensional and transtensional tectonic events during the Cretaceous period. The late calcite stage is interpreted to be the result of the mixing of meteoric water with a hydrothermal fluid during telogenesis.

Example of natural fracture patterns in Westphalian deposits: Occurrence and Controls

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Keywords: Campine Basin, Mineralogy, Quantitative x-ray diffraction, Computed Tomography, Photogrammetry

Abstract

The Campine Basin in the NE of Belgium forms the southern margins of the North West European Carboniferous Basin and is characterised by a long tectonic history of subsidence and uplift. The Variscan orogenic deformation corresponds to the first phase of subsidence, characterised by a compressional regime. The associated syn-sedimentary and block faulting resulted in a heavily faulted sedimentary basin with the formation of vein systems in the Westphalian siliciclastic deposits. Later subsidence from the late Permian onwards is due to the formation of the Roer Valley Graben, resulting in normal faulting.

In this case study core material from the KB186 drilling of Lommel-Kerkhoven was examined for the presence of dickite veinlets in a silty layer of several decimeters thick. The extent of the veins are limited by mud layers that lie above and underneath the silt layer. It is known that the mineralogical content and the texture of the sediment have an effect on the geomechanical behaviour of the rock. The mineralogical content of the core material was deduced by means of quantitative x-ray diffraction with Rietveld refinement. A photogrammetric survey was performed on the core by constructing a three-dimensional model of it. This was established by taking an image each 20° around the core sample from three different angles. The model was used to observe the structure and the texture and to quantify the orientation of the different dickite veins present the rock. This information can give an insight on the regional tectonic stress regime causing the vein formation. CT scans of the core material were taken to make the comparison with the photographic three dimensional model.

In summary, the combination of the mentioned techniques can deliver an understanding on the occurrence and controls of veinlets in Westphalian siliciclastic deposits of the Campine Basin.

Mechanical stratigraphy of the Cenomanian chalk of Cap Blanc Nez (France)

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Keywords: chalk, fractures, joint, mechanical unit, fracture density

Abstract

Chalk reservoirs are usually characterized by a high porosity, but also by a low primary permeability. Argillaceous chalk intervals, described in the reservoirs of the North Sea, reveal a matrix permeability which is lower than 0.2mD. Hence, fracture networks within these types of reservoirs are of a major importance to predict fluid flow and reservoir behavior. In order to understand the fracture pattern of argillaceous chalk, the approach of mechanical stratigraphy was used on the 73 m thick section of Cenomanian chalk of Cap Blanc Nez (FR). This reservoir analogue enables the observation of a transition between argillaceous chalk (Lower Cenomanian) towards white chalk (Upper Cenomanian). Fracture spacing, for each of the in total 24 mechanical units, was measured in the field with the use of manual scanlines. Next to fracture spacing the amount of crosscutting, initiating and terminating fractures on each mechanical interface was measured as well. The reliability of the scanline-data was verified using QGIS, which allows the fractures to be visualized as a two-dimensional network in plan-view. This original method indicated that the error related to the sampling bias in heterogeneous fracture networks, is less important than the error associated with the Terzaghi-correction. This lead to the conclusion that it is permitted to work with the uncorrected data-sets. The verified data was compared with other parameters, but the main factor constraining the fracture intensity prove to be the thickness of the mechanical units. The fracture spacing (y) increases, together with the thickness of the mechanical units, leading to the mechanical law of y = 0.53x-17.7, except for two densely fractures zones (DFZ), characterized by large sigmoidal fractures and stratabound joints. These very fractured intervals show a highly connected fracture network, which would act in a reservoir as a preferential production target. Besides those DFZ the mechanical interfaces, which delimitate mechanical units and constrain fractures, result from changes in sedimentation (e.g. clay layers) or diagenesis (e.g. hardgrounds). This study also indicates that the fracture intensity of the smaller mechanical units of argillaceous chalks tends to be higher than in pure chalks. This would make those low-permeability tight chalk intervals potential fluid-pathways, rather than intra-reservoir seals.

Reservoir capacity assessment and ranking of potential targets for geological storage of CO_2 in Austria

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Keywords:CO_2 geological storage, CCS, matched capacity, techno-economic simulation, source-sink matching

Abstract

Capturing CO_2 and storing it in geological reservoirs (CCS) can drastically reduce the emission of greenhouse gasses into the atmosphere. Geological storage of CO_2 is currently prohibited and not on the political agenda in Austria. Still, Austria failed to reach their Kyoto goal of 13% emission reduction by 2012. In case storage is welcomed as a mitigation option, a number of known potential storage options are available in Austria, in the form of depleted or active oil fields. These are the Schönkirchen Tief, Höflein, Schönkirchen Übertief, Reyersdorfer Dolomite, Aderklaa, Atzbach-Schwanenstadt and Voitsdorf reservoirs. An assessment was made with the techno-economic PSS III simulator for the CCS–relevant industry, which makes realistic investment decisions regarding source-sink matching considering geological, technological and market uncertainties. Reservoir data is provided as expert opinions. A scenario for the power and iron & steel industry was carried out where CO_2 export was disabled and the ETS price for CO_2 increased gradually until it reaches 100 €/tonne in 2050. The total average available (practical) capacity for Austria is assessed at about 120 $MtCO_2$ (uncertainty range P5: 47 $MtCO_2$; P95: 215 $MtCO_2$), of which on average 40Mt (P5: 5 $MtCO_2$; P95: 130 $MtCO_2$) would be used in the simulated scenario (matched capacity). This amounts to 14% of all CO_2 emissions from electricity and iron & steel production until 2050. An exploration priority ranking, based on reservoir development probability, shows that the Schönkirchen Übertief reservoir has the highest potential for storage, with an estimated average matched capacity of 40 $MtCO_2$ and a development probability of 31%, and should be a primary target for further exploration. Other reservoir development probabilities result around 20 to 25%, except for the Reyersdorf Dolomite reservoir, which is not very favourable. The individual reservoirs are assessed to have a relatively limited capacity. Either smaller CO_2 sources can connect to these reservoirs, or multiple reservoirs can connect to a single large emitter to optimize the CCS chain. For the first time a detailed source-sink matching and an assessment of the practical and matched capacity for CO_2 storage in Austria was addressed, considering the current level of reservoir exploration, the techno-economic environment, and realistic uncertainties. These results can help direct future exploration and infrastructure planning, and show that CCS and domestic geological storage reservoirs in particular can provide a significant effort for reducing the CO_2 emissions of the country.

CO_2-enhanced oil recovery in the North Sea region and its importance for Belgium

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Keywords: CO_2-EOR, CO_2 capture and storage, CCS, uncertainties, techno-economic simulation

Abstract

The development of CO_2 capture and storage (CCS) demonstration projects in Europe, to prepare for its commercial deployment, has come to a standstill in the past years. Uncertainty about the future and funding gaps in e.g. NER300 project proposals and a low EU Emission Allowance price are its main inhibitors. Apart from storing it, CO_2 can be turned into a useful product. The only current application which requires CO_2 quantities in the million-tonne range is enhanced hydrocarbon production, where CO_2 is used to dissolve and push out additional oil or gas. Apart from the possibility of a more efficient use of a natural resource and a positive impact on economy in general, the CO_2 can be stored permanently. An additional advantage is that this scheme can be used as a stepping stone for large scale introduction of CCS, because it can benefit from knowledge and infrastructure such as capture and transport that was financed by the oil production. CO_2-enhanced oil recovery (CO_2-EOR) has been applied onshore for several decades mainly in North America. In the North Sea, around 80 oil fields would be suited for CO_2-EOR, with an expected incremental oil production of 4-15% of OOIP (original oil in place). There is however hesitation to apply it in the North Sea environment because of higher costs, large uncertainties and a lack of a continuous and sufficiently large CO_2 stream. While there are no oil reservoirs on Belgian territory, there lies a significant potential in capture from the CO_2-intensive industry at industrial clusters such as the port of Antwerp. Up to 15MtCO_2 could be available for capture in this region. CO_2 could be transferred via pipeline to the Rotterdam harbour, which is anticipating to become an international CO_2 hub. Analysing the full CO_2-EOR chain is necessary for planning such infrastructure for capture and transport. Timing of CO_2-EOR investment is also crucial, as there is a window of opportunity which is closing as a number of oil fields are nearing depletion. The PSS IV techno-economic CO_2-EOR simulator was specially developed to integrate the geological, technological and market uncertainties. Policy incentives, timing, effect of reservoir behaviour and uncertainty on the deployment of CO_2-EOR can be investigated. In a first test case, simulations were performed in a UK context for the Claymore, Scott and Buzzard oil fields.

Wednesday January 27th

KEYNOTE

Early life: its hydrothermal starting point and early evolution

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Abstract

Current theories for the origin of life are mostly centered around hydrothermal vents (1, 2). Unfortunately, rocks that could have recorded the critical period of the emergence of life during the Hadean are not preserved or are completely metamorphosed. The oldest, well preserved sedimentary rocks containing traces of life date from the Early/Mid Archaean (3.5-3.3 Ga), possibly 700-800 My after the appearance of life (although there is circumstantial evidence for life in metamorphosed sediments from Greenland ~3.8 Ga, (3)). The Early/Mid Archaean rocks document a continuing hot Earth, strongly influenced by hydrothermal fluids at least at the water/sediment/rock interface (4, 5). These rocks contain biosignatures of both chemotrophic and anoxygenic phototrophic life (review in (6)). Chemotrophs are thought to have been the first life forms to evolve (7). While no recognisable biosignatures of these organisms are preserved in rocks older than ~3.5 Ga, they are preserved (or at least interpreted) in Early-Mid Archaean shallow water volcanic sediments (3.5-3.33 Ga) from the Pilbara, Australia, and Barberton, South Africa (5, 8). Chemotrophs are not rapidly evolving organisms and the examples preserved in the Early-Mid Archaean sediments are likely highly representative of their Hadean ancestors and thus can be used as proxies for the earliest forms of life. We have documented carbonaceous clots interpreted to be chemotrophic colonies on the surfaces of volcanic particles and in fine grained sediments. Apparently widely but thinly distributed in these volcanic sediments, chemotroph biomass development is most intense in the vicinity of hydrothermal fluids, the latter providing essential nutrients (e.g. H_2, small organic molecules, (9)). The coexistence of chemotrophs with phototrophs indicates that the phototrophic metabolism must have evolved well before 3.5 Ga (some think it was present at 3.8 Ga, (10)).

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SESSION 13
PROTEROZOIC LIFE I

Ultrastructural and chemical characterization of the Cryogenian acritarch *Cerebrosphaera*

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Keywords: Cerebrosphaera, Acritarchs, Eukaryotes

Abstract

The late Tonian- early Cryogenian period is both a time of diversification and extinction of eukaryotes [1, 2]. Within this period of time the acritarchs *Cerebrosphaera* is a distinctive index taxon for pre-Sturtian succession [3]. This genus is characterized by dark robust walls ornamented by cerebroid folds. Two species were previously described based on the folds' width: *C. buickii* [4] and *C. ananguae* [5]. To further characterize these acritarchs and determine their biological affinity, we analysed the ultrastructure and chemical composition of specimens from the 802±10 Ma Hussar and younger Kanpa Fm., Australia and from the ~820 Ma Svanbergfjellet Fm., Spitsbergen.

Two hundred and twenty one specimens were studied under light microscopy for the observation of morphological details and the estimation of the diversity of the population of vesicles. Fourteen specimens were studied under SEM for fine-scale morphological details. The combination of information showed that the two *Cerebrosphaera* species display a morphological continuum suggesting they are two extreme morphotypes of a single population. Ultrastructural analyses using TEM were performed on 11 Australian specimens and three specimens from Svalbard and revealed two complex wall ultrastructures: a three-layered wall ultrastructure a bi-layered wall ultrastructure. No ultrastructural feature explained the distinctive folding of the walls. Infrared and Raman micro-spectroscopy were performed on 22 specimens from Australia and two specimens from Svalbard to determine the chemical composition of the vesicles wall biopolymer and their thermal maturity. The wall biopolymer showed a highly aromatic composition with very short/highly branched aliphatic chains and a weak to medium thermal maturity unrelated to the opacity of the specimens. Comparisons were also made with leiospheres from the same samples.

The complex morphology, ultrastructure and chemistry, combined with its large size and recalcitrant composition indicate that *Cerebrosphaera* was a eukaryote, taking part of the eukaryotic diversification observed prior to the onset of Snowball Earth glaciations. In the same time, the absence of significant differences between the two species plead for a taxonomic revision of the two species, *C. buickii* being the senior species.

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Dating the origin of plastids

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Abstract

Cyanobacteria, also named blue-green algae, form a large and morphologically diverse group of prokaryotes (Rippka et al, 1979), ranging from simple unicellulars to highly complex filamentous organisms. This phylum has been present since the Proterozoic, with fossil forms dating of 2000 Ga (Golubic & Hofmann, 1976). Because of the appearance of oxygenic photosynthesis in this group, Cyanobacteria have had a crucial impact in early life on Earth by increasing the level of free oxygen in the atmosphere (Kopp et al, 2005; Ochoa et al, 2014). Cyanobacteria have also played a role in another major biological event: the spread of photosynthesis into Archaeplastida through a single event of endosymbiosis between a cyanobiont and a eukaryotic host giving birth to plastids (Keeling, 2010). If the unique cyanobacterial origin of the plastids is widely accepted, the debate about the extant group that is closest to the donor is not yet settled. A number of phylogenies of Cyanobacteria, including plastids, have been published, some based on dozens to hundreds of genes (e.g., Criscuolo & Gribaldo, 2011), others on only one or two genes (e.g., Schirrmeister et al, 2013). The first type of studies, termed phylogenomics, yields a better phylogenetic resolution but at the expense of a scarce taxonomic diversity. The second type of studies is the opposite in terms of strengths and weaknesses: a denser taxonomic diversity but with a weaker phylogenetic resolution. The most frequently used gene in latter ones is the 16S rRNA, in particular for taxonomically or ecologically oriented issues. In these studies, different possible origins for plastids have been obtained, from a basal point in the cyanobacterial tree (Criscuolo & Gribaldo, 2011) to a much later emergence from within the very diversified Nostocales (Ochoa et al, 2014). We have recently performed two phylogenomic analyses taking advantage of more than 300 cyanobacterial genomes, one using a supermatrix of 182 plastid genes and one based on 116 genes encoded in the eukaryotic nucleus. Both corroborated the early origin of plastids (Cornet et al, unpublished). Dating the origin of plastids can be carried out using a relaxed molecular clock calibrated with reliable cyanobacterial fossils. Due to the impossibility to map enough calibration points on scarcely sampled phylogenomic trees, it is often the 16S rRNA that is used in molecular dating studies, despite its low phylogenetic resolution (e.g., Schirrmeister et al, 2013). Here, we present the proof of concept of a different approach for dating the origin of plastids. In order to simultaneously take advantage of the resolution of phylogenomics and of the taxonomic diversity of 16S rRNA, we inferred a 16S rRNA tree, of which the backbone was constrained by the topology of our phylogenomic trees. This allowed us to use a relaxed molecular clock calibrated with several fossils on a more reliable 16S tree.

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What 20 years of phylogenetics teach us: the Last Universal Common Ancestor (LUCA) is not the origin of Life and might have been more complex than we used to believe

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Keywords: rooting the Tree of Life, LUCA the Last Universal Common Ancestor, phylogenetic tree reconstruction artefact, eukaryotes origin, Great Chain of Beings

Abstract

The origin of the eukaryotes remains one of the most contentious puzzles in evolution. In the late 1970s, C. Woese discovered Archaea and put an end to the dichotomous view of Life (eukaryote *vs* prokaryote). Since Woese's revolution, the Tree of Life (ToL) has been divided into three domains (Bacteria, Archaea and Eukaryota), yet with unclear relationships. Rooting the ToL then became a problem. Indeed, the question of the origin of eukaryotes is directly related to the location of this root, which also affects the nature of the Last Universal Common Ancestor (LUCA). Several scenarios might explain the origin of the eukaryotic cell: (a) the three domains have an independent origin and directly stemmed from the primordial soup; (b) the three domains stemmed from a simple LUCA, and their evolution proceeded by increasing complexity in eukaryotes; (c) the three domains stemmed from a complex LUCA, and their evolution proceeded by simplification in prokaryotes; (d) eukaryotes originated from a fusion event between an archaeon and a bacterium, the latter being the mitochondrion and their other properties evolving after this event; (e) eukaryotes originated from a fusion event between an archaeon and a bacterium, the result being a proto-eukaryote not yet equipped with a mitochondrion.
During the last 15 years, technical advances in phylogenetic methods have relocated many simple organisms higher in the ToL, which means that they are actually secondary simplified. However, even the best evolutionary models are not yet able to address difficult phylogenetic issues, whether at shallow depth or at deep evolutionary times. This raises a fundamental question: does simple always mean ancestral? For the time being, the commonly accepted bacterial root for the ToL (in scenario (b)) is still unproven, so that the current consensus can be traced back to the prejudice of Aristotle's Great Chain of Beings, in which simple organisms are ancestors of more complex life forms. Indeed, during early evolution, there might have been many independently arising lineages, both before and along LUCA, none of them having left extant descendants. The major bottlenecks that occurred as a result of catastrophic events in Earth's history (e.g., meteorite impacts or snowball Earth periods) might explain why we only have three domains of Life nowadays. Furthermore, extant lineages coalesce to a LUCA that was not necessarily simple and located at the base of the ToL. Instead, it probably lived much later and was more complex than generally acknowledged.

SESSION 14
CENTRAL AFRICA DURING THE CENOZOIC

First paleostress tensors from the Kivu – North Tanganyika rift region, Central Africa (D.R.Congo, Burundi): Insight its Phanerozoic brittle tectonic evolution

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Keywords: Kivu rift region, fault kinematics, paleostress tensor inversion, brittle tectonic evolution

Abstract

The Kivu rift region lies in the central part of the western branch of the East African rift system, over Rwanda, Burundi, Eastern D.R.Congo, SW Uganda and NW Tanzania. It developed in the Mesoproterozoic Karagwe-Ankolean belt and the Paleoproterozoic Rusizian belt between the Congo and Tanzanian cratons. Rifting in this region started at about 10 Ma as a consequence of the divergence between the Nubian and the Victorian plate, but it entered in the brittle deformation regime at the end of the Pan-African amalgamation of Gondwana, in Early Cambrian. From this event to the onset of rifting, little is known although this ~500 Ma-long period is essentially characterized by brittle tectonics which can be investigated by fault kinematic analysis and tectonic stress reconstruction using now well established methods.

We performed preliminary fault-kinematic analysis of a few but good quality sites in different tectonic settings, along the western shore of Lake Kivu (Katana, Bukavu), along the northern extremity of Lake Tanganyika (Bujumbura, Uvira) and along the Twangiza-Namoya gold belt, in the southwestern continuation of the Kivu rift basin. The studied outcrops expose well expressed slickensided faults, tension fractures and conjugated fractures, sometimes corresponding to two successive brittle deformation events. The fault-kinematic data have been inverted using the Win-Tensor programme to compute the 4 parameters of the reduced stress tensor (3 stress axes and stress ratio). These are further used to determine the horizontal stress directions and stress regimes.

The results allow to identify brittle tectonic elements that formed under markedly different stress conditions. We have identified at several locations, expressions of a deep brittle E-W compression, with low-angle thrust faulting and a transport direction generally top-to-the-West. This event is tentatively related to the late Pan-African deformation. It was followed by pure normal faulting in E-W extension and transpressional faulting with N-S horizontal compression in relatively deep conditions, with no particular expression in the topography. Cross-cutting relations show that they are younger than the E-W compression, but the relation between these two could not be observed. We propose that the E-W extension could mark a local expression of the post-orogenic extension after the cessation of the pan-African convergence, while the N-S transpressional faulting could be related to an early Mesozoic event known elsewhere in Tanzania and in Katanga. The last brittle deformation is normal faulting which occurred under more superficial conditions and is related to the neotectonic rift faults.

Relief and topographic evolution of Central Africa during Cenozoic times

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Keywords: Congo, Uganda, Cenozoic, Geomorphology, Palaeogeogeography

Abstract

The growth of the relief and topography of Central Africa (from Cameroon to Angola to the West to the Kenya-Tanzania divide to the East) is a subject of debate, mainly on its age (Late Cretaceous or Cenozoic) and on the driving processes (mantle processes vs. lithospheric deformation).

To address these questions we did an analysis of the main landforms of Central Africa: the planation surfaces of etchplain and pediplain types. Different generations of planation surfaces were mapped at the scale of Central Africa (with great details in Uganda), dated using their relationships with magmatic rocks (Cameroon Volcanic Line, Virunga-Kivu, Kenyan Rift) and sediments. The vertical movements were quantified using the stepping of successive pediment systems each of them recording a local base level.

(1) **65-46 Ma (Paleocene-Middle Eocene)**. The Congo Basin and most of the surrounding areas are near sea level and experienced a severe weathering with laterites formation. The resulting flat relief corresponds to the African Surface.

(2) **45 – 30 Ma (Late Eocene- Early Oligocene –** poorly age-constrained). This is the initiation of the growth of most of the Central African relief: the **Cameroon Highlands** with two increasing periods, 45-23 Ma and since 11 Ma, the **Ubangian Rise** (moderate uplift) to 11 Ma, the **East African Dome** with an increase around 11 Ma and a decrease since that period.

(3) **20-16 Ma (uppermost Early Miocene)**. This is a period of major relief reorganization with uplift of the **Central African Atlantic Swell** and the **Angolese Plateau** (including the western part of the Kasai-Lunde-Kwango Plateau). This is also the initiation of the Western Branch of the EAR (Albertine Rift system) and the capture of the upstream part of Congo pediplain flowing toward the Atlantic Ocean by the Albertine Rifts.

(4) **11 Ma (base Late Miocene).** This is the period of uplift of the **Central Cuvette** and the creation of a local base level decoupled from the Atlantic Ocean.

(5) **2.5 – 0 Ma (Pleistocene).** This time interval corresponds to the growth of the surrounding relief of the western branch of Albertine Rift (Ruwenzori, Blue Mountains) and to the increase of the uplift of the Virunga-Kivu dome. Around 400 Ka, the Tanzania Craton is flexured controlling the birth and location of Victoria Lake.

The Landana section (Cabinda, Angola): a unique Paleocene-Eocene biotic and sedimentary record in the Congo Basin

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Keywords: Landana, sedimentology, vertebrates, dinoflagellates, carbon isotopes, Paleogene

Abstract

The Landana section (Cabinda, Angola) has been a known fossil locality since the late 19th century. During the first part of the 20th century, Edmond Dartevelle, a Belgian palaeontologist and explorer made several visits to the coastal area of Central Africa, including Cabinda. At Landana, he collected numerous fossil vertebrate and invertebrate specimens as well as many rock samples. This material is now part of the collections of the Royal Museum for Central Africa (RMCA) in Tervuren. The Landana site is probably most renowned for its vertebrate fauna, which includes: the dyrosaurid crocodyliform *Congosaurus bequaerti*, the bothremydid turtle *Taphrosphys congolensis*, the oldest scrombrid fishes and ample amounts of elasmobranch species. The invertebrate fauna on the other hand is dominated by cephalopods and bivalves. Several evolutionary phases ranging from the Danian to the Lutetian can be recognized in this tropical shallow marine faunal assemblage. The overall faunal composition is similar to that of assemblages recovered from the Moroccan phosphate basins, except for the abundance of torpediniformes (electric rays) and the composition of Paleocene actinopterygians. Samples from the Dartevelle Landana collection were analysed as part of a multidisciplinary research project (PalEurAfrica, Belgian Science Policy), focussed on vertebrate evolution (RBINS), dinoflagellate associations (UGent), stable isotope composition (UNamur), and sediment properties (RMCA). $\delta^{13}C_{org}$ variations and dinoflagellate cyst occurrences were subsequently calibrated against revised data on foraminifer assemblages. Preliminary results suggest that the Landana section can be divided into two main parts. A lower part, consisting of foraminiferal limestone of Danian (layer 1-10), Danian-Selandian (layer 10-15), Thanetian (layer 15-21), Ypresian (layer 24-28) and Lutetian? (layer 29-32) age. A shallowing-upward sequence, a silicified hardground level and pervasive dolomitization, mark the transition to the upper part of the sequence (layer 33-42), which consists of feldspar-bearing sandstone, of likely Miocene age. Quantitative and qualitative analysis of dinoflagellate cyst occurrences also provides constraints for deducing local palaeoenvironmental changes and it contributes to the reconstruction of the Cenozoic depositional history of coastal marine Central Africa, at or near the estuary of the huge Congo Basin. As evidence of contemporaneous continental sediments deposited within the Congo Basin is lacking at present, the Landana section provides what appears to be a unique faunal and sedimentological record for the early Paleogene (Paleocene-Eocene) in Central Africa.

SESSION 15 POSTERS

GEOENVIRONMENT, GEOHAZARDS, HYDROGEOLOGY

Groundwater flow and chemistry of the oases of Al Wahat, NE – Libya

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Keywords: Post-Nubian Aquifer, Post-Middle Miocene, Calanscio Formation, Jalu Oasis, Awjilah Oasis, Shakherah Oasis, Libyan Desert, chromatographic sequence, cation exchange reactions, freshening

Abstract

The quality and geochemistry of groundwater are significantly affected by the depositional environment of aquifer sediments. Miocene sediments in Al Wahat area (Jalu, Awjilah and Shakherah Oases) in the Libyan Desert at the north-east of the country have been deposited in fluvial marginal-marine and marine environments. The purposes of this paper are to describe the areal distribution of the dominant water quality constituents, to identify the major hydro-geochemical processes that affect the quality of water and to evaluate the relations of sediment-depositional environments and groundwater flow to the quality and geochemistry of water in aquifer sediments of Post-Eocene. The area involved in this study is within the boundaries 28°N-29°N and 21°E-22°E. Eighteen wells are selected in the area and 10 samples were analysed from wells used for domestic and agricultural purposes. Results show high and significant increase of total dissolved solids, especially Na^+, Cl^- , SO_4^{2-} and NO_3^{-2} compared to the previous years.

The chemical results for the groundwater samples in Al Wahat are classified according to the Stuyfzand groundwater classification system; the water type is mostly brackish and brackish-saline NaCl in the downstream direction and fresh-brackish $NaHCO_3$ upstream. These water types indicate that groundwater chemistry is changed by cation exchange reactions during flushing of the diluted saline aquifer by freshwater from the south. The different stages of cation exchange produce a chromatographic sequence of groundwater types, theses cation exchange reactions during the freshening process occurring mainly in the intercalated clay, resulting in a Na^+ increase, and peaks of K^+ and Mg^{2+} in the aquifer. In the north, the synsedimentary marine influence on the groundwater is stronger and the abstraction for irrigation is higher.

High rate of pumping, evapotranspiration and anthropogenic pollution may contribute significantly to the aquifer water quality. Calcite equilibrium and gypsum dissolution are also important hydrochemical process in the aquifer.

Towards an innovative modelling framework to assess environmental change impact on the water cycle at the catchment scale

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Keywords: *coupled modelling, material parameters, probabilistic inversion, state variable observation, palaeohydrology*

Abstract

The hydrological cycle at the catchment scale integrates a large number of spatially and temporally variable processes that are influenced by environmental changes. Integrating all these processes into one consistent modelling framework is an enormous challenge; yet it is crucial to understand and identify the contributions of different factors (climate, land use, socio-economic demands, model parameter and conceptual model uncertainty, catchment settings) to the expected change in hydrological response as a result of global environmental change. Equally important is to quantify the uncertainties in terms of water quantity (and quality) at the catchment scale under future changes over various time periods.

Here we present the first steps taken into developing an innovative modelling framework to tackle the issue of changes in water cycle under future environmental change in the Nete catchment, NE Belgium. The overall approach consists of (i) an integration of different components of the hydrological cycle into a coupled model focusing on unsaturated-saturated zone coupling at the catchment scale, (ii) advanced material parameter characterization efforts, (iii) an efficient probabilistic inversion methodology to derive spatially and temporally variable model parameters, conditioned on the available data, (iv) the use of alternative state variables other than groundwater head, and (v) hydrological model response validation using palaeohydrological proxies covering the last few centuries. Results from each of these framework components and their interaction will be presented and discussed.

Exploring the potential of Lake Hamana to hold a long and reliable sedimentary record of paleotsunamis along the Nankai-Suruga Trough

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Keywords: Nankai-Suruga Trough, Lake Hamana, tsunami deposits, reflection seismics, sediment cores

Abstract

Coastal Lake Hamana is located near the convergent tectonic boundary of the Nankai-Suruga Trough, along which the Philippine Sea slab subducts underneath the Eurasian Plate, giving rise to repeated tsunamigenic megathrust earthquakes (Mw≥8). A good understanding of the earthquake- and tsunami-triggering mechanisms in terms of rupture mode and recurrence pattern in time and space, is crucial in order to better estimate the complexity of seismic risks for the densely populated Enshu-nada coast. Based on existing historical data of paleoseismicity (last ~1300 years), the easternmost segment (Tōkai segment) of the Nankai-Suruga Trough appears to exhibit a seismic gap and is expected to rupture in the near future, causing the next 'Tōkai earthquake'. Studying the sedimentary infill of Lake Hamana may help to fine-tune hazard assessment in the area of interest. Thanks to its extensive accommodation space, the Hamana lake basin is considered to be a good archive for past events. Fieldwork (Oct.-Nov. 2014) comprised a reflection-seismic survey for imaging the lake's stratigraphic features, based on which favourable locations for gravity coring were selected. A systematic sampling of bottom sediments from different sites enables us to evaluate vertical as well as lateral changes in depositional environment, including event deposits generated by tsunamis, tropical storms (typhoons) and slope failures. An important part of the study is dedicated to qualitatively distinguish sedimentary facies of storm deposits from the ones generated by tsunamis, since this is an essential step in correctly assess future hazards. For identification of marine tsunami incursions, a set of sedimentological, geophysical, geochemical and micropaleontological analyses are applied on the cored sequences in a multi-proxy approach. Radionuclide dating provides the necessary timeframe and information on prevailing sedimentation rates. Sites bearing the potential of recording complete and long event histories are sampled with long cores (Oct. 2015) in order to retrieve more information on tsunami recurrence patterns in the study area.

Numerical groundwater model of the dessication and dissipation of an unlined treated sewage effluent pond in Doha, Qatar

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Keywords: numerical modelling, groundwater, unlined TSE pond, desssication and dissipation, arid climate

Abstract

The Abu Nakhla sewage pond is located southwest of Qatar's capital city Doha. The pond started in a natural depression in 1985, initially receiving raw sewage water and later treated sewage effluent (TSE) from nearby water treatment plants. As the pond is unlined, water has been infiltrating into the subsoil and has been recharging the groundwater reservoir ever since. Due to the rapid expansion of Doha, the area has come into sight for development projects. For this reason, discharge of TSE to the pond has halted and the pond is principally under natural outflow conditions (evapotranspiration and infiltration). Qatar has an arid climate with high evaporation and low rainfall. Natural groundwater heads can be 20 to 30m below surface, but the presence of the pond has led to a substantial rise in heads in the area. Even though the pond at the surface will disappear in a matter of years, the subsurficial remains of the lake will last for a far longer time. The aim was to model the desiccation and dissipation of the Abu Nakhla pond under the natural conditions of infiltration and evapotranspiration, and to see how this influences the groundwater reservoir. From a hydrogeological point of view, the subsoil is subdivided into two carbonate aquifers separated by a gypsum aquitard.

The groundwater flow model was constructed with the MOCDENS3D-software, a 3D density dependent groundwater modeling code. As starting point for the model, the date of 8 May 2014 was chosen. At that time a hydrodynamic equilibrium was assumed. The model simulates the evolution of the hydraulic heads under and in the vicinity of the lake once discharge of TSE has stopped. As such the pond will slowly desiccate due to high infiltration and evaporation of the lake and its surrounding area. Results show that changes in the groundwater heads are slow as long as the pond at the surface has not completely lost its water. The large storage of the water reservoir delivers a continuous recharge to the groundwater reservoir which slows down the drawdown of the hydraulic heads. Once this component of dynamic water balance becomes very small, the hydraulic heads show an accelerated drawdown. A sensitivity analysis of four key hydraulic parameters pointed out that the main parameter regulating the evolution of the hydraulic heads in the subsoil is the horizontal conductivity of the upper aquifer.

An Inventory of Underwater Landslides in Lake Baikal Suggests a Strong Link with Gas Hydrates

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Keywords: gas hydrate, landslide, morphology, lake, Russia

Abstract

Multibeam bathymetry data from Lake Baikal were analyzed for the identification of morphologies that could indicate the presence of underwater landslides. The data were collected in 2009 by a Belgian-Russian-Japanese consortium, using a 50 kHz Seabeam 1050 echosounder, operated from RV Titov. The data cover the entire lake floor –in water depths between 200 m and 1637 m– of the Southern and Central Basins, i.e. a total surface of 15,000 km^2.

Our analysis revealed the presence of 26 possible underwater landslides. At least 11 of these are characterized by distinctive headwalls, scars and overall morphology, and were confirmed to be mass-wasting features by high-resolution reflection seismic data.
Most of the identified underwater landslides scar the slopes of the Selenga river delta, and the sediment-charged slopes of the shoaling eastern margin of the half-graben basins.
Most of the underwater landslides have a headwall occurring at water depths between 300 and 450 m; only a few occur at larger water depths.
All underwater landslides occur in areas in which gas hydrates have been inferred (i.e. based on the observation of bottom-simulating reflections on seismic data) or confirmed (i.e. by deep drilling or shallow coring). The clustering of many headwalls at a water depth that is not characterized by any distinct change in slope gradient or stratigraphy, but that is close to the stability limit of gas hydrates (i.e. ca. 380 m, for pure methane hydrates, under Lake Baikal conditions), suggests that the presence of the hydrates may be one of the most important controlling factors in conditioning the underwater slopes of Lake Baikal and rendering them unstable and prone to failure. The exact conditioning process remains, however, unclear as the hydrate reservoir in Lake Baikal is considered to have remained stable, even over relatively long time scales, in the absence of any important fluctuations in lake level and in bottom-water temperature.

Cartography of the Belgian monuments at risk via PSI analysis of the ground movements, the GEPATAR project

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Keywords: InSAR, Subsidence, Uplift, PSI, Radar Interferometry

Abstract

In Belgium, the federal collection of built heritage is visited every year by millions of people. This built heritage is of exceptional cultural and economic importance for the country and its protection is a priority at federal and regional levels. Due to heavy industrial and urban development, cultural heritage buildings suffer from physical, mechanical, chemical, and biochemical pathologies. Furthermore, external human activities such as groundwater extraction, digging of underground galleries and temporary excavations all contribute to structural instability of the buildings. An adequate protection and preservation of the built patrimony requires the integration and the analysis of environmental, architectural and historical parameters. The project GEPATAR (GEotechnical and Patrimonial Archives Toolbox for ARchitectural conservation in Belgium) aims the fusion between the archives of the Geological Survey of Belgium (GSB) and the Royal Institute of Cultural Heritage (RICH) for better management of federal patrimony by estimating the stability of the monuments by radar interferometry. In the first stage of the project, a PSI processing chain will be developed by Centre Spatial de Liège (CSL) for the exploitation of the ERS and ENVISAT SAR archive available at GSB. It will be possible to map with accuracy of millimeters ground movement at local and regional scales. The GEPATAR toolbox will be created by the Royal Military Academy (RMA) in GIS allowing the integration of data from the RICH archive with inputs from RBINS at three scales: national, regional and local. 'National' refers to the Belgian country, 'regional' to the region in risk of ground movement and 'local' is the building. The integration of geodata and ground stability with historical, structural engineering and architectural data will allow a risk analysis for Belgian cultural heritage. At National and regional levels, GEPATAR will provide to the staff involved in defining conservation strategies at RICH the possibility to prioritize the conservation actions. At local level (i.e. building level) GEPATAR will provide all the necessary data set to assess the risk for a patrimony building. Evaluation of GEPATAR toolbox will be done using identified test cases. The selected monuments are located at areas where intensive urbanism and post-industrial activities have occurred. A ground movement risk model will be developed for each building for which a large set of environmental, geographical, historical and architectural data sets needs to be collected. The information will be combined using the GEPATAR modules for further structural engineering analysis, assessing the strength of the building structure by the Catholic University of Leuven (KUL).

Hydrogeology of weathered limestones

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Keywords: fracture network, karst, weathering, modelling, upscaling

Abstract

'Ghost-rock' karst aquifer has recently been highlighted. In this particular type of aquifer, the karst is not expressed as open conduits but consists in zones where the limestone is weathered. The in-situ weathering of limestone leaves a soft porous material called 'alterite'.

The hydro-mechanical properties of this material differs significantly from those of the host rock: the weathering enhances the storage capacity and the conductivity of the rock. This type of weathered karst aquifer has never been studied from a hydrogeological point of view. In this study, we present the hydraulic characterization of such weathered zones. We also present a modelling approach derived from the common Equivalent Porous Medium (EPM) approach, but including the spatial distribution of hydrogeological properties through the weathered features, from the hard rock to the alterite, according to a weathering index. Unlike the Discrete Fracture Network (DFN) approaches, which enable to take into account a limited number of fractures, this new approach allows creating models including thousands of weathered features.

As the properties of the alterite have to be considered at a centimeter scale, it is necessary to upscale these properties to carry out simulations over large areas. Therefore, an upscaling method was developed, taking into account the anisotropy of the weathered features. Synthetic models are built, upscaled and different hydrogeological simulations are run to validate the method. This methodology is finally tested on a real case study: the modeling of the dewatering drainage flow of an exploited quarry in a weathered karst aquifer in Belgium.

Numerical simulation of Weichselian permafrost depth in the Netherlands

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Keywords: waste disposal, safety assessment, uncertainty, stochastic, finite element

Abstract

The Rupelian clay in the Netherlands is currently being the subject of a feasibility study with respect to the storage of radioactive waste in the Netherlands (OPERA-project). Many features need to be considered in the assessment of the long-term evolution of the natural environment surrounding a geological waste disposal facility. One of these is permafrost development as it might affect, e.g., the hydrogeological system. In this study, the Weichselian glaciation is used as an analogue for future permafrost development. Permafrost depth modelling using a best estimate temperature curve of the Weichselian indicates that permafrost would reach depths between 140 m and 180 m. Without imposing a climatic gradient over the country, deepest permafrost is expected in the south, due to the lower geothermal flux and higher average sand content of the post-Rupelian overburden. Taking into account various sources of uncertainty, such as type and impact of vegetation, snow cover, air surface temperate gradients across the country, possible errors in palaeoclimate reconstructions, porosity, lithology and geothermal flux, stochastic calculations point out that permafrost depth during the coldest stages of a glacial cycle such as the Weichselian, for any location in the Netherlands, would be between 120-200 m at the 2σ level. In any case, permafrost would not reach depths greater than 270 m. The most sensitive parameters in permafrost development are the mean annual air temperatures and porosity, while the geothermal flux is the crucial parameter in permafrost degradation once temperatures start rising again. The calculations presented here are robust and conservative.

Using mixing ratios to quantify chemical reactions in groundwater

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Keywords: *urban aquifer, mixing analysis, non-conservative species, chemical reactions quantification*

Abstract

This work is motivated by a sound understanding of the chemical processes that affect the organic pollutants in an urban aquifer. We propose an approach to quantify such processes using mixing calculations. The methodology consists of the following steps: (1) identification of the recharge sources (end-members) and selection of the tracers (conservative and non-conservative) to be used, (2) identification of the chemical processes and (3) evaluation of mixing ratios including the chemical processes as new end-members. This methodology has been applied in the Besòs River Delta (NE Barcelona, Spain), where the River Besòs is the main aquifer recharge source. A total number of 51 groundwater samples were collected from July 2007 to May 2010 during four field campaigns. We assumed that the composition of the observation points is the sum of river water mixing (conservative) and groundwater-aquifer interactions (non-conservative). Three river end-members were necessary to explain the temporal variability of the River Besòs: one river end-member is from the wet periods (W1) and two are from dry periods (D1 and D2). This methodology has proved to be useful not only to compute the mixing ratios but also to quantify processes such as calcite and magnesite dissolution, aerobic respiration and denitrification undergone at each observation point when river water infiltrates the aquifer.

Design and Calibration of a System for Monitoring Highly Variable Dripwater Flows in Caves

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Keywords: dripwater, flow, monitoring, karst, cave

Abstract

Monitoring dripwater flows in caves is of great importance when studying infiltration processes in the vadose zone. Many systems exist, such as rain gauges of various types, that measure dripping water flows. However such systems, especially those with moving parts, tend to fail quickly due to calcite deposition. Here, we present an original system designed to monitor highly variable dripwater flows in caves ranging from less than one litre per hour to several tens of litres per hour.

In this system, the dripping water collected in an inverted cone flows in a container feeding a small upper tank which in turn feeds a larger lower tank. The emptying of the tanks is done by auto siphoning. A capacitive sensor plunging in each tank returns a high frequency FM signal dependent on the water level in the tank. Signals from these sensors are integrated over time and monitored with a datalogger at rates ranging from 1 Hz to 0.2 Hz in order to be able to report rapid changes in flow rates.

The design step of the tanks and sensors included the development of a specific code to simulate the functioning of the system and predict the responses of the sensors. A special attention was given to the characteristics of the admission and siphoning tubes as well as the shapes of the tanks and sensors. Several designs were tested before selecting the final one. In the selected design, the system is about 1.2 m high, the upper tank has a capacity of about 0.25 l and the lower one is about ten times larger. At very low flows, the limited capacity of the upper tank leads to maintain an acceptable resolution on the measurement while at very high flows, the upper tank is overloaded and an overflow channels excess water directly in the lower tank.

Calibration and control of the system, is done with a peristaltic pump circulating water at several flow rates in a closed circuit. Water is pumped from a container to the top of the monitoring system, flows inside the monitoring system and the outflow returns in the container. In this way, it is possible to maintain a constant flow in the system for long periods as well as to explore a large range of flow rates.

A new soil map approach in the frame of the NAGiS Project

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Keywords: soil map, multidisciplinary approach, GIS, NAGiS

Abstract

The NAGiS abbreviation stands for National Adaptation Geo-information System. The duration of the project is 2014–2016 and is financed by Icelandic, Liechtenstein and Norwegian Fund. The project has multiple goals:

- to support the nationally, regionally, and locally made decisions in the scope of adaptation to climate change,
- impact analysis and climate modelling of regional climate change,
- elaboration of the methodology of vulnerability assessment,
- development of an internet based climate policy information hub and
- to facilitate the implementation of the National Adaptation Strategy.

The project is co-ordinated by the Geological and Geophysical Institute of Hungary and researchers in different fields (environmental geology, soil science, hydrogeology, climatology and forestry) are participating. This presentation summarizes the first geological results of the project.

A multidisciplinary approach is suggested to compile a new, detailed soil map of Hungary, in scale 100 000. This methodological research of geological, morphological and landscape geographical basis for a new soil map includes six different fields of data sources, organized in ArcGIS environment. These fields are as follows: rock facies, landscape classification, geological age and genetics, climate, morphology, sedimentological and chemical parameters. Based on these data sources a special GIS database can be built step by step. The result is a complex cartographic line network which can be interpreted as a well detailed soil map.

The rock facies, as the first data source coming from a former hydrogeological project and published in 100.000 scale. The landscape classification map as the second data source is available in 500.000 scale. The covered geological map as the third data source provides a base to connect and test geological age and genetics data in point of view of pedology. The climate as the fourth data source can be associated to regional landscape classification. The morphology as the fifth source relies on a slope category map based on a digital terrain model, in scale of 50.000. Nevertheless, this source should be verified by satelite images. The sixth data source comes from a so-called Shallow Drilling Database, which contains basic (geographical), sedimentological and chemical data of more than 15.000 drillings established in Hungary in the 1960-80s. From our point of view carbonate and pH data seem to have a special importance.

A history of mass transport complexes related to earthquake shaking: the case of Lake Motosu (Japan)

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Keywords: Paleoearthquakes, Mass-transport deposits, turbidites, Nankai-Suruga Trough

Abstract

The QuakeRecNankai project focuses on geological records of paleoearthquakes along the Nankai-Suruga subduction zone, south central Japan. In the framework of the project, we investigated the Fuji Five Lakes, located at the eastern end of the Nankai-Suruga Trough. Here, we present results from Lake Motosu, the deepest of the Fuji Five Lakes (max. depth 122 m), including seismic reflection profiles and gravity cores. We identify mass transport deposits and turbidites possibly triggered by earthquakes. We study the lake sedimentary architecture and the Holocene sedimentation with a very high resolution GEOPULSE pinger system. A seismic grid with total length of 39 km covered the lake. We identify a specific seismic horizon that may be related to the Aokigaraharamarubi lava flow (864 A.D.). Strong reflectors may also correlate with tephra layers from Oniwa-Okuniwa eruptions (620-790 A.D). In the western part of the lake, the seismic reflection profile reveals a change after the proposed Oniwa-Okuniwa eruptions in terms of volume and length of mass transport deposits. Large mass-transport deposits occurring before the eruptions are characterized by chaotic seismic facies. After the eruptions, the mass-transport deposits are much smaller than previously and characterized by transparent seismic facies attributed to a turbiditic flow. Six gravity cores (max. 90cm) provide samples of the lake bottom sediments. In these cores, turbidites were identified based on facies analyses, combined with X-ray scanning, geophysical properties, grain-size analysis, mineralogy and XRF. An age-depth model was established based on radionuclide dating. We compare the timing of sedimentary events in Lake Motosu with a historical catalogue of natural hazards in the Fuji Five Lakes area, including historical records of megathrust earthquakes rupturing the Nankai subduction zone, the Sagami Trough and other earthquakes occurring along inland faults. Several analyses were performed to understand why we have a change in type of mass transport deposit after the eruptions and to define the minimum shaking intensity required to destabilize the slope. To assess slope stability, we investigated the clay content and the clay mineralogy of the slope. Spatial statistics was also performed in order to evaluate the degree of the slope and the accumulation of sediment. We suggest that the presence of a scoria layer might have contributed to slope destabilization.

Measuring the amount of CO2 in oversaturated waters by mass balance: an overview of trials and errors

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Keywords: Spa, Pouhon Delcor, CO_2 quantification

Abstract

The area around the Belgian town of Spa is well-known for the occurrence of naturally carbonated water springs. The Geological Survey of Belgium is monitoring the stream at 'Pouhon Delcor', and a low-cost methodology is being developed to quantify the CO_2 content in the water and the release of CO_2 into the atmosphere. The subject area comprises oversaturated waters and several iron-rich sources, which is a main reason for choosing this location. Here we present an overview of the development and trials of different methodologies. A quantification methodology in the field would be preferred, which would expose the oversaturated samples to a minimum of open time and leakage risk. Apart from analysis with a field laboratory, results proved to be unreliable. A laboratory mass-balance methodology was developed, which evolved from the first trial open air trial experiments to the current current approach, a closed set-up. The open air setup involves weighing the samples with a microbalance before and after exposure to free air, but water evaporation generated significant errors. Therefore a new, tightly closed system was developed which allows storage and relatively quick measurement. CO_2 is first fixated with NaOH to prevent leakage. In a closed reaction chamber, acid is added to release the CO_2 in a gaseous phase, which is captured again in a NaOH solution. Weighing all components with a microbalance provides the original CO_2 content. After this modification no significant errors were recognized.

Sublacustrine landslides in several Alaskan lakes reveal a long history of strong earthquake shaking

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Keywords: sublacustrine paleoseismology, landslide record, southcentral Alaska

Abstract

In 1964, the "Good Friday Earthquake" ruptured a 800 km-long segment of the Alaskan-Aleutian Subduction Zone (AASZ), representing the largest measured earthquake in North America (Mw 9.2). Lake sediments potentially record such large earthquakes, since seismic shaking can generate subaquatic mass-wasting deposits. Several short cores, high-resolution seismic (3.5 kHz) and multibeam (50 khz) data were collected in Eklutna, Skilak and Kenai Lakes in southcentral Alaska. The data reveal the presence of sublacustrine landslides related to the 1964 earthquake. The seismic profiles also show a succession of older landslide deposits in the subsurface. It has been shown that strong earthquake shaking can trigger such landslides and as such they are useful for paleoseismology research, especially in low-seismicity regions. In high-seismicity regions (e.g. South-Central Chile), however, the turbidite record has shown to be a much more sensitive seismometer, because frequent and strong seismic shaking is under-represented in landslide deposits in the lake records. Eklutna, Skilak and Kenai lakes are also located in a high-seismicity setting (the Prince William Sound segment of the AASZ), but they exhibit significantly larger sedimentation rates (4 mm/yr), potentially reducing the effect of under-representation.

Our multi-lake approach allows us to compare landslide records between lakes with different characteristics: low sedimentation rates cause under-representation of the landslides in Skilak Lake with respect to other independent paleoseismic records, while higher sedimentation rates in Eklutna Lake produce more frequent event deposits, potentially thus resulting in a more precise sedimentary archive of past earthquake events.

Multiple lake records will also help us understand segment boundaries of megathrust earthquakes. This is crucial for inferring information on variability between ruptures and interplate coupling.

Settlements around pumping wells: distribution, relation with the storage coefficient and role of surrounding layers

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Keywords: Differential Settlements, Pumping, Storage Coefficient, Young's Modulus

Abstract

The contraction occurred in aquifers during pumping produces settlements, which are really feared. These settlements are generally predicted to avoid unexpected events, but these are sometimes overestimated. The reason of this mismatch between observed and predicted settlements is studied numerically by investigating the mechanical response of pumped aquifers. Firstly, results show that pumping settlements occurring near wells are not proportional to the drop of pressure. Settlements are not differential within a distance from the well that depends on the thickness of the aquifer. Two procedures to determine pumping settlements considering this fact are proposed (an analytical approximation and a dimensionless method). Secondly, the impact of aquitards located above aquifers is also assessed since these layers influence pumping settlements towards the surface. Finally, the relation between the pumping settlements, the specific storage coefficient and the mechanical parameters is considered. The specific storage coefficient observed during pumping tests overestimates the Young's Modulus, as the stiffness of the formations surrounding the aquifer. Additionally, it is observed that boundary constrains must be considered since they affect the storage coefficient of the aquifer, and therefore, the pumping settlements.

Pumping settlements should not be feared since they are less dangerous than the expected, especially near wells. However, they must be predicted considering the nature of the layers that surround the aquifer and carefully selecting the mechanical parameters.

Risk assessment in an abandoned coal field: ten years of hydrological monitoring in Liège (Belgium)

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Keywords: post mining monitoring, water management, time serie analysis, risk assessment

Abstract

Mining activities can affect the environment decennia after extraction activities stopped. One of the major environmental changes observed after extraction activities stopped are the changes in groundwater flow and the coupled stress redistribution in the underground. Flooding of the mined voids starts as soon as the extensive pumping required for the mining activities stops. This process called “ground water rebound” continues until the mine water surface equilibrates with the regional ground water surface or reaches a point of discharge, e.g. a drainage adit (Wolkersdorfer, 2008). Consequently, outbreak, flooding and/or stability problems can occur in the surrounding area (Wolkersdorfer, 2008).
Mining risk management is thus an important issue to ensure public safety where extraction activities were intense during several centuries, e.g. in Wallonia (Pacyna and Salmon, 2012). To assess these risks, flow rates and groundwater levels are monitored since 10 years in exploited voids and drainage adits of the area of Liège. A statistical study is performed on the long term data, aiming to understand groundwater behavior and to improve the measurement network. Trend decomposition of these time series allows extracting seasonal cycles from general trends and random variation. To evaluate if groundwater rebound is still active or not, the general trend is analysed. Auto-correlation functions are calculated for each time serie to determine the memory effect of the data. This analysis shows that some locations are influenced by slow recharge processes in contrast to other locations which are sensitive to shorter recharge periods, i.e. induced by rain events. This is also proven by cross-correlation functions which allow to understand connections between the exploited areas and to calculate retardations between rain peaks, groundwater peaks and drainage peaks. Based on these results the monitoring network can be improved and further research will be undertaken to verify if low discharges are only measured in the adits when infiltration is negligible.

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Coastal erosion and accretion: translating incomplete data and information into vulnerability assessments

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Keywords: EMODnet-Geology, vulnerability index, cliffs, bluffs, soft-sediment coasts, EUROSION

Abstract

Building on the results of EUROSION, an EU-project completed some ten years ago, the partners of EMODnet-Geology have been compiling coastal erosion and sedimentation data and information for all European shorelines. As part of this process, coverage is being expanded, and data and information are being updated. The main challenges faced during this compilation phase are posed by a) differences between parameters used as indicators of shoreline migration, b) restricted access to third-party data, and c) data gaps. There are many indicators of coastal behaviour, with inherent incompatibilities. High- and low-water lines of barriers, for example, migrate land- and seaward in different ways. The behaviour of cliff tops and bases shows even less correspondence, with tops moving exclusively landward whilst bases can move seaward. Regionally, low data availability and limited access result in poor coverage. With increasing volumes of satellite data expected to become available, especially from the Sentinel programme, it is high time to invest in automated methods to derive coastal-erosion data from satellite monitoring at a regional level. It needs to be emphasized that consistency of data and derived information on coastal erosion and accretion does not necessarily translate into usability in pan-European coastal-zone management. Indicators of shoreline change need to be assessed and weighted regionally in light of other parameters (physical and socio-economic) and be converted into indicators of coastal vulnerability. Studies published so far demonstrate that there is no single way to portray coastal vulnerability for all of Europe in a meaningful way. A common legend, however attractive intuitively, results in data products that work well for one region but show insufficient or excessive detail elsewhere. For decision making, uniform products are often not very helpful. The ability to zoom in on different spatial levels is not a solution either. It is better to compile and visualize coastal-vulnerability studies with different legends, and to provide each map with a confidence assessment and other relevant metadata.

Time-series analysis of SAR images for detecting ground subsidence in the Scheldt estuary

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Keywords: Ground subsidence, Compaction, Risk assessment, Synthetic Aperture Radar, Persistent Scatterer Interferometry

Abstract

Within the framework of the GEPATAR (GEotechnical and Patrimonial Archives Toolbox for ARchitectural conservation in Belgium) project, time series of Synthetic Aperture Radar (SAR) images are used for the systematic assessment of ground movement risk across the whole country. Here, we present some preliminary results from an area around Antwerp.

Recent advances in the analysis of time series of SAR images reduce the inherent error sources and allow detection of very small Earth surface displacements. In this study we use the StaMPS/MTI software package, which combines two complimentary algorithms for the detection of spatially correlated deformation: Persistent Scatterer Interferometry (PSI) and the Small Baseline (SBAS) approach.

The processed datasets include 67 ERS1/2 images (period 1992-2001) and 74 ENVISAT images (period 2003-2010). The results indicate a clear contrast in ground stability between the subsiding Scheldt estuary (at rates up to 7.4 mm/year) and adjacent stable areas. The most significant subsidence appears in reclaimed lands (polders) of the present-day port area of Antwerp. Based on geological and geotechnical evidence, we can attribute the observed subsidence patterns to the compaction of soft alluvial sediments (clay and peat layers) and overlying land fill material. Still, geotechnical validation of the results remains challenging due to the spatial variability in sediment properties and parameters.

Further research will focus on the possible impacts of observed ground movements on exposed built heritage and infrastructure.

Hydrogeological and hydrogeophysical monitoring of vadose and saturated zones at the Rochefort Cave Laboratory

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Keywords: Hydrogeology, Hydrogeophysics, Gravimetry, Electrical Resistivity Tomography, Karst

Abstract

The vadose zone of karst systems plays an important role on the water dynamics. In particular, temporary perched aquifers can appear in the subsurface due to changes of weather conditions, reduced evapotranspiration and the vertical gradients of porosity and permeability. It is therefore crucial, but challenging, to separate the hydrological signature of the vadose zone from the one of the saturated zone for understanding hydrological processes that occur in the vadose zone.

Although many difficulties are usually encountered when studying karst environments due to their heterogeneities, cave systems offer an outstanding opportunity to investigate vadose zone from the inside. We present results covering two years of hydrogeological and geophysical monitoring at the Rochefort Cave Laboratory (RCL), located in the Variscan fold-and-thrust belt (Belgium), a region that shows many karstic networks within Devonian limestone units.

Hydrogeological data such as flows and levels monitoring or tracer tests performed in both vadose and saturated zones bring valuable information on the hydrological context of the studied area. Combining those results with geophysical measurements allows validating and imaging them with more integrative techniques.

A microgravimetric monitoring involves a superconducting gravimeter continuously measuring at the surface of the RCL. Early in 2015, a second relative gravimeter was installed in the underlying cave system located 35 meters below the surface. This set up allows highlighting vadose gravity changes. These relative measurements are calibrated using an absolute gravimeter. 12 additional stations (7 at the surface, 5 in the cave) are monitored on a monthly basis by a spring gravimeter.

To complete these gravimetric measurements, the site has been equipped with a permanent Electrical Resistivity Tomography (ERT) monitoring system comprising an uncommon array of surface, borehole and cave electrodes. Although such an unconventional ERT setup is challenging in terms of data processing and interpretation, it provides valuable data for inferring variations of the vadose zone saturation rate

SESSION 16
PROTEROZOIC LIFE II

Palaeoecological model of the Mesoproterozoic Taoudeni Basin and implications for early eukaryotes evolution

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Keywords: Meso-Neo-proterozoic, Atar/El Mreïti Groups, Ornamented acritarchs, Process-bearing acritarchs, Early eukaryotes

Abstract

The mid-Proterozoic rock record preserves a relatively moderate diversity of early eukaryotes, despite the early evolution of fundamental features of the eukaryotic cell. Common hypotheses involve the redox state of stratified oceans with oxic shallow waters, euxinic mid-depth waters, and anoxic and ferruginous deep waters during this time period. Mid-Proterozoic eukaryotes would have found suitable ecological niches in estuarine, fluvio-deltaic and coastal shallow marine environments near nutrient sources, while N_2-fixing photoautotrophs bacteria would have been better competitors than eukaryotic algae in nutrient-poor niches. Here, we present the first palaeoecological model of the late Mesoproterozoic Taoudeni Basin, Mauritania, Northwestern Africa. Previous palaeontological studies in the basin reported stromatolites, a low diversity of microfossils – including one species of presumed eukaryotes: verrucae-bearing acritarch – and biomarkers of anoxygenic phototrophic purple and green sulfur bacteria, cyanobacteria and microaerophilic methanotrophs. However, no biomarkers diagnostic for crown group eukaryotes were reported so far. In addition to exceptionally well preserved microbial mats showing chain-like aggregates of pyrite grains, we observed a total of sixty-two morphotaxa including nine presumed prokaryotes, thirty-five possible prokaryotes or eukaryotes, fifteen presumed species of eukaryotes – ornamented and process-bearing acritarchs, multicellular morphotaxon, putative VSMs, large budding vesicles, and vesicles with a sophisticated excystment structure: the pylome – and three remains of structured kerogen. Here, we combined the geological context, iron speciation – with the aim of reconstructing palaeoredox environmental conditions –, and microfossils quantitative analysis. Sediments were deposited under shallow waters in distal (pericratonic) and proximal (epicratonic) marine environments during a depositional sequence linked to a marine transgression and regression. Both microfossil assemblages and iron speciation were analyzed on the same samples, with the aim of better understanding the palaeoecology of early eukaryotes. Palaeoredox conditions rapidly fluctuated from oxic to anoxic states across the basin, but in terms of anoxic episodes, ferruginous conditions dominated in epicratonic environments, while euxinia was more prevalent in pericratonic environments. A relatively higher fossil eukaryotic diversity, both in terms of richness and abundance, was observed in the more proximal environments during the marine transgression. Our results could possibly suggest that both the availability of molecular oxygen and nutrients are needed for a high eukaryotic diversity and could confirm a previous hypothesis suggesting that mid-Proterozoic eukaryotes would have found suitable ecological niches in shallow marine environments near nutrient sources.

Proterozoic time constraints on the deposit of the Mbuji-Mayi Supergroup, Democratic Republic of Congo (DRC)

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Keywords: *Geochronology, diagenetic minerals, Mbuji-Mayi Supergroup, ICP-MS, Electron Microprobe*

Abstract

The Sankuru-Mbuji-Mayi-Lomami-Lovoy (SMLL) basin, DRC, located between the Archean-Paleoproterozoic Kasai Craton and the Mesoproterozoic Kibaran Belt, includes the Mbuji-Mayi Supergroup, a sedimentary sequence unaffected by regional metamorphism and containing a large diversity of well-preserved acritarchs [1]. Lithostratigraphically, this Supergroup is composed of two distinct successions (i) a lower siliciclastic sequence of BI Group (ca. 1175 Myr to ca. 882 Myr [2] or ca. 1050 Myr [3;4]) unconformably overlying the ca. 3.0-2.6 Gyr granitoid Dibaya Complex to the North [5] and (ii) a poorly constrained upper carbonate sequence with sparse shales of the BII Group. Basaltic pillow lavas overlying the Mbuji-Mayi Supergroup were dated around 950 Myr [6; 7].

To better constrain the age of this Supergroup, we combine different geochronological methods, in particular on monazite and xenotime which are sometimes diagenetic [8; 9; 10] but also on zircon. For the BI Group, results of *in situ* U-Pb datings with LA-ICP-MS on monazite, xenotime and zircon (Laboratoire Magmas et Volcans, Clermont-Ferrand) provide ages between 2783 and 1029 Myr for monazites and xenotimes and between 2911 and 1284 Myr for zircons. Preliminary results of age maps using Electron MicroProbe (Camparis, UPMC, Paris), highlight that some monazites display zonations with an inherited core around 1155 Myr and thin diagenetic rims providing a new age around 1075 Myr for the diagenesis of BI Group. Sm-Nd datings (Laboratoire G-Time, ULB, Bruxelles) on basaltic pillow lavas overlying the Mbuji-Mayi Supergroup are in progress to precisely limit in time the diagenesis of this Supergroup.

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Organic-walled microfossil assemblage and Chemostratigraphy of the Mbuji-Mayi Supergroup (Democratic Republic of Congo): Evidence for a Late Mesoproterozoic-Early Neoproterozoic age.

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Keywords: Biostratigraphy, Chemostratigraphy, Mbuji-Mayi, Supergroup, Proterozoic

Abstract

The Mbuji-Mayi Supergroup is a sedimentary sequence in DRC unaffected by regional metamorphism. It consists of two distinct successions: a lower, ~500 m thick siliciclastic sequence of the BI Group (dated at 1125 Ma or between *ca.* 1175 Ma and 882 Ma) and an upper, ~1000 m thick carbonate sequence with stromatolitic build-ups and black shales of the BII Group directly overlain by basaltic lavas dated at 948 ± 20 Ma. Five boreholes from Sankuru – Mbuji-Mayi region have been sampled in detail. A well preserved and diversified microfossil assemblage is reported including 54 taxa belonging to 32 genera. The typical late Mesoproterozoic - early Neoproterozoic acritarch, *Trachyhystricosphaera aimika*, is reported herein for the first time in central Africa, and co-occurs with other eukaryotes and prokaryotes. The available biostratigraphic data enable to suggest a minimum Tonian, pre-Sturtian age for the Mbuji-Mayi Supergroup. This age is consistent with the published and new geochronological data. Comparison with worldwide Proterozoic assemblages permits to define microfossil assemblages useful for biostratigraphy. Moreover, $\delta^{13} C_{carb}$ positive and negative excursions in the BIe - BIIc interval are similar to variations in late Mesoproterozoic - early Neoproterozoic carbonate successions.

SESSION 17
GEOHERITAGE AND GEOARCHEOLOGY

Geo-archaeological prospection of the intertidal area: case study of Ostend-Raversijde

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Keywords: intertidal zone, geo-archaeology, acoustic techniques

Abstract

The contact zone between land and sea is known to be rich in archaeological remnants, yet at the same time it is often subject to large infrastructural works which form an important threat to the heritage. However this zone is rarely studied due to the technological challenges posed by the extreme shallow water depth, wave action (surf zone), strong currents and large tidal range. In recent years geophysical investigations have been carried out at Ostend-Raversijde aimed at efficient geo-archaeological and palaeogeographical prospection of the intertidal zone. The Holocene landscape is highly dynamical and marked by a succession of tidal flats and marshes, tidal channels and small islands/peninsulas. The site is also known for archaeological artefacts and structures dating from Roman and medieval times, including an old dyke, remnants of a drowned fishing village, and intensive peat and salt exploitation. Due to the construction of breakwaters in the seventies and regular sand suppletion works the archaeological remains are now buried beneath 1-2 m of sediment. Marine 2D acoustic profiling evidenced a highly complex system of buried palaeogullies, some of which are likely related to past islands and coastal defense structures. A number of the observed acoustic features also could clearly be linked to former trench systems and peat digging; these data correlated well with electromagnetic (EMI) maps obtained on the beach at low tide. Recent 3D acoustic measurements have allowed to map the peat and salt excavation pattern in the highest detail (cm/dm resolution). Using a multitransducer echosounder system a 3D volume could be obtained with a grid cell size as small as 20x20x1 cm. Cross sections through the volume show the characteristic pattern of peat strips, rectangular and circular excavation pits, and long (often diagonal) trenches. They match perfectly with the features observed on old aerial photographs of the area (before the sand accretion). These results show that the integrated use of complementary geophysical methods (marine and terrestrial) is highly efficient to map the intertidal sedimentary environment and the archaeological heritage buried within. The multitransducer echosounder system thereby sets a new standard for ultra-high resolution geo-archaeological research in shallow water areas.

Evolution of the palaeoenvironment of the Medjerda delta (Tunisia) and geoarchaeology of the ancient city of Utica

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Keywords: Geoarchaeology, Utica, ancient harbour, palaeoenvironment, Medjerda, delta, Tunisia

Abstract

Phoenician Utica remains today largely unknown, as is its role in the Phoenician expansion in the western Mediterranean. Aristotle and Pliny the Elder mention Utica as a maritime and port city and estimate its origin around the 11th c. BC. However, in the present state of research, no archaeological evidence is earlier than the 9th c. BC, and the location of the Phoenician and Roman port infrastructures remains unknown. Today, the ancient city is located on a promontory in the heart of the Medjerda delta, 10 km inland.

This project proposes an interdisciplinary effort to understand the Medjerda delta landscape changes during the Holocene. It starts from an archaeological problem and proposes the contribution of geoarchaeology to the understanding of the relationship between ancient societies and their environment. The fluvial palaeoenvironments and sedimentary processes are studied through the mechanical extraction of cores (15-20 m deep) to reach the early Holocene. Selected sediment samples are then studied in laboratory, using different and complementary approaches.

The location of port infrastructures will bring initial answers to the question of the foundation of the city. The study of river palaeoenvironments of the Medjerda delta during the Holocene aim at a better understanding of the nature of the settlement, as well as the function of the city of Utica over time. This study will also assess the impact of the ancient city on the environment and understand how the city adapted to the mobility of this Mediterranean delta. Furthermore, the analysis of sedimentary processes causing the filling of the harbour basin will lead to speculation about the causes of the abandonment of the structures and more generally the decline of the city in favor of Carthage. It will also examine whether natural or anthropogenic factors have influenced this deltaic progradation over the centuries.

Deciphering sedimentary dynamics in cave entrances. Implications for archaeology and palaeoenvironmental reconstructions

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Keywords: *Sedimentary dynamics, Pleistocene, cave entrance, Palaeolithic, Neandertal, site formation processes, taphonomy, palynology, anthracology, magnetic susceptibility*

Abstract

Significant advances in the knowledge of sedimentogenesis in cave entrances have been realized these last 20 years, notably through experiments in active periglacial environment. They led to a better understanding of sedimentary dynamics and post-depositional processes in this particular sedimentary environment where Palaeolithic sites are frequent. These recent improvements have major implications for the interpretation of archaeological sites, especially concerning site formation processes, the assessment of site integrity, and the characterization of human behaviour. Similarly, consequences for palaeoenvironmental reconstructions in cave entrances are important.

Here, we will present results obtained from Scladina Cave (Andenne, Belgium) to illustrate the importance of an accurate control of sedimentary dynamics for Palaeolithic archaeology. Identification of processes such as debris flow, run-off or solifluction allowed a better understanding of the spatial and vertical distribution of the artefacts and bones. While some sedimentary processes can redistribute the archaeological and palaeontological material, the recognition of post-depositional processes is also critical as they can also produce strong disturbances. In addition, alongside other studies such as lithic technology and typology, refitting, archaeozoology, or taphonomy, the geoarcheological approach enables to tackle the contemporaneousness of the objects within a single stratigraphic unit as well as to critically analyze the results from radiocarbon dating. Our results highlight the crucial importance of an interdisciplinary approach in Palaeolithic archaeology from the first steps of the excavation onwards. A particularly impressive situation concerns the fragmentation and redistribution of the remains of the Scladina Neandertal child mandible and maxillary.

The importance of an accurate control of sedimentogenesis for palaeoenvironmental reconstructions will also be exposed, notably through the problem of reworking phases, frequent in cave entrances. This issue will be addressed through examples involving large mammals, palynology, anthracology and magnetic susceptibility studies.

Geo-archaeological study of a broken stalagmite structure in the Bruniquel Cave, Tarn-et-Garonne, France

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Keywords: Paleolithic, karst, speleothem, prehistoric cave site, Neandertal

Abstract

The Bruniquel Cave is located in southwestern France, south of the calcareous plateau of the Quercy region, east of the Aquitaine Basin. The cave opens at 165 m asl and overlooks the Aveyron valley. It is situated in a region which is rich in Palaeolithic sites. The cave was discovered in 1990 by local cavers. They dug a 30 m long and narrow passage through the collapsed entrance. The passage is very narrow and only allow non-claustrophobic persons to the main gallery. The main gallery consists of a 10-15 m wide and 4-7 m high corridor, currently known to be 482 m long. A strange arrangement of two annular structures made of whole and broken stalagmites is located inside the main gallery at ~300 meters from the entrance. On the structure, numerous traces of fire and pieces of burned bones are observed. These structures were identified as human-made by a former archaeological study by Rouzaud et al. (1996). Other than these structures, signs of human activity are almost non-existent or uncertain. The authors provided a detailed plan of the structures and a single ^{14}C AMS dating of a burned bone found in the main structure gave an intriguing age of >47.6 ka[6] _ENREF_2. Unfortunately, the premature death of the archaeologist F. Rouzaud along with the restricted access to the cave, prevented any further research until 2013 when we decided to date and study these enigmatic constructions. In order to more precisely date the structures, calcite samples were taken from the stalagmites inside the structures as well as from the more recent speleothems, sealing the structures, to perform Multi Collector-ICP-MS U/Th dating. The age of the top of the stalagmites used in the structure represent a maximum age for the structure. The age of the bases of the stalagmites growing on the structure and sealing it, represent a minimum age for the structure.

Reference:

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SESSION 18
POSTERS

PALEOCLIMATOLOGY AND QUATERNARY GEOLOGY

EARLY AND PAST LIFE

SEDIMENTARY ROCKS AND STRATIGRAPHY

Session 18 posters

PALEOCLIMATOLOGY AND QUATERNARY GEOLOGY

Surface exposure dating of the Campine Plateau, NE Belgium: first results

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Keywords: cosmogenic radionuclides, denudation, unconsolidated sediments, uplift, climate change

Abstract

ONDRAF/NIRAS currently investigates the safety and feasibility of geological disposal in poorly indurated plastic clays such as the Boom Clay. An important requirement for geological formations hosting a repository for radioactive waste is sufficient depth to ensure isolation of the waste and to protect it from potential detrimental processes occurring at the surface, up to 1 Ma from now. Over such long timescales, the overburden thickness may vary significantly due to various geodynamic processes. This study aims at looking into the past, and reconstruct the variations in Boom Clay burial depth in the Campine area, as an analogue for the future.

The Campine Plateau is considered a classical case of relief inversion. As a result of differential uplift, its surface altitude dips from 100 m in the south to 30 m in the north over a distance of ca. 60 km. It is covered by Early and Middle Pleistocene erosion-resistant fluvial sediments from the Rhine and Meuse and can thus be regarded as a fluvial terrace. There is still much debate about the age of this terrace, both in terms of deposition and abandonment. We apply the cosmogenic radionuclide (CRN) profiling technique that, in ideal circumstances, would allow to constrain the exposure age, burial age and amount of post-depositional erosion of the studied landform.

Samples were taken from a 3.5 m deep cross-section in coarse river sands deposited by the Rhine, at an altitude of ca. 50 m. Nine of them were prepared for CRN measurements according to state-of-the-art techniques. The ^{10}Be concentration was measured using accelerator mass spectrometry (ETH, Zurich). The resulting in-situ ^{10}Be concentrations are 1.5×10^5 atoms/g (at/g) for the uppermost sample (at 0.3 m depth) and 0.9×10^5 at/g for the lowermost sample (at 3.1 m depth), yielding an estimated 0.6×10^5 at/g of radionuclide accumulation following deposition. Assuming zero erosion, these concentrations correspond with an apparent exposure age of 21.5 ± 1.5 ka, which is a very strong underestimate of the anticipated geological age of the sediments (between ca. 0.6-1 Ma). Instead, according to simulations, the ^{10}Be depth concentration profile would be in line with scenarios involving erosion rates of between 10-20 m/Ma, depending on the assumed age of the plateau.

New analyses will focus on the ^{26}Al concentration, which would help in reducing the uncertainty on the exposure age and the driving forces behind the geomorphological evolution (climate change, tectonics) of this particular landscape.

Using varve thickness records from three proglacial lakes in south-central Alaska as proxies for climate variations on multidecadal and interannual timescales

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Keywords: Alaska, laminated lake deposits, age-depth models, varve thickness, climate calibration

Abstract

Glacial varves are powerful tools for environmental reconstructions thanks to their annual timeframe and capacity to record high-resolution climate variability. This study paves the way for future environmental investigations in the proglacial Eklutna, Kenai and Skilak Lakes (south-central Alaska) by confirming the annual nature of laminations in a series of gravity cores. Radionuclide dating (^{210}Pb/^{137}Cs) has been conducted on top sections from Eklutna and Skilak. Both ^{210}Pb age-depth models and AD 1963 ^{137}Cs-peaks show good agreement with lamination counts, permitting the term 'varves' to be used. Especially in Skilak Lake, this has been a topic of speculation in the past. Repeated varve counts have been conducted by independent observers, allowing their reproducibility to be assessed and chronology errors on age-depth models and varve thickness records to be estimated. Apart from radionuclide dating, marker beds are also able to provide absolute dates if they can be related to historically reported events (e.g. earthquakes, floods). Identification of erosive mass-transport deposits and turbidites triggered by the AD 1964 Prince William Sound (PWS) earthquake (Mw 9.2) is fairly secure, given their position close to the AD 1963 ^{137}Cs-peaks in Eklutna and Skilak cores. In the Kenai Lake records as well, a similar turbidite can be observed and attributed to the AD 1964 PWS earthquake, compensating for the absence of other absolute dates in the latter lake deposits. In order to assess the relationship between annual sedimentation rates (i.e. varve thicknesses) and climate parameters (temperature, rainfall and snowfall), average varve thickness records for each lake were constructed and calibrated with data from weather stations close to the studied lakes. Relationships between varve thicknesses and climate parameters were investigated on multidecadal (by visual comparison) as well as on interannual timescales (by calculation of linear correlation coefficients). Results show that annual cycles of sediment accumulation in Eklutna and Skilak Lake on the one hand, and in Kenai Lake on the other hand, respond differently to fluctuating climate parameters. This difference can be related to the degree of proximity and dominance of large glaciers in the lake catchments. Water and sediment supply to Eklutna and Skilak are strongly bound to climate influenced glacier dynamics, whereas Kenai possesses a rather complex catchment, in which glacier-free valleys are prominent. As a result, rainfall in the Kenai catchment plays a larger role in generating increased river discharges with elevated sediment entrainment capacities, and hence thicker varves.

Benthic foraminiferal and isotopic patterns during the Early Eocene Climatic Optimum (Aktulagay section, Kazakhstan)

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Keywords: Early Eocene; Benthic foraminifera; Paleoecology; Kazakhstan; Oxygen deficiency; Trophic conditions

Abstract

The early Eocene is characterized by long-term global warming culminating in the Early Eocene Climatic Optimum (EECO). During this time interval, the Peri-Tethys was connected to the Arctic and Atlantic Oceans by north-south and east-west trending seaways. The Aktulagay section in Kazakhstan provides an expanded record of the middle Ypresian (NP11-13, ~54-50 Ma; King et al., 2013), including the EECO. The marl sequence features a series of sapropel beds, observed throughout the Peri-Tethys, indicative of basin-wide episodic hypoxic events. In order to unravel paleoenvironmental changes, we carried out quantitative faunal studies and stable isotopic (C, O) investigations on excellently preserved foraminiferal assemblages. The period from 54 to 52.5 Ma (NP11 to lower NP12; Alashen Formation) is characterized by a diverse assemblage of deep outer neritic (~200-250 m) benthic foraminifera, with common *Pulsiphonina prima* and *Paralabamina lunata*. The initially (54 Ma) well-ventilated oligo- to mesotrophic seafloor conditions gradually changed to more eutrophic and oxygen-limited. These conditions were more permanent in the sapropel-bearing unit at 52.5-52 Ma (middle NP12; Aktulagay B1 unit). This observation is based on the dominance of *Anomalinoides acutus* and *Bulimina aksuatica* and the lower diversity. Also the upward migration of endobenthic species, as suggested by rising $\delta^{13}C_{endobenthic}$, supports this interpretation. These low-oxygen conditions might have been caused by a transgression, flooding lowlands. Benthic foraminiferal assemblages dominated by *Epistominella minuta* at ~52-50 Ma (top NP12-NP13; Aktulagay B2 unit) suggest an oligotrophic environment, with transient pulses of phytodetritus. Dinoflagellate blooms and *Acarinina* isotope values at ~50.5 Ma indicate lower salinity (lower $\delta^{18}O$) and higher productivity (higher $\delta^{13}C$), possibly due to riverine input. Large river plumes, episodically reaching the area, in a monsoonal climate context, might explain this basin development. Akhmetiev and Beniamovskii (2009) also found a transition from a paratropical to a monsoonal (seasonal) climate, based on simultaneous land vegetation changes. This change coincides with the peak of the EECO, as indicated by its position close to the base of NP13 and rising $\delta^{13}C_{epibenthic}$ values from 52 to 50 Ma. Although it is tempting to link the observed patterns to climate change, we cannot exclude that changing paleogeography and variable connections between the Peri-Tethys and the Tethys, Atlantic and the Arctic Oceans largely determined the long-term period of dysoxia and anoxia during deposition of the sapropel beds at the Peri-Tethyan seafloor.

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Holocene paleoenvironmental reconstructions from speleothem and peat bog archives

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Keywords: Dust, peatbog, climate, speleothem, Holocene

Abstract

The geological materials (speleothems and peatbogs) presented in Belgium (Hautes-Fagnes Plateau, Ardennes caves) are interesting archives for atmospheric pollution record and climate variability. Both archives are easily dated (U/Th and counting for laminated speleothems, ^{210}Pb and ^{14}C for peatbogs), have a high temporal resolution (decadal to seasonal), contain multiple measurable parameters (elemental geochemistry, stable isotopes, radiogenic Nd and Pb isotopes, pollens, rates of peat humification, luminescence and thickness of laminated speleothems) and depending on environmental conditions of temperature and / or humidity. The aim of this study is to determine the sensitivity of both archives (speleothems and peatbogs) to human perturbations and climate changes. Our ultimate goal is to contribute to a better understanding of natural interglacial climate variability by generating and confronting high resolution paleoclimate reconstructions from 2 continental archives.

Palaeoceanographic implications of current-controlled sedimentation in the Alboran Sea after the opening of the Strait of Gibraltar

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Keywords: Contourite, alongslope processes, Alboran Sea, palaeoceanography, stratigraphy.

Abstract

This study focuses on the Alboran Sea area (Westernmost Mediterranean), where a seismic analysis of the Pliocene and Quaternary stratigraphy was conducted in the Alboran Sea (Westernmost Mediterranean) using ~2000 profiles consisting of single and multi-channel seismic records. The seismic facies and architectural analysis of the deposits evidence the presence of bottom-current deposits (plastered, sheeted, elongated-separated and confined monticular drifts) and associated erosive features (terraces, scarps, moats and channels). Many of these deposits were previously considered to be open slope turbidite deposits which have now been reinterpreted as contourites.The contourite features have developed under the continuous influence of Mediterranean water masses, after the opening of the Strait of Gibraltar (roughly divided into light and dense Mediterranean waters), with plastered drifts dominating on the Spanish and Moroccan continental slopes, and sheeted drifts infilling the subbasins. The location and growth of contourite features have been mainly controlled by two main factors: i) tectonics, which has governed the relocation of the main pathways of the water masses; and ii) climate, which has influenced both water mass conditions and the depth of interfaces, as well as hinterland sediment sources, conditioning the morphoseismic characteristics of the drifts (facies and geometry) and terrace formation (dimensions). The mapping of the contourite facies through time has allowed defining three main scenarios for deep water circulation since the opening of the Strait of Gibraltar, which are: i) Atlantic Zanclean flooding; ii) the Pliocene sea, with two different stages caused by the progressive relocation of flow pathways; and iii) the Quaternary sea, with well defined characteristics and mostly stable flow pathways for the AW, and light and dense Mediterranean waters.This work lead us to consider the geologic framework characterizing the Alboran Sea may have played an important role in the interaction of the Mediterranean Waters before entering the Strait of Gibraltar, and thus in forming the MOW. Additionally, the results of this work may help in understanding the sedimentation in other Mediterranean margins affected by the same water masses and other partly land-locked basins with exchanges of waters over a confining sill.

Towards an improved holostratigraphy of the Ypresian Clays

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Keywords: holostratigraphy, Eocene, Ypresian, Belgium, North Sea

Abstract

The early Eocene greenhouse world is characterized by a succession of orbitally-controlled global stable carbon isotope excursions (CIE's), of which some are associated to abrupt climate changes and perturbation of marine ecosystems. These unique events allow a detailed global chemostratigraphic correlation, even within dissimilar environmental settings. Here we aim at deciphering the stratigraphic signature of the successive early Eocene hyperthermals in the shallow marine context of the southern edge of the North Sea Basin.

The Paleocene-Eocene thermal maximum (PETM) has already been identified in the lagoonal Tienen Formation, representing the earliest Eocene of Belgium (Steurbaut et al., 2003). The Belgian Basin also contains a relatively complete, rather fossiliferous and well-studied marine lower Eocene succession (the classical Belgian Ypresian Clays). The thickness of these heterogeneous Ypresian silts and clays reaches almost 120 meters in the Belgian Geological Survey Kallo core, which is used for a regional stratigraphic framework. Nannoplankton subzonations (e.g., Steurbaut 1991), foraminiferal bioevents (e.g., King, 1991) and benthic foraminiferal associations (e.g., Willems, 1980; Willems and Moorkens, 1991) have been utilized for regional biostratigraphic correlations, yet their (eco)stratigraphic meaning remained unresolved and might be related to these global warming events.

The stable isotope record ($\delta^{13}C_{org}$) and sequence stratigraphic interpretations of the Kallo core highlight the relationship of the basin-wide observed distinct lithologic and biotic events, within this succession of multiple CIE's in the Belgian Ypresian deposits. This chemostratigraphic approach enables a reappraisal of the existing holostratigraphic overviews of the Belgian Ypresian Clays and the creation of an up-to-date age model, linking the regional depositional setting with the global Eocene climate evolution. Our data emphasize the potential application of hyperthermal event stratigraphy to correlate over a wide range of different environmental settings in the North Atlantic Ocean and adjacent basins, and to understand the spatial heterogeneity of climate changes in these shallow-water settings.

Session 18 posters

EARLY AND PAST LIFE

New description and phylogenetic relationships of 'Balaena' belgica, a large right whale from the Pliocene of Belgium

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Keywords: anatomy, baleen whales, Belgium, phylogeny, Pliocene

Abstract

Fossils assigned to *'Balaena' belgica* were described by Abel and Plisnier-Ladame and Quinet around 70 years ago. They include several bones from different individuals that were thought to be Pleistocene in age. In recent years, *'Balaena' belgica* was included in phylogenetic analyses of Balaenidae (right and bowhead whales) mainly because a large and reasonably complete skull is assigned to this taxon that may be proficiently used in this kind of studies; however, a detailed redescription of the skull is still necessary to completely understand anatomical peculiarities and taxonomy. Recent studies, in fact, suggested that the large skull originally assigned to *'Balaena' belgica* actually belongs to *Eubalaena* as it shares several anatomical characters of the frontal, squamosal, parietal and supraoccipital with *Eubalaena*. The present authors made a new study of *'Balaena' belgica* with the scope of getting more information about its anatomy and phylogenetic relationships to make a sound taxonomic decision. The new study revealed that the specimens assigned to this taxon are Pliocene in age and not Pleistocene as thought by the early students. Moreover, the new study revealed also that the anatomical characters of *'Balaena' belgica* are extraordinarily similar to *Eubalaena*. This work demonstrates that the specialized characters of the skull of the right whales were already present during the Pliocene suggesting a quick evolution of these traits in the early history of Balaenidae that was followed by substantial morphological stasis. A new phylogenetic analysis of Balaenidae will make it clear the sister group relationships of *'Balaena'* belgica within the genus *Eubalaena*.

Early Carboniferous marine ecosystem recovery after the Hangenberg Crise, insight from the Tournaisian brachiopod-coral fauna from South Belgium

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Keywords: Tournaisian, recovery, brachiopods, corals, palaeoecology

Abstract

The Hastarian Substage (Lower Tournaisian, Lower Carboniferous) was a period of recovery in the marine realm after the large-scale extinctions associated with the Hangenberg Event (Devonian-Carboniferous Boundary). The marine fauna remains relatively poor and dominated by cosmopolitan opportunistic organisms during almost the whole Hastarian times. The first diversification occurred at the end of this substage with the development of new faunas. In the Condroz sedimentation area, the Hun Member (base of the Yvoir Formation) corresponds to this diversification period. This 12 m-thick member is composed of sandy bioclastic limestone alternating with shale layers and cherts; it is interpreted as the lowstand system tract of a third order sequence. In the Chansin quarry (Bocq valley), this member has yielded an abundant association of silicified fauna showing an exquisite preservation. The association is dominated by rugose and tabulate corals along with brachiopods whereas bryozoans, gastropods and trilobites are only minor components. The rugose corals fauna is composed of solitary trochoid, ceratoid or cylindroid forms belonging to *Amplexus coralloides*, cf. *Amplexizaphrentis* sp., *Bradyphyllum* sp., *Caninia cornucopiae*, *C.* aff. *cornucopiae*, *Caninophyllum patulum*, *"Lophophyllum" konincki*, *Proheterelasma omaliusi*, *Rotiphyllum* sp., *Saleelasma delepinei*, *Siphonophyllia cylindrica*, *Sychnoelasma konincki*, *Zaphrentites delanouei*, and *Zaphrentites* sp. The good preservation of some specimens allows the observation of the calicular features that are rarely observed in time-equivalent fauna. Moreover, several corals show coiled or attached protocorallites. The tabulate corals are mainly small-sized (5 cm in diameter) micheliniid colonies, cladochonids and isolated corallites of *Beaumontia*. The massive colonies commonly show growth rings and talons. This coral association corresponds to a moderate diversified level-bottom community in which the external morphologies converge towards a single habitus. The brachiopod fauna, which is currently under study, is quite diverse but dominated by spire-bearers: athyridides (e.g. *Lamellosathyris lamellosa*, *Coveenia* sp.), spiriferides (*Unispirifer* sp., *Tylothyris laminos*a), and spiriferinides (e.g. *Syringothyris* sp.). It also includes some productides, strophomenides (*Leptagonia* gr. *analoga*), orthotetides (*Shellwienella* sp.), orthides (*Rhipidomella michelini*), rhynchonellides and terebratulides. The degree of disarticulation of the shells is particularly high, especially among spiriferides and spiriferinides, and it is clear that they have been disturbed and displaced from their living position, but the transport was probably over a short distance as indicated by the preservation of some delicate structures (e.g. mucronate cardinal extremities, flanges). Such accumulations might have been produced by storm events as suggest by the non-orientation of the corals preserved in chert layers.

Late Devonian arthropods and tetrapods palaeoenvironments: the example of the Late Famennian of Strud and Becco

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Keywords: Devonian, Famennian, fluvial environment, continental ecosystem

Abstract

The Belgian Famennian is renowned for its floral and faunal content. The Strud locality recently received much attention after the discoveries has yielded a diversified flora and fauna including seed-plants, *Ichthyostega*-like tetrapod, various placoderms (groenlandaspids, phyllolepidids, antiarchs), actinopterygian, acanthodians and sarcopterygians (porolepiformes, osteolepiformes, lungfishes), eurypterids, decapods, crustaceans (conchostracans, notostracans and anostracans) and a putative complete insect. The study of the palaeoenvironment of this Lagerstätte was made possible by the reinvestigation of classical and new section in the upper Famennian strata. The fluvial facies of Strud recorded a primordial period of the tetrapod evolution (after their emergence but before their terrestrialization) and what is thought to be the oldest continental, probably fresh-water ecosystem of arthropods. It raises the question of the ecological conditions and selection pressures occurring at the onset of the tetrapod and hexapod terrestrializations. The outstanding preservation of arthropods and plants in the main fossiliferous layers is explained by a quick burial in the fine-grained sediment of a calm and confined flood plain and temporary ponds environment. Recent stratigraphic correlations allow to review the age of the fossiliferous horizon that is now definitely considered to be Late Famennian (VCo '*rad*' palynozone). The Becco locality yielded a diverse flora dominated by early seed plants, highlighting the diversity of early spermatophytes in southern Belgium. The vertebrate are very diverse and dominated by antiarch, groenlandaspid and phyllolepid placoderms, diplacanthiform acanthodians, actinopterygians and several sarcopterygians. The recognition of such diverse assemblage is currently used as a prospective method for the identification and characterization of new tetrapod localities in southern Belgium.

Bernissart : Back to the crime scene

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Keywords: Bernissart, Iguanodon, Geological modelling, 3D

Abstract

In Bernissart, a large number of Iguanodons skeletons, many of them complete and articulated, were unearthed between 1878 and 1882. The discovery of these skeletons was made in a coal mine when an exploration gallery encountered a sinkhole affecting the coal seams. In order to reconstruct the geometry of the Bernissart sinkhole (a.k.a "le cran"), its neighbouring environment and the excavation works of the skeletons within the sinkhole, we designed a workflow to processes the available data and build a 3D model.

For a start, we inventoried the documents available at the RBINS and other relevant sources. These documents were scanned or photographed. A special attention was given to minimize distortions of plans and cross-sections. The documents were then georeferenced and relevant information in these documents where vectorised using semi-automatic procedures. The vertical axis is specified as depth below the Sainte-Barbe mine shaft.

From maps and cross-sections of the coal works, the geometry of coal seams such as "Luronne", "Présidente" or "Veine du Fond" seams is then reconstructed in the vicinity of the Iguanodon and South sinkholes. Outer limits of the sinkholes were also modelled. This reconstruction shows in detail the relationships between the geometry of the seams and the position of the sinkholes and sets the general geological context of the bonebeds.

The next part of our work is dedicated to process the descriptions made during the paleontological excavation, especially sketches of the plaster casts of the skeletons. These sketches have to be vectorised, oriented and scaled. Georeferencing is much more difficult with this data. Available information from cross-section and general setting plans must be included in the reflexion. Moreover, the spatial information are often incomplete and cross-checks or even hypotheses have to be made in order to replace these data in a 3D framework.

The evolution of the Upper Ordovician to Silurian basin in the Condroz Inlier: litho- and biostratigraphy with chitinozoans

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Keywords: Silurian, Upper Ordovician, Condroz Inlier, chitinozoans, biostratigraphy

Abstract

Verniers et al. (2002a) summarized the knowledge on the Cambrian to Middle Devonian basin evolution and deformation history of Belgium, eastern England and surrounding areas. The PhD dissertation, presented here, considers the third of their three megasequences: from middle Katian to upper Silurian, and mostly in the Condroz Inlier in Belgium. The area was poorly studied before, in contrast with the knowledge on that megasequence in the Brabant Massif. Vanmeirhaeghe (2006), in his PhD study revised the stratigraphy of the second megasequence of the Condroz Inlier (Ordovician and parts of the lower Silurian) in combination with a chitinozoan biostratigraphy.
We propose a new lithostratigraphy and dating of the units mostly with chitinozoans but also with graptolites and brachiopods. Once the stratigraphy of the Condroz Inlier established, correlation with the Brabant Massif becomes possible.

During megasequence 3 the sediments of the Condroz Inlier were deposited on the shelf, but the sedimentation changed through time. In contrast during the same megasequence sedimentation in the Brabant Massif started with a shelf deposition, but slope conditions with deposition of turbidites soon prevailed most of the Silurian. The thickness of the lithostratigraphical units generally increases upwards through the Llandovery with thick units in the upper Telychian. The basin in the Brabant Massif began to deepen in the upper Katian and we can place the start of the development of the foreland basin at the onset of the deepening in the upper Katian.
From the lower Telychian onwards, oxic-anoxic alternation are noted in the stratigraphical column of the Condroz Inlier. From the upper Telychian onwards until the end of the Wenlock anoxic sedimentation takes place almost continuously, with deposition of dark grey, finely laminated mudstone and with limited amount of oxic intervals. Those laminated hemipelagites, already recorded previously in the Brabant Massif in the same time range, are discovered here for the first time in the Condroz Inlier.

Iron isotope fractionation in a Modern iron-oxidizing bacterial mat

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Keywords: Iron isotopes, biotic oxidation, iron spring, Belgium

Abstract

^{54}Fe, ^{56}Fe and ^{57}Fe isotopes were measured in Fe(III) oxyhydroxides (ferrihydrite) that preciptated during the year 2011 in a bacterial mat in east Belgium. The mat developed in an iron spring ("Pouhon des Cuves") on the bank of the Trô Maret river. Five mat samples were collected during the course of one year in a specifically designed sampling box (sampling in February, May, July, September and November). Several biological, physico-chemical and mineralogical parameters were measured among which iron isotopes, pH, temperature, chemical composition, ferrihydrite crystallinity, etc. Sustained precipitation of Fe(III) indicated oxidizing conditions throughout the year and the environment was dysoxic based on low but significant oxygen concentration (<3 mg/L dissolved O_2). The $\delta^{57}Fe$ vs. $\delta^{56}Fe$ plot consistently reflected the persistence of oxidizing conditions in the mat. $\delta^{56}Fe$ varied from 0,42 to 1.42‰, which indicates an important fractionation during iron accumulation. Published data report that both abiotic and biotic iron oxidation may result in an increase in $\delta^{56}Fe$, with a stronger effect for biotic processes ($\delta^{56}Fe$ >1‰). Here, the highest $\delta^{56}Fe$ were observed in winter/spring and coincided with the maximum abundance of the neutrophilic iron-oxidizing bacteria *Gallionella ferruginea* as measured by quantitative polymerase chain reaction (qPCR) targeting the 16S rRNA gene. The abundance of a specific filamentous morphotype of this bacteria also culminated at the same period. While these parameters fluctuated, oxygen concentrations remained constant and pH slightly increased. These data strongly suggest the presence of a biological iron fractionation in the bacterial mat.

Raman characterization of the UV-protective pigment gloeocapsin-potential biosignatures of early Earth records

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Keywords: Raman microspectroscopy, Biosignatures, Gloeocapsin, Parietin, Scytonemin

Abstract

Extracellular UV-screening pigments gloeocapsin and scytonemin present in the EPS envelopes of freshwater and marine cyanobacteria were studied by different spectroscopy methods. The Raman spectral analysis and the UV-VIS light absorbance spectra of the extracellular pigment gloeocapsin showed that it shared Raman and UV spectral signatures with parietin, a radiation-protective pigment present in lichens. Gloeocapsin occurs in several cyanobacterial species, mostly with exclusion of scytonemin, indicating that these pigments have evolved in cyanobacteria as separate protective strategies. Both gloeocapsin and scytonemin are widely and species-specifically distributed across different cyanobacterial taxa. The widespread occurrence of these pigments may suggest an early origin, while their detection by Raman Spectroscopy makes them potential biosignatures for cyanobacteria in the early Earth record and demonstrates the usefulness of non-destructive Raman spectroscopy analyses for the search of complex organics, including possible photosynthetic pigments, in early Earth and extraterrestrial samples.

Session 18 posters

SEDIMENTARY ROCKS AND STRATIGRAPHY

H3O – a better understanding of Campine cross-border Cenozoic stratigraphy

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Keywords: cross-border, correlation, lithostratigraphy, Belgium, the Netherlands

Abstract

H3O – DE KEMPEN

In June 2014, the final results of the project H3O – Roer Valley Graben were delivered. A cross-border, three-dimensional geological and hydrogeological model of the Roer Valley Graben has been constructed. The Dutch and Flemish geological and hydrogeological units are now modelled as one continuous entity in this region. The process of correlating units in the Dutch and Flemish subsurface proved to be applicable in future cross-border projects. Once the H3O – Roer Valley Graben project was finished, the area of focus shifted towards the west.

A new project, H3O – De Kempen (H3O – Campine) was initiated, focussing on the Campine Basin and its transition zone towards the Roer Valley Graben. Indeed, inconsistencies exist between the current Belgian and Dutch models, leading to uncertainties in understanding the groundwater system in this border region. As unambiguous (hydro)geological knowledge is essential for sustainable subsurface management, parties in the Netherlands (Province of North Brabant) and Flanders (Environment, Nature and Energy Department of the Flemish Government and the Flemish Environment Agency) expressed again their interest to attune the (hydro)geological models, this time focussing on the Campine border region.

WORKFLOW

The aim of the H3O-project is to make a cross-border, up-to-date, three dimensional geological and hydrogeological model of the Campine area, which covers partially the southern part of the Netherlands and partially the northern part of Flanders. For this purpose, existing (hydro)geological data (fault traces, nomenclatures, seismic and well(-log) interpretations, existing (hydro)geological maps, etc.) was gathered and will be reinterpreted into one consistent dataset that will serve as input for the 3D modelling process. A first important step however, consisted of correlating the existing Dutch and Belgian hydro- and lithostratigraphic units. This correlation was based on available knowledge (e.g.

palaeontology, paleogeography, deposition type, sediment petrology, etc) and by correlating geophysical well logs. Three geophysical well correlation profiles were constructed, covering the whole geological complexity of the area. This complexity becomes specifically clear when focussing on the shallow Quaternary and Neogene units. Transition from marine to fluvio-estuarine deposits with different origins (Rhine, Meuse, Belgian rivers) resulted in a wide variety of geological units, abruptly transforming or incising into each other over short distances (e.g. upper levels in figure 1).

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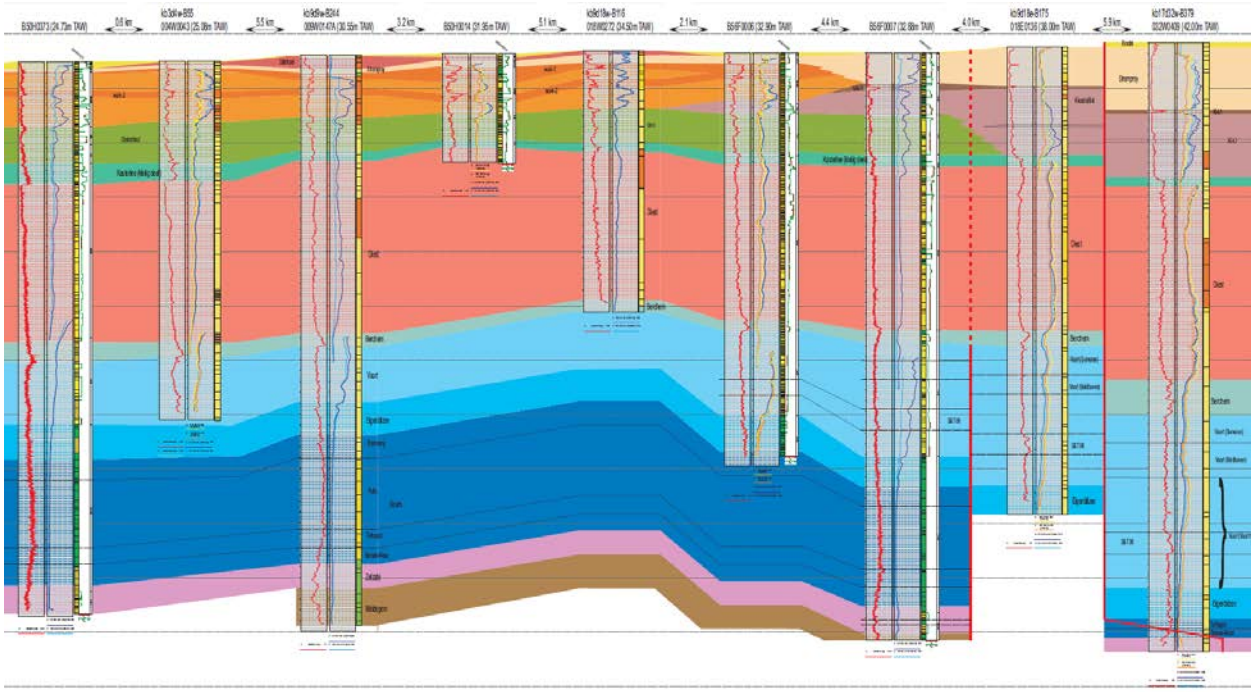

Figure 1. Geophysical well correlation profile from Poppel (NW) to Lommel (SE)

The Miocene – Pliocene boundary in the eastern North Atlantic: dinoflagellate cyst biostratigraphy

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Keywords: biostratigraphy, Miocene, Pliocene, North Atlantic, dinoflagellate cysts

Abstract

The lacking of an accurate biostratigraphic framework for the transition between the Miocene and the Pliocene in the North Atlantic has hampered geological studies in this area. In this study we present the first biozonation scheme for the eastern North Atlantic, spanning an interval between 9.0 and 2.5 Ma (late Miocene – Pliocene), based on dinoflagellate cysts and acritarchs. The material used to establish our biozonation was acquired from ODP Site 982, which is situated in the Hatton–Rockall Basin. This site contains a continuous sedimentary sequence spanning the required time interval, and thus a complete record of marine palynomorph evolution. Different sections of Site 982 have furthermore been calibrated to the astronomically tuned timescale by multiple studies. For this study we constructed a composite age model for Site 982, mainly based on oxygen isotope stratigraphy, spanning the desired time interval. Analysis of 40 samples revealed a rich assemblage of 58 dinoflagellate cyst and 21 acritarch species. We identified 25 bio-events and calibrated these to the astronomically tuned timescale (Gradstein & Ogg, 2012) through the age model for Site 982. To determine the reliability and biostratigraphic potential, we compared the bio-events recorded in this study to events from the Nordic Seas, the western North Atlantic and the nearby Rockall Trough. This allowed us to establish a biozonation scheme for the Miocene–Pliocene transition in the eastern North Atlantic, consisting of 10 HRB (Hatton–Rockall Basin) biozones and 2 subzones. Two HRB biozones span the latest Tortonian to Messinian; the remaining 8 span the Pliocene. Excellent agreement of the Pliocene bio)-events of this study with the Rockall Trough allows correlation for the eastern North Atlantic. To a lesser extent can the HRB biozonation furthermore be applied for the western North Atlantic Ocean and the Nordic Seas.

SESSION 19
ENVIRONMENTAL CHANGE

Evaluation and modelling of the response of gas hydrate reservoirs to changing environmental conditions across a high-latitude continental margin

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Keywords: gas hydrate, methane, climate change, modelling, high-latitude margin

Abstract

Vast amounts of gas hydrate occur at low temperature and high pressure conditions in sediments on continental margins, in deep lakes, and in continental and relic sub-shelf permafrost. A temperature increase or pressure decrease (e.g. through falling sea level) could destabilize gas hydrate reservoirs, and release methane (i.e. the most common gas component in hydrates) to the ocean and eventually the atmosphere. Since methane is a potent greenhouse gas, this would cause an additional warming effect that further reinforces hydrate dissociation. This feedback mechanism was suggested to play a prominent role in geologically rapid Quaternary climatic oscillations and variations in atmospheric greenhouse gas concentrations, and has also been proposed to manifest in the (near) future as a response to contemporary climate warming. (Ant)Arctic hydrate reservoirs are believed to be most susceptible to this process, because climatic changes are more pronounced and hydrates prevail below shallower water depths at high-latitudes.

Nevertheless, these hypotheses remain highly speculative. Argumentation in favor of a dynamic gas hydrate system, responding to environmental change and releasing methane on decadal or centennial timescales, is often based on site-specific observations and modelling efforts that only consider a limited set of processes and parameters. This study therefore presents a new numerical model that integrates the most decisive factors in the gas hydrate system. The model is applicable to all hydrate-bearing settings across a high-latitude continental margin. Realistic subsurface hydrate distributions were constrained by implementing formation models, and the consumption of latent heat during hydrate dissociation was accounted for in the modelling of the heat flow.

Simulations of the last deglaciation and contemporary climate change suggest that hydrates associated with sub-shelf permafrost and in upper continental slope sediments are most sensitive to pressure and temperature changes. However, even in these most sensitive hydrate reservoirs, dissociation timescales are in the order of tens to hundreds of thousands of years. In addition, evaluation of the volumes of methane that can be potentially transferred from hydrate reservoirs to the atmosphere, indicate that these are insignificant to the global carbon budget. Hence methane release from decomposing high-latitude hydrate reservoirs, and by extension the entire global hydrate inventory, is not likely to create a geologically rapid feedback with warming climate. Since climate (especially during the Late Quaternary) oscillates faster than the size of the hydrate inventory can adapt, gas hydrate reservoirs must be most of the time in a transient, non-equilibrium state.

RIDEC – Rwenzori Ice dynamics and Environmental Changes

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Keywords: Glaciology, Rwenzori Mountains, Climate change, Remote Sensing, Geophysics

Abstract

At the border between Uganda and the D.R. of Congo, the Rwenzoris (0.386°N; 29.872°E) form a remote and high-altitude mountain range stretching near the equator, through the East African Rift System. With heights of 4-5 km, they include Africa's third highest peak (Mt. Stanley, 5109 m) as well as some of the last African glaciers. The combined area of the Rwenzori glaciers declined by more than 75% during the 20th century, and halved between 1987 and 2006. This extreme mass loss may have strong implications for the local hydrology, ecosystems and communities, and recent estimates suggest that the glaciers will disappear in the next decade(s). This trend correlates well with similarly dramatic glacier retreats on Mt Kilimanjaro (TZ) and Mt Kenya (KE) in the same period, and is attributed to debated causes like increased air temperature or reduced humidity/cloud cover. Despite recent work on the evolution of glacier extent in the last decades, the measured glacier retreat, as well as the interpretation of the responsible driving climatic factors, remain controversial partly owing to the lack of data.
Our new project RIDEC has been designed with a view to better understand and document the recession dynamics of Rwenzori glaciers. We will survey the current state of the two largest Rwenzori glaciers, Stanley and Speke glaciers, using a panel of remote sensing, geophysical and geochemical methods. These results will be compiled with a view to provide a first estimate of modern, past and future ice budgets in the area of interest. Given the limited expected time period before Rwenzori glaciers disappear entirely, this project will be a unique opportunity to investigate, before they melt completely, the invaluable body of information retained in them.

SESSION 20
GEOHERITAGE AND GEOARCHEOLOGY II

Stony immigrants in the Bruges area (West Flanders, Belgium) traced back to their geological origin: Jurassic building stones from the Boulonnais area (Nord - Pas-de-Calais, northern-France)

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Keywords: building stones, geoheritage, petrography, Jurassic, Boulonnais.

Abstract

Two peculiar natural building stones have been identified in a medieval context within the Bruges area (W-Flanders, Belgium): the Baincthun Stone (Portlandian sandstone also called « Pierre de Boulogne » or « Grès Bâtard » or « faux grès ») and the Marquise Stone (oolitic limestone). They share their geological origin, as they are both of Jurassic age and derived from the Bas-Boulonnais region, where they were either collected at the foot of coastal cliffs or extracted in open air quarries. The Marquise Stone has been used in buildings at least since Roman times, the Baincthun Stone since medieval times for sure. A comparative petrographical analysis has been carried out on samples taken from both historical monuments in the Bruges area (the Church of Our Lady Ascension in Damme, the Saint-Quentin church tower of Oostkerke) and natural outcrops (coastal cliffs between Cap Gris-Nez and Boulogne-sur-Mer) or former quarries (near Rinxent and Baincthun).

Baincthun Stone is a relatively hard building stone, difficult to work: it is a fine- to medium-occasionally coarse-grained (granule-type) sandstone with carbonate cement, locally enriched in shell debris (coquina); it frequently shows sedimentary structures (e.g. cross stratifications and bioturbations) and it displays a characteristic greyish beige, bluish grey to greenish grey colour that soon takes a slightly brownish patina by oxidation of the ferroan calcite cement. Stratigraphically it corresponds to sandstones that belong to the Grès de Chatillon and the Grès de la Crèche Formations, respectively of Kimmeridgian and Tithonian age (formerly of Portlandian age, Upper Jurassic). Baincthun Stone has been actively quarried until 1962 in several quarries close to Boulogne-sur-Mer. Marquise Stone is a relatively soft building stone: it is a fossiliferous oolitic limestone displaying both a heterogenous composition and a varying grain size, with a pale to dark yellow colour that soon takes an orange patina. Geologically it corresponds to the Marquise-Rinxent Formation of Upper Bathonian (Middle Jurassic) age. It has been quarried at least since Roman times but only few quarry sites have survived.

The occurrence of these particular building stones from the Boulonnais area is restricted to some emblematic historical monuments around the former Zwin estuary. However, it is in line with the use of other building stones from the Nord – Pas-de-Calais region (e.g. the pale Ostrevant Sandstone, the ash-white Quesnoy Sandstone, the white chalky limestones from the Lille or Valenciennes - Cambrai areas) and from the Normandy coast (e.g. the pale yellow Caen Stone), all indicating the importance of the stone industry and its trade routes. Moreover, our observations confirm the trade of building materials plying the coastline between the Low Countries and Normandy in medieval times.

A geological context for ancient copper production in the Niari basin (Republic of Congo)

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Keywords: Republic of Congo, Niari basin, archaeology, copper, manufacturing process

Abstract

Copper deposits of the Niari basin (Republic of Congo) are known from historical texts since the 16thC and the metal produced has been involved in long distance trade, particularly to provide copper to regional kingdoms. Highly appreciated and exchanged in ancient central African cultures, copper is hence essential to understand the economic networks in this vast part of Africa. Recent archaeological survey and excavation near the deposits in this area – at Mindouli, Boko-Songho, and Mfouati – allowed the unambiguous identification of copper production sites in the vicinity of all three ore deposits. Results indicate that the area of Mindouli, where the Cu-Pb-Zn deposit is widely exposed, has been actively exploited in the 13th-14thC AD, concomitantly with the rise of regional kingdoms. Copper production in this area was later continued, until the industrial exploitation of these polymetallic deposits began in the early 20thC, by the French colonists. Besides these first-hand data, late 19thC European texts record various manufacturing processes and give an overview of copper metallurgy in pre-colonial times.

Joint archaeological and geological investigation led by the authors in the Summer 2015 (see also De Putter and Nikis, this volume) had as double objective to improve the understanding of the geological formation of these poorly known deposits, and to document the use of the copper ore in archaeological sites, with further view on copper sourcing analyses, throughout Central Africa.

Fieldwork yet allows several preliminary interpretations. In most areas, the location and nature of archaeological sites suggest that copper was smelted from carbonate ore (mostly malachite), in the immediate vicinity of the deposits. Ore procurement strategy also seems to have changed with time, as some deposits have been exploited at precise periods, at the exclusion of others. Almost any ore showing/deposit with obvious evidence of copper minerals has been exploited in the past, irrespective of the variable quantity/grade of suitable ore for copper production. Variable exposure of supergene deposits in the Niari basin also accounts for different exploitation modes – in open trenches, pits or in galleries. These exploitation modes in turn influence the type of raw material (copper or lead ore, carbonates or sulfides) recovered and used in manufacturing processes, at different periods. For instance, the ore was crushed at smelting sites in 13th-14thC to select suitable minerals while in the 19th c. this ore sorting apparently took place in the mines.

Multidisciplinary study of prestige ornamental stones or 'marbles' in the Roman city of Alba Fucens (Abruzzo, Italy)

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Keywords: Alba Fucens, ornamental stones procurement, opus sectile, Roman 'marbles', stone material characterization

Abstract

Ornamental colored hard stones were highly prized in the earliest Antiquity and their procurement often involved long-distance trade chains, as illustrated by the use of lapis-lazuli from Afghanistan in 4th millennium Early Dynastic Egypt. Trade chains however remain largely conjectural in early civilizations, as Ancient Egypt. Procurement changed drastically with the rise of the Roman Republic and later Empire, when long-lasting occupation allowed a secured procurement of the mineral wealth of 'colonies', in Northern Africa, Greece, and the Middle East.

The taste of the Roman elite for imported ornamental stones, often referred to as 'marbles' – even though improperly, geologically speaking – is demonstrated in Alba Fucens (Abruzzo, Italy), a Roman city founded in the 4thC BC whose archaeological excavation has been conducted by the Université Libre de Bruxelles – Centre de Recherche en Archéologie et Patrimoine (ULB-CreA), and the Royal Museum for Art and History (RMAH) since 2007. The Belgian excavation has in 2008-2012 revealed the existence of an absidal room with a remarkable range of ornamental marbles/stones. These luxury materials were obviously used for the wall decoration of one or more important rooms, while a locally found indurated limestone was used for most commonplace building purposes.

Here we focus on the multidisciplinary study of the elaborate and lavish wall decoration in the so-called 'marble hall'. This room probably belonged to a sanctuary and its wall decoration comprises a wide range of variegated 'marbles' whose use typically dates to the 1stC AD: '*africano*', alabaster, '*cipollino*', '*giallo antico*', '*pavonazetto*', '*rosso antico*'. Some of these materials are quantitatively abundant in the recovered material, as for instance the bright yellow marble ('*giallo antico*') from the antique Simitthu, now Chemtou in Tunisia. The study of the numerous fragments excavated in the Belgian concession allows: (1) interesting observations on the technique used to cut, carve and fix marble fragments, and (2) a first proposal of a possible 2m-high *opus sectile* wall decoration pattern.

The marbles used in Alba Fucens are also present in the late 19thC lithological collection assembled by Émile de Meester de Ravestein in Rome and now kept in the RMAH, whose study is ongoing by the authors. This research on the stones used in Alba Fucens and those in the RMAH collection is intended to geologically characterize 'marbles' used in the Roman Empire as well as to understand their procurement, trade, use and recycling in the Antiquity and later periods, notably in Italy.

SESSION 21
LATE CENOZOIC I

Timing and distribution of Plio-Quaternary uplift in the NW European Alpine foreland

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Keywords: morphometry, lithospheric buckling, alpine foreland, tectonic uplift, drainage network response

Abstract

A way to explore the causes of Plio-Quaternary uplift in NW Europe consists in identifying the distribution of uplifted areas and their respective uplift age. Here we use the composite metric R (Demoulin, 2011) involving different hypsometric integrals calculated for more than 7000 basins and map the derived time-dependent index SR over the NW European alpine foreland. As a complex descriptor of the progress of the fluvial landscape response to tectonic signals, SR is a quantitative proxy of the age of the last uplift phase undergone by every particular area. Here, we discuss various approaches for SR mapping and examine preliminary results of the study. Systematic increase of SR from south to north suggests northward migration of the uplift axis with time, i.e., propagation of an uplift wave that started from ~200 km north of the alpine collision front in Pliocene times and travelled across the Paris Basin and the Rhenish Shield. Other regions, such as the Bohemian Massif or the French Central Massif, show more complex SR patterns that may be linked to interferences between the identified uplift wave and other phenomena (related, e.g., to WNW-oriented compression in front of the Carpathian arc). In any case, this new geomorphometric approach provides a wealth of promising data, whose careful analysis should help get fresh insight into the causes of Plio-Quaternary uplift in NW Europe.

Detailed analysis of the interaction between alongslope and downslope sedimentary processes in the Alboran Sea during the Pliocene and Quaternary

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Keywords: contourite, turbidite system, alongslope processes, downslope processes, Alboran Sea

Abstract

This work aims to analyze the interaction between alongslope contouritic and downslope gravitational processes in the Alboran Sea. Recent results (Juan et al., 2012, 2016) demonstrated that the Pliocene and Quaternary stratigraphic architecture is mostly made up the vertical stacking of contourites interrupted by turbidite systems (TSs). The accurate analysis of all available seismic profiles has revealed several morpho-sedimentary signatures produced by the interaction of the Atlantic Water (AW) and Mediterranean waters (MWs) with the gravity flows in the Pliocene and Quaternary sedimentary record, as well as on the present-day seafloor. Different levels of interaction have been identified and they move between two-end-members: from bottom currents dominating gravity flows, to gravity flows dominating bottom currents. In between these extreme cases, a range of possibilities can occur. First, downslope and alongslope processes can alternate, with vertical and cyclic stacking of both types of deposit. Second, these processes can be balanced, allowing the simultaneous outbuilding of contourites and gravity flow deposits. Last, bottom currents can influence gravity flows. This last interaction is the most common in the Alboran Sea, resulting in the migration of the fan deposits in the direction of the dominant current, and also with effects on the architecture of the turbidite fans, and on their sedimentary composition (grain size). The different levels of interaction change in space and time. These changes have controlled the different depositional architecture displayed by the Spanish and Moroccan margins and the lateral changes along the Spanish margin as a consequence of the different architecture of the turbidite systems. Although interaction occurs in both margins, it is especially complex and varied on the Spanish margin, where the alongslope action is related to the AW, the light intermediate and the dense deep Mediterranean waters (LMw and DMw, respectively). This complex interaction has resulted in a depositional architecture that changes laterally as a consequence of the different architecture of the turbidite systems. Contrasting, on the Moroccan margin the alonsglope action is dominant, being mainly governed by the energy of the AW and the WMDW, that primarily inhibits the formation of canyons and related fan lobe deposits. This inhibition has been interpreted to be result of the topographical acceleration of the WMDW core that would favour an intense alongslope sediment transport, preventing deposition, avoiding the convergence of sediment, and thus inhibiting the formation of downslope gravity flows.

Paleoclimate reconstruction in the Levant region from the petrography and the geochemistry of a MIS 5 stalagmite from the Kanaan Cave, Lebanon

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Keywords: Paleoclimate, Stalagmite, Stable Isotope, Kanaan Cave, Lebanon

Abstract

Lying at the transition between the temperate Mediterranean domain and subtropical deserts, the Levant is a key area to study the palaeoclimatic response over glacial-interglacial cycles. This paper presents a precisely dated last interglacial (MIS 5) stalagmite (129–84 ka) from the Kanaan Cave, Lebanon. Variations in growth rate and isotopic records indicate a warm humid phase at the onset of the last interglacial at ~129 ka that lasted until ~125 ka. A gradual shift in speleothem isotopic composition (125-122 ka) is driven mainly by the δ18O source effect of the Eastern Mediterranean surface waters during Sapropel S5. The onset of glacial inception began after ~122 ka, interrupted by a short wet pulse during Sapropel S4. Low growth rates and enriched oxygen and carbon values until ~84 ka indicate a transition to drier conditions during northern hemisphere glaciation.

SESSION 22
GEOLOGICAL RISKS

Lake Kivu biogeochemistry: complex interactions between hydrothermal recycling, bathtub ring oxic-anoxic reactions and hydrodynamic mixing

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Keywords: Lake Kivu, Si isotopes, Major and trace elements, water recycling, bathtub ring effects

Abstract

It is often presumed that volcanic and seismic activity occurring close or within Lake Kivu could trigger or boost a total or partial overturn of the lake and subsequent expulsion of its dissolved gases. To assess this limnic CO_2 eruption risk, it is essential to constrain the lake hydrodynamic, the source of the water and its dissolved elements as well as the factors controlling the biogeochemistry. Vertical profiles of conservative cations (Na+, K+), nutrient (P, D_{Si}), cations sensitive to precipitation dissolution (Mg^{2+}, S, Ca^{2+}, Mn, Sr^{2+}, Ba^{2+}, REE^{3+}), and Si isotopic compositions ($\delta^{30}Si$) were used at three locations (Kabuno Bay, Ishungu Basin, Gisenyi basin) to (1) quantify the diatom uptake in the mixolimnion and the diatom mineralization in the intermediate water mass; (2) investigate the composition and origin of the intermediate and deep water inflows linked to the subaquatic springs. The water profiles were carried out at the closure of the dry season (18/09/12–16/10/12 and 20/08/13-06/09/13) to capture the chemical changes occurring at the end of the diatom productivity in response to the lake oscillation between the dry (June-September) and the rainy season (October-May) when deeper mixing supply the nutrients in the epilimnion. Our data confirm that most of the solutes of the Lake Kivu waters are mainly controlled by the hydrothermal alteration of the volcanics along the northern shoreline, the most probable recharge source for these hydrothermal fluids being the surface water of the lake itself, locally mixed with magmatic-derived and meteoritic-derived fluids. The hydrothermal inflows differ in chemistry and intensity at the Kabuno Bay relative to both Ishungu and Gisenyi localities, being at higher temperature as shown by the strong negative Eu anomalies, the high Sr/Ca (>20), and the large Ba-Si contents. The annual quick changes in Ba, Mn D_{Si} distributions, Sr/Ca, and P/Na as well as the rapid $\delta^{30}Si$-D_{Si} re-equilibration of the upper chemocline after the diatom mineralization demonstrate that the lake water mixing is more dynamic on annual and decadal bases than previously thought, especially in Kabuno. The strong P limitation that controls the diatom productivity is dependent of a "bathtub ring" oxic-anoxic precipitation at the mixolimnion-chemocline interface. The impact of this bathtub effect on the water geochemistry is quantified by the amplitude of the Ce anomalies ($0.5<Ce/Ce^*<1.1$). It is strictly dependent of the intensity of the lake oscillation, being proportionally larger in the restricted sub-basins like the Kabuno Bay or the Ishungu basin.

Landslides' mechanism and evolution in the west Rwanda

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Keywords: mass movement, landslides, landscape evolution, geohazard

Abstract

The mass movement, and especially the instability of the soil and rocks, play a significant role in the changing aspect and the evolution of the landscape worldwide and particularly in tropical region. In central Africa the landslides and other kind of instabilities are very frequent, important and represent a real threat for both population and economy. The case of Rwanda is remarkable, this country which is known as the country of thousand hills, is rich of various and very complex morphology characterized by very steep slopes crossed by a dense network of watercourse, powered by a considerable amount of precipitation distributed in two wet seasons. The growing economy of the country brings a lot of project of infrastructures and mines and quarries exploitation (embankments and cuttings) which have a strong impact on the triggering of huge instabilities and so the modification of landscape. These instabilities and the intense activity of the rivers and streams could be considered as the engine who control the shaping and the remodeling of the landform. To understand the evolution process of these instabilities, and then the landscape change we started by the mapping of the instabilities using satellite images and then we went on the field to validate the inventory to identify the morphological aspect of the terrain, to refine our knowledge of the geological nature of the materials by sedimentological analyses on selected samples, and of course to try to better know the impact of the rock's weathering process leading to the constant modification of the landform. The computer-based quantitative analyses using GIS's data processing, were carried out to help to understand the distribution of the instabilities and the geomorphological phenomena observed to better connect and explain the whole information collected. The aim of the study is to bring in more than the mapping of instabilities a response about the process and the evolution of the instabilities and the factors impacting the phenomenon.

Nankai Trough (Japan) palaeoseismology: progress since the 2011 Tōhoku earthquake

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Keywords: Palaeoseismology, Earthquake, Tsunami, Seismic hazards, Japan

Abstract

The Nankai Trough, the subduction zone that lies immediately south of Japan's densely populated southern coastline, generates devastating great earthquakes, characterised by intense shaking, crustal deformation and tsunami generation. Historical records suggest recurrence intervals between inferred magnitude 8+ earthquakes average 115 ± 89 years. The limitations of developing seismic hazard assessments based solely on historical data are, however, well documented and were devastatingly illustrated by the Tōhoku earthquake and tsunami, which struck the Japan Trench, northeast Japan, in March 2011. Before 2011, Japanese seismic hazard assessments relied on source models developed from a small number of well-documented historical earthquakes. Less well understood historical earthquakes were largely disregarded if their seismic intensities or tsunami heights could not be reconciled with the chosen seismic sources. Following the unexpectedly large size of the Tōhoku earthquake, the Japanese Cabinet Office advocated renewed investigation of earthquake and tsunami occurrence over historical and longer timescales, with a particular focus on defining the largest possible magnitudes using geological data. The new guidelines pay close attention to the Nankai Trough, where the Philippine Sea Plate descends beneath the Eurasian Plate. The subduction zone features a well-known seismic gap along its eastern Tōkai segment and a full length rupture of this and the adjacent five seismic segments could generate a magnitude 9+ earthquake. Palaeoseismic approaches may increase the length and completeness of chronologies of past earthquakes, allowing investigations into the variability in past magnitudes, rupture zones and recurrence intervals. Here, we summarise the wealth of palaeoseismic research previously conducted along the Nankai Trough. Evidence for past earthquakes and tsunamis comes from wide variety of sources, including uplifted marine terraces, turbidites, liquefaction features, subsided marshes and tsunami deposits in coastal lakes and lowlands. More than 70 sites have been investigated, however the number of events recorded at each site varies depending on site-specific evidence creation and preservation thresholds. The palaeoseismic catalogue is also limited due to issues over alternative hypotheses for proposed palaeoseismic evidence, poor chronological control and sampling approaches insufficient to address the recurrence of the largest past earthquakes and tsunamis. We make recommendations for further investigations of this critical subduction zone and introduce the QuakeRecNankai project, a Belgian-led collaboration that seeks to develop new palaeoseismic records for the purpose of improved seismic hazard assessment.

Bimodal recurrence pattern of tsunamis in south central Chile

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Keywords: tsunami deposits, coastal lakes, megathrust earthquakes, recurrence paterns, age-depth modeling, south central Chile

Abstract

Establishing the recurrence time of large-scale tsunamis is one of the main objectives of paleotsunami research, as it is fundamental for any tsunami risk assessment. Typically, the result is given in form of the mean recurrence time and a standard deviation as a range of uncertainty, assuming a normally distributed recurrence. We present a 5.5 ka long coastal lake paleotsunami record from south central Chile, which contains 17 tsunami deposits, 9 of which were previously unknown. Our record matches all 3 of the historically known tsunamis, as well as all of the 5 known paleotsunami in the region without over- or underrepresentation. We used Bayesian age-depth modelling to calculate an age-depth model and extracted recurrence intervals for 16 recurrence intervals. Our findings confirm the previously published mean tsunami recurrence time on the Valdivia seismic segment of ~300 years. However, our analyses show a strongly bimodal recurrence pattern with one mode at ~115 years and the other mode at ~490 years. The least likely recurrence time between the modes is at ~300 years and coincides with the mean recurrence time. The reasons for the bimodal distribution remain speculative. They can be attributed to either spatial variability, e.g. incomplete segment rupture, splay fault rupture, up- or down-dip rupture, or to temporal variability, e.g. megathrust earthquake clustering, earthquake supercycles. Our findings highlight the importance of recognising the variability in tsunami recurrence patterns before using mean recurrence time for tsunami risk assessment.

Macroseismic analysis of online "Did You Feel" responses to M_L > 3 earthquakes felt/heard in and around Belgium

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Keywords: Seismology, online questionnaire, Sediment cover thickness

Abstract

Since 1938, when an earthquake occurs, the Royal Observatory of Belgium (ROB) sends out national earthquake inquiries to each municipality to create intensity maps of the felt area. Since 2002, only few hours after the ML 4.9 Alsdorf earthquake, the paper inquiry was complemented by an online "Did You Feel It?" (DYFI?) inquiry on the seismology.be website to gather witness reports. Since 2010, the ROB has established a partnership with the Bensberg Seismic Network (University of Cologne) to acquire real-time transfrontier macroseismic data. Analysis of macroseismic DYFI? data contributes to seismic hazard calculation and the construction of real-time shake maps in the near future.

In this presentation, nearly 14 years of DYFI? data will be evaluated. Macroseismic analysis of felt earthquakes is important as the perception of people can be used to detect local/regional site effects without covering the whole country with seismometers. Investigations on (strong) ground motions generated by earthquakes provide evidence that the regional/local geological structure of a site, especially the presence of soft sediment layers, modify the characteristics of seismic shaking at the surface. Especially the thick sediment cover above the Brabant Massif basement rocks dominate how moderate-magnitude earthquakes are felt in central and northern Belgium. The 1938 ML 5.6 Zulzeke-Nukerke, 2002 ML 4.9 Alsdorf (Germany), 2011 ML 4.3 Goch (Germany) and 2015 ML 4.1 Ramsgate (UK) events all resulted in a particular non-concentric macroseismic distribution in which higher intensities are farther reported in an E-W direction than in a N-S orientation. This peculiar intensity distribution cannot be explained by circular geometrical amplitude attenuation alone, relating energy decay to increasing epicentral distance, but rather illustrates a low-pass filtering effect of the cover sediments above the Brabant Massif resulting in the absence of sensible higher frequencies in seismic waves arriving at the surface for these earthquake magnitudes.

Another interesting aspect is the sound earthquakes produce at the surface. Since 2009, the ROB added a question to the DYFI? questionnaire inquiring the sound perception of people. If a sound was heard, people are asked if it was either light (brief or prolonged) or strong (brief or prolonged), hereby hinting on the audible frequency content of seismic waves arriving at the surface. The sound reported after ML > 3 earthquakes typically show an increasing intensity (louder and longer) with decreasing epicentral distance. However, also hypocentral depth plays an important role with a shallower sources resulting in a higher percentage of heard responses.

SESSION 23
REGIONAL GEOLOGY I – PALEOZOIC

Field evidence of turbidite deposit in the lower Member of the Quatre Fils Aymon Formation (QFA) of the Deville Group (Rocroi Inlier) and revision of the paleoenvironmental deposit conditions of these rocks

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Keywords : Turbidite, cross-lamination, continental shelf, slope, rise, deep-sea plain, greywacke, petrography

Abstract

In the scope of a sedimentological (re)view of both Deville and Revin Groups (Middle Cambrian of the Caledonian Rocroy Inlier), an in-depth field studies of the lower Member of the QFA Formation allow to discover some evidence of turbidite deposit, in at least two different locations of the Quatre Fils Aymon Crags in Bogny-sur-Meuse (Ardennes, France).
Several “terms C” and therefore complete suites (“A to E terms”) of the classical Bouma turbidite sequence were identified. Some important slumps and resulting intraformational brecciation, a lot of evidence of sub-aquatic slides, channel-like deposit, fluid escape figures and so on were observed.
Furthermore, microscopic examination of the rocks based on observation and interpretation of petrographic thin sections leads to conclude that they are actually greywackes (however for ages considered as quartzite).
Then QFA Formation is a clear flysch-like deposit whose origin is in all likelihood turbidity currents.
Both field and petrographic studies results imply a revision of the deposit mode and the paleoenvironment of this formation.
The QFA Formation formerly admitted to develop on the shelf margin looks to build up on the slope of the continental margin.

Reappraisal of the deep Devonian strata under the Mons Basin

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Keywords: Saint-Ghislain borehole, Deep Devonian

Abstract

To investigate the deep geothermal potential of Hainaut, the Saint-Ghislain borehole and more specifically its deepest section (depth -4393 to -5403 m) is the main, if not the only, local source of information. The only available descriptions and interpretations about the deepest 1000 m of this borehole, drilled between 1973 and 1978, are a brief overview published by Groessens et al. (1979) and the detailed description by Legrand of the few meters of cored material, sampled between -5.000 and -5.260 m, in the Geological Survey archives. During the drilling operations, cuttings were sampled nearly every meter along this section. The samples have been stored at the Geological Survey. This work consists of extracting the maximum information on the deep Devonian formations concealed under the Carboniferous rocks and the Meso-Cenozoic Mons Basin, by means of a thorough examination of the cuttings and other related information.

The 850 available cutting samples (a 78 m long section could not be retrieved) were studied by stereomicroscopy. Based on these observations the main rock type proportions (shales, siltites, carbonates …) were estimated, providing a rough lithologic section. Complementary analyses were performed to try to corroborate the results. Particularly, palynological content was studied on the deep cored intervals and some selected cutting samples. Magnetic susceptibility and X-ray diffraction were also performed. The integration of archive data such as calcimetry and relevant information from drilling operator reports complemented our new results. The upper section of the investigated interval is mainly composed of green siltites, while the middle section is dominated by carbonates, while the lower section consists of mixed shale and carbonate. Legrand interpreted the latter as Frasnian based on the macrofaunal content, which is similar in Tournai and Vieux-Leuze boreholes. Our work provides new geochronological constraints of the two lowest core samples through palynomorph analysis, which suggests an Upper Givetian – Lower Frasnian transitional age.

As a conclusion, we propose a new lithostratigraphical interpretation of the lowest part of the Saint-Ghislain borehole. The Famennian, with its top at -4300 m (according to Delmer, 1977), appears to be quite thick and its base might lie at about -4800 m. The underlying calcareous shales can be considered as Upper Frasnian in age. Finally, the lowest formations, between -5100 m and the bottom of the borehole at –5406 m, is interpreted as Lower Frasnian, and possibly the uppermost Givetian is also present. These results open new insights for palaeogeographical and structural interpretation of the deep geology under the Mons Basin.

Upper Silurian magmatism in the Rocroi Massif, Ardennes : new constraints from geochronology and geochemistry of microgranite dyke at Mairupt

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Keywords: magmatism, geochronology, Upper Silurian, Rocroi Massif, Ardennes

Abstract

The Rocroi Massif (Ardennes) is essentially composed of Cambrian to Early Ordovician low-grade metamorphic pelites and quartzites. It is intruded in its southern part by WSW-ENE-orientated, mafic and felsic dykes, such as the ones in Mairupt and Grande Commune. At Willerzie (eastern edge of the Rocroi Massif), occurrences of volcanites are found in Upper Silurian to Lower Devonian sediments, which locally contain abundant quartz phenocrysts and rhyolitic clasts associated with brecciated horizons in the Haybes Formation (Meilliez, 2006). A cogenetic origin for the Willerzie volcanites and the bimodal magmatism in the Rocroi Massif was first proposed by Beugnies (1969). This proposition was invalidated by zircon U-Pb geochronology on the Mairupt and Grande Commune igneous rocks, which yielded a lower intercept age of 373+8/-9 Ma (i.e. Upper Devonian; Goffette et al., 1991). Ongoing investigations of Cambrian metapelites of Mairupt required a re-evaluation of the age of the microgranite. *In situ* U-Pb geochronology was conducted by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at Géosciences Rennes on zircon grains from microgranite samples from two different outcrops in Mairupt. Upper Silurian (Pridoli) concordia ages were obtained for the two sample sets, i.e. 420.5±2.9 Ma (2σ) and 421.1±4.0 Ma (2σ). These results reinforce the hypothesis of a genetic link between dyke magmatism in the southern part of the Rocroi Massif and the volcanites of Willerzie. Raman spectrometry of the carbon material and mineralogy of REE-bearing phases in the metapelites are consistent with a sub-surface intrusion in the pelites before they were buried at monazite stability conditions. The Mairupt microgranite displays some variations in SiO_2, K_2O, Na_2O, Zr/Hf and Nb/Ta. Together with petrographic and cathodoluminescence observations, these geochemical data suggest that this peraluminous microgranite has undergone two types of secondary alteration. The first type is silicification+albitization, which, based on textural observation, developed prior to the Variscan orogeny. The second type is a greenschist facies alteration, marked by chloritization and carbonation, and developed during the regional deformation. Strontium and neodymium isotope geochemistry (initial $^{87}Sr/^{86}Sr$ isotopic ratios from 0.7116 to 0.7161, $\varepsilon Nd_{(t)}$ between -6.3 and -3.7) indicates a crustal source for the Mairupt microgranite. The Pridoli age found for the bimodal magmatism points to a Silurian magmatic event in an extensional context (passive margin), which occur at the onset of the Devonian sedimentation in the Ardennes area.

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Exploration of the geothermal reservoirs of Hainaut (Belgium) : preliminary results of the 2DMons2012 seismic survey. New deep structures revealed in the Brabant Parautochton

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Keywords: Geothermal Reservoirs, Brabant Parautochton, Deep Structures, 2D Reflexion Seismic, 2DMons2012

Abstract

Under the impulsion of the Wallonia Regional Government to improve the knowledge of the deep geothermal reservoirs. The two beneficiaries, IDEA and Earthsolution S.A., pooled their resources to explore the deep Carboniferous limestones for low-enthalpy energy and the deep mid-Devonian limestones for mid-enthalpy energy in the Brabant Parautochton. To precise the structure of these targets, a 2D seismic survey was conducted in 2012 (a.k.a. 2DMons2012). The acquisition was realized by DMT, the scientific follow-up and interpretation was provided by UMONS. The 2DMons2012 survey consist of two 2D seismic reflexion lines of ~20km long each. These North-South lines cross perpendicularly the known structural units. The acquisition parameters were designed based on the experience and the results of older surveys in this area (Hainaut79 and Belcorp86) and preliminary tests. Down to ~1000 m (0-600 ms TWT), the interpreted 2D seismic sections show the expected structures within the Mons Basin, the Ardennes Allochton and the HSM Overturned Thrust Sheets (i.e. Masse-Borinage Unit). From the northern outcrop, the Brabant Parautochton shows a monocline structure dipping southward. At the southern boundary of the explored zone, the deep Parautochton is subhorizontal. The two main reflectors occurring in this unit are considered as the top of the lower-Carboniferous limestones and the mid-Devonian limestones strata. In the northern part, the second reflector is weaker, suggesting different sedimentological settings (cf. Licour et al. (2016)). The separation between these two reflectors increases significantly to the North, in line with the Saint-Ghislain and Jeumont boreholes. The western line section reveals a set of normal faults in the southern border of the Brabant Parautochton, affecting mid-Devonian up to upper-Carboniferous strata, named Deep Fault Zone of the Borinage (DFZB). Some of these faults were recognized on the top of the Parautochton during coal mining activities next to this seismic line (Crachet-Picquery mine, Frameries). These faults may explain the increase in thickness of the mid-Devonian/lower-Carboniferous strata from South to North. This is suggesting that a passive margin was active during this period between the Condroz Horst and the Brabant Parautochton. The DFZB is less obvious on the eastern line section, however interpretation suggests that its extension is largely reduced, probably because of transtensional tectonics. These deep structures are also affecting variscan faults, especially the Masse-Borinage Fault, showing that another extensional and/or transtensional tectonic phase occurred after the Variscan orogenesis, probably reactivating former faults. A link with the transtensive context highlighted in the Mons Basin is not excluded. Further research is conducted on the implications in the regional geology and links with nearby structures (ZCNA, Mélantois-Tournaisis Faulted Anticline…) as well as the interference with deep karstification within the lower Carboniferous strata.

The map of the Brabant Massif for off-shore Belgium

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Keywords: Lower Palaeozoic, aeromagnetic, gravimetry, Asquempont Detachment System, North Sea

Abstract

The cartographic boundary of the Brabant Massif in the northwest is the North Sea, which is an observational limit. Nevertheless the Lower Palaeozoic rocks continue as part of a larger unit, referred to as the Anglo-Brabant Deformation Belt. Maps of the Brabant Massif largely rely on borehole data. The latest map of the Brabant Massif (Piessens et al., 2005) uses structural concepts and direct information, rather than geophysical information. Nevertheless, an aeromagnetic survey and gravimetric data corroborate the large scale distribution of the units.

This map is extrapolated to the off-shore territory of Belgium. Direct information from drillings is not available for the off-shore region, and it is therefore not possible to draw this map at the same stratigraphic resolution. The formations are therefore grouped into Cambrian, Ordovician and Silurian units. Magnetic susceptibility is high for the Cambrian, which allows tracing their continuation from on-shore to off-shore. The formations at subcrop level along the central axis of the Brabant Massif are on-shore Cambrian in age, but young in a WNW direction. Also the magnetic pattern becomes less intense, likely corresponding to an increasing depth of the more magnetic lower Cambrian units. This trend continues off-shore, indicating that the Cambrian units disappears at subcrop level. Superimposed on this general trend an aeromagnetic anomaly about 15 km off-shore of Ostend marks the probable local reappearance of the Tubize Formation. A secondary and less continuous Cambrian axis passes near Diksmuide. A second isolated off-shore aeromagnetic anomaly, indicative of the Cambrian unit, lies along the trace of this secondary axis.

The gravimetric map shows a low gravimetric anomaly of which the circular shape suggests a genetic link with the chain of gravimetric lows that underlie the southern part of the on-shore part of the Brabant Massif. The higher densities in the northern part of the off-shore territory confirm, in continuation of the on-shore formation boundaries, the presence of the Silurian unit.

The validity of the inferred distribution of the stratigraphic units was verified with the structural 3D concept that was developed for the on-shore part of the Brabant Massif, concluding that the inferred distribution of the geological units is in agreement with the structural model derived on-shore. It for example explains the positions of the two magnetic anomalies relative to each another. A central element in the structural model is the Asquempont Detachment System of which a limited number of possible traces is possible.

Extended abstract with figures: DOI: 10.13140/RG.2.1.3468.4002

SESSION 24
LATE CENOZOIC II

Age constraints for the Pliocene Mol Sands as observed in the 2014 palaeoseismological trench at Mol-Postel (NE, Belgium): a combined ESR-OSL-CRN dating study

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Keywords: burial dating, cosmogenic radionuclides, optically stimulated luminescence, electron spin resonance, sedimentary quartz

Abstract

The Mol Formation is defined as a coarse to medium sand with lignite and clay lenses. It is intensively quarried due to the high quartz content of the sand. The formation witnesses the general shoaling of the southern North Sea basin during the late Neogene, from a marine environment to a continental one. Based on geological correlations and floral remains, the formation is assigned a late Pliocene age, roughly between 3.5 Ma and 2.5 Ma. Recently, sediments assigned to the Mol Formation have been observed in a palaeoseismological trench near Mol where they were found to have been offset by normal faulting up to 6 m. We present preliminary results of a multi-method dating study of the Mol Sands as observed in the trench. A unique combination of three methods was applied that would, in optimal circumstances, be able to cover the anticipated age range. These are electron spin resonance (ESR), optically stimulated luminescence (OSL) and cosmogenic radionuclide (CRN) dating of quartz. Using ESR and OSL, the timing of the last exposure to sunlight is determined, and hence the burial age. Both methods are based on the accumulation of radiation damage during burial and rely on the same assumption that sunlight exposure prior to burial would have efficiently removed any pre-existing signals. Using the CRN technique, the burial age is determined from radioactive decay of ^{10}Be and ^{26}Al that are produced through cosmic ray interaction with elements in the quartz lattice when the sediments were at or close to the surface. After sufficient burial, the production of radionuclides becomes negligible and owing to their differing half-lives, the ratio allows to determine the burial age. Two samples were taken near the bottom of the trench at a depth of ca. 2 m, each on one side of the fault (Rauw fault) and prepared according to standard procedures. Preliminary ESR results suggest that the sampled sediment is not older than ca. 3.5 Ma because of the relatively poor bleaching characteristics of the ESR signals involved and hence their tendency to overestimate the burial age. The OSL data suggest that the sediments are not younger than ca. 1 Ma, given the likelihood of age underestimation with samples that are close to signal saturation. Awaiting data from the CRN analyses, we conclude that the preliminary results do not contradict the geological and palaeobotanical age estimates of the Mol Formation in NE Belgium.

Sedimentology and magnetic susceptibility of recent littoral sediments from New Caledonia, France and Belgium

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Keywords: littoral, recent, magnetic susceptibility, New Caledonia, France, Belgium

Abstract

The interpretation of the magnetic susceptibility (MS) signal from ancient rocks suffers notably from the scarcity of recent studies. To bring new data, a study of littoral sediments of New Caledonia (Jadot & Boulvain, 2015), Brittany, Belgium and north of France was undertaken. New Caledonia is surrounded by a nearly uninterrupted reef barrier, isolating a wide lagoon from the open ocean. The erosion of extremely varied rocks (from mantle rocks to laterites) produces different types of detrital sediments, which are mixed with the indigenous precipitated carbonates. This generates different types of coastal sediments, detrital-, chlorozoan carbonate-dominated or mixed. The coast running from Belgium to Picardy is characterized by a detrital dominated sedimentation with mature quartz sands and the Brittany sites are mixed detrital-foramol carbonate sediments.

More than 400 samples from 28 beaches were analyzed for grain size, nature of sediment, MS and geochemistry (major elements). The first results show that: (1) tropical carbonate sands and silts are characterized by lower MS than detrital sediments; (2) MS signal of mixed sediments is mostly influenced by the proportion of detrital sediments; (3) MS is directly correlated with Mn and Fe content; (4) beachrocks are characterized by lower MS than equivalent loose sediment; (5) MS signal of carbonate sediments is locally positively correlated with granulometry; (6) there is no MS change between surface and 20 cm deep samples; (7) when the subsurface sediment is reducing, MS is higher than that from surface sediment.

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A First Assessment of Belgian Continental Shelf Prehistory

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Keywords: Belgian Continental Shelf, Quaternary, Top-Paleogene, paleovalley, stratigraphy

Abstract

Until recently, little attention had been paid in Belgium to submerged prehistoric landscapes and to the related underwater cultural heritage. This is undesirable given the increasing pressures of commercial activities at sea and in light of the unique setting of the Belgian Continental Shelf (BCS), close to the nearby confluence of major Late Quaternary fluvial systems at times of lower sea level. Moreover, the relatively thin and fragmented Quaternary sediment cover renders prehistoric sites extremely vulnerable to disturbance of commercial activities and to natural erosion at the seabed, as most of them occur at limited burial depth. In 2014, systematic mapping of the archaeological potential of the BCS commenced within the project SeArch. A first major step concerned the development of an improved 3D geological layer model of the Quaternary, based on all existing and newly collected seismic, core and CPT data. Where needed, existing data were reinterpreted, and concepts of process-response relationships revised. At the start of the project, a lot of the topographic features and their relationships with formative processes and environments remained unexplained. Despite the large volume of available data, the associated paleolandscapes were still poorly constrained and understood. The new 3D model provides a first glimpse of the potentially preserved prehistoric archaeology within the Quaternary layers and in the context of the associated landscape remnants. Embedding the layer model in information and knowledge from the neighbouring Dutch, French and UK marine area as well as from Belgian and Dutch land areas has been key to generating new insights into submerged landscapes (e.g. old river valleys connections) on the BCS. In support of the interpretation of the 3D layer model, new chronostratigraphic evidence was collected from a detailed palynological analysis of an 80-m-long core from the Ostend Valley, a large paleo-river valley off the coast of Ostend. First results show that the upper part of the ~45-m thick Quaternary sequence is represented by ~10-m of very fine to fine silty sediments with tidal mud drapes and a Holocene pollen content overlying a ~3-m-thick layer of fine silty sands that are presumably of Weichselian age. Below this unit, approximately ~20-m of beige coloured, very fine sands occur that are characterised by Eemian pollen (PAZ E4, E5, E6). Locally tidal mud drapes occur in this unit. Between ~33 and 41 m depth, the sediments are much coarser grained and contain abundant reworked shell fragments. The age of these sediments is unknown. Below this unit, fine- to medium sands occur with a higher clayey-silty admixture and well-developed tidal mud drapes. The pollen data suggests an Eemian assemblage (PAZ E2, E3) although at this stage an older Middle Pleistocene interglacial age (MIS7, 9, 11) cannot be excluded. By linking this new information to seismic data, it is possible to provide a tentative chronostratigraphy to larger parts of the BCS subsurface.In a next step, a number of geo-archaeological 'profile-type' maps will be created on the basis of the 3D layer model and both stratigraphic and chronostratigraphic information. The layer succession visualized in these maps will serve as the foundation for the future archaeological potential map of the BCS, the main deliverable of SeArch.

Mapping the marine Miocene sediments of the southern Netherlands

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Keywords: Tertiary, Breda formation, marine sediments,stratigraphy, Roer Valley Graben

Abstract

Miocene marine deposits have a wide-spread occurrence in the Netherlands' subsurface. Except for some marginal facies they mainly consists of glauconite-bearing sand and clay. Lithostratigraphically they are assigned to the Breda Formation which is the lowermost unit of the Upper North Sea Group. Regional subdivisions of the formation are known for some areas along the eastern and southern distribution limits of the formation. A threefold subdivision of the marine Miocene deposits is well-known for the area of South Limburg. Here the Kakert Member forms the basal unit, overlain by the Heksenberg Member, a unit that consists of pure silica sands. The uppermost Vrijherenberg Member consists of slightly glauconite-bearing shallow marine deposits. These shallow marine and/or near-coast members can be mapped rather well outside the subsiding Roer Valley Graben but fade-away in northern directions. Medium to coarse-grained strong glauconite-bearing deposits occur in the southwestern part of the study area, just north of the Belgium border. In the Dutch lithostratigraphical scheme they are assigned to the Rucphen Member. They correlate roughly with the so-called Antwerpen and Deurne Sand.

In this study we present the results of a recently carried out mapping project in the southern part of the Netherlands. Our main aim is to get more insight in the composition and distribution patterns of the various facies within the Breda Formation. In addition, we attempt to work out a correlation with detailed stratigraphical subdivision as known in Belgium.

Mapping of the marine Miocene sequence is mainly based on (re)interpretation of existing data such as lithological borehole descriptions and well-logging data. Added to that, we evaluated the existing data from biostratigraphical and heavy mineral investigations which is available in the archive of the Geological Survey. Three main sections across the study area form a sound basis for our interpretations. They illustrate the Miocene sedimentary sequences of the Roer Valley Graben and the adjacent area as the tectonically complex Peel Block and Kempen High.

Changing facies from basin margin to basin centre forms a main and complex issue in interpreting and correlating the various regional or even local known deposits. Preliminary results show that large parts of the formerly lithostratigraphical not subdivided deposits of the Breda Formation in the Netherland can be correlated with some of the well-known units in Belgium. This enhances palaeogeographical reconstructions and correlation for example with the Diest Formation in Belgium.

The Meinweg site and the Pretiglian: onset of the Quaternary?

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Keywords: Quaternary, Pliocene, stratigraphy, pollen, heavy minerals, Lower Rhine Embayment

Abstract

Based on marked changes in the vegetation development the Plio-Pleistocene fluvial sequence of the Meinweg section (NL) is seen as a firm evidence for the onset of the Quaternary in NW-Europe already since the late 1950s.
However, re-evaluation of Pliocene and Pleistocene key-reference sites in the south-eastern part of the Netherlands has questioned this interpretation and two main research questions arise:

1) What is the (litho)stratigraphical position of the section and what are the boundary characteristics of the Plio-Pleistocene transition in the Meinweg section.
2) Is the pollen record of the Meinweg section a reliable base for defining the Pretiglian stage as the first cold period of the Quaternary.

Detailed mapping and lithostratigraphical studies of the Meinweg site demonstrate that the flood basin fines (the so-called Reuver and Meinweg Clay) of the Pliocene Rhine-Meuse fluvial system here are overlain by Lower Pleistocene fluvial deposits from to the North draining Belgian rivers. The transition itself is a marked regional hiatus. The Meinweg site forms part of the Lower Rhine Embayment and the region has a well-elaborated heavy mineral stratigraphy. With respect to that the shift from a pre-dominance of so-called stable heavy mineral associations to a predominance of instable heavy mineral association forms a regional marker horizon in the area. This shift is linked to the extension of the Rhine catchment towards southern Germany and the Alpine area. The shift took place during the second part of the Pliocene.
Recently a new core of the Meinweg section was carried out at nearly the same site as the original core studied in the 1950s. The pollen record of the new core is comparable to the original pollen diagram. Concurrently, a detailed heavy mineral record of the fluvial sequence is produced. The data clearly show a predominance of a stable heavy mineral association for the uppermost part of the Pliocene deposits. As a result it is concluded that the formerly as Pretiglian defined part of the sequence in fact has formed during the Pliocene and cannot represent the Plio-Pleistocene transition. Moreover, the recorded changes in vegetation should be interpreted as a result of varying local environmental conditions instead of a major change of the climate.

THURSDAY January 28th

KEYNOTE

The Paleoproterozoic Manganese Bonanza in Africa

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Keywords: manganese deposits, GOE, Paleoproterozoic, Africa.

Abstract

Africa hosts just over 80 percent of the currently known land-based resources of manganese (Mn). The bulk of the African Mn resource is of sedimentary origin and hosted by strata of Paleoproterozoic age, although epigenetic processes, including hydrothermal enrichment and/or deep chemical weathering, have significantly enriched some of the deposits. Host strata and geological context have been used to categorize the deposits into four types, namely BIF-associated, black shale-associated, sandstone-associated (oolitic) and karst-associated. Mn deposits occur geographically clustered and related to a number of prominent sedimentary successions of Late Archean to Late Paleoprozerozoic age. The greatest concentration and genetic diversity occurs undoubtedly on the Kaapvaal Craton of Southern Africa. The Transvaal Supergroup (TVL SG) hosts the ~ 2,2 Ga BIF-associated deposits of the Kalahari Manganese Field – with an estimated 4,2 Gt of contained Mn by far the largest of all land-based Mn deposits globally. However, the TVL SG also hosts the ~ 2,4 Ga BIF-associated Rooinekke deposit and the 2,0-2.2 Ga Postmasburg Manganese Field, the latter comprising the worlds oldest karst-associated Mn deposits. The record of sedimentary Mn deposits of Paleoproterozoic age on the Kaapvaal Craton is complemented by the Tolwe deposit of the ~1,9 Ga Soutpansberg Group, the oldest known example of sandstone-associated oolitic Mn ores.

Other important Paleoproterozoic manganese deposits in Africa are all limited to sedimentary strata of ~ 2,1-2,2 Ga age. These successions may comprise cratonic cover sequences, such as the Francevillian Supergroup on the northwestern part of the Congo Craton, or are associated with the formation of Paleoproterozoic juvenile crust, such as the Birimian Supergroup of West Africa or the Lukoshi Complex in the DRC. Manganiferous carbonate beds closely associated with greywackes and pyritic black shales are geographically and stratigraphically widespread in these successions. In most cases, Late Mesozoic and Cenozoic lateritic weathering markedly enrich the manganiferous strata to form high-grade manganese oxide ores.

All major African Mn deposits occur in strata that immediately postdate the great oxidation event (GOE). Furthermore, they are associated with – or immediately postdate the deposition of banded iron formations. Together with an abundance of geochemical evidence this close temporal affiliation may be used to invoke that the unique concentration of Mn in the sedimentary environment is a consequence of the establishment of oxic conditions in the shallow marine as well as the terrestrial environment.

SESSION 25
GEOMATERIALS

Multi-scale imaging of stones: getting the inside-story

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Keywords: Building stone characterisation, computed tomography, microscopy, multi-scale

Abstract

Characterisation of geological building materials is typically done using traditional research techniques such as optical microscopy and scanning electron microscopy. Although these techniques provide valuable 2D information on structure and mineralogy of these materials, they are unsuitable to acquire insights in the 3D distribution of these minerals or the connectivity of the pore network. To fill in this gap, micro-computed tomography (µCT) has become a standard method in many geological fields, enabling researchers to obtain quantitative information not only on the overall porosity of materials, but also on the complexity of their pore networks, grain size distributions and orientation of fractures.
Unfortunately, µCT data contains only limited information on a sample's exact mineralogy, and high-resolution imaging is always restricted to a very small field of view.
Here we show the combined use of different traditional and innovative imaging techniques, in order to characterise geomaterials from the nano-scale to the centimetre-scale. Furthermore, we combine methods that gather structural information with chemical analysis techniques, to gain insight in the 3D chemistry of a material. Data-fusion between 2D and 3D images provides an extra dimension to traditional microscopy images, enabling researchers to use their benefits in a (pseudo-) 3D environment. We use these methods on a variety of sandstones with varying complexity, trying to visualise both the structure of the extremely fine-grained clay fraction that is present in the interparticle pore space, without losing touch with the overall, macroscopic heterogeneity. Therefore, analysis was performed on different sample sizes from each material, using optical microscopy, scanning electron microscopy combined with energy-dispersive spectroscopy and micro-computed tomography. Besides these mature geological research methods, the first geological application of ptychographic tomography, performed at the cSAXS beam line of the Paul Scherrer Institute (Villigen, CH) is shown. Using this method, structure and behaviour of clay minerals inside sandstones is shown, under changing external conditions. We can demonstrate that by combining all of the methods above, a complete structural and compositional overview of a geological material can be acquired, imaging features sizes over an interval of seven orders of magnitude: from 10 nm to 1 cm.

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Freezing Rocks: a pore scale study

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Keywords: freeze-thaw processes, natural building stones, ice crystallization, stone properties, X-ray micro-CT

Abstract

Freeze-thaw processes can result in very effective rock weathering. The process has been well studied in natural environments, under laboratory conditions and through theoretical approaches. Freeze-thaw action is especially relevant for environmental studies, geomorphology and geohazards and the built heritage. The susceptibility of rocks to freeze-thaw action depends on environmental conditions, such as humidity and temperature, and intrinsic rock parameters, such as rock strength and the geometry of the pore network. Here, we present an experimental study on laboratory induced freeze-thaw weathering on Eocene limestones. Freeze-thaw experiments were conducted on a lab scale in a climatic chamber and according the European standard EN 12371:2010 supplemented with dilatometric experiments using LVDT sensors. Pore scale experiments were conducted using X-ray micro-CT to link the pore scale dynamics to observed rock behavior and decay.

X-ray CT experiments were performed using a gantry based system “EMCT” at the Centre for X-ray Tomography of Ghent University. This system allows fast scanning of stationary samples and mounted add-on modules. For these experiments, a custom-built freezing stage was developed to perform in-site freeze-thaw cycling on 9 mm diameter rock cores. This allowed to scan the samples at ambient temperatures during the thawing, the cooling and the freezing stage. Fast scanning in the order of < 1 minute allowed the discretization of processes in this time order.

The results show that ice crystallization pressure is responsible for freeze-thaw deterioration. The stress is built up at the moment ice crystallization occurs and results in ice wedging which causes a dilatation of the sample. The stress is released when the temperature is increased and the ice crystals melt. Dilatometric measurements and time-resolved structural analysis using X-ray CT provides spatial and temporal information on the crystallization of ice in relation to ambient temperature and the pore system of the sample.

X-ray (micro) computed tomography to study turbidite structures and fabrics: state-of-the-art and future challenges

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Keywords: turbidite, X-ray CT, sedimentary structure, sedimentary fabric, flow direction

Abstract

Even though X-ray computed tomography (CT) is becoming an increasingly widespread technique in many disciplines – among which sedimentology –, applications are still scarce in turbidite research. In the past few years we showed that medical X-ray CT scans of sediment cores can provide a wealth of information about turbidites and especially their internal structures. In Aysén fjord (Chile) as well as several Chilean and Alaskan lakes, we showed that sedimentary structures such as ripples can be used to reconstruct flow directions, as they can be visualized in 3D. When sedimentary structures are absent, fabrics (e.g. grain imbrication) can also be used. However, the resolution of medical X-ray CT scans is usually not sufficient to visualize single grains or clasts inside the sediment cores. Therefore, medical X-ray CT scans do not allow the determination of single grain orientations. Recently, however, subsamples of sediment cores from a Swiss and an Alaskan lake were scanned at the Centre for X-ray Tomography (UGCT, Ghent University) to obtain µCT data. The data allows to isolate single grains, determine their grain size, orientation, as well as other parameters. However, the obtained resolution depends strongly on the size of the subsample (i.e. smaller sample equals higher resolution and vice versa). Therefore we compare the µCT data with results from more classical techniques (e.g. microscopy, laser diffractometry). This comparison will allow to determine the appropriate sample size for each µCT scan based on results from these fast classical analyses. The future will show whether extracted grain orientations can be used to determine paleoflow directions within turbidites, and whether X-ray µCT will thus become a new valuable technique in e.g. turbidite paleoseismology.

SESSION 26
TELEDETECTION

Aerial imagery from an high-altitude drifting balloon platform : applications in geohazards monitoring (Sierra Arana, Spain and Mons Province, Belgium)

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Keywords: remote-sensing, high-alttude balloon, structure-from-motion

Abstract

A new type of untethered balloon based mapping platform allows affordable remote sensing applications from higher altitudes and with a greater range and payload capacity than common motorized UAV's. The airborne device, called « Stratochip » is based on a dual helium balloons configuration. At a defined altitude (comprised between 500 and 30000m), the first balloon is released, drastically reducing the platform climbing rate. The payload (up to 10kg) can then drift in a sub-horizontal trajectory until it leaves a pre-defined area of interest. Leaving the pre-defined area, the second balloon is released and the payload is recovered after a parachute landing.

The predicted flight path of the Stratochip, launch site and surveyed area are calculated using both forecasted (NOAA model) and real-time (inborne instruments) meteorological data, along with the physical parameters of the balloons and parachute. The predicted recovery area can also be refined in real-time to secure and facilitate equipment retrieval.

In this study, we present the results of two cartographic campaigns made in Belgium (Ground collapse near Mons) and Spain (karstic field in the Eastern part of Sierra Arana, Granada region). Those campaigns aimed to test the usability of the Stratochip to survey a large area (up to 900km² for Spain) at medium and low altitudes (8000m - 500m) and produce an updated Digital Elevation Model and orthophoto mosaic of those regions. For that purpose, the instrument installed in the Stratochip payload was constituted of a digital camera stabilized with two IMU's and two brushless motors. An automated routine then tilted the camera at predefined angles while taking pictures of the ground. This technique allowed to maximize the photogrammetric information collected on a single pass flight, and improved the DEM reconstruction quality, using structure-from-motion algorithms. The quality of produced DEM were then evaluated by comparing the level and accuracy of details and surface artefacts between available topographic data (LIDAR, SRTM, topographic maps) and the Stratochip sets. This evaluation showed that the models were in good correlation with existing data, and can be readily be used in geomorphology, structural and natural hazard studies.

Tidal flats, characteristic and change in North of Vietnam

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Keywords: tidal flats, waterlines extraction, morphological change, inter tidal flats

Abstract

More than 350km of coast North of Vietnam beside Gulf of Tonkin is under the moon soon tropical weather and in semi-diurnal tide regime, which is only one high tide and low tide time a day. This area owns a large strip of tidal flats along the coast, which plays a very important role in environment conservation, livelihood of local people and military security. However, the knowledge about the morphology of tidal flats in this region is still negligible and unconnected. By using multi temporal satellite images technology combines with coastline method, the digital elevation model (DEM) of tidal flats along the coast is constructed and analysis the change over period 2000-2014. More than 260 scenes of Landsat TM, ETM+ and Landsat 8 have received from USGS in which mostly 80 images are processed to create DEMs. To get the best reliable of results, the meteorological factor and tide regime is mentioned in selecting satellite images. The waterlines extracted by slicing spectral bands or ratios is compared with the waterlines digitalized from very high resolution images(0.5m) and select the suitable solution for each area of spectral reflectance condition on image. Correlation value calculated between elevation collected on the field by Theodolite instrument and on the DEM is base data for accuracy assessment of tidal flats DEM mapping. The research results indicated the specific morphology of tidal flats corresponds with different elements in the study area. The tidal flats closed to Red river mouth receives a vast volume of sediment supports from Red river system is not only expand to the South average 186m/year but also is the most deposition with maximum to 2m vertical increate. The tidal flats contributed by sediment from coal exploitation in Cam Pha city tend to erosion in the middle tidal flats and deposition in the low tidal flats area. The North of study area in Hai Ha, Mong Cai district is a large area of tidal flats with the material is almost coarse sand. Here the deposition is negligible over period of 2000-2014 even erosion happened in some sites.

Overview of the ground mouvements highlighted by the Persistent Scatterer Technique (PSI) in Belgium

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Keywords: PSI Subsidence, Uplift, Radar Interferometry

Abstract

Persistent Scatterer Interferometry (PSI) technique (Ferretti, Prati & Rocca 2000 & 2001) is a valuable technique for studying ground deformation in Belgium and providing more information on their spatial and temporal patterns. In this work, we exploit about 600 SAR images of different tracks from the European satellites ENVISAT and ERS using PSI technique over the entire country. The SAR data covers the time range from 1991 with ERS to the end of 2010 with ENVISAT. More than 2 10^6 Persistent Scatterer (PS) issued from the processing giving a reasonable density even in the countryside. A mapping of the annual average velocity of the PS of the entire period highlighted already known ground movements from the literature. Thanks to its millimetre precision, it permitted to highlight new movements that were not identified before by less sensible techniques such as levelling. Seven large subsidence or uplifting areas can be spotted from the velocity map (see figure 1). From north to south, the regions facing ground movements are: West-Coast, Antwerp and along the Schelde river and estuary, the Limburg Campine coal mines basin, Merchtem-Londerzee, the cities of Brussels and Liège as well as a large area related to the Tournai-Mons-Charleroi coal mines basin. The purpose of this work is to make an overview of the situation (observations, first interpretations) of these moving zones. The highest positive (uplift), 20 to 25 mm/year and negative (subsidence) -17 to -20 mm/year velocity values are recorded around the former Limburg coal mines areas. The movements are closely linked to the groundwater extraction needed during the exploitation time and the recharge of the mining aquifer occurring at the end of the pumping. Indeed, the groundwater extraction seems to affect the ground level of all the highlighted areas exception being made for the Antwerp area.

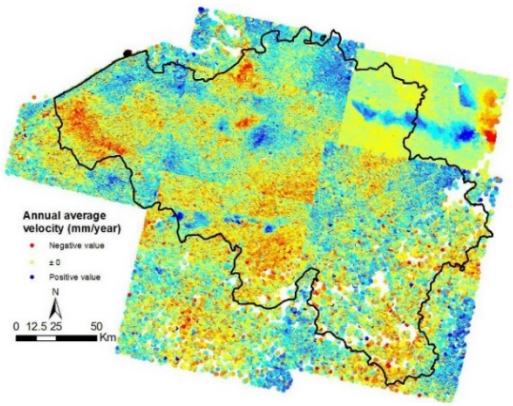

Figure 1: Map of the processed areas in Belgium. The legend is specific to each zones in order to avoid masking low amplitude velocities

Reference:

FERRETI, A., PRATI, C. & ROCCA, F. (2000) - Nonlinear subsidence rate estimation using permanent scatterers in differential SAR Interferometry. IEEE Transactions on Geoscience and Remote Sensing, 38(5), 2202-2212.

FERRETI, A., PRATI, C. & ROCCA, F. (2001)- Permanent scatterers in SAR Interferometry. IEEE Transactions on Geoscience and Remote Sensing, 39(1), 8-20.

SESSION 27
POSTERS

AFRICAN GEOLOGY
MARINE GEOLOGY

Session 27 Posters

AFRICAN GEOLOGY

The Mindouli (Republic of the Congo) mining district revisited (1): geological context and preliminary results on the formation of complex, multiphase, Cu-Pb-Zn deposits

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Keywords: Boko-Songho, Cu-Pb-Zn hydrothermal deposit, Mindouli, Mfouati, paleometallurgy, Republic of the Congo, supergene deposit

Abstract

The Niari Syncline (Republic of the Congo) hosts complex Cu-Pb-Zn deposits, associated with ENE-WSW-trending sets of regional faults (Maurin *et al.*, 1990). Abandoned mines at Mindouli, Ntola, M'Passa Mines, Mfouati, Boko-Songho have been investigated, with a double objective: (1) get an improved understanding of the formation of these deposits; (2) get an improved understanding of the use of copper and lead exploited from these mines in pre-colonial metallurgy (Nikis and De Putter, this volume). The studied Cu-Pb-Zn deposits are hosted along or near the N60°E faulted contact between the Neoproterozoic stromatolitic limestone of the "Schisto-Calcaire" and the younger Neoproterozoic pink sandstone of the Mpioka Group, both in the West-Congolian Supergroup. At some post-depositional and pre-mineralization stage, the stromatolitic limestone has undergone extensive karstic dissolution, and later dolomitization/silicification. A hydrothermal origin has been proposed for these deposits (Buffet *et al.*, 1987), which is substantiated by the presence of massive Fe-Cu-Pb-Zn sulphides (chalcopyrite, sphalerite, galena) and sulphide-cemented breccia at depth in most deposits. Further work is ongoing to characterize/date the post-Mpioka hydrothermal phase of these (MVT-like?) deposits, possibly allowing connections with major geodynamic events in the study area. In later phases, the deposits experienced supergene overprints that varied according to their specific settings. At Mindouli, the porous and permeable faulted contact between the karstic limestone and the Mpioka sandstone favoured the formation of a rich paragenesis of Cu-Pb-Zn secondary minerals, dominated by silicates (dioptase, plancheite, hemimorphite) and carbonates (malachite, azurite) in the upper part of the deposits. At Mfouati, the karstic cavities in the limestone are filled with a highly porous iron-rich alterite that hosts a paragenesis dominated by Pb-Zn minerals (hemimorphite, smithsonite, wulfenite), with accessory Cu minerals (dioptase, chrysocolla, malachite). At Boko-Songho, the deposits are capped by a thick iron-rich alterite and the paragenesis is dominated by void-filling malachite (crusts, botryoids: De Putter *et al.*, 2010). Supergene overprints on the studied deposits need to be dated and further connected with major regional paleosurfaces (De Putter *et al.*, 2015). Fluid circulation patterns through these deposits – both hydrothermal and meteoric – have resulted in a vertical elemental distribution: Pb deeper than Cu deeper than Zn. As in the Katanga Copperbelt (D.R. Congo), a "late" (Cenozoic?) meteoric phase has remobilized copper and allowed the formation of void-filling malachite in the subsurface. This mineral is present/abundant in most deposits and has been exploited to fuel pre-colonial metallurgy, at the vicinity of the mines (Nikis and De Putter, this volume).

Cu-Pb-Zn mineralization in the West-Congo belt: Bas-Congo (DRCongo) and the Niari Basin (Rep. of the Congo)

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Keywords: Cu-Pb-Zn mineralization, West Congo belt, Neoproterozoic, sulphides

Abstract

The Copperbelt, at the border of the Democratic Republic of Congo (DRCongo) and Zambia, is known for its world-class Cu-Co deposits hosted in the Neoproterozoic Katanga Supergroup. The copper potential of other Neoproterozoic belts in Central Africa has often been less explored. In this study, we focus on base metal deposits associated with the Neoproterozoic West Congo belt in the DRCongo (Bas-Congo province) and the Republic of the Congo (Niari Basin). The West Congo Belt is an approximately 1400 km long and 150-300 km wide orogenic belt, subparallel to the Atlantic Ocean and extending between 1°S and 12°S. It is part of the larger Aracuai-West Congo orogen, formed during the Pan-African amalgamation of the Gondwana supercontinent.

In the Bas Congo province, the Cu-Pb-Zn mineralization is found along fault systems in the foreland of the belt that consists of rocks belonging to the West Congo and Inkisi Supergroup. The Cu-Pb-Zn mineralization is characterized by a composite paragenesis, where most of the primary sulphide mineralization has been oxidized and remobilized to form a complex secondary mineralization. The Cu-Pb-Zn sulphide stage consists of veins and lenses that occur along faulted zones, crosscutting the Lukala limestones and the Inkisi sandstones. Before the deposition of the primary hypogene ore minerals, dolomitization of the limestone host-rock occurred. Research indicated that this primary sulphide mineralization formed from high-temperature (> 180°C), high salinity Ca-Na fluids that circulated through to West-Congo foreland. In the Niari Basin, the Cu-Pb-Zn deposits occur along a series of subparallel N60E oriented faults in the Lukala limestones and Mpioka sandstones. Massive sulphides and sulphide-cemented breccias, often associated with karstification, are exposed in the Mindouli area and are regarded as the hypogene ore, affected by an extensive supergene overprint. A post-Neoproterozoic Inkisi age is indicated by field evidence for the sulphide mineralization.

A Mesozoic age is proposed for the Niari Basin, relating the mineralization with the opening of the Atlantic Rift, which reactivated the regional fault systems. After the formation of the primary mineralization, significant erosion and secondary enrichment took place, as evidenced in the formation of the supergene deposits and iron-rich laterite caps. The mineralogical composition of the secondary deposits is rather complex, with vanadates, arsenates and molybdates, besides more common copper carbonates and silicates. The supergene overprint requires the exposure of the deposits to meteoric fluids, most probably following the Cenozoic uplift period. A Miocene age for such a supergene overprint has been proposed for the roughly equivalent deposit in Tsumeb (Namibia).

Geology of the Sn, Nb-Ta and W mineralization in the Karagwe-Ankole belt, Central Africa: current state of knowledge

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Keywords: Karagwe-Ankole belt, cassiterite, columbite-tantalite, pegmatite, quartz veins

Abstract

The Mesoproterozoic Karagwe-Ankole belt (KAB) in the Great Lakes area (DRCongo, Rwanda, Burundi, Uganda and Tanzania) forms a metallogenic province that hosts a variety of granite-related mineralization, which contains cassiterite, columbite-tantalite, wolframite/ferberite, spodumene and beryl. The belt consists of Palaeo- and Mesoproterozoic supracrustal units, of mainly metasedimentary and –volcanic rocks, which are intruded by voluminous S-type granitic rocks and subordinate (ultra-) mafic bodies. The mineralized pegmatites and quartz veins are related to a fertile granite generation formed at ~986 Ma, probably during the transition from orogenic compression to orogenic collapse and extensional tectonics, shortly after the deformation event at ~1000 Ma.

The Sn and Nb-Ta mineralization is hosted in pegmatites, while Sn and W mineralization can be found in quartz veins. The mineralization is preferentially emplaced along places of structural weakness, such as bedding and cleavage planes and fractures, which demonstrate the control that these discontinuities had during pegmatite/quartz vein emplacement and which confirm a late to post-orogenic origin of the fertile granite system. The lithological and structural control (foliation) on the mineralization, however, also resulted in many, but relatively small ore deposits.

Pegmatites in the Great Lakes area can contain important Sn, Nb-Ta and Li mineralization. They show a regional mineralogical and geochemical zonation related to the parental granites, which has been interpreted as the result of a single magmatic fractionation path. The emplacement of the pegmatites resulted in an alteration of the host-rocks, mostly sericitization, tourmalinization and silicification. The individual pegmatites can show a mineralogical and geochemical zonation typical for granitic pegmatites which is affected by metasomatic/hydrothermal alteration, mainly albitization and greisenization. The latter alteration is associated with the main phase of cassiterite mineralization that occurs in local pockets. A first stage with Nb-Ta, Li and minor Sn, however, already formed pre-alteration, directly associated with pegmatite crystallization.

The Sn mineralized quartz veins can occur in the metasediments, at the margin of the granitic rocks or directly crosscutting the granitic rocks. W veins are mostly hosted by typical dark-coloured, often organic-rich, metapelites. The emplacement of the quartz veins resulted in an intense alteration of the host-rocks, mainly sericitization, tourmalinization and silicification. Cassiterite and wolframite/ferberite occur associated with muscovite in fractures in and along the margins of the quartz veins. Different sulphides precipitated after the crystallization of the main Sn-W stage. Although a magmatic origin is suggested for the Sn-W mineralization, a metamorphic overprint disguising the primary magmatic origin can be observed.

Structural trends in the geology of Burundi as emphasized from geophysical datasets

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Keywords: Burundi, geophysics, gravimetry, magnetic field, vertical gradients

Abstract

The digitization of the geological map of the Burundi (a joint RMCA-Burundian Geological Survey project, funded by the BTC) has been the opportunity for a joint valorization of datasets kept in the national Geological Survey, at Bujumbura. Among these data were unexploited results of geophysical surveys of the early 90s.

Gravity data, with a total of 788 station and a density measurement of 1 station per 5 km², using the G312, G342 and G 437 Lacoste Romberg gravimeters, have been surveyed in 1993 on the whole country (i.e. 25,650 km²) by the Council for Geoscience of the South African Geological Survey (Pretoria). The survey resulted in the setting of 10 first order stations and one base station (at Duni), linked to the Bujumbura Airport, that can be used in the international BGI network or the IGSN 71 network. Such a survey allows a densification of the network. These data have been reprocessed and different maps extracted. Another geophysical dataset comprises magnetic field measurement on a 13,000 km² area in the central part of the country, surveyed at a helicopter-flown 50 m elevation by Kenting Geophysics. This dataset is completed by additional records obtained by the German BGD. An interesting record is the magnetic signal reduced to the pole as these data enhance short wavelengths and hence emphasize visible or concealed lineaments in the regional geology.

Maps recalculated from these two gravity and magnetic datasets will be used in the context of a wider re-appraisal and update of the geological history of the Burundi – that will be soon published in the forthcoming explanatory notice of the digitized geological map. They help constraining the complex and still debated relationship between major geodynamic units, particularly in places where geological contacts have been obliterated by tectono-metamorphic events. Examples include: (1) the mylonitized contact between Mugera or Gikuka Archean complexes and the base of the Mesoproterozoic Kagera Supergroup in the East and South-East of the country; (2) the stacked repetition zone within the basal group of the Mesoproterozoic Kanyaru supergroup, hosting V and Ni-PGE deposits along the regional Kabanga-Musongati lineament; (3) the “décollement” sheets in the border zone of Mesoproterozoic metasediments on western and northern Paleoproterozoic granito-gneissic domes hosting Sn-Nb-W mineralizations. They also help delineating North-South transversal fault zones, to which are associated the 1205 Ma Gitega-Makebuko alkaline granitoïd rocks, the 740 Ma Matongo carbonatitic rocks, and the 540 Ma veins swarms, mineralized in REE at Gakara or in gold when they crosscut magnetite-pyrites rich horizons (Muyinga, North-East; Mabayi North-West).

Session 27 Posters

MARINE GEOLOGY

Cold-water coral mini-mounds on the Ferrol Canyon (Cantabrian Margin): initiation and controlling factors

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Keywords: Cold-water coral mounds, Lophelia pertusa, palaeoceanography

Abstract

The Ferrol Canyon is located on the northwestern Iberian Margin, in the southern part of the Bay of Biscay. The 2009 R/V Belgica campaign revealed the existence of small mounded features on the upper flanks of this canyon. These so called "mini-mounds" are 100-300 m in diameter and up to 2.5 m high and occur in water depths ranging between 400 and 550 m. Their size and distribution is different on the northern and southern flank of the canyon with the northern mounds being smaller and more clustered while the southern ones are larger and are further apart. Video groundtruthing revealed that the mounds are covered with fossil *Lophelia pertusa* branches with an early Holocene age. This supports the hypothesis that these mini-mounds are a failed experiment of cold-water coral (CWC) mound growth. In this study we use geophysical and video data to identify the processes involved in the initiation, growth and demise of these CWC mini-mounds.

In the shallower part of the southern flank of the Canyon, an extensive network of pockmarks is identified. These features are likely caused by gas migration from Albian Units along NE-SW oriented faults. They have a size and distribution strikingly similar to the southern mini-mounds located further downslope. Therefore, these mini-mounds could potentially have formed on top of seepage features which can provide methane-derived authigenic carbonates acting as hardgrounds for settling of coral polyps. Furthermore, the lack of observed pockmarks in the vicinity of the northern mini-mounds could explain their different morphology and distribution. This would indicate that hydrocarbon seepage forms no prerequisite for coral mound initiation but could have an important influence on the mound start-up phase. The deeper part of the study area is characterized by erosional and depositional processes related to the Mediterranean Outflow Water (MOW). Contemporary CWC's in the area dwell within the range of this water mass, relying on its density and dynamics for their food supply. Contrastingly however, the fossil mini-mounds are located right above the present upper boundary of the water mass. This could mean that the mini-mounds on the Ferrol Canyon flanks were linked to the re-introduction of a shallow MOW in the NE Atlantic during the last glacial to Holocene transition, bringing favorable conditions for CWC growth to the shallower canyon flanks.

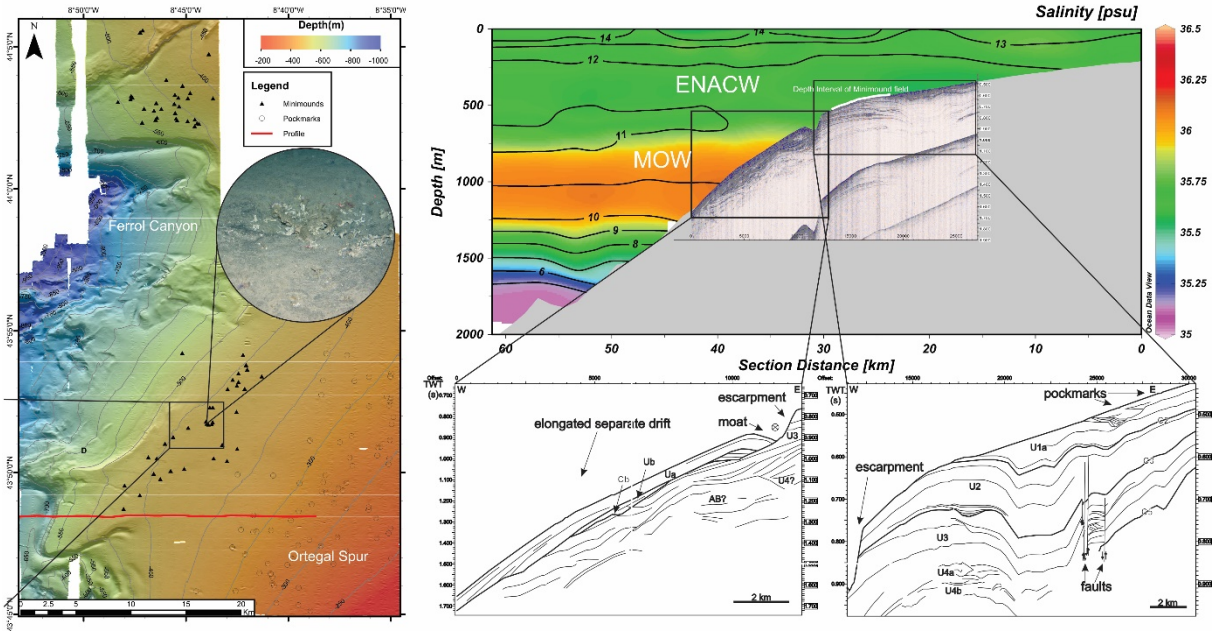

Figure. Left: Multibeam bathymetry map of the Ferrol Canyon Area with indications of minimounds (black triangles), pockmarks (black circles) and seismic profile (red line) and ROV still of *L. pertusa* branch on mound; Right: Seismic profile and interpretation plotted on hydrographic salinity profile with temperature contours based on CTD data from WOD13.

A high-resolution DEM for the Top-Paleogene surface of the Belgian Continental Shelf

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Keywords: Belgian Continental Shelf, Quaternary, Top-Paleogene, paleovalley, stratigraphy

Abstract

A 1:250.000 scale map of the surface of the Top-Paleogene for the Belgian Continental Shelf was created based on extensive analyses of older and recent geological and geophysical datasets. The Top-Paleogene is an important polygenetic unconformity that truncates older strata of the Paleogene and to a smaller extent some of Neogene age from the overlying Quaternary deposits. As such it represents the base of the latter. The represented surface has been diachronously shaped and reworked through Late Quaternary times by different geological processes (e.g., fluvial, marine, estuarine, periglacial). Additionally, the offshore surface has been attached to the landward Top-Paleogene surface and was transformed into a uniform 3D surface allowing new and better interpretations to be used for multidisciplinary scientific research (e.g. geology, archaeology, palaeogeography) and commercial applications (e.g. wind farms, aggregate extraction, dredging).

Cold-water coral occurrence and critical bottom current conditions in the Pen Duick Escarpment (Gulf of Cadiz, Moroccan margin)

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Keywords: Pen Duick Escarpment, contourite drift, cold-water coral, primary productivity, bottom currents

Abstract

The Pen Duick Escarpment is located at about 35°20'N latitude in the El Arraiche mud volcano province (southern Gulf of Cadiz) and was formed by the complex interplay of tectonic ridges and mud volcanoes, active from the Neogene to present. Subsequently, bottom currents interacted with the rising topographic obstacles and led to the development of a contourite drift along the escarpment's southern foot. The top of the Pen Duick Escarpment, nowadays ranging between 500 to 600 m water depth, constitutes in turn a so-called graveyard of past flourishing cold-water coral (CWC) ecosystem. Being suspension feeders, the scleractinian CWC are found in various deep sea habitats as they tolerate a wide range of temperatures, salinities and dissolved oxygen concentrations. Nowadays, environmental conditions are favourable for CWC in the Pen Duick Escarpment although living specimen have rarely been observed. In contrast, the Pen Duick Escarpment CWC seem to periodically thrive and decay within well-defined time intervals, closely associated with past glacial periods such as MIS2-4, MIS6 and MIS8. Previous studies demonstrated that CWC strongly depends on primary productivity which constitutes the base of their food chain. Additionally, the co-occurrence of CWC ecosystems and enhanced hydrodynamic environment widely prevails. Bottom currents are known to induce sediment and nutrient resuspension, lateral transport and vertical mixing, which play a substantial role in term of food particle availability for the living CWC.

However, the extent to which bottom currents play a role in providing and sustaining a favourable environment for CWC growth is still poorly understood and poorly constrained. This study is based on the multi-proxy analysis of a sediment core recovered from the Pen Duick drift at 642 m of water depth. When compared to known CWC occurrences over the last 45 kyr, results indicate that CWC growth periods are associated with regional enhanced bottom current regime, mainly inducing sediment bypass and/or sediment erosion. Such critical bottom current conditions, that prevent sedimentation over adjacent CWC thriving sites, were also observed in many other sites from the northeast Atlantic margin, across different time scales. This limited sedimentation largely hampered the characterisation of CWC palaeo-environment variability. We here promote bottom currents (along with primary productivity) as a limiting factor for cold-water coral growth.

Origin of morphological depressions on the Guadalquivir Bank uplifted area (Gulf of Cadiz middle slope)

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Keywords: Gulf of Cadiz, Contourite System, Erosional features, Seismic Stratigraphy; Morphology.

Abstract

We have investigated the origin of morphological depressions (circular-elliptical depressions, amphitheatre-shaped escarpments and valleys) on the Guadalquivir Bank uplifted area (Gulf of Cadiz middle slope). This work is based on swath bathymetry and high- and mid-resolution reflection seismic datasets. Depressions occur on the distal (depositional) sector of the Gulf of Cadiz Contourite Depositional System, which has been developed under the influence of the Mediterranean Outflow Water (MOW). The Guadalquivir Bank is a NE-oriented relief that was uplifted along the Neogene and Quaternary. It forms the southern limit of the Bartolomeu Dias and Faro Sheeted Drift (SD) plateaus that are separated by the NW-trending Diego Cao Contourite Channel. Circular-elliptical depressions occur on the Bartolomeu Dias SD plateau, aligned parallel to the rim of the Diego Cao Channel. Irregular, crescent-shaped depressions occur to the SE of the study area and a valley surrounds the Guadalquivir Bank. The origin of these features is interpreted as the result of the interplay between oceanographic, mass-wasting, tectonic and fluid-escape processes. Four stages define the development of these features: 1) Onset of a contourite mounded drift associated with a proto-Diego Cao moat originated by a weak MOW circulation as it interacted with the structural features of the Guadalquivir Bank during the Lower Pliocene; 2) Evolution to a more complex multi-crest drift and moat system, probably as a result of an enhanced MOW and increased deformation of the underlying structures during the Upper Pliocene-Early Quaternary; 3) Event of enhanced tectonic activity that provoked widespread mass-wasting events along middle slope sheeted drift plateaus during the Mid Pleistocene. It was recorded in a prominent erosive surface under the present-day Diego Cao channel western rim and numerous slide scars displaying amphitheatre shapes on the limits of the plateaus; 4) Final stage (Late Quaternary) when the Mediterranean Intermediate Branch started flowing towards the N-NW along the deep gateway that was opened as a result of the mass-wasting event and/or structural adjustments. The contourite system evolved, due to tectonic events, to the present-day channel and a complex separated drift that includes circular depressions. They result from the interaction between the bottom current and the irregular basal surface created by the slide scars. During this phase, crescent-shaped depressions were created, probably by the interplay between bottom currents and fluid escape processes, and the marginal valley around the Guadalquivir Bank resulted from current reworking of the irregular topography of contouritic deposits affected by slide scars.

Buried cold-water coral mounds along the Moroccan Atlantic Margin: new insights in cold-water coral mound growth processes?

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Keywords: Quaternary, bottom currents, seismic stratigraphy, AAIW, cold-water coral mounds

Abstract

During the past two decades, many marine geoscience studies have focused on the genesis, growth and decay of medium-sized to large cold-water coral (CWC) mounds, especially along the margins of the northeastern Atlantic Ocean. A key study site was the Belgica mound province, located on the eastern slopes of the Porcupine Seabight, where during IODP expedition 307 core samples were drilled through the base of a mound, enabling to date mound initiation at 2.65 Ma. Although this expedition offered a lot of insight in the evolution of CWC mounds, still a lot of questions regarding the "start-up" phase and growth remain unanswered. This is partly due to the inability to obtain a continuous high-resolution environmental record from such a mound, to compare with continuous "off-mound" records. Luckily, the Belgica mounds are just one of the many expressions of CWC mound growth. More enigmatic is the buried Magellan mound province, located in the northern part of the Porcupine Basin, featuring over 1000 relatively closely spaced buried mounds, which are all rooted on a common reflector. This indicates a common and sudden start-up event, but the true driving forces behind the initial settling, growth and demise of this province are also still unknown.

In 2013, some 3000 km south of the Magellan mound province, a new province of buried CWC mounds was discovered along the Moroccan Atlantic Margin, which may shed new light on the "life" cycle of CWC mounds. About 487 buried CWC mounds have been identified from high-resolution seismic reflection profiles, and can be associated to a vast province of several clusters of seabed mounds. They have an average height of 10-20 m and are approximately 250 m wide. They occur in water depths between 500 and 1000 m, buried under up to 50 m of sediment. With respect to the Magellan mounds, they are smaller, but more importantly, they do not root on one single stratigraphic level. At least 8 different initiation levels were identified. The off-mound reflectors indicate a slight influence of bottom currents, since the mounds are located in a large sediment drift that is related to the Pen Duick CDS. The individual initiation levels of these mounds seem to indicate fast and relatively short-lived mound growth during one or more climatic cycles (Marine Isotope Stages). This site may thus very well contain the key to better understand mound growth in relationship to palaeoclimatological variability.

Faults System Evolution in the Baiyun Sag of the Pearl River Mouth Basin, Northern South China Sea

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Keywords: Baiyun Sag, Fault System, Tectonic Evolution, Fault Activities

Abstract

This study is based on the structural interpretation of seismic profiles, combined with a study of the geometry and kinematics of faults system in the Baiyun Sag which is located on the continental slope of the northern South China Sea.

The Baiyun Sag fault system mainly consists out of small-scale normal faults with little displacement, which are distributed in the peripheral slope of the Baiyun Sag. There are NWW-trended faults, NEE trended faults and nearly EW-trended faults, whereas the NWW-trended faults are the dominant fault system. The trend of the faults underwent a clockwise rotation from 65 Ma to 30 Ma. In vertical sections, a single fault may be of platy or listric shape, while multiple faults form ladder, parallel, flower, or fastigiated shape combinations. On map view, these faults form parallel, fastigiated or echelon combinations. According to their distribution, the faults can be divided into three clusters; along the northern slope, eastern slope and southern slope. Parallel, flower and fastigiated shape combinations are observed along the eastern slope, whereas parallel and ladder are present on the northern slope, and a ladder configuration in the western slope.

Knowing multi-phase activities during the Cenozoic, these faults sustained activity during the rifting and post-rifting stages, while some faults developed up to the Quaternary shown in the profiles. The fault activity during the rifting stages were strongest. Statistics show that the strongest activities between 50-30 Ma controlled the formation and the syn-rifting sedimentation, whereas less stronger activities were deduced from 18.5Ma to 16.5Ma according to the Faults Growth Index. After 12.5Ma, the activity slightly increased again. The fault activities were strongest from west to east during the post-rifting phase in the northern slope of the Baiyun Sag, while in the east, the activity period is longer than the western one during the second phase of the activities between 18.5Ma to 16.5Ma.

SESSION 28
STRUCTURAL GEOLOGY

Eastward extrusion of the North Tibetan plateau: insight from the Altyn Tagh fault offset and a 3D crustal budget in North Tibet

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Keywords: northern Tibetan plateau, Altyn Tagh fault, Qaidam basin, extrusion, crustal budget

Abstract

How the Tibetan plateau developed has long been a puzzling question,yet with implications for the understanding of the mechanical behaviour of the continental lithosphere in convergent zones. As one of the major strike-slip fault systems on the Tibetan plateau, the Altyn Tagh fault accommodates a significant amount of post-collisional convergence between India and Eurasia through left-lateral strike-slip faulting. However, estimates of the total displacement along the fault vary anywhere from over 1000 km to less than 100 km. In addition, a major issue concerning the tectonic evolution of the northern margin of the plateau that remains to be explored is whether the huge amount of displacement along the Altyn Tagh fault is totally absorbed by NE–SW crustal shortening within the northeastern margin of the Tibetan plateau (Qilian Shan wedge), or whether some of the displacement is transferred farther east in the Qinling region or further into North China. Seismic data, stratigraphy and detrital zircon U-Pb age spectra of Cenozoic to Mesozoic samples within the western Qaidam basin, allowed identifying two probable piercing points suggesting ca. 360 km of displacement along the Altyn Tagh fault since its Eocene initiation. Based on these 360 km of north-eastward migration of the relatively rigid Qaidam block along the Altyn Tagh fault and 3D isovolumetric balancing of the crustal deformation within the Altyn Tagh fault–Qilian Shan system, we propose a new quantitative evaluation of the Cenozoic crustal shortening and lateral extrusion budget in the northern Tibetan plateau. We demonstrate that the deformation is partitioned between 250 ± 28 km (43.8–49.4%) of N20E directed crustal shortening and an additional ~250–370 km of eastward motion of the Qilian Shan crust accounted for by strike-slip faulting in the Qilian Shan and crustal thickening in the Qinling area, as well as by extension in the adjoining North China block graben systems. The crust of the Tibetan plateau largely extrudes eastward along its northeastern margin, potentially driving the deformation further to the east.

The Central North Anatolian Fault Segment: insights from cosmogenic nuclide dating of the Kizilirmak River terraces and from 10Be erosion rate data

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Keywords: North Anatolian Fault, shortening rate, slip rate, cosmegenic dating

Abstract

Shortening in the Central Pontide in Turkey occurred in a wide orogenic wedge centered on the central segment of North Anatolian Fault (NAF), which formed a positive flower structure. The shortening is tied to the NAF broad restraining bend in that region. The present study provide new insights regarding erosion rates of the Ilgaz Mts range crossed by the central NAF and shortening rate deduced from incision rates along the Kizilirmak River which flows along the NAF in that region. ^{26}Al, ^{10}Be, ^{36}Cl cosmogenic dating on different terraces constrained two different episodes of river incision occurring 75 000± 20 000 yrs and 35 000±15 0000 yrs ago using ^{10}Be ages. ^{36}Cl ages are significantly older that ^{10}Be ages pointing to probable regarding ^{36}Cl production rate as the ^{10}Be and ^{36}Cl ages were obtained from the same pebbles. Surface dating on the low terrace levels shows a contamination by marble pebbles having ^{36}Cl ages of 24500±2500 years. These younger pebbles are coming from the slopes above the terrace and are probably related to the intense frost cracking that occurred during the LGM. The low level surface also contains boulders having the same age as the upper terrace levels pointing to a local remobilization. The obtained incision rate from the two terrace levels along the Kizilirmak along the central NAF are ranging from 1.4 to 1.8 mm/yr which is significantly larger than the 0.28 mm/yr fluvial incision in the nearby tributary north of the NAF (Yildirim et al., 2013). The later would indicate a higher tectonic shortening close to the NAF positive flower structure than further north in the larger orogenic wedge formed across the NAF bend. Finally the lower terrace age puts some constraints on a 550 m lateral offset across the NAF implying a slip rate of 16 cm/yr in the last 35 000±15 0000 years.

Stagnant-lid tectonics in the early Earth history revealed by ^{142}Nd variations in late Archean rocks

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Keywords: plate tectonic, mobile lid, stagnant lid, Archaean

Abstract

A traditional view of the Archaean implies that because the heat flux was larger, then the Earth mantle was convecting more vigorously, and had to lose more heat by faster and more efficient plate tectonics. However, this view is challenged by a paradox: if the rate at which the Earth is now loosing heat is extrapolated to the Archaean, then the Earth was so hot that it would have been totally molten by 1 billion years (Gyr) ago [1]. Short-lived isotope systems can be a powerful tool for investigating the geological processes that occurred during the Archean. As such, early Archean rocks show a progressive decrease for their µ142Nd from +20 to 0 between 3.9 to 3.6 Gyr, until rocks younger than 3.5 Gyr show no µ142Nd anomalies. This decrease is interpreted as the efficient remixing of the first primitive crust into the Archaean convecting mantle that ultimately produce a well-mixed present-day convecting mantle with µ142Nd = 0 [2]. Such a timescale from 4.5 to 3.5 Gyr implies mixing time longer than expected for a fast convective mantle (i.e. around 100 Myr).

The finding of a resolvable positive 142Nd anomaly of µ142Nd = +7 ± 3 ppm relative to the modern convecting mantle in a 2.7 Gyr old tholeiitic lava flow from the Abitibi Greenstone Belt in the Canadian Craton challenges even more the traditional view as it extends the early Archean convective mixing time to ~1.8 Gyr. This is even longer than present-day mantle mixing timescale of ~1 Gyr [3]. Using a numerical modelling, we show that a delayed mixing, even in a strongly convective mantle, is well explained by long periods of stagnant-lid plate tectonics, with scarce episodes of subduction throughout the Hadean and Archean [4]. In addition, a stagnant-lid regime during the Archaean permits avoiding the paradox of a molten Earth.

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Neoproterozoic oceanic arc complexes in the Moroccan Anti-Atlas: tracking its genesis, accretion and collision

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Keywords: oceanic arcs, subduction, arc accretion, panafrican orogeny, HP-HT metamorphism

Abstract

Intra-Oceanic Subduction Zone (IOSZ) in the Moroccan Anti-Atlas crop out in two tectonic windows moulded along the Anti-Atlas Major fault: the *Sirwa* (western-) and the *Bou Azzer* (eastern- part) inliers, associated with 760 Ma back-arc ophiolites. These arc sequences are located at the south of the ophiolites and are named the Iriri-Tachakoucht (Sirwa window) and the Asmlil arc complexes (Bou Azzer inlier). *(i) The Iriri-Tachakoucht unit* is composed of coarse grained hornblendite lenticular plugs, medium-grained hornblende gabbro dykes intruding andesitic to dacitic porphyroclastic gneiss. The contact between both lithologies is gradual and marked by an increasing migmatitization of the gneisses towards hornblendite intrusions. Phase diagram calculation were performed on garnet-bearing gneisses. Garnet cores have grown during a prograde P-T path up to upper amphibolite facies conditions (660°C at ~9 kbar) and recorded the burial of the Tachakoucht metavolcanics, while rims composition indicates that the rock recrystallized under higher temperature conditions (800°C at 4-5 kbar). These HT conditions match those for hornblendites igneous emplacement (850°C and 4 kbar) and this event leaded to more pronounced but still limited partial melting (< 10% melting) of the porphyroclastic gneisses. New geochronological data on the migmatitic gneiss (zircon U-Pb dating) constrain the protolith age at 733 ±7 Ma (zircons core) and the HT tectono-metamorphic event at 654 ±7 Ma (zircons rim). *(ii) The Asmlil arc complex* is made of hornblende gabbros and garnet-bearing gabbros intruded under HT conditions by dykes of medium-grained hornblendites, hornblende-gabbros and leucodiorites. These metagabbroic intrusions have been dated at 700 ± 7 Ma (U-Pb zircons). P-T pseudosections were calculated for garnet-bearing gabbros and established that they were recrystallized upper-amphibolite to granulite facies P-T conditions (700-800°C at 11 kbar).This event has been dated at 659 ± 7 Ma (U-Pb rutiles). Preliminary geochemical data of hornblende-gabbros and garnet-bearing granulites portray similar trace geochemical signatures ((La/Sm)N: 0.8–1.6 ; (Nb/La) < 0.46) as studied paleo-arc complexes. These P-T results and new geochemical data argue that Asmlil mafic complex could represent a deep arc root magmas comparable to the deep section of exposed oceanic arcs (*i.e.* Kohistan, Talkeetna). We propose that Iriri and Asmlil units depict the deep-to-shallow sequence of a single Cryogenian oceanic arc (760-740 Ma), as discrete exposures along the southern edge of Anti-Atlas ophiolitic assemblages. Nevertheless, this primary arc has been likely broke up and intruded by subsequent hydrous arc-related magmas under medium- to high-grade P-T conditions (700 to 650 Ma). We interpret this period as an oceanic pre-collision stage when subduction geometry is intensively perturbed (*c.g.* composite subductions, polarity inversion), enhancing production of typical hydrous arc magma that intrudes original arc.

SESSION 29
MARINE GEOLOGY

Using cold-water coral mini-mounds as analogue for giant mound growth: assessment of environmental drivers and anthropogenic impact

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Keywords: Cold-water coral mounds, Lophelia pertusa, palaeoceanography

Abstract

Cold-water coral (CWC) reefs are formed by framework building scleratinians *Lophelia pertusa* and *Madrepora oculata* that baffle sediment and over time, have the potential to develop into large coral mounds of up to 300m high (e.g. Belgica Mound Province). The detailed mechanisms of initiation and build-up of such large CWC mounds are however not yet fully understood. It is therefore essential to study smaller mounds (often termed "mini-mounds") that can be interpreted as earlier growth stages that haven't had the time to coalesce and develop into larger mounds. The FWO Minimound project (2013-2017) aims to investigate CWC mini-mounds within the Bay of Biscay in order to determine the impact of: (1) palaeoceanographic changes related to glacial-interglacial climate change in the last 15 ka, (2) hydrocarbon seepage processes and (3) anthropogenic fishing activities on CWC habitats.
The project targets three minimound provinces: the Ferrol Canyon (Cantabrian Margin), the Guilvinec Canyon (Armorican Margin) and the Explorer and Dangeard Canyons (Celtic Margin). These mini-mounds are fossil and occur at relative shallow depths on the interface between the Eastern North Atlantic Central Water (ENACW) and the Mediterranean Outflow Water (MOW). Contrastingly, most living CWC reefs in this region of the Atlantic, dwell in the deeper MOW depth range, relying on the density and dynamics of this water mass for their food supply. In order to investigate the initiation, growth and demise of CWC mini-mounds, 35 m of USBL guided sediment cores were retrieved from the Explorer and Dangeard Interfluves. We present data of sedimentological, geochemical and palaeoceanographic analyses throughout the cores, coupled with high-resolution geophysical data. Preliminary results indicate that coral growth initiation is associated with a strong shift in sedimentation regime potentially linked to climate driven palaeoceanographic changes of the MOW-ENACW interface.

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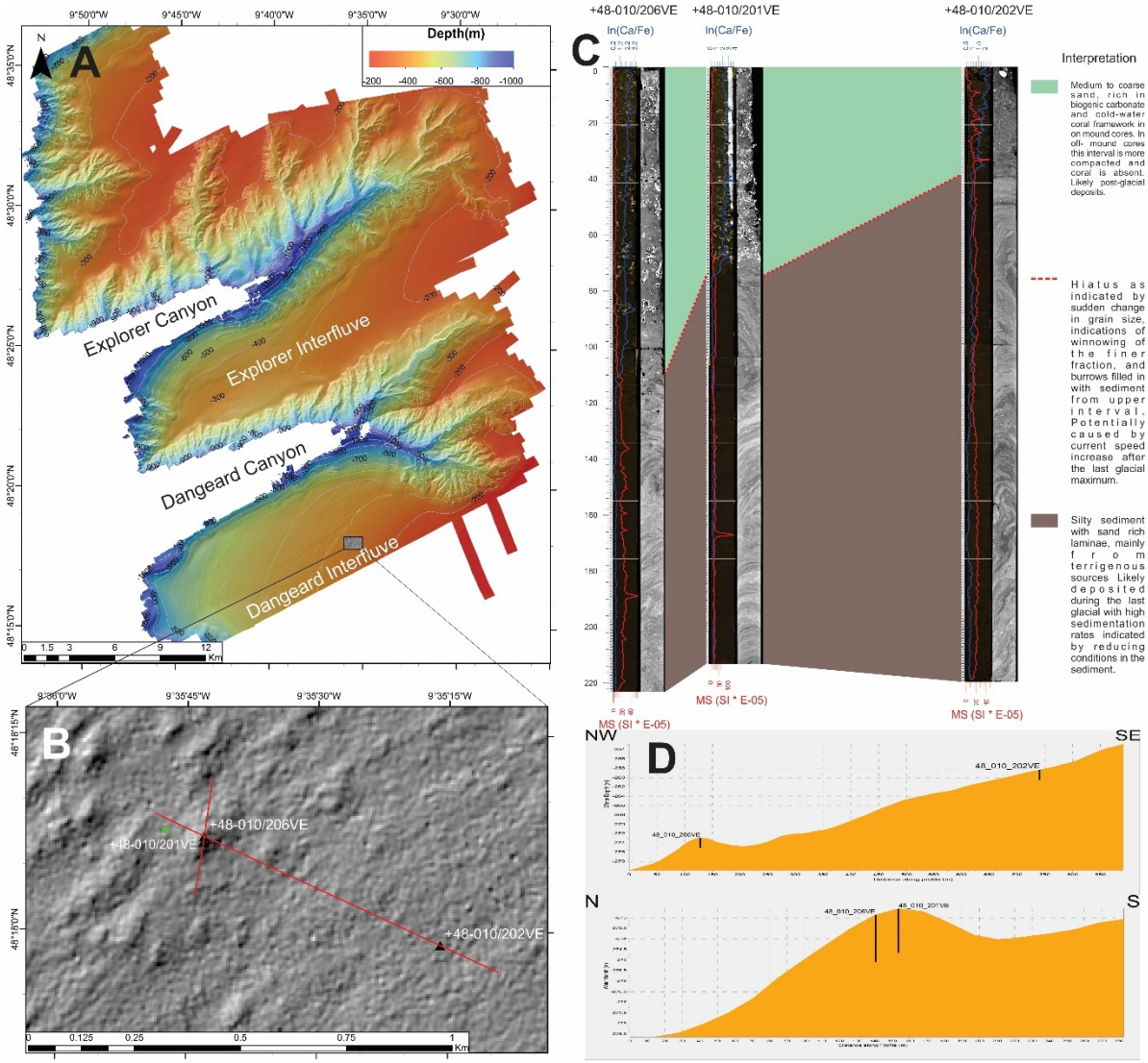

Figure. A: Multibeam bathymetry map of the Explorer and Dangeard Canyons on the Celtic Margin; B: Hill shaded detail of the cored mounds (black triangles) and indications for profiles (red lines); C: Preliminary correlation of sediment cores with core images, CT scans, XRF log-ratios of Ca/Fe (in blue) and magnetic susceptibility (in red); D: bathymetry profiles over the cored mounds.

Pleistocene gravels on the Belgian offshore investigated for composition and provenance, towards a reassessment of the transport models

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Keywords: Hinder Banks, petrography, Jurassic, Paleozoic, Scotland

Abstract

Two sampling campaigns of the stony substrate in the Belgian offshore were conducted in the framework of IWT-SBO project SeArch with the oceanographic research vessel BELGICA in April and November 2014, with the objective of finding sites with potential archaeological remains and determining composition and provenance of gravel. The location of target areas was based on preliminary scanning for stony substrates. Priority was given to areas in between sand banks or in channels, where the Quaternary is known to be thin and Pleistocene paleochannels could be expected underneath the Holocene Southern Bight Formation. A bottom trawler, designed to catch coarse elements - from 6 to 40 cm - from the sea bottom was remade after the original model of Gilson (1900). Seven sites were sampled, producing different quantities of gravel material. Two sampling sites in the Hinder Banks area provided the majority of (encrusted and perforated) gravel samples, derived from thick exposed gravel beds. A sampling site in between the Goote and Akkaert Banks, consisted of in-situ "Paniselian" marly sandstone from the Gentbrugge Formation and some gravel as well.

Nearly 3000 (2995) stones were counted and grouped according to grain size and petrographic class on board of the research vessel. Of these 68% consisted of flint, 17% of (meta)sedimentary and (meta)igneous rocks, 13% of Paniselian sandstones (considered in-situ) and 2% other (from recent-anthropogenic to Cretaceous limestones). More than 1000 (1076) measured above 10 cm, in which the proportion of flint dropped to 50%, for 26% of (meta)sedimentary and (meta)igneous rocks, 22% of in-situ Paniselian (ripped of exposed sandstone layers, hence coming up in platy blocks) and 2% other. Samples of the different rock types are registered in the geo-collection of RBINS and provided thin sections for petrographic analysis. Of particular relevance is the frequent occurrence of Jurassic sandy limestones including Portlandian sandstones, Cretaceous silicified chalks, Paleozoic sandstones and arkoses, metamorphic psammites to pelites, orthogneiss and a suite of igneous rocks. Petrographic mixing and morphology point to a periglacial fluvial transport process of northwestern, British provenance, stratigraphically included in the California Glaciogenic Group, Well Ground Formation (MIS 3). Cretaceous to (mainly) Jurassic rocks suggest the NE English coastal zones as source area, the (meta)sedimentary rocks suggest the Scottish Midland Valley, the orthometamorphic and igneous rocks the Scottish Highlands, as none of the diagnostic Baltic igneous rocks are present. These preliminary results are not in line with recent ideas about sediment fluxes in the North Sea Basin, but confirm earlier petrographic investigations both on land and offshore in Belgium and the UK.

The significance of contourites in marine palaeoenvironmental studies

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Keywords: drift, bottom current, cold-water coral, physical oceanography, marine geophysics

Abstract

Contourite drifts are sedimentary deposits in oceanic or lake basins, which are influenced by an alongslope bottom current. Behind this rather straightforward definition hides a wide variety of complex environmental settings, as well as the possible diagnostic criteria. Although the contourite paradigm is not new to marine sedimentology, being nearly as old as the turbidite paradigm, it has only received the deserved attention some 2 decades ago due to a renewed interested due to technical and analytical developments in palaeoceanography and marine geophysics, as well as a growing awareness of its economic potential. In 2014, a total of 117 contourite drifts were identified, but this number is steadily growing. Still, the impact and occurrence of these deposits remains underestimated and understudied, which is probably due to a low awareness of its diagnostic criteria and applicability. Admittedly, the further progress is made in understanding these deposits, also more complex questions arise. Here we will highlight some exemplary issues that may be of application for the Belgian scientific community.

In the first place, contourites and palaeoceanography are closely tied to each other. The composition and dynamics of the bottom water masses lying at the base of the bottom current flow may be reconstructed using geochemical analyses or in studying seismic profiles through the sediment drift. However, still a lot needs to be understood how physical oceanographic processes actually affect the sedimentary record. Therefore, a close(r) collaboration with physical oceanographers and modellers becomes an essential step in future studies. Secondly, contourites and deep-water ecosystems nearly go hand-in-hand. For example, the presence of cold-water coral mounds can almost be used as a clear indication of contourites in the near vicinity. The bottom currents are needed to sustain the ecosystem in terms of food particle delivery, but also to keep them free from sedimentation. On the other hand, larger biogenic constructions may increase the ambient hydrodynamic behaviour through obstacle-related enhancing of the bottom current flow. This knowledge may also be crucial in studies of "ancient" marine deposits which are now outcropping on land sections. Whereas the marine environment hosts many possibilities to study contourites, the land sections are even more complex due to their poor accessibility and analytical constraints. Therefore, the translation of the present diagnostic criteria towards land sections necessitates further attention… and maybe this means that during the next Geologica Belgica congress contourite deposits in Belgium will be announced?

Contourite deposits in the El Arraiche area, southern Gulf of Cadiz

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Abstract

The El Arraiche area is situated in the southern part of the Gulf of Cadiz, between 35° and 35°45' north and 6°30' and 7°15' west. This area contains nine mud volcanoes, thousands small cold-water coral (CWC) mounds, several small contourite drifts and two tectonic ridges. CWC mounds are present both on top and at the foot of the Pen Duick Escarpment, but recent multibeam and seismic data indicate the ubiquitous presence of small mounds both beneath and on top of the seafloor.

All of the topographic obstacles in this region interfere with the contourite deposits, e.g. the Quaternary Pen Duick drift displays pinch-out due to uplift of the Pen Duick Escarpment, a Christmas-tree structure due to the outflow of mud from the nearby Gemini Mud Volcano and CWC mounds deflect the pathway of the moat [1]. The Renard South drift is much smaller (a moat of 2 km long) and surrounded by uplifted sediments, while the Renard North drift has a deeply incised moat. The location of the different drift deposits can be explained by the steepness of the slope along which they are deposited: slopes >12° are associated to drift deposits, while smaller slopes are bordered by uplifted hemi-pelagic deposits. These steeper slopes may cause increased bottom currents, which in turn enhance basal erosion deposition on the side, creating the contourite deposits.

Nutrient data from the bottom water masses indicate that the region is located at the boundary between (modified) Antarctic Intermediate Water and North Atlantic Central Water. Both water masses flow from south to north and are deflected by the topographic obstacles. Coriolis deflection ensures that the bottom currents remain at the base of the topographies. The boundary between the two water masses also creates internal tides, which are east-west aligned. These semi-diurnal tidal currents can be responsible for the contourite deposits along the mud volcanoes, as west-to-east currents are inferred from the orientation of their moats [2].

References:

[1] Vandorpe et al. (2014) Marine Geology 349: 136-151
[2] Vandorpe et al. (In Press.) Marine Geology

SESSION 30
CRETACEOUS – EOCENE CLIMATES

Isotopes and elements from Mollusk shells: Tracing Cretaceous seasonality

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Keywords: Bivalves, Seasonality, MicroXRF, Stable Isotopes, Cretaceous

Abstract

Bivalve mollusks have been important producers of calcium carbonate since their origin in the Cambrium period. They are abundant in the fossil record as well as in the present day ecosystems. Their long evolutionary history and the great fossilization potential of their shells makes bivalves ideal targets for paleoenvironmental reconstruction. The calcium carbonate in bivalve shells is known to faithfully record proxies for the conditions of shell formation and can therefore be used to study paleoclimate in deep time. The incremental growth of bivalve shells allows for studying these paleoenvironmental proxies on a high temporal scale, which has led to the reconstruction of seasonal changes in deep time.

In this study, elemental abundances are measured in Cretaceous Rudist bivalve shells as well as modern bivalves in high spatial resolution using the new micro X-Ray Fluorescence (microXRF) scanner at the AMGC group of the Vrije Universiteit Brussel. This state of the art microXRF scanner allows for fast, non-destructive and statistically accurate measurements of elemental abundances in fossil material. It is faster and less destructive than other methods for obtaining elemental abundances and is therefore a promising tool for acquiring high-resolution (25 µm) proxy data on valuable samples that would not be available for destructive sampling.

Seasonal changes in elemental abundance ratios from the microXRF are interpreted together with profiles of stable carbon and oxygen isotope ratios through the same shells. Results from fossil shells are compared to their modern counterparts in order to validate paleoenvironmental proxies. Differences in absolute values of reconstructed environmental parameters as well as in their seasonal fluctuations between modern and fossil bivalve species are discussed, as well as their implications for the Cretaceous paleoenvironment of the Rudists. Finally, results of the novel microXRF method are compared with those from other methods for elemental analysis, and the accuracy and repeatability of the method for elemental analysis in carbonates is discussed.

Deep-sea benthic foraminiferal faunal and isotopic records of the Latest Danian Event from Walvis Ridge (ODP Site 1262), Southern Atlantic Ocean

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Keywords: Benthic foraminifera, Walvis Ridge, Stable isotope, Latest Danian Event, ODP Site 1262. Paleocene

Abstract

During the early Paleogene, the marine ecosystem was severely disturbed by several transient (<200 kyr) hyperthermal events, of which the Paleocene-Eocene Thermal Maximum or PETM (~56 Ma) was the most prominent one. Since 2000, a number of other Paleocene and Eocene events have been discovered. The Latest Danian Event (LDE) is characterized by a >0.7‰ negative benthic foraminiferal CIE in various Tethyan and deep-sea secions. This raises interesting research opportunities, as the deep-sea benthic foraminiferal faunal record of Paleocene events, such as the LDE (~62.25 Ma), is particularly relevant to the broader understanding of hyperthermals. In this study, we present new benthic foraminiferal faunal and stable isotope data from Walvis Ridge ODP Site 1262 (Atlantic Ocean) in order to reconstruct the prevailing seafloor conditions at ~3000 m water depth. The studied 9 m interval covers ~1 Myr and includes the 200 kyr of the LDE. The high percentage of planktic foraminifera (on average 99.2%) indicates good carbonate preservation.

Stable isotope analyses on the benthic foraminifer *Nuttallides truempyi* show a ~0.9‰ $\delta^{13}C$ shift at ~62.19 Ma. A concurrent ~0.8‰ $\delta^{18}O$ excursion indicates a ~3°C temperature rise, ~1°C more than at Shatsky Rise. A second $\delta^{13}C$ peak is apparent at ~62.09 Ma, coinciding with a second negative $\delta^{18}O$ excursion of 0.5‰, an XRF Fe peak and decreasing $CaCO_3$ percentages. Also the ODP Site 1209 (Shatsky Rise) record shows these double Fe, $\delta^{18}O$ and $\delta^{13}C$ peaks. This feature is shared with some early Eocene hyperthermals, like ETM-2/H1-H2 and I1-I2, and might point to a common origin as these events.

The studied interval was characterized by a highly diverse assemblage. *Gyroidinoides octocameratus*, *Paralabamina lunata*, *Siphogenerinoides brevispinosa*, *N. truempyi* and *Gavelinella beccariiformis* each reach an average relative abundance of 5-10%. No faunal turnover is associated with the onset of the LDE at Walvis Ridge. This contrasts with results from other events, such as ETM2 at Bay of Biscay, where smaller isotope excursions are associated with more prominent faunal change. At the end of the LDE, absolute abundances of *P. lunata* increase; abundances of other taxa remain constant. Throughout the whole interval, there is a gradual decreasing abundance of *G. beccariiformis* and *N. truempyi*, combined with a slightly increasing abundance of *S. brevispinosa*, possibly indicating a gradually rising food flux. Although the isotope excursions are slightly more prominent at Walvis Ridge than at Shatsky Rise, the benthic fauna seems unaffected during the LDE at Walvis Ridge.

A climatic change at the Danian/Selandian boundary: increasing weathering fluxes

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Keywords: *Danian-Selandian boundary, Paleocene, gamma-ray spectrometry, smectite/kaolinite ratio, climate*

Abstract

The abandoned Loubieng quarry located close to Pau (France) encompasses the Danian/Selandian boundary (DSb). The Danian consists of an alternation of almost horizontally-bedded limestone layers and tiny marl intercalations. Marls with few thin limestone beds are observed in the Selandian. A very short-term hyperthermal event at the very base of the Selandian is marked by a short-term $\delta^{13}C_{org}$ negative excursion. This event is followed by a long-term cooling interval highlighted by a decoupled carbon isotope event (Storme et al., 2014). These events have been observed in three sections, which belong to the Atlantic (Zumaia and Loubieng) and the Tethys (Sidi Nasseur, Tunisia) realms. A detailed multi-proxy approach is under study on the Loubieng section aiming at unravelling how this cooling event does affect other proxies across the DSb. Clay mineral analyses by XRD reveal an assemblage dominated by smectite, illite, kaolinite and traces of mixed layers (illite-smectite). The amount of kaolinite increases during the Danian, reaching 15-20% at the end of the Danian, and decreases progressively during the basal Selandian. The smectite percentage increases inversely during the Selandian reaching 94 % ten meters above the DSb. The smectite/kaolinite ratio could highlight a change from warm climate with alternating wet and dry seasons in the Danian towards a warmer humid climate with heavy precipitations (rainfalls) before and across the DSb followed by a progressive return to dryer conditions upwards in the Selandian. The gamma-ray spectrometry highlights a progressive increase in K and Th contents from the Danian to the Selandian. The positive and good correlation between K and Th values suggests a primary detrital influx of fine-grained minerals. The input of detrital minerals seems to follow a rhythmic evolution during the Danian with a clear enhancement starting a few meters before the DSb towards the highest values in the Selandian. This enhanced detrital influx is also highlighted by the magnetic susceptibility data and represents an increased weathering input during the basal Selandian. The calculated proportions of U_{authig} and U_{det} reveal four intervals during the Danian where the proportions of U_{authig} are higher. The U/Th ratios indicate dysoxic to anoxic conditions during the three first intervals. The last interval and most of the section correspond to oxic conditions. These data reveal that the paleoredox conditions were only restricted at the base of the section.

Early Eocene climate changes in the North Sea Basin: a Belgian perspective

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Keywords: hyperthermals, Eocene, Ypresian, Belgium, North Sea

Abstract

Abrupt climate changes, involving threshold crossings towards new climate states, frequently occurred in the past with the early Eocene rapid global warming events (hyperthermals) as the most conspicuous. The environmental impact of these hyperthermals has been primarily studied in deep-sea sites under comparably stable conditions, while their impact on shallow-marine ecosystems is relatively unexplored, specifically for the less prominent hyperthermals that occur after the Paleocene-Eocene Thermal Maximum (PETM). Here we present the lithologic, biotic, and geochemical expression of the successive hyperthermals as recorded in the classical Belgian Ypresian Clays, deposited in shallow-water setting at the southern edge of the North Sea Basin.The stable isotope record ($\delta^{13}C_{org}$) indicates the presence of distinct facies changes within a succession of multiple CIE's in the Belgian Ypresian deposits. These levels are biostratigraphically correlated with coeval isotope excursions at DSDP site 550 (Gulf of Biscay) using a regional mid-latitudinal nannoplankton subzonation. Major regional biotic events and changes in depositional settings seem to relate to these isotope events. During the H1/H2-CIE's (Elmo/ETM-2) a lowermost incursion of planktic species occurs, coincident with the establishment/preservation of calcareous benthic foraminiferal faunas, marking the end of stagnant corrosive bottom-waters. The I1/I2-CIE's mark the consistent occurrences of planktic foraminifera and incursion of *Nummulites*. This establishment of a well-diversified foraminiferal fauna is indicative of an improved marine connection with the Atlantic Ocean. During the J and K-CIE's (X-event/ETM-3), a temporary major influx of characteristic planktic foraminifera (*Subbotina patagonica*) and an acme of *Asterigerina bartoniana kaasschieteri* are recorded. The latter is considered indicative of the vicinity of a shallow tropical sea and may thus represent a basin-wide zonal expansion of its life habitat or massive downslope displacement. The onset of the Early Eocene Climatic Optimum (EECO) probably coincides with the basin-wide deposition of fine-grained sediments, marking the beginning of a new distinct foraminiferal fauna. Although Early Eocene hyperthermals in shallow-water sequences still need to be fully characterized relative to regional background conditions, our results seem to indicate that also these less extreme hyperthermal events had short-term impacts on the development of regional shallow-marine ecosystems, although the evolutionary impact is very limited. These regional lithologic and biotic expressions of early Eocene climate evolution thus reflect dissimilar paleoenvironmental responses to short episodes of global warming in a greenhouse world. Our data also emphasize the potential application of hyperthermal event stratigraphy to correlate over a wide range of environmental settings in the North Sea Basin.

FRIDAY January 29th

KEYNOTE

Physiological and morpho-functional (secondary) adaptations of Amniotes to an aquatic life

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Keywords: Amniote, Aqualic lifestyle, Adaptation, Functional, Physiology

Abstract

Extant aquatic non-avian reptiles are scarce. However, they were much more diverse in the fossil record. As for aquatic mammals and birds, they are numerous in both the fossil and modern record. Indeed, secondary return to an aquatic life has happened several times independently in various amniote lineages (Reptilia, Mammalia), which lead to numerous convergences (e.g., hydrodynamic body, limb transformation into flippers, modification of sense organs, reproductive mode, diving adaptations, inner bone structure specializations). The various adaptations vary pending on the degree of adaptation to an aquatic life, between shallow water taxa still able to occasionally locomote on land and open-marine forms totally independent from the terrestrial environment, but also between surface swimmers and deep divers, freshwater and marine forms… As a consequence, despite convergences, there is a high diversity within aquatic amniotes in shape, size, physiology, swimming mode… This is also naturally explained by the fact that the types of adaptation, as any biological features, are the outcome of the combination of phylogenetic, functional and structural constraints.
The various amniote lineages/taxa that secondarily adapted to a marine life (e.g., cetaceans, sirenians, mosasaurs, sauropterygiens, ichthyosaurs, etc.) will be presented in their geological context and their peculiar features introduced. The importance of the K/Pg boundary will be highlighted in the change from a reptile-dominated to a mammal-dominated open ocean habitat. Results from various types of studies, such as morphological, isotopic, microanatomical, and histological ones, will enable to discuss the various locomotor (swimming abilities) and physiological (growth speed, metabolism) adaptations of these numerous aquatic amniotes and how they interact. It will also highlight some new research directions.

SESSION 31
TERRESTRALIZATION AND RETURN TO THE SEA – MESOZOIC MAMMALS

(Sub-)Fossil whale barnacles (Coronulidae) provide indirect evidence about the presence of baleen whale populations in the southern North Sea and about the routes followed towards their subtropical breeding grounds

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Keywords: North Sea, baleen whales, migration routes, epibiont barnacles, (sub-)fossil record

Abstract

The return to the aquatic environment of small-sized even hoofed mammals more than 50 My ago resulted, after about 15 My of evolution, in the appearance of echo locating toothed whales (Odontoceti) on the one hand and of filter-feeding baleen whales (Mysticeti) on the other hand. In the course of their evolutionary history, mysticetes progressively acquired a series of morphological, physiological, and behavioural traits corresponding to adaptations to bulk filter-feeding (benthic feeding in gray whales, gulp feeding in rorquals, and skim feeding in right whales). In addition, many extant mysticetes are known to repeatedly undertake long migrations from their cold feeding grounds in the Arctic and Southern oceans to warmer (subtropical) areas where they breed and give birth. The history of the acquisition of a migrating behaviour is extremely difficult to investigate based on the baleen whale fossil record and data demonstrating past migratory behaviour is virtually absent. Epibiont commensal barnacles (Crustacea, Cirripedia, Coronuloidea) first colonised slow moving turtles. Later they spread to sirenians (dugongs and manatees) and sea snakes, and finally they adapted to life on whale skin. Nowadays, each barnacle species has its favourite host species. Monitoring the fossil and subfossil record of the epibiont commensals of northern hemisphere mysticete whales gives us clues about the routes the migrating whale populations followed to their southern winter breeding grounds and possibly also about the size of these populations. Indeed, fossil (Middle Pliocene) and subfossil (about 400 BC) whale barnacles from the genera *Cryptolepas*, *Cetopirus* and *Coronula* recently discovered in the Scheldt estuary (Dutch coast) and in the Antwerp region (Belgium) prove to be useful tracers, providing indications about the former presence in the southern North Sea, and especially in the Scheldt estuary, of their respective hosts: the gray whale, the right whale and rorquals, all absent from the North Sea now (except for *Balaenoptera acutorostrata* a species that is not infected by Coronulidae).

Reappraisal of the fossil seal *Phoca vitulinoides* from the Neogene of the North Sea Basin, with bearing on the geological age, phylogenetic affinities, and locomotion of a diminutive Miocene phocine species

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Keywords: Miocene, North Sea Basin, Phocidae, Phoca vitulinoides, Pusa

Abstract

Among secondary aquatic tetrapods, pinnipeds are among the few taxa to retain the capacity to move on land. Hence, pinnipeds can be regarded as a group which' transition from land to sea is still in progress.

Ever since the initial establishment of the fossil species *Phoca vitulinoides* by Van Beneden in 1871 and its more detailed description in 1877, this phocid (Pinnipedia, Phocidae) remained largely unstudied until now. More recently, the validity of *P. vitulinoides* as a species was questioned, despite the fact that the number of specimens assigned to this taxon substantially exceeds all other Neogene fossil seal taxa from the southern North Sea Basin. Hence, a reinvestigation is needed.

Spurred by the recent acquisition of several partial postcranial skeletons by the Royal Belgian Institute of Natural Sciences, the current study clarifies multiple aspects of our knowledge of *P. vitulinoides*.

First, the stratigraphic interval occupied by the species is redefined. While originally assigned to the –currently disused– early Pliocene 'Scaldisian' stage, the species is now identified in upper Miocene layers. At least part of the previously recognized Pliocene records may in fact be isolated bones reworked in the gravel at the base of the Zanclean Kattendijk Formation.

Second, an exhaustive cladistic analysis of *P. vitulinoides* nests the species among species of *Pusa* (including the ringed, Caspian, and Baikal seals). While the exact position relative to *Pusa* spp. remains poorly resolved, it is clear that *P. vitulinoides* is more closely related to *Pusa* than to *Phoca.* While only tentatively proposed in the past, this assignment is robustly supported in the current analysis. The smaller size, shallow gluteal fossa of the innominate, and highly raised greater trochanter of the femur are the most prominent characters distinguishing *P. vitulinoides* and extant species of *Pusa* from *Phoca.*

Finally, the renewed anatomical description reveals important osteological characters correlated with limb musculature and aquatic locomotion. A large humeral head, weakly developed lesser tubercle compared to the greater tubercle, and deep insertion scars for the supraspinatus and infraspinatus muscles on the humerus suggest an increased mobility and a more intensive, and less derived, use of the forelimb for propulsion as compared to most other phocines. Similarly, a greatly enlarged greater trochanter of the femur, a strongly concave patellar facet on the femur, and a strongly developed popliteal surface on the tibia suggest an intensive use of the hind limb during swimming.

The fossil record as a tool for studying the convergent evolution of deep diving abilities in beaked whales and sperm whales

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Keywords: deep diving, beaked whales, sperm whales, convergent evolution, fossil record

Abstract

Occurring multiple times in the evolutionary history of tetrapods, the return to an aquatic environment resulted in the colonization of varied environments, from oceanic tropical regions to freshwater systems and from polar seas to upwelling-related temperate regions. Adding a vertical component further increases this environmental diversity, with bentho-pelagic to benthic areas visited by members of different tetrapod clades. Although some pinnipeds, sea turtles, and even a few seabirds are known to regularly undertake deep dives, the most iconic deep divers are odontocetes (= echolocating toothed whales). Together with a few true dolphins, beaked whales (family Ziphiidae, 22 species) and the sperm whale (Physeteroidea, *Physeter macrocephalus*) perform some of the deepest (record up to 3000 m) and longest (over 2 hours) dives, to catch benthic and bentho-pelagic squid and fish.

As the paleontological record of beaked whales and sperm whales progressively improves (from the middle Miocene and latest Oligocene respectively), could the available fossils provide clues about the timing, context, drivers, and impact of this major ecological shift?

Different datasets are currently used. First, phylogenetic bracketing allows inferring ecological traits for extinct species of crown Ziphiidae; it results in a tentative middle Miocene minimum age for the acquisition of a deep diving ecology in the latter. Secondly, skeletal morphology gives useful indications about the feeding and locomotion abilities of extinct beaked whales and sperm whales (e.g., presumably macroraptorial species among the latter), to be compared with the suction feeding and deep diving skeletal specializations of extant forms. Furthermore, the discovery of fossil crown ziphiids in deep-sea deposits vs. stem ziphiids in shelf deposits is an additional indication for a shift occurring at around the stem-crown transition. Finally, such contrasted fossil records can be combined with data on the associated faunas and paleoenvironments, revealing competitors and potential prey (together with the analysis of extremely rare fossil evidence of predator-prey relationships).

Although the analysis of bone pathologies related to decompression syndrome (i.e. avascular osteonecrosis) did not yet reveal any pattern among fossil beaked whales and sperm whales, several other research fields may help further elucidating this process: bone histology (in relation with locomotion and buoyancy) and stable isotope analyses (C, O) of mineralized tissues (bones and teeth).

Phylogenetic signal or functional analogy in cochlear shape of Mysticeti

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Keywords: Miocene, taxonomy, 3D reconstruction, geometric morphometrics, Northern Europe

Abstract

The Miocene and Pliocene baleen whale fauna of Northern Europe is highly diverse. Well known is the large Van Beneden collection at the Royal Belgian Institute of Natural Sciences. The inner ear morphology of mysticetes is rather conservative and its taxonomic significance is widely recognised (Steeman 2010, Fordyce and Marx 2013, Gol'din and Steeman 2015). µ-CT observations including the famous but also problematic Van Beneden collection (Steeman 2010, El Adli et al. 2014) and newly discovered ear bones from the Middle Miocene of the German Niederrhein area reveal clearly distinguishable characteristics. Landmark-based geometric morphometrics of the cochlear region offers a potentially efficient approach to elucidating the taxonomic confusion and to enhancing our knowledge about hearing strategies. We extracted cochlear shape data from CT scans by placing equally-spaced landmarks along the complete length of the bony lamina of 38 specimens of fossil and modern mysticetes. For comparison modern odontocetes, felids, rodents, and lagomorphs were used. Statistical analysis of shape information suggests that various distinctive cochlear shapes exist among mysticetes, e.g. showing more narrow or loose coiling and higher or lower cochlear height. Our results thus look to be promising for future phylogenetic as well as functional studies.

SESSION 32
RESERVOIR PROPERTIES

The behaviour of Westphalian mudstones both as source and reservoir rock (Campine Basin, NE Belgium)

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Keywords: Carboniferous, hydrocarbon potential, nitrogen sorption, illite, kerogen type

Abstract

The Westphalian deposits in the Campine Basin consists of coal deposits, sandstones and mudstones which were deposited in cyclic sequences. Sedimentation was driven by internal basin dynamics, glacial and interglacial cycles and the northward migrating Variscan deformation front. In the past few decades many research has been performed on the hydrocarbon potential of the coal deposits and its capability to produce coal seam gas. However, this aspect has never been examined for the surrounding mudstones, despite many of them can be considered as organic-rich. Therefore, in this study the source rock and reservoir qualities of these mudstones were studied by means of TOC measurements, Rock-Eval pyrolysis, quantitative X-Ray Diffraction, subcritical gas adsorption with nitrogen and high-pressure methane sorption.

In general these continental shales have a high clay content, with illite being the most dominant mineral. Based on the TOC and S2 values, which show averages of respectively 5% and 13 mg/g, the source rock potential can be considered as promising. Nearly all the samples are within the oil window. The kerogen content reflects a type II-III mixture, indicating that these shales are not solely gas-prone, but are also capable of producing condensates. The storage of hydrocarbons in a shale reservoir relies on two mechanisms, i.e. the storage in the pore space between mineral grains or organic particles or the sorption onto a substrate surface. Pore characteristics, such as micropore volume and surface area, were measured by means of nitrogen sorption at 77K and shows a strong correlation with the amount of illite in the studied samples. Despite that the samples are within the oil window and contain kerogen type II, the amount of organic matter in the sediment did not seem to affect the pore characteristics. The sorption capacity on the other hand seems to be correlated to the amount of organic matter in the sample, but showing no correlation with the illite content. The amount of methane sorption at elevated temperatures of 45°C is comparable to other shale deposits of marine origin (Gasparik *et al.*, 2012).

In summary the continental mudstone deposits of the Westphalian in the Campine Basin show a promising source rock potential. Due to its kerogen type II-III mixture they likely produced gas and condensates which can be stored in the illite dominated pore network or became sorbed onto the surface of organic particles.

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Burial dolomite in the Variscan foreland fold-and-thrust belt of N-Spain: examples from the Bodón Unit

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Keywords: dolomitization, foreland fold-and-thrust belt, reservoir quality, isotope mass spectrometry, geochemistry

Abstract

The Variscan foreland fold-and-thrust belt (FFTB) of N-Spain comprises alternating successions of carbonates and siliciclastic rocks, with the occurrence of mud-dominated carbonate platforms during the Namurian stage. Late Variscan extensional tectonics influenced the FFTB (due to the creation of a secondary orocline) as well as Mesozoic extension (due to the opening of the northern Atlantic Ocean and Bay of Biscay) and Paleogene compression (due to the Alpine Orogeny). In the Bodón Unit (i.e. one of the structural units of the FFTB), the Namurian platforms have been epigenetically dolomitized. The dolomite geobodies have been investigated geochemically and are interpreted as hydrothermal products of the Late-Variscan extension (Gasparrini et al., 2006). They range from fracture-related to massive and display wide variations in dolomite textures and pore types. A contrasting type of dolomite occurs along a Variscan thrust in the eastern part of the unit and might imply a late fluid event associated with the Alpine compression. The first aim of the current study is gaining more insights in the genesis and diagenesis of the dolomite geobodies. New outcrops, as the one along the Variscan thrust, can give more clues into the origin and circulation mechanisms of the dolomitizing fluids as well as into diagenetic processes affecting the dolomite geobodies (e.g. dedolomitization and karstification). Fieldwork indicates that the latter processes can positively affect the reservoir characteristics of the geobodies. Moreover, the study area is used to apply new and innovative methods to better constrain the temperature and nature of the dolomitizing fluids. Clumped isotope thermometry is applied in combination with Rock-Eval pyrolysis. Preliminary data suggest lower dolomitization temperatures (100-140°C) compared to the temperatures experienced by the host rocks (120-190°C). An origin other than “hydrothermal” could thus be argued. Mg-isotope geochemistry will be applied to better understand the nature of the dolomitizing fluids. The last aim is assessing the reservoir quality of the dolomitized carbonate platforms. Fieldwork indicates that the porosity of the different dolomite textures strongly varies. Fracture-related dolomite chimneys are tight. Porosities up to 10 % are found in dolomitized microbial mounds (implying a strong influence of the platform lithofacies) and in the dolomite geobodies along the Variscan thrust. The quality of outcrops in the Bodón Unit allows a detailed study of dolomite occurrences in a Variscan FFTB. The study area provides analogues for the Variscan FFTB in S-Belgium, where comparable dolomite textures have been reported from boreholes (Nielsen et al., 1998).

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Hydrothermal diagenetic evolution of Upper Cretaceous Bekhme Formation, NE Kurdistan, Iraq

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Keywords: *Hydrothermal, Calcretization, Hot-cold fluids, Hydrocarbon migration, Bekhme Formation*

Abstract

Partly dolomitized Upper Cretaceous Bekhme Formation is studied from three outcrops (Spelek, Sulauk A and B) integrating fieldwork, petrography, CL, SEM, geochemistry and fluid inclusion microthermometry. Petrological study indicates that early diagenetic dolomites frequently formed small-medium size, planar-s crystals. Saddle dolomites and blocky calcites were related to an aggrading process associated with hydrothermal fluids, leading to geodic dolomites and calcites during mesogenesis. An ultimate telogenic process with calcretization of the rocks ended the diagenetic evolution of the Bekhme Formation in Spelek. This section is highlighted by strongly depleted $\delta^{18}O$ (-6.3‰ to -17.5‰) and $\delta^{13}C$ (2.3‰ to -9.7‰) values. The $\delta^{18}O$ values in Sulauk A & B sections are less negative with a smaller range, their $\delta^{18}O$ and $\delta^{13}C$ values range from (-6.7‰ to -10.2‰ and 0.0‰ to 2.1‰, respectively). Microthermometry results point out that homogenization temperatures in the hydrothermal minerals vary from 85°C to 190°C in the Bekhme Formation. The three sections record a considerable range of salinity (15.8 to 25% eq. wt%NaCl-zone I) suggesting that calcite and dolomite precipitated from basinal brines. As these high salinity fluctuations occur within the same range of homogenization temperatures in the hydrothermal minerals, a fault-derived hot fluid channeled through the Bekhme Formation after passing through two oil source rocks is proposed. In contrast to the Sulauk sections, the Spelek section, in addition to be fed by high salinity fluids, is characterized by a very low saline fluid (0.2 to 2.6 eq.wt.% NaCl-zone II). This zone is associated with secondary single phase liquid oil or liquid aqueous inclusions, which is consistent with the late diagenetic calcrete products. Its $\delta^{18}O$ and $\delta^{13}C$ values are also depleted. These data are consistent with the presence of meteoric water under low temperature (< 50°C). Two upward and laterally hydrocarbon migrations affected the Bekhme Formation. The first migration is inferred from 2-phase (liquid+vapour) and 3-phase (liquid oil+ aqueous liquid + vapour) inclusions trapped in carbonates coeval with the hydrothermal fluids. The second migration, only recorded in the Spelek section, is related to single phase secondary oil inclusions, thus with low temperature inclusions. This study highlights two different diagenetic styles. The first started with early dolomitization of a former matrix (eogenesis) and ended with the opening of fractures by saddle dolomititic and calcitic precipitation in a shallow deep diagenetic setting (mesogenesis). The second style, only present in the Spelek, suffered a telogenetic evolution with pedogenic products. These results could have broader implications at a regional scale in order to consider the Bekhme Formation as a potential oil reservoir despite diffuse hydrocarbon seepage can also occur along the fault-controlled hydrothermal dolomitization.

Seismic of a shallow-lacustrine Delta in the Southern Huanghua Depression, Eastern China

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Keywords: Shallow lacustrine Delta, Seismic sedimentology, horizon slice, Southern Huanghua Depression, Eastern China

Abstract

A shallow-lacustrine delta, which is less than tens of meters deep, usually is characterized by abundant thin channel sands, as document from previous studies (Postma, 1990; Zhou 2013). On account of these widely distributed and overlapping sand bodies, core samples and logging data only provide limited “point data” to analyse the sedimentary features and geomorphology of the delta. This paper discusses the feasibility of seismic sedimentologic methods to study the models of a shallow-lacustrine delta and how it changed over geological time, illustrating a most favorable reservoir of the study area.

The Huanghua Depression is a NE-SW trending Cenozoic rift basin within Bohai Bay Basin Groups, Eastern China. The study area lies in the uplift area of southern Huanghua Depression. Core samples show the delta mainly consists of light grey fine-grained sandstones and purple mudstone, revealed an oxidized shallow-water environment. The delta was mainly developed within the Paleocene Kongdian Formation. Within these layers, typical sedimentary structures of channels such as erosional surfaces, lag deposits, parallel bedding and trough cross-bedding are shown. The geophysical downhole logging data, using sonic and gamma-ray traces, shows that channels are the leading electrofacies.

Seismic sedimentology is the combination of seismic lithology and seismic geomorphology to study sedimentary rocks and their genetic processes. Within the 3D seismic data block, each layers was divided into several geologic time-parallel groups. Horizon slices are used to display the seismic attributes on the geologic time surfaces of these groups. The total of 72 horizon slices shows that the shallow-lacustrine delta was developed continuously in the Kongdian Formation within nearly 700 meters. In addition, at the bottom of the Kongdian Formation, some patch-shaped beach bars were developed. The sand bodies of the channels trend into a NE-direction as bandings. From the bottom to top, the scale of the delta changed from small to large, and small again. Correspondingly, the geomorphology of the channels changed from anabranched to anastomosing, and anbranched again. The width of the anastomosing channels is from 600 m to 1000 m. The average thickness of the sand bodies is 4.5 m. The anabranched channels are about 500 m to 800 m wide. The average thickness of the sand bodies here is 2.4 m. These quantified data not only assist in improving the sedimentary model of the delta, but also help to analyse any palaeoclimatological variations. The anabranched and anastomosing channels may respectively illustrate drought and humid conditions.

SESSION 33
POSTERS

REGIONAL GEOLOGY

GEOARCHEOLOGY, GEOHERITAGE, GEOEDUCATION

Session 33 Posters

REGIONAL GEOLOGY

Karst subsidence in the Iguanodon Sinkhole, Bernissart, Belgium. Evidence for active collapse processes during the Lower Cretaceous

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Keywords: Karst subsidence, Lower Cretaceous, Iguanodon Sinkhole, Bernissart, Belgium

Abstract

Archive documents and data from the 2003 drilling program in the Iguanodon Sinkhole show a thickening of the Mesozoic formations in (and above) the sinkhole relative to adjacent areas. Thickening is maximum for oldest deposits and decreases upwards, which is consistent with the fading out with time of karst subsidence due to anhydrite dissolution in Visean strata concealed at depth. A more detailed analysis shows that the iguanodon-bearing strata at the base of the Sainte-Barbe Fm. (Lower Cretaceous) deposited shortly after the sinkhole reached the surface, which raises the question of the possible influence of collapse processes on the formation of the dinosaur deposit. The Iguanodon Sinkhole was soon considered “unusual” as described in earlier mine reports. Contrarily to other known sinkholes in the Hainaut area, this sinkhole is widening- and not narrowing-upwards or cylindrical. In addition, the NW wall of the sinkhole is offset vertically by ca. -30 m relative to the opposite SE wall, which indicates the presence of a fault, likely coinciding with the highly-fractured zoned called “brouillage” by coal miners. Other similar fractured zones occur in the Bernissart area and probably relate to the boundary between blocks that were subjected to different subsidence rates due to heterogenous karstification at depth. Strong asymmetry of the breccia infill, which is flanking the southeast wall of the sinkhole, could then be explained by the occurrence of a fault scarp. Pinching out of a few clay strata in the Lower Cretaceous infill are observed to the west as well as a few cm-thick slump intervals. The former sedimentary structure could be interpreted by slumping as well but also by sedimentation in a narrowing basin, which is consistent with the evolution of subsidence processes when a sinkhole reaches the surface. At a smaller scale, abundant synsedimentary, listric micro-faults are observed in the finely laminated clay. Their morphology, with frequent rollover and back-folding provides evidence for synsedimentary horizontal stretching of the lake bottom, which may be interpreted as due to the presence of localized areas with strong subsidence.

The importance of the pseudonodules in sedimentology : a review and some conclusions based on the study of the pseudonodules of the Roc de la Tour (Rocroi Inlier)

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Keywords : Pseudonodule, liquefaction, hydroplasticity, gravitationnal movement, seismite, greywacke

Abstract

At the place known as *Roc de la Tour* near Monthermé (France) there are outcrops of subhorizontal beds of sandstone belonging, subject to confirmation, to the lower Member of the Quatre Fils Aymon Formation of the Deville Group (formerly Sous-Assise Dv2a, "Quatre Fils Aymon" Assise, Devillian), Middle Cambrian of the Caledonian Rocroy Inlier .
These layers contain numerous "pseudonodules" (first described at the beginning of 20th century as "balls or pillow-structures" in the Middle and Upper Ordovician of Denbighshire in Wales), structures that are synsedimentary or immediately post-sedimentary.
A review of these rather frequent structures all over the world since their first discovery shows that several origins and/or process generate pseudonodules: creep due to gravity on a slight slope, sub-aquatic slides, slumps, fluid escape, liquefaction, storm waves, earth tremors …
An in-depth macroscopic study (based on a land survey) and microscopic study (based on observation and interpretation of petrographic thin sections) result in re-identifying the rocks of The Roc de la Tour as greywackes (instead of quartzite, generally accepted as true till now) and lead us to several interesting conclusions concerning the sediment deposit, the sedimentary basins and some paleoenvironmental features.
And finally, those studies coupled with forensic use of the bibliography as well as contextual geodynamic considerations, allowed to conclude that the pseudonodules of the Roc de la Tour are primary seismites.

Reinterpretation of a Mons Basin geological cross-section based on ERT survey : the Hainin-Hautrage pumping station site

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Keywords: Mons Basin, ERT, fault, extensive tectonic

Abstract

The Mons Basin overlies the Paleozoical basement and is composed by Upper Cretaceous chalks and calcarenites followed by Paleogene calcarenites, sands and clays. Thickness of this unit can exceed 300m. Sands, loess and alluvium deposited during Cenoizoic Era and overlie the Basin.
Despite their limited geographical extend, the carbonate formations of the Mons Basin form an important aquifer, providing about 10% of the drinking water used in Belgium.
Between 1935 and 1949, the TMVW water company set up a pumping plant of 15 wells in the western part of the Basin. The wells are approximately disposed along a 3.5 km North-South profile. The geological description of the wells and a synthetic cross-section of the pumping site was established by Marlière (1949).
Recently, the SWDE water company wanted to check the pumping wells, and a geophysical survey was conducted to complete the geological data in this area. This survey contains 2D ERT sections that were interpreted to give detailed imaging of the subcropping formations. New discontinuities crossing both Upper Cretaceous and Paleogene formations have been highlighted and interpreted as unrecognized faults. An updated cross-section of the site is proposed, based on these new phenomena and the data from Marlière (1949).
The main consequence of this reinterpretation is the replacement of the folds drawn on the primitive section by faults. Along the section, the geological formations are now disposed in monoclines separated by normal faults, in agreement with the tectonic context of the Basin. In particular, the Ypresian syncline which was drawn in the Basin axis is now interpreted as a graben. ERT sections show vertical offsets in the Paleogene sands and clays too, pointing at a later tectonic activity.
In conclusion, this reinterpretation shows the potential complexity of the Mons Basin structure. Many fault systems have been already observed in quarries located in the area, but no previous exploration has recognized the Basin structuration on a kilometric scale so obviously. According to the analysis of these fault systems, the structure highlighted along the Hainin-Hautrage pumping site should be related to an extensive context, in agreement with a pull-apart system associated to the ZCNA (Dupuis et al., 1989).

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Speleogenesis by alterite erosion within ghost-rock features in the Ardenne Allochton (Sprimont syncline, East Belgium)

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Keywords: speleogenesis, ghost-rock, Sprimont, Carboniferous limestones.

Abstract

Ghost-rock karstification consist in the in-situ partial dissolution of carbonate rocks forming volumes of residual material (alterite) within the fresh rock. In-situ alterite volumes determine geometric features called ghost-rock features (GRF). Cavities may develop in a later phase by the internal erosion of in-situ alterite within GRF. This process of creating cave networks has been recently demonstrated experimentally.

Evidence of GRF has been discovered in the Sprimont syncline, composed of lower-Carboniferous limestones. Several stages of weathering were highlighted in the Correux quarry, in the Ourthe Formation encrinite and the cherty limestone of Yvoir Formation.

The most spectacular phenomena consist in two caves exposed in the northern front of the quarry. These caves are formed in a highly weathered part of the Yvoir Formation limestone. They are partly filled by detrital sediments. By place, flowstones seal in-situ alterite (both floor and walls) and detrital fillings. The highest stalagmitic flowstone was dated by uranium disequilibrium series, giving ages ranging from 53,851±2493 yBP to 61,542±1235 yBP (isotopic stage 4).

Several facts strongly indicate that these cavities are formed within pre-existing weathered corridors. The walls of the caves are made of friable in-situ alterite. One of the cave is clearly located in the upper part of a GRF. Considering the shapes of the caves, these GRF would be formed along slightly N-S fractures. This fracture direction is common in the Sprimont syncline.

To form the caves in the pre-existing ghost-rock features, friable parts of the alterite were eroded by underground streaming. This is comforted by several observations. The erosion left pillars of in-situ alterite, and one of them is conserved by a recent detrital filling. The later erosion of in-situ alterite below a stalagmitic flowstone has been observed. Moreover, limestone alteration products (i.e. weathered crinoids fragments) were found within the detrital fillings, mixed with typical minerals from upstream mid-Devonian formations.

These facts suggest for the first time a direct evidence to link ghost-rock karstification to the formation of cave systems in the Ardenne Allochton.

Upper Silurian-Lower Devonian SEDEX mineralization as a primary source for alluvial gold in the Rocroi Massif, Belgium

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Keywords: SEDEX mineralization, alluvial gold, Silurian-Devonian, Rocroi Massif, Belgium

Abstract

The occurrence of alluvial gold in the eastern part of the Rocroi Massif is known for a long time. While the morphology of gold particles points to a nearby source, probably hosted in the Cambrian basement, the primary Au mineralization still remains obscure.

Here we document a mineralogical, petrographical and geochemical study of samples collected in Rocroi Massif and its eastern edge, mainly in the field and in the Willerzie borehole. Two concentrates of stream sediments panned in the Marotelle and Barbais creeks were also investigated.

No native gold has been found likely due to the small size of our sample set. However, electron probe micro-analysis (EPMA) yielded up to 431 ppm Au in pyrite and arsenopyrite in the Willerzie borehole. Comparable Au concentrations are reported in primary sulphides from gold mining areas worldwide as, for example, Burkina Faso. Pyrite in the Willerzie borehole and stream concentrates also contains significant gold, in concentration that are higher than in pyrite from the northern part of the Rocroi Massif, where no alluvial gold was reported to date.

The sulphide assemblage in Upper Silurian-Lower Devonian sediments in the Willerzie borehole consists of arsenopyrite, pyrite, pyrrhotite, chalcopyrite, Zn-rich sphalerite and galena as determined by EPMA analyses. The mineralization is mainly disseminated but it often concentrates around rhyolite clasts in brecciated shale intervals. Large element maps obtained with the EPMA show that the various sulphides are intimately mixed together. This is interpreted as a result of recrystallization of a fine-grained sulphide mud. Such a sulphide-rich mud was precipitated in exhalative environment, as supported by abundant volcanic products such as rhyolite clasts, abundant quartz phenocrysts, possible tuffs, etc.

We therefore propose that a Upper Silurian-Lower Devonian sedimentary-exhalative (SEDEX) system occur on the eastern part of the Rocroi Massif and is the most likely source for alluvial gold in this area.

A new synthetic subcrop map of the Brabant Massif, SE area

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Keywords: Brabant Massif, geological map, Lower Paleozoic, Asquempont Detachment System

Abstract

Following the "new geological map of Wallonia" program undertaken by the Walloon Government since 1990, the maps covering the entire outcropping part of the Brabant Massif have been realized. These 19 maps at 1/25000 scale were carried out by the teams of Bruxelles, Louvain and Mons universities. The author participated to the achievement of 8 maps and during the last two decades his researches has been focused on the geology of the Brabant Massif (e.g. Debacker et al., 2005; Herbosch et al., 2008; Debacker & Herbosch, 2011; Linnemann et al., 2012; Herbosch & Verniers, 2013, 2014). The time has now come to realize a larger scale synthesis of the area and to extend the observations below the Meso-Cenozoic cover. Moreover, as the mapping was performed over a long period of time, our understanding of the stratigraphy and tectonic of the Brabant Massif has evolved, leading to some heterogeneities and inconsistencies between the maps. This contribution proposes a synthetic subcrop map which permits to overcome this lack of consistency and allows a better view of the different units and their relationships.

The **Brabant E map** presented here extends from the eastern Méhaigne and Grande Gette basins to the western Thisne and Hain valleys, covering about 13 maps. The lithostratigraphy fits the most recent synthesis (Verniers et al., 2001; Herbosch & Verniers, 2013, 2014). The tectonic concept that prevailed during the elaboration of this map is a Cambrian core with steep folds separated from the gentle folds of the Ordovico-Silurian rim by an early, pre-cleavage low-angle extensional detachment system, the "Asquempont Detachment System" (ADS Debacker et al., 2004, 2005, 2012). The drawing of the map below the cover was facilitated by the aeromagnetic map which allowed to distinguish the non magnetic Blanmont Fm. from the magnetic Tubize Fm.

Two first order tectonic units stand out: the northern **Brabant Massif Autochthon** separated from the southern **Namur Parautochthon** by the conglomerate of the Caledonian Unconformity. Two others tectonic subunits are clearly observed in the Brabant Massif: the **Central Brabant Unit** to the N and the **External Brabant Unit** to the S. These two units are separated by the ADS whose sinuous and lobate shape is a witness of its early pre-folding formation. They are also separated everywhere by a large stratigraphic hiatus caused by the ADS low-angle extensional detachment. A thick volcanic level (Nivelles Mbr. of the Brutia Fm.) marks the base of the Silurian and crops out quite continuously from Nivelles to Gembloux. We propose to extend this level eastwards although observational evidences are very limited.

Acknoledgement:

We thank Dumoulin V., Blockmans S., Delcambre B. and Pingot J.L. for their important contribution to the mapping of the E Brabant Massif.

A new lithostratigraphic and seismostratigraphic interpretation of the Cenozoic strata for the Molenbeersel well (049W0226) in the Roer Valley Graben, NE Belgium

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Keywords: lithostratigraphy, seismostratigraphy, Molenbeersel well, Roer Valley Graben

Abstract

VITO constructed a 3D model for the subsurface of Flanders. Flemish Government made it available through http://dov.vlaanderen.be. Geologically the model's most north-eastern part belongs to the Roer Valley Graben, a tectonically active area known for its major subsidence since the beginning of the Cenozoic era. Few boreholes reach the base of the Paleogene strata. Therefore the area was modeled using seismic survey data. In order to have a good time/depth conversion a new lithostratigraphic and seismostratigraphic interpretation of the Molenbeersel well and the PLM-8412 and VITOLIM-0711 seismic lines, passing through the borehole, was necessary. The classic lithostratigraphic interpretation of the Molenbeersel well is given in Demyttenaere & Laga (1988). It was based on cuttings and several geophysical measurements. Unfortunately, only 15 meters within the Cenozoic were cored. VITO's new interpretations were based on a correlation with geophysical well logs inside (Miocene, Pliocene) and just outside of the graben (Paleocene, Oligocene). Three well geophone surveys were performed at the Molenbeersel borehole. The combination of the acoustic velocity and density logs resulted in a synthetic seismogram which can readily be compared with the actual seismic sections. Two lithostratigraphic horizons, the bases of the Opglabbeek and the Sint-Huibrechts-Hern Formations, are easily recognizable on the seismic survey data as they both represent an angular unconformity. This made a good time/depth control possible. A small difference was observed between the two-way traveltime calculated from the well geophone survey and acoustic velocity log and the two-way traveltime from the seismic sections at the well site. Nevertheless the research resulted in a new seismostratigraphic interpretation firmly coupled to the new lithostratigraphic interpretation of the Molenbeersel well. Most of the classic lithostratigraphic interpretations remain at approximately the same depth. Three get attributed a considerable different depth (Heers, Voort, Bolderberg Formations). The Middle to Upper Miocene section remains somewhat problematic as no straightforward correlation with boreholes nearby was possible. The 2 horizons within this reach are thus abandoned (Berchem, Diest/Kattendijk Formations). The glauconiferous sands on top of the Bolderberg Formation are incorporated in the undifferentiated Breda Formation. One interpretation, the Someren Sand on top of the Veldhoven Clay, is newly introduced. Three seismic horizons of Demyttenaere & Laga (1988) remain approximately the same (Clastic Tertiary, Boom, Voort Formations), 3 get attributed another lithostratigraphic interpretation (Landen Formation, Miocene, Heksenberg Formation), 2 are abandoned (Top Boom, Top Heksenberg Formations) and 4 are newly introduced (Hannut, Sint-Huibrechts-Hern Formations, Someren, Genk Members).

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The underground sedimentary series of the upper gallery in cave of "Pont d'Arcole", Hastière, Belgium

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Abstract

The cave of "Pont d'Arcole" constitutes an underground autocapture of the river Féron. The upper gallery is linear and contains a rich sedimentary series. This series is constituted by a basal detrital formation covered by a speleothems. The basal formation includes a first unit of pebbles of some centimeters in a rare fine matrix. This formation can be considered like a mud lava. We have a pebbles formation in the basis, with some clay centimeters channels, a stratum of sandy loams and an upper pebbles formation. This pebbles formation is covered by an upper loamy formation. A flowstone caps this detrital unit. The pebbles formation is caused by torrential flows in the cave and, thus, in the valley. We have several flooding phases because of the presence of clayed and sandy-loamy layers. This is characteristic of a glacial period. The upper loamy formation is a witness of a drying sequence before the abandonment by the underground flow waters from this gallery. The rest of the evolution is constituted essentially by speleothems development. A first dating by uranium disequilibrium series gives an age of 175.000 yBP. This result proves that the detrital formation is older than 175.000 yBP and belongs to the isotopic stage 8.

Session 33 Poster

GEOARCHEOLOGY, GEOHERITAGE, GEOEDUCATION

Bedrock ballast stones in Flanders: first evidence for the presence of Baltic glacial erratic boulders and their historical re-use in Belgium

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Keywords: Ballast stones, glacial erratics, geoheritage, building stones, Baltic sea

Abstract

From the 12th cent onwards, Flanders grew into a prime commercial region, establishing trade connections with both southern and northern Europe. The city of Bruges developed into an extended linear economic network of small towns and landing sites situated along the tidal channel (Zwin) leading from the sea to the town. Foreign merchants such as Germans (Hanseatic league) established permanent settlements in this portuary network. The study of re-used natural rock fragments in 13th century churches and monuments in the Bruges area, has eventually lead to the discovery of exotic building stones interpreted as ballast stones, testifying of the intensive trade activities of the Hanseatic League in Flanders. For instance, the trade post site of the Hanseatic league at Hoeke (near Bruges), which had a landing site and ship yard, produced hundreds of ballast stones whose study proves to be a valuable tool for revealing trade connections at landing sites. Their general morphology and lithological composition point to a Scandinavian glacial erratic origin. Moreover, the broad lithological spectrum most probably indicates a Southwestern Baltic coastal origin: well-rounded Proterozoic-Palaeozoic igneous rocks (granites and porphyries), metamorphic rocks (quartzites, gneiss, amphibolites, phyllites) and sedimentary rocks (flints, sandstones, conglomerates). Particular key or reference erratic boulders point to specific geological provenances (prior to their glacial transport), including: Larvikite (Oslo area), Ostsee quartz porphyries (Baltic sea bottom), Kalmarsund sandstone (Sweden), and Rapakivi granites (Aaland). Besides glacial erratics, several limestone boulders have been identified showing a quite different geological origin. The latter are composed of bioclastic wacke/packstones enclosing plurilocular foraminifera and small rugose corals, pointing to a Lower Carbonifereous (Late Visean) age. Their overall microfacies characteristics and the presence of pholad borings, rather suggests coastal outcrops of Lower Carboniferous limestones, possibly along the eastern coast of the UK, such as those of Northumberland and the Midland Valley (Scotland)

The study of ballast stones provides thus ample evidence of connections to coastal areas in the Baltic Sea and the eastern coast of the UK, linking up with historically attested trade. Furthermore, the occurrence of these exotic boulders on the surfaces of the fields of the lost Zwin towns, as well as their re-use within Medieval monuments and road pavements of the same area, constitutes an unique element within the Belgian Geological heritage, referring to a historically important but short lapse of time during the Middle Ages of Flandres.

The Colfontaine forest : vestiges of multi-secular an multi-ressources extractive activities in the Mons Basin Geopark

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Keywords: Colfontaine forest, Midi Fault, geomaterials, pre-industrial extraction, coal

Abstract

The Colfontaine forest is located southward the highly urbanised area called Borinage, wherein coal mining activities occurred from at least the 13th c. to 1976.
Despite its low extent (8 km²), this forest has great geological interest: Palaeozoic formations are outcropping while they are essentially present under a thick Mesozoic cover in the Borinage.
Moreover, some old quarries illustrate past extraction and use of geomaterials: coal, sandstone, limestone.

The forest exposes a classical geological cross-section of the unconformity between the Upper Carboniferous coal measures and the Lower Devonian siltstones and sandstones (the “Midi Fault”). At regional scale, this unconformity consists of a faulted zone between the Ardenne Allochton and the Brabant Parautochton (or Haine-Sambre-Meuse Overturned Thrust Sheets). Within the faulted zone, a hectometric unit of highly fractured Lower Carboniferous limestones occurs in the Colfontaine forest.

Several old quarries show that geomaterials were extracted within the forest at different ages: Lochkovian siltstones and sandstones for building (possibly from Gallo-Roman era, to Late Middle-Age), Visean limestones for lime and building (18th c.), and Upper Carboniferous coarse sandstones and quartzites for road ballast (19th-20th c.).

Coal extraction is documented is the western part of the forest since the 14th century. Later collieries were present in this zone, the best known is called “Sauwartan”, closed in 1938. Ruins of the headframe and the sorting buildings of this colliery remain in the forest.

Recently, LIDAR imaging from the Walloon administration have shown many surface evidences of pre-industrial coal extraction in the forest just east to the “Sauwartan” : dozens of old backfilled shafts have been detected and traces of outcropping coal mining along vertical seams have been highlighted. According to historical records, these evidences date prior the end of the 18th century. Because of the favourable geological context for coal extraction, the oldest evidences might date from the beginning of the coal extraction in this area.

Geology and legends in the Ardenne(s) : another form of Geoheritage

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Keywords: geolandscape, legend, Ardenne, geoheritage

Abstract

The scenic beauty of the Ardenne region makes it a popular tourist destination. Involving two countries, the Ardenne Massif shows numerous and famous outcrops from the Paleozoic era. Low-grade metamorphic and sedimentary rocks are affected by the Caledonian and/or the Variscan orogenies, outcropping in various steep-sided valleys (Meuse river, Semois river…) formed after a recent low uplift. This landscape show small "isolated villages" separated by wide and "deep" forests. Through geomorphological forms, geology and legends are related in several ways. The poster will present these links with local legends as the the "4 Aymon's sons" (Bogny-sur-Meuse, FR), and the related "Pas Bayard" (Hargnies & Hirson, FR) or "Rocher Bayard (Dinant, BE), the "Roc-la-Tour", the "Trou des fées" and other devil's stones, bloody spring.

Holocene landscape evolution of the Waasland Scheldt polders in relation to human occupation and exploitation

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Keywords: landscape evolution, Waasland Scheldt polders, Holocene

Abstract

The Holocene landscape evolution of the Waasland Scheldt polders, and its effect on human habitation, has been visualized in different palaeogeographical maps. Two map series were produced: (1) pre-medieval palaeogeographical reconstructions (11000 BP – 1000 AD) based on geotechnical, geological and archaeological data, and (2) post-medieval landscape reconstructions (sixteenth to nineteenth century) based on historical maps, land registers and soil data. The basis for the Holocene reconstructions was provided by the top Pleistocene relief map, which was used to determine the maximum extent of the successive marine, peat and estuarine deposits. A solid timeframe was provided by relative sea-level curves and a dated peat growth evolution model (Holocene landscapes) or old historical maps (post-medieval landscapes). Palaeoenvironmental information from fossil pollen and plant remains provided information on the vegetation changes, particularly for the middle to late Holocene. Only through combined methodologies it was possible to obtain an accurate reconstruction of the dynamic landscape and interpret successive stages of human settlement and land-use.
At the start of the Holocene the landscape was marked by coversand, locally eroded by channels of the palaeo-Scheldt river; human occupation was concentrated along the edge of a sand ridge. Rising temperatures caused woodland development, with peat growing in the low-lying areas. Human occupation decreased considerably, the last hunter-gatherers settling on the higher banks of the (fresh water) Scheldt river. Further sea level rise during the Middle Holocene changed large parts of the area into a tidal landscape and human occupation returned to the few remaining coversand ridges. During the late Holocene peat took over the entire area; this probably explains the absence of Iron Age and Roman settlements. Peat growth probably continued till roughly 1200 BP. During the last millennium the transformation of the landscape was largely due to human interventions. The latter started with the building of small dams, but gradually larger dikes, ditches and roads were constructed, often to excavate and transport peat. Intensive land reclamation through embankment took place, and large parts of the earlier excavated peatland were drained and converted to agriculture land. By 1570 almost the entire area was embanked, and a large number of villages had been founded. During the next 50 years military inundations resulted in large-scale flooding of the area which was gradually In re-embanked over the next centuries.

Cone Penetrating Testing to map deeply buried palaeolandscapes for geo-archaeological prospection of polder areas

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Keywords: CPT, palaeolandscape mapping, archaeology, prehistoric wetlands

Abstract

Geoarchaeological mapping of wetlands conventionally involves extensive coring. Especially in wetlands marked by a deep palaeosurface (> 3 m deep) this can be very difficult and time-consuming. We present an alternative approach based on Cone Penetration Testing (CPT) for structured, rapid and cost-effective evaluation of buried palaeolandscapes. Both estuarine environments (Doelpolder Noord) and river floodplain environments (Kerkhove) were investigated, including the water-land transition zone (marsh). The efficiency, reliability and repeatability of the CPT method was tested through the comparison with ground-truth core data and geophysical data. The CPT data generally allowed highly accurate mapping of the palaeotopography of the prehistoric surfaces and the overlying peat sequences. The use of a lightweight, mobile rig allowed to obtain CPT data on the tidal marsh. Also here the buried palaeosurface and peat surface(s) were clearly identified. Thin organic-rich clay intercalations within the peat layers could often still be identified. However it was difficult to distinguish between recent estuarine sand and clay deposits. Additional pore pressure and conductivity data (from CPT-U and CPT-C) did not add much crucial information and their main use seems to lie in the added value for near surface geophysical measurements. Velocity information obtained from simple seismic CPT measurements showed a good correlation with the CPT logs and nearby cores. However to obtain a high accuracy and resolution this method requires much time, which seriously affects the cost-efficiency. A major disadvantage of CPTs is that they do not provide information about possible erosion, truncation and/or bioturbation of sediment levels. Conventional coring will therefore still be needed, but the palaeotopographical and lithostratigraphic information obtained from CPT data will allow a much more efficient coring and sampling strategy in the view of geo-archaeological landscape mapping.

The "Arkose of Macquenoise": a suitable Lochkovian raw material for ancient millstones: quarries, properties, manufacture and distribution (France-Belgium)

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Keywords: geoheritage, millstone, ancient quarry, devonian sandstone

Abstract

Since a few years a French-Belgian team of archeologists and geologists work on the characterization of ancient quern stones and millstones (mainly from the Antique period) linked with the identification of their stratigraphical and geographical provenances.
This fruitful collaboration aims at reconstructing the ancient commercial roads and economic organization of territories during that period.
In addition to the better-known volcanic rocks from the Eifel area, our study revealed the frequent occurrence of particular Devonian conglomerates and sandstones from the Ardenne area, as raw materials for the manufacturing of querns and millstones. The latter sandstones as well as the related antique millstone quarries, form an important and until now undervalued geological and cultural heritage in Belgium.
Near the Ardenne border between France and Belgium, the earliest Devonian (Lochkovian) sediments deposited on the Caledonian substrate are conglomerates, which are interpreted as continental alluvial fans. The first marine sediments are littoral sandstones/quartzites or shales/slates. A sandstone formation, formally defined as the "Arkose d'Haybes" is closely linked to the former Lochkovian conglomerates (called also the "Poudingue de Fépin"). The outcrops of this particular formation around the reference localities of Haybes, Fépin and Hargnies (Ardennes, France), show a partly recrystallized, well-sorted grey to greenish sandstone (turbidite facies) with wine-red coloured joints. Another important area displaying old quarries in the same formation is located between Hirson (Aisne, France) and Macquenoise (Hainaut, Belgium): here, a more homogenous grey coarse sandstone facies occurs, with a better consistency and small amounts of dark green tourmaline crystals.
These detrital formations were locally quarried, not only for building stones but also for the production of querns and millstones. The huge Proto-historical and Roman millstone quarries in Lochkovian conglomerates and sandstones from Macquenoise, are known since the 19th century. Even if the lack of recent archeological excavations do not allow yet to precise the exact age of their quarrying, the dating of the various products derived from these quarries allow to unravel the duration of the active extraction and to deduct how far the millstones from Macquenoise area were transported into the northern Gallo-Roman provinces.

Board games as scientific communication tools for black-box methodologies: the principles of the geo-techno-economic PSS III simulator translated into an interactive educational game

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Keywords: CCS, policy, climate, energy, CO_2

Abstract

PSS III is a techno-economic simulator that creates forecasts on the implementation and economic viability of Carbon Capture and geological Storage (CCS) as a mitigation option for the adverse effects of CO_2 emissions. When explaining this tool to policy makers and other stakeholders, a technically detailed elaboration is ineffective to come to a proper understanding and credence of the outcome of the intrinsic complex economic and mathematical calculations. This board game was subsequently created as an alternative scientific communication tool.

First, the principles and the fundamental components of the simulator were simplified. This simplification consists of firstly, redefining the quantities and units, secondly visualizing models and calculations using interactive tables and graphs and lastly, a reduction of the quantity and complexity of calculations. Special attention is needed here, as an ideal balance needs to be found between the the reduction of the calculations and the preservation of the representational value of the game. This cannot be achieved solely by the aforementioned operations and should be supplemented by a process of trial and error. An important focus point here is balancing the risk and costs of assets, to assure that the desirability of the various technological options is representative for its economic viability in PSS.

The game is played by one game master and 2-3 players, playing the role of investor. The board consists of a fixed network of pipeline segments with predefined transport costs, connecting various CO_2 sources and geological reservoirs. Interactive graphs show both the past evolution, as well as the probability of the future evolution of stochastic parameters. At the start of the game a certain policy is chosen. This is followed by eight iterations wherein first stochastic economic parameters are fixed and subsequently an economic analysis is run. The first step is for each player to decide which investment is the most economically viable. Two parameters are considered: production cost which is based on the present economic climate, and risk on investment, which is given for each technological option on dynamic cards. During the last step, the game master plots each proposal on an interactive cost-risk graph and determines which investor can activate a power plant.

This board game proved to be a promising and suitable high-level educational tool that stimulates players to think in a way that accurately represents the decision making processes implemented in PSS

KEYNOTE

Continuous 2.8 million year record of Arctic climate change from Lake El´gygytgyn (NE Russia)

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Keywords: Paleoclimatology, paleolimnology, Pliocene, Pleistocene, Arctic, super interglacials

Abstract

Scientific deep drilling at Lake El´gygtygyn in Chukotka, northeastern Russia (67.5 °N, 172 °E), has revealed the first high-resolution record of environmental history in the Arctic that spans the past 2.8 Ma continuously. In this presentation we focus on the end-member glacial and interglacial climatic conditions during this period, as clearly reflected in the pelagic lake sediments recovered, excluding event layers from volcanic ashes and mass movements. Peak glacial conditions, when mean annual air temperatures at least 4 (± 0.5) °C lower than today led to perennial lake ice, first appeared at Lake El´gygytgyn 2.602 - 2.598 Ma ago, during marine isotope stage (MIS) 104. These pervasive glacial episodes gradually increase in frequency from ~2.3 to ~1.8 Ma, eventually concurring with all glacials and several stadials reflected globally in stacked marine isotope records. Particularly warm interglacials, in contrast, experienced a long ice-free season and enhanced nutrient supply from the catchment, which allowed for significantly higher primary production than today. These settings were most pronounced for MIS 11c, 31, 49, 55, 77, 87, 91, and 93. Their exceptional character becomes evident based upon pollen-based climate reconstructions in selected interglacials, showing that the mean temperature of the warmest month and the annual precipitation during the thermal maxima of MIS 11c and 31 (“super” interglacials) were 4-5 °C and ~300 mm higher than those of MIS 1 and 5e (“normal” interglacials), respectively. According to climate simulations, the exceptional warm and moist climates at least during MIS 11c and 31 cannot be explained by the natural variability in Earth´s orbital parameters and greenhouse gas concentrations alone. A remarkable coincidence of the super interglacials at Lake El´gygytgyn with diatomite layers in the Antarctic ANDRILL 1B, which reflect periods of a diminished West Antarctic Ice Sheet (WAIS), suggests intra-hemispheric climate coupling, which could be due to a reduction of Antarctic Bottom Water (AABW) formation and/or a significant global sea-level rise during times of WAIS decays.

Research opportunities for Belgian earth scientists through the International Continental Scientific Drilling Programme (ICDP)

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Keywords: Paleoclimatology, Geohazards, Deep geological processes, Early and past life

Abstract

On a densely populated Earth, both the diverse consequences of climate change and natural hazards such as earthquakes and volcanic eruptions present a growing risk to life, property and natural resources. The rocks and fluids of our dynamic planet contain heat, energy and a deep biosphere, as well as archived records of Earth's history at short and long time scales. Better understanding of these systems and history require large infrastructures for observation, probing, monitoring and analysis. The International Continental Scientific Drilling Programme (ICDP), the terrestrial counterpart of the International Ocean Discovery Programme (IODP), is the principal international platform for earth-system studies requiring deep drilling in continental settings. Earth scientists and stakeholders from its 23 member countries cooperate at the highest scientific and technical level to develop and execute such projects (more than 30 since 1996) on paleoclimate, tectonics, meteorite impacts, the deep biosphere, geological resources and natural hazards. The current ICDP membership of Flanders provided by FWO (2014-2017) creates unique opportunities for Belgian earth scientists to participate in ICDP projects currently being developed, and to take initiative in proposing and coordinating new projects. Such initiatives are supported by ICDP via exploratory workshops, operational assistance, and access to drilling facilities and logging tools. In this presentation, we present a brief overview of the wide range of earth system studies promoted by ICDP, its structure of governance, and its procedure of co-mingled funding to finance a large earth-science project.

SESSION 34
TERRESTRALIZATION AND RETURN TO THE SEA II – MESOZOIC REPTILES

Peculiar macropredatory convergences in Cretaceous marine reptiles

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Keywords: Cretaceous, marine tetrapods, palaeoecology, convergence

Abstract

Colonization of ecological niches in the marine realm forced the evolution of profound evolutionary convergences between several clades of tetrapods, with textbook examples regarding isodonty and body shape. Craniodental details have, however, received less attention. As a result, both the depth of diet-related convergences and niche partitioning mechanisms among contemporaneous clades are poorly understood, particularly during the Early Cretaceous. Here, we analyse the craniodental morphology of new ichthyosaurs and pliosaurs that exhibit unique macropredatory adaptations. One new brachauchenine pliosaur from the Hauterivian of Russia is the first plesiosaur exhibiting complex, serrations of its carinae. This taxon appears convergent with some metriorhynchid crocodyliforms and occurs just after an important diversity drop in these taxa. Contrary to common belief, cluster analyses of diet-related craniodental measurements indicate several ichthyosaur clades colonized a macropredatory niche during the Early Cretaceous, with one extreme example in the latest Aptian of France. Inference of ecological niches or ecological parameters in updated phylogenetic datasets for ichthyosaurs and pliosaurs suggest their ecological diversity was high in the Early Cretaceous and low to very low in the Late Cretaceous, where both clades disappeared prematurely.

Complex variability in microanatomical specializations in marine reptiles (Sauropterygia) from the Middle Triassic

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Keywords: aquatic adaptation, shallow marine, active swimmers, near coastal, passive swimmers

Abstract

During the evolutionary history of tetrapods many groups went back to an aquatic life style, among them, numerous Mesozoic reptiles that secondarily adapted to a marine environment. Sauropterygia are a diverse and successful group of diapsid marine reptiles. Their Triassic radiation included predominately shallow marine forms, such as Placodontia, Pachypleurosauria, and Nothosauria, but also open marine forms such as Pistosauria. Triassic Sauropterygia are notable for showing a large variety of ecologies, life histories and feeding strategies, which enabled them to live contemporaneously in the same habitats. The study of humeral microanatomy of Sauropterygia documents various ecomorphotypes, indicating different swimming abilities, which do not necessarily fit inferences solely based on morphology. Non-armoured Placodontia for example, have a cylindrical, sea cow-like body shape with pachyostotic ribs. They have always been interpreted as slow bottom walkers, which fits to their thick cortex and reduced medulla, pointing to osteosclerosis. However, well vascularized radial fibrolamellar bone tissue and resorption processes in their cortex are comparable to what is known for fast and active swimmers living in open marine habitats. Eosauropterygia (Pachypleurosauria, Nothosauria, Pistosauria) share a dorsoventrally flat skull and body shape with an elongated neck. Limb, pectoral, and pelvic girdle bones show morphological modifications to an aquatic life. Their swimming style is thought to have been predominately anguilliform. Humerus morphology is plesiomorphic in pachypleurosaurs and basal pistosauroids and most advanced in nothosaurians and *Pistosaurus*. Morphology indicates that already the oldest nothosaurs seem to have used their forelimbs for paraxial swimming. Humeral microanatomy of nearshore pachypleurosaurs is osteosclerotic, which fits to their pachyostotic ribs and vertebrae. Microanatomy of Nothosauria ranges from osteosclerotic humeral cross sections in small taxa (< 1.5 m) to extremely thin-walled humeral cross sections in some large taxa (> 4 m). However, some large nothosaurians and large *Simosaurus* retain an osteosclerotic condition, although in a different intensity. Between the two extremes (osteosclerotic vs. thin-walled), several intermediate stages are documented, which points to taxonomic specific differences and possibly high developmental plasticity. Microanatomy further indicates different swimming capabilities and habitats between small and some large nothosaur taxa. Small nothosaur taxa are less active swimmers bound to nearshore environments whereas some large forms seem to have inhabited open water and had been active swimmers. Humeral microanatomy of open marine pistosaurs appears similar to that of placodonts exhibiting osteosclerosis.

The evolution of plesiosaur bone histology: evidence from long bones and vertebrae

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Keywords: Plesiosauria, bone histology, radial vascular canals, K-strategy, fibrolamellar bone

Abstract

Considering that Plesiosauria are the most diverse clade of Mesozoic marine reptiles, their bone histology and microanatomy has received remarkably little study. As in other marine tetrapods inhabiting open waters, a cancellous bone structure has been reported for plesiosaurs. This microanatomy represents a decrease in skeletal mass as an adaptation to fast swimming and deep diving. An extensive histological sample of long bones and vertebrae now reveals more complex patterns and unexpected evolutionary trends. The sample includes the only Triassic plesiosaur skeleton as well as a diversity of European Jurassic taxa and Japanese Cretaceous taxa. Plesiosaurs show distinctive histological differences between long bones (humerus and femur) and vertebrae. Vertebrae exhibit cancellous bone in most taxa, revealing the expected bone mass decrease. Long bones, however, more commonly show an osteosclerotic or even pachyosteosclerotic condition, representing bone mass increase. Only one Jurassic plesiosaur in our sample also has a cancellous midshaft region. Plesiosaur long bones show the radial vascular pattern and lack of perimedullary resorption activity already present in stem Pistosauria such as Pistosaurus. Plesiosaurs differ from stem Pistosauria in the low number of growth marks and better developed primary osteons in a woven bone matrix (fibrolamellar bone), suggesting higher growth rates in the plesiosaurs. In addition, plesiosaur long bones show light to sometimes extensive cortical bone remodeling, absent in stem Pistosauria, with secondary osteons either being developed inside the radial primary ones or as longitudinal Haversian canals. Cortical bone remodeling increases with age, contributing to the maintenance or increase of high cortical density. Most plesiosaurs studied preserve a complete growth mark record in their long bones because of the lack of perimedullary resorption activity and only light bone remodeling. Growth marks always start at a relatively large size and give low counts (< 5), consistent with large, K-selected offspring and fast growth. In some plesiosaurs, growth marks, particularly the first one, are highlighted by an abrupt change in orientation of the radial vascular canals, from curving in one direction to curving in the other. This appears to be linked to a rugose midshaft surface. Plesiosaur histology thus shows many peculiarities, attesting to the convergent evolution of fibrolamellar bone in this group, otherwise seen in synapsids and avemetarsalian archosaurs.

Flexible eggshell in Lower Jurassic prosauropod dinosaurs and the origin of the dinosaurian egg

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Keywords: dinosaur, eggshell, evolution, amniote, ancestral state

Abstract

Early dinosaur reproduction remains poorly understood. The earliest dinosaur eggshell record comes from Late Jurassic and Cretaceous dinosaurs. These dinosaurs generally have a thick mineralized eggshell and typical dinosauroid or ornithoid microstructure. The diversity and distinct structural morphologies of eggshells found in the extant phylogenetic bracket of dinosaurs, i.e. crocodiles, turtles and birds, combined with the discoveries of soft eggshells in pterosaurs, raise questions about of the nature of eggshell in the earliest dinosaurs. Recent discoveries of several Early Jurassic basal sauropodomorph embryos and associated eggshells allowed us to perform a detailed analysis of the eggshell microstructure of the 'prosauropod' dinosaurs *Lufengosaurus* from the Lower Jurassic Lufeng Formation of YunNan (China), *Massospondylus* from the Lower Jurassic Elliot Formation of South Africa, and *Mussaurus* from the Upper Triassic to Lower Jurassic Laguna Colorada Formation of Argentina. These remains represent the oldest known amniote eggshells. The very thin calcitic layer (50-100 µm) with units showing radiating crystals and an equally thick shell membrane, suggest semi-flexible eggshells in these early sauropodomorphs, which is in contrast to the >500 µm thick calcitic layer found in the eggshells of Late Jurassic and Cretaceous similar sized dinosaurs. This implies that early sauropodomorph eggs were incubated in buried nests similar to modern turtles, crocodiles, mound-building birds, and some squamates. Maximum likelihood reconstruction of ancestral states illustrates the complexity of eggshell character evolution among oviparous amniotes. The presence of mammillae with acicular crystal organization in all dinosaurs suggests mammillae are plesiomorphic in Dinosauria. Flexible eggshell in basal sauropodomorphs, however, may suggest thick mineralized eggshell evolved independently in sauropods, theropods, and ornithischian dinosaurs, or alternatively represents an autapomorphic thinning in basal Sauropodomorpha.

The first Triassic plesiosaur: a skeleton from the Rhaetian of Germany and its implications for the evolution of plesiosaur locomotion

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Keywords: Plesiosauria, Triassic, new taxon, bone histology, stiff neck

Abstract

Previously known from the earliest Jurassic to the end of the Cretaceous, plesiosaurs are among the most common and best studied Mesozoic marine reptiles. Despite a history of research spanning nearly 200 years, the origin of their unique, barrel-shaped body and paraxial locomotion by underwater flight is poorly understood. The recent discovery of the first Triassic plesiosaur skeleton, from the Rhaetian of Westphalia (Germany), markedly improves this situation.

The new specimen preserves intermediate morphologies between non-plesiosaur pistosaurs and plesiosaurs, with phylogenetic analysis revealing it to be a new taxon and placing it basal to all other plesiosaurs. The skeleton is nearly complete and largely articulated, with an estimated total length of 1.6 m. Parts of the skull, the vertebral column, parts of the shoulder girdle and pelvic girdle, as well as the left humerus and femur, the complete left zeugopodials, and some phalanges are preserved. Open neurocentral sutures and unfinished neural spines identify the specimen as a subadult.

A conspicuous character, also seen in some Early Jurassic plesiosaurs but not in pistosaurids, is the V-shaped neurocentral suture of the cervical vertebrae, with the neural arch extending far ventrally on the side of the centrum. The resulting three-dimensionally folded suture surface gave the neurocentral suture strength while allowing continued growth. The limbs are developed as paddles with a straight- shafted humerus and femur and zeugopodials that are only slightly longer than wide. Together with the paddles, the reinforced, V-shaped cervical neurocentral suture may have evolved as an adaptation to underwater flight. The stiff neck would have compensated for the dorsoventral moments generated by paraxial paddle movement. Foreshortened zeugopodials are a plesiosaur synapomorphy which is not present in *Bobosaurus* from the Carnian of the Italian Alps, arguing against *Bobosaurus* representing the most basal plesiosaur.

To further constrain the ontogenetic stage of the new specimen, the humerus and femur and some ribs were sampled histologically. The long bones show radial fibrolamellar bone with abundant woven tissue, suggesting rapid growth. Growth marks indicate an age of less than two years. The new taxon thus suggests that the paraxial swimming style evolved in concert with a high metabolic rate in the most basal plesiosaurs in the latest Triassic, possibly enabling them to survive the Triassic/Jurassic extinctions and leading to their explosive radiation in the earliest Jurassic.

SESSION 35
REGIONAL GEOLOGY II

Stratigraphy and Commissions. Do we need stratigraphic commissions?

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Keywords: stratigraphy, lithostratigraphy, ncs website, Belgium

Abstract

The practice of stratigraphy evolved from a single-category stratigraphy, over an analytical stratigraphy to an integrative stratigraphy which is popularized today as sequence stratigraphy. The ever growing necessity for improved time resolution is at the base of the present progress in astrochronology. Still, the basis of all stratigraphic work is the recognition of units that can be characterized, described and analyzed, in a way that correlations between sections and areas become possible. Basic characterization of strata to understand the physical build up of an area can be achieved by lithological properties or by physical properties as is done in seismic stratigraphy and well log correlation.

Although defining such basic lithostratigraphic unit-stratotypes can be straightforward, different opinions often do exist, and in particular unequivocally defining boundaries can be a matter of debate. Nevertheless, there is a necessity for an accepted and well-defined lithostratigraphic frame and nomenclature, for more reasons than the sheer necessity for allowing communication between geologists, also across national borders, and between geologists and the applied geoscience and engineering community. Indeed also regional maps need defined units in the legend and setting-up and consulting geological data bases requires precise stratigraphic codes.

Lithostratigraphy is of regional geological concern. Internationally an analogous effort for defining chronostratigraphic units and their boundaries, the GSSP's, exist and developing a standard chronostratigraphic time chart is a major objective of the ICS and its subcommissions.
Defining the lithostratigraphic standards on the other hand is a major task for the National Stratigraphic Commissions existing in most countries where they are generally linked to the Geological Surveys, organisations establishing geological norms and standards in many fields. In Belgium the NCS is installed by the National Commission for Geological Sciences, the correspondent of the IUGS.
The organisation and the activities of the NCS will be explained and the use of its website http://ncs.naturalsciences.be will be demonstrated. The lithostratigraphic part of the NCS website has an easy accessible entry to all defined units over the whole stratigraphic column. Aside the defined units, a discussion section and a formal proposal section exist which are open for all contributions; the themes under discussion for which the contribution of the geological community is invited are systematically announced in the Miscellanea Geologica Belgica issues.

Flanders Soil and Subsoil Database (DOV) – The web portal to the geological information of Flanders

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Keywords: Database, geology, Flanders, maps, 3D model, data, DOV, web application, public, webservice, portal, voxel model, GIS

Abstract

Since 2002 a vast amount of subsoil information is freely available on the Flanders Soil and Subsoil Database (DOV, www.dov.vlaanderen.be). Three departments of the government of Flanders cooperate to build the infrastructure. The Land and Soil Protection, Subsoil, Natural Resources Division (ALBON) is responsible for the information on geology and natural resources. The other partners manage the information about the soil, the hydrogeology, geotechnical characteristics and groundwater licenses. DOV is the public web portal through which this regional administrations deliver INSPIRE-compliant Open Data, available for re-use. DOV contains more than 300 geological GIS 2D maps and 3D layers. More than 100.000 field data, including measurements, descriptions and interpretations are available as well. Geothermal maps and voxel models for the natural resources are also available, such as loam, sand and gravel. In 2016 a large amount of recent drilling data can be expected, as a result of the obligation of drilling companies to register newly executed drillings.Special attention goes to the user friendly publication of the information through different data formats and applications.The **(Sub)Soil Explorer** gives an overview of all geological data, including geothermal and natural resources information to use for own applied research. This straightforward web viewer allows to combine and query layers to get customized information. Even external data can be geographically added using a WMS URL. Exports can be made in pdf, tables, GIS files, XML and images.The **Geological Explorer** and the **Natural Resources Explorer** are thematic viewers that guarantee a quick start with specific layers and customized functionalities. The Natural Resources Explorer allows to query the Loam Voxel Model (van Haren et al., 2015) through a point, an intersection or a volume.The **3D SubsurfaceViewer®** combines 2D maps, sections and 3D views and gives a clear visualization of the composition of the Flemish subsoil. The Geological 3D Model of Flanders and the Brussels Capital Region, G3D v2 (Matthys et al., 2013), the H3O-Ruhr Valley Graben model (Deckers et al., 2014) and the Loam Voxel Model (van Haren et al., 2015) are available in this specialized viewer. DOV allows you to work with the GIS data on your own computer by serving INSPIRE compliant metadata, **webservices** (WMS, WFS, WCS), Google Earth KMLs and downloadable files.

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Recent insights in the Cenozoic tectonic evolution of the Roer Valley Graben

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Keywords: Roer Valley Graben, Cenozoic, tectonic evolution

Abstract

This abstract forms a brief compilation of the new insights in the tectonic (and sedimentary) evolution of the Roer Valley Graben that were recently (in the years 2014 and 2015) published. These insights are based on the new geological models of the Roer Valley graben, called G3Dv2 and H3O-Roer Valley Graben (Broothaers et al., 2012; Deckers et al., 2014b).

After Mesozoic rifting and inversion pulses, the Roer Valley Graben experienced relative tectonic quiescence from the latest Maastrichtian to early Paleocene. During the subsequent middle Paleocene phase, the Roer Valley Graben was - together with its flanks - subjected to subsidence into a shallow depocenter (Deckers et al., 2014a; Deckers and Matthijs, 2014). Similar middle Paleocene depocenters were formed in the Central Netherlands and Danish Basins (Deckers, 2015c).

The middle Paleocene deposits in the Roer Valley Graben are overlain by late Paleocene deposits which, on their turn, are unconformably overlain by early Oligocene deposits. The hiatus that comprises the entire Eocene was (at least partly) related to the latest Eocene Pyrenean inversion phase that caused uplift and erosion of the Roer Valley Graben and its flanks (Deckers et al., 2015). The latter authors show that uplift was domal and non-ruptural and, therefore, similar to simultaneous uplift in the nearby Broad Fourteens and West Netherlands Basins and to existing models of relaxation inversion.

During the late Oligocene, subsidence of the Roer Valley Graben strongly increased as rifting started. During the late Oligocene start of rifting, a high number of faults and several large folds developed in the pre-rift strata and rapidly linked into several km long systems (Deckers, 2015b). Some of the faults and forced folds in the Paleogene pre-rift strata were decoupled from deeper faults in the Triassic and older pre-rift strata (Deckers, 2015d). The latter author shows that decoupling consistently took place in the evaporite-rich strata in the upper part of the Upper Germanic Trias Group, which therefore probably acted as a detachment along which late Oligocene extension was transfered. A relative high number of faults died out around the Oligocene/Miocene boundary, which might be related to a regional change in the intra-plate stress-field and caused a maturation of the fault systems in the Roer Valley Graben (Deckers, 2015b). During continued Miocene rifting, a large delta system was build out in the Roer Valley Graben (Vandenberghe et al., 2014). Within this delta system, Mass Transport Deposits were identified (Deckers, 2015a).

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H3O: Crossing borders in 3D geological modelling

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Keywords: 3D modelling, lithostratigraphy, hydrogeology, Roer Valley Graben, Campine area

Abstract

The sustainable use and management of natural resources in border regions requires unambiguous geological information from neighbouring countries. However, the available data often lack compatibility and the same level of detail across borders.
Various stakeholders in the Netherlands and Flanders expressed their interest to harmonize the (hydro) geological models in the shared border region. Accordingly, the first H3O project was initiated in March 2012, focussing on the Roer Valley Graben across the Dutch-Flemish border. A second project (H3O2) set off in April 2015 and deals with the adjacent Campine area. Aim of these successive projects was (is) to produce cross-border, up-to-date, three-dimensional geological and hydrogeological models of the Cenozoic deposits. Existing (hydro) geological data (boreholes, well logs, seismic data, fault traces, geological maps and models) are collected, re-interpreted according to a harmonized lithostratigraphic scheme and fed into the 3D modelling process.
Results of the first H3O project (Deckers at al., 2014) include:

- A correlation scheme between Dutch and Belgian/Flemish (hydro) geological units;
- A consistent fault model of the Roer Valley Graben;
- Geometrically and stratigraphically consistent geological and hydrogeological models of the Cenozoic deposits in the Roer Valley Graben across the Dutch-Flemish border.

The resulting 3D models can be considered as a state-of-the-art reference for the subsurface structure of the project area and can be used as a base for cross-border management of natural resources. The correlation scheme serves as a guideline for present (H3O2 – Campine area) and future cross-border projects.
The H3O projects are carried out by a partnership between TNO – Geological Survey of the Netherlands, VITO and RBINS – Geological Survey of Belgium. The H3O models will be available in the public domain via the online data portals of DOV (Databank Ondergrond Vlaanderen) and DINOloket (Data en Informatie van de Nederlandse Ondergrond).

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Endokarstic breakdown and earthquakes: The relation between the "dome" room collapse (Han-sur-Lesse cave) and the 1828 earthquakes in Belgium

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Abstract

The possible relationship between earthquakes and their consequences in caves such as speleothems breakdown or fallen blocks is discussed since the 90th. The main difficulty of these studies is the absence of direct field observations during strong earthquakes. These observations would to establish without ambiguity the link between the strong ground motions of earthquakes and the observed changes in the caves. During the year 1828, two strong earthquakes occurred in Belgium. The earthquake of 23 February 1828 caused significant damage in central Belgium, while another seismic event on 3 December 1828 affected the region of Spa and Stavelot. Several publications on speleology and the history of caves in Belgium mentioned a vault collapse in the "dôme" room in the Han-sur-Lesse cave, attributing it to the 23 February earthquake. In our study, we first present the dating results of a stalagmite, actively growing on one of the fallen blocks proving the concordance of this breakdown with the 1828 earthquakes. The second part of our investigation is an historical investigation suggesting that this collapse is the consequence of the 3 December earthquake.

SESSION 36
HOLOCENE CLIMATES AND ENVIRONMENTS

Holocene paleoenvironmental reconstructions from Belgian peatbog

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Keywords: Dust, peatbog, climate, Rare Earth Elements, Holocene

Abstract

Atmospheric deposition is an important part of the global climate system, and plays a key role in the marine and terrestrial biogeochemical cycles as a source for major and trace nutrient elements. Reconstruction of atmospheric deposition is crucial to understand the effects of the increased atmospheric depositions induced by humans on the environment and to help understanding Holocene climate variability. This study investigated potential paleoenvironmental proxies provided by major and trace elements and stable isotopes compositions of peat bogs. Peat bog cores were collected from Hautes-Fagnes plateau (Misten bog) (SE-Belgium). The analyses of Rare Earth Elements (REE) and lithogenic element concentrations as well as Nd isotopes were performed by HR-ICP-MS and MC-ICP-MS respectively, in a ~ 7 m peat section representing 7300 years, dated by ^{210}Pb and ^{14}C methods. The Misten bog is highly affected by atmospheric supplies (natural and anthropogenic) and can be used to establish the changes in atmospheric dust during the Mid-Late Holocene. Dust fluxes show pronounced increase at 3200-2800BC, 600BC, AD600, 1000AD, 1200AD and from 1700 AD corresponding to local and regional human activities combined with climate change. Peat humification and testate amoebae were used to evaluate hydroclimatic conditions. The εNd values show large variability, between -5 and –13, identifying three major sources of dust: local soils, distal volcanic and desert particles. Our results provide evidence that climate forcing may be detected in ombrotrophic peat, even for the historical period that is characterised by a mixed climate-human control.

Holocene hydroclimate shifts in tropical East Africa and their link to the African Humid Period termination: the multi-proxy sediment record from Lake Rutundu, Kenya

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Keywords: Paleoclimatology, Holocene, lake sediment records, African Humid Period termination

Abstract

Following the generally arid conditions of the Last Glacial Maximum (LGM), a large part of Africa experienced the Early to Mid-Holocene as a much more humid period than today. This so-called African Humid Period (AHP) coincided with high summertime insolation over the Northern Hemisphere subtropics, causing invigorated monsoons to create moist conditions over the northern and equatorial parts of Africa. The timing and abruptness of the onset and ending of the AHP in different regions of the continent have received major discussion. On the other hand, shorter-lived climate fluctuations within the AHP have received much less attention, due to a scarcity of well-dated, high-resolution African paleoclimate records spanning the entire Holocene.

In this study we used the sediment record of Lake Rutundu, a high-altitude crater lake on Mount Kenya, to document century- to millennial-scale hydroclimate variability on the East African equator from the LGM to the present. A multiproxy approach combining core-surface scanning techniques (magnetic susceptibility, X-ray fluorescence) and close-interval bulk-sediment analyses (organic matter and biogenic Si content) resulted in a high-resolution record firmly anchored in time by an age model based on 210Pb and 14C dating. The record reveals a sequence of abrupt century-scale droughts overlying the longer-term, orbitally-forced climate trend of the Holocene. Interestingly, the timing of these arid events can be related to the temporally and spatially variable abrupt ending of the AHP as described earlier from multiple records throughout the continent. This means the drought episodes described from Lake Rutundu have catalyzed site-dependent permanent shifts in local ecosystems by crossing system-specific moisture-balance thresholds. Erroneous assumption that these abrupt changes reflected climate history itself has significantly impacted the way the AHP termination has been perceived by paleoclimatologists. By linking the Rutundu record to robust higher-latitude paleoclimate records, these events can now be adequately dated and described.

Holocene dinoflagellate cysts from fjords of western Vancouver Island (British Columbia, Canada)

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Keywords: dinocysts, ecology, estuary, palynomorphs, Pacific Ocean

Abstract

Forty-six surface sediment samples from 16 coastal inlets of western Vancouver Island and two shallow bays of the Broughton Archipelago NE of the island were investigated for dinoflagellate cysts and other palynomorphs. Well preserved and abundant dinoflagellate cyst assemblages have been recovered and a total of 43 cyst types of three orders were identified.

Cyst assemblages were dominated by *Operculodinium centrocarpum* sensu Wall & Dale 1966, *Spiniferites* spp. and *Brigantedinium* spp. Total dinoflagellate cyst concentrations vary two orders of magnitude between 7,279 and 918,584 cysts.g-1 of dry sediment, with the highest values observed in samples from Tofino Inlet. As expected, cyst concentrations and assemblage diversity yielded higher values in the western Vancouver Island inlets, compared to the shallow bays of the Broughton Archipelago where the values were the lowest. Tofino Inlet had the highest abundance of *O. centrocarpum* sensu Wall & Dale 1966, whereas Neroutos Inlet samples were characterized by high concentrations of Arcellacean testate amoeba. Cysts of autotrophic dinoflagellates dominate in the southern inlets where the waters are warmer and less cloud cover is present; whereas, heterotrophic species increase in importance towards the north. Sedimentary biogenic silica concentrations were measured at each studied site and we find rather weak correlation to the total cyst concentrations.

Cysts of the potentially toxic dinoflagellate *Alexandrium* spp. were found in most of the samples with the highest abundance in the Kyuquot and Quatsino Sounds. Process length variation of *O. centrocarpum* sensu Wall & Dale 1966 are measured and significantly correlate with sea water density when considered in a regional context.

The dinoflagellate cyst assemblages and their distributions are related to both regional environmental parameters determined by latitude (e.g. sea surface temperature, salinity, upwelling, cloud cover), and local properties of the inlets themselves (e.g. sill depth, runoff, anthropogenic influence).

A 10m core has been obtained from Tahsish Inlet in the Kyoquot Sound, where surface sediment samples indicated high modern productivity. Radiocarbon dating indicates a bottom age of ~10ka. The dinoflagellate cyst record is being studied at centennial resolution in order to reveal Holocene climatic change in the NE Pacific realm.

Color reflectance spectroscopy of profundal lake sediments: a novel moisture-balance proxy for tropical East Africa

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Keywords: Paleoenvironment, Holocene, Lake Challa, sediment color, fossil pigments

Abstract

Investigations of the continuous sediment record from Lake Challa, a deep freshwater crater lake on the eastern slope of Mt. Kilimanjaro, are expanding our knowledge about past climate and environmental changes in equatorial East Africa. During a field campaign in 2005 a 20.65-m long composite sediment sequence was retrieved from the center of the lake, covering the past 25,000 years. Unlike many other East African lakes, Lake Challa never dried out during this period and therefore provides one of the few continuous and high-resolution regional climate-proxy records since before the LGM.

Continuously taken digital line-scan images (GeoTek MSCL core logger) revealed systematic colour variation from greenish to yellow-brownish sediments throughout the core sequence. To characterize the origin of these colour variations, high-resolution colour reflectance spectrometry was carried out.

The relative absorption band depth (RABD) at different wavelengths was calculated to distinguish between sediment components with distinct absorption/ reflection characteristics. $RABD_{660/670}$ can be used as a proxy for chlorophyll and its derivates, and $RABD_{610}$ as a proxy for carotenoids and their derivates. Comparison of $RABD_{660/670}$ with independent reconstructions of rainfall (the Branched and Isoprenoid Tetraether (BIT) index of bacterial lipids) and seismic lake level reconstructions showed a positive correlation between these proxies. During times of wetter climate and higher lake level, e.g. the early Holocene, the $RABD_{660/670}$ value is higher than during times of inferred dry conditions and low lake level, e.g. the early late-Glacial period (during which no chlorophyll or its derivates were detected). We attribute this positive correlation to reduced preservation of chlorophyll contained in the settling remains of dead phytoplankton during lowstands, when bottom waters may have been better oxygenated. This data is supported by the variation in fossil pigment concentration and composition analyzed by high performance liquid chromatography (HPLC). During humid/highstand episodes, chlorophyll and carotenoids are more diverse and abundant than during dry/lowstand episodes.

Our data confirm the utility of reflectance spectroscopy as a tool for rapid, non-destructive and cost-effective analysis of long sequences of lithological change at high temporal resolution. They also support the previously published BIT-index record of Lake Challa as proxy for regional moisture-balance history.

Physico-chemical characterisation of dust deposition in snow from NE Antarctica

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Keywords: dust in snow, SEM-EDS, NE Antarctica

Abstract

Mineral dust is a major source of micronutrients (e.g. Fe) in open oceans and HNLC zones. In the Southern Ocean in particular, the properties and impacts of current dust deposition are not well constrained.

Here, several dust-bearing snow samples collected in the NE Antarctica coast are investigated in order to : (i) characterize the mineralogy, size, and morphology of dust by single particle analyses (automated-FEG-SEM-EDS and TEM-SAED), (ii) trace the origin and the relative contribution of natural and anthropogenic particles in dusts through elemental and multi-isotopic analyses (HR-ICP-MS and MC-ICP-MS) and (iii) quantify the Fe bioavailability in dusts (via extractions).

Our first results show a fine size distribution (98% of particles < 5 µm, n=1550). A large fraction exhibits a Fe contribution, either from mineralogy or coating. While the mineralogy suggest a substantial contribution of proximal rocks, high Cr, Zn, Cu & Pb enrichment factor (x10 to x90 relative to upper continental crust - UCC) indicates an anthropogenic contribution to the dust deposition.

Overall, this study will improve our understanding of dust reaching the coast of NE-Antarctica, which may represent a proxy for the dust material supplied to the Southern Ocean, by far the largest HNLC.

FIELD TRIP DOCUMENTS

POLYTECH MONS

UMONS Université de Mons

- La Malogne Underground Quarry -

Field Trip Documents

Thursday January 28th 2016

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1. The Mons Basin

The Mons Basin is an EW-elongated (10 x 25 km in dimension) subsiding area in which up to 300m-thick sediments accumulated during the Meso-Cenozoic. It is located in the Hainaut Province and the basin coincide with the Haine river valley (fig. 1).

The Palaezoic basement beneath is constituted of south-dipping, thick Carboniferous formations of the Brabant Parautochton and Haine-Sambre-Meuse Overturned thrust sheets. Dinantian carbonate formations are largely outcropping to the north and are lying at ca. 2000 m right under the Mons Basin. On the northern rim of the basin, Namurian siliciclastics are exposed and most of the overlying >1500 m-thick Westphalian coal measures is concealed under the Meso-Cenozoic cover. To the south, Lower Devonian siliciclastics (Ardennes Allochton) are uncomformably overlying the Carboniferous (Midi Fault). Intensive mining of the coal in the past contributed much to the current geological knowledge of the Hainaut area. However, the discovery of karstified evaporite layers (anhydrite) interbedded within the Visean in the deep borehole at Saint-Ghislain in the 70-80ies pushed forward this knowledge (besides the discovery of an unexpected source of geothermal energy at -2500 m). Evaporite dissolution and subsequent collapse of the overlying rocks provided a viable mechanism for the particular subsidence in the Mons Basin, which long remained difficult to explain by tectonic processes only. Depocentre movement with time is one of the peculiar aspects regarding subsidence processes in the Mons Basin. The numerous breccia pipes (sinkholes), ring faults and highly-subsiding areas (so-called “cuves”) are all the consequences at different scale of deep karstification. The sedimentary record in the Mons Basin is thus controlled by a complex combination of tectonics and eustatism, like in any other basin, but mostly by deep karstification processes.

The Meso-Cenozoic lithological sequence of the Mons Basin records different pulses of transgression–regression phases (fig. 2). It starts with the Haine Group (Barremian – Aptian, or “Wealden” facies), which consists of continental siliciclastics. Subsequent Albian and Cenomanian shallow-marine deposits are known in the basin but most of them are not exposed. While their thickness may exceed 150 m, all these deposits are discontinuous and consist of lenses that are clustered along the northern rim of the basin. Maximum marine flooding occurred at Turonian times, with a better continuity (both lateral and vertical) and more carbonate in the sedimentation. The Chalk Group (Coniacian to Maastrichtian) is the thickest sedimentary sequence in the Mons Basin (together with the second most important aquifer in the region). During the Cenozoic, sedimentation was first dominated by shallow carbonate (Haine Group, Lower Palaeocene) and then by siliciclastics (Landen and Ieper Groups, Upper Palaeocene to Upper Eocene). Continental deposits are observed in the Upper Danian (“Montian” lacustrine formations) and Upper Thanetian/Lower Ypresian (fluvial sands and silcretes).

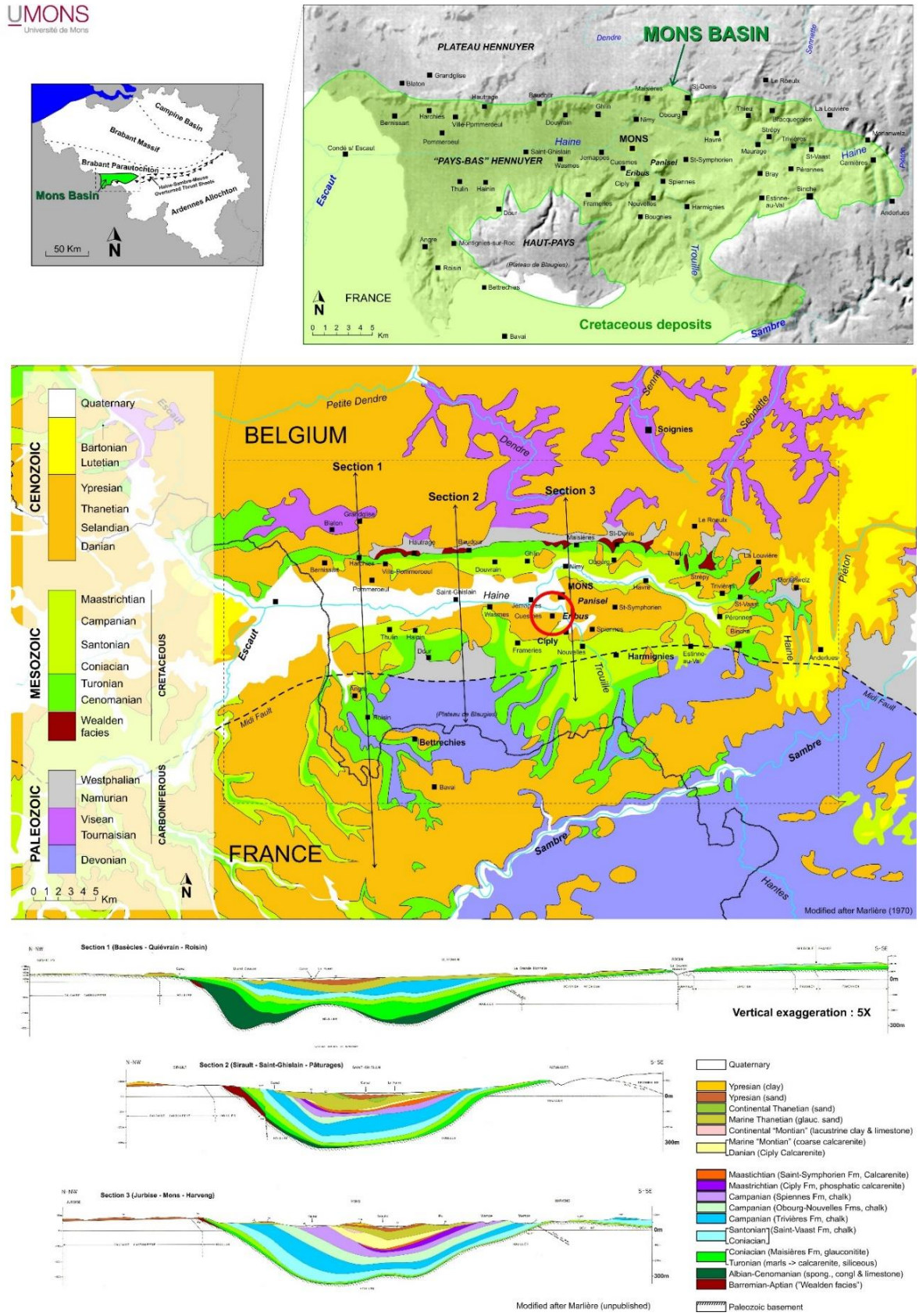

Figure 1. Location and geology of the Mons Basin. La Malogne is indicated by a red circle.

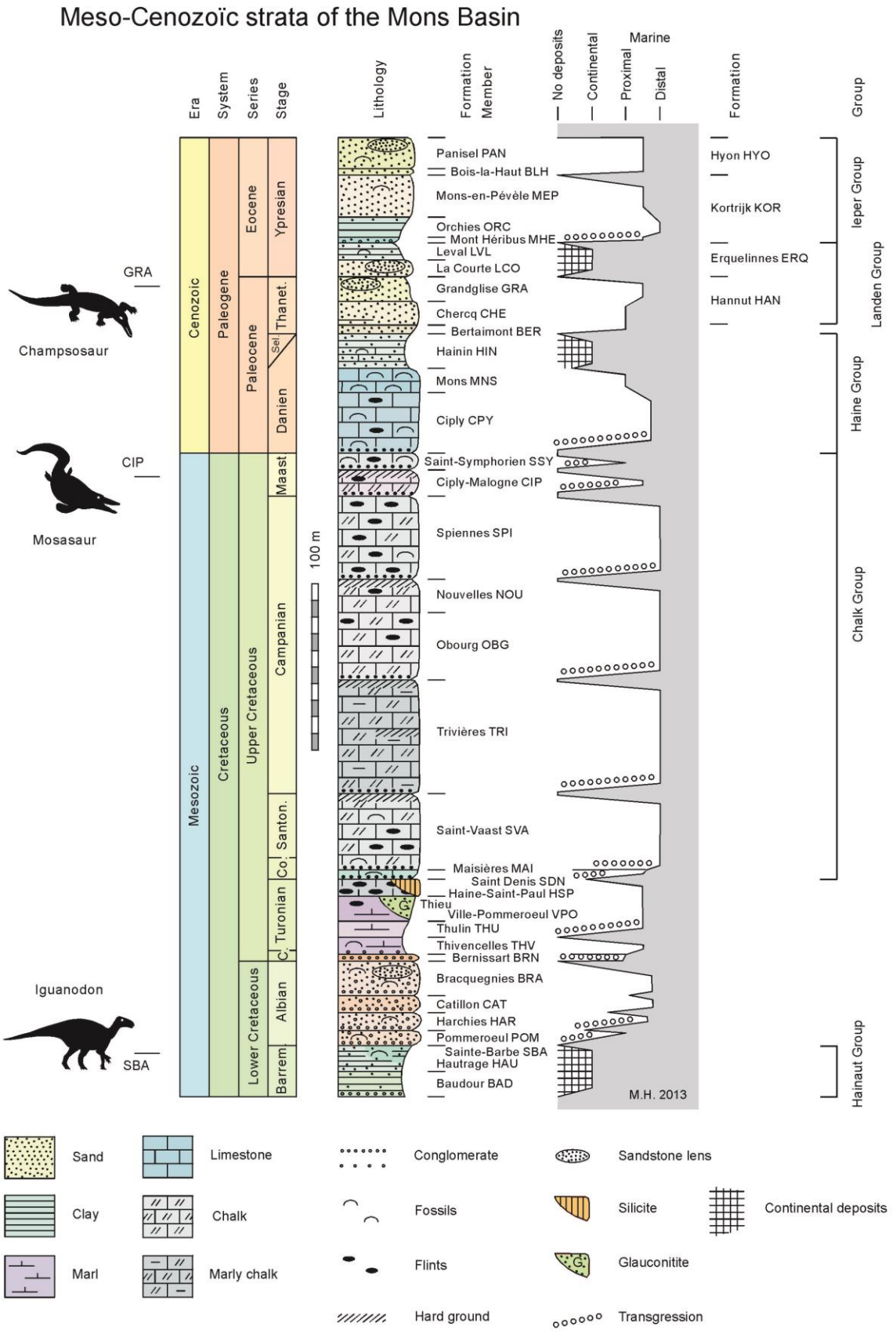

Figure 2. Meso-Cenozoic lithological sequence of the Mons Basin (after Hennebert, 2013).

2. La Malogne underground quarry (Cuesmes)

The La Malogne underground quarry is located in the central part of the Mons Basin, slightly off to the south (fig. 1). The excavating galleries spread over kilometers in the Maastrichtian phosphatic “chalk” (Ciply-Malogne Fm ; fig. 2), which has been actively mined between the 19th to mid-20th century, mainly for feeding the fertilizer industry (average production : 200-250 kt/year).

The Ciply-Malogne Fm is overlying the Spiennes Fm, which may be observed in a few places at the floor where it is not covered with waste dumps. The fossiliferous Cuesmes Conglomerate is found intercalated between these two formations. The thickness of Ciply-Malogne Fm. grades from a few meters at the outcrop to 50 m in its deeper parts to the north. Phosphate occurs as dark-brown carbonate-apatite grains, mostly <1mm in diameter. Average phosphate content is ca. 10% P_2O_5 but post-Thanetian cryptokarstification locally induced a secondary enrichment in phosphate. Regression during the Maastrichtian probably created restricted marine conditions favorable to phosphate accumulation.

Flints are virtually absent in the Ciply-Malogne Fm of the La Malogne Quarry but they are abundant nothward in the nearby Ronveaux Quarry (Mesvin).

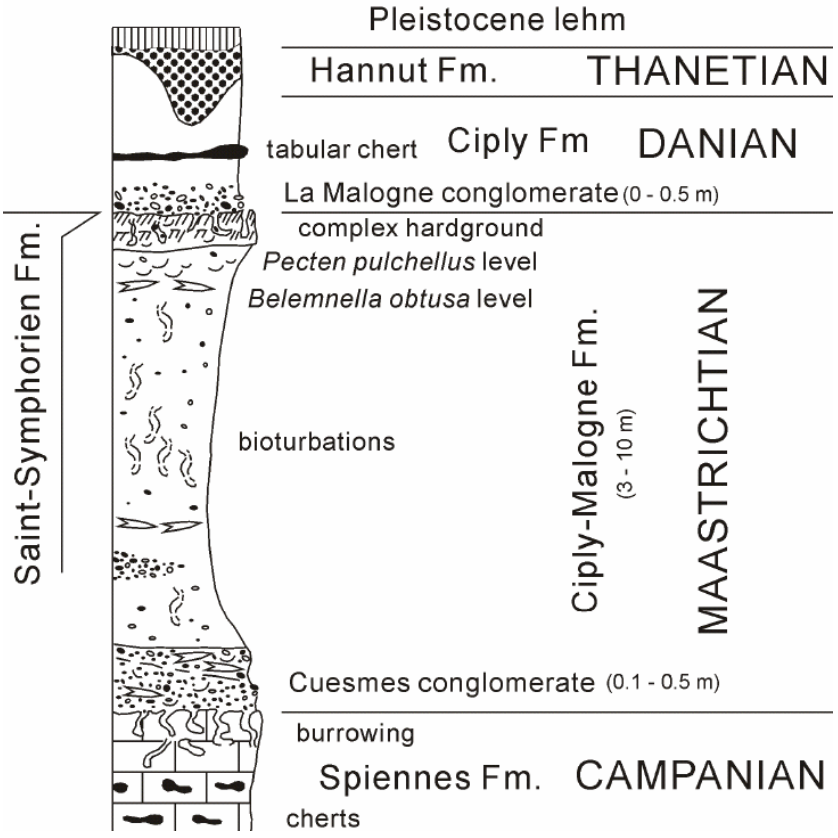

Figure 3. Stratigraphical section in La Malogne underground quarry (after Robaszynski et al., 2011).

A thick hardground caps the Ciply Formation. It is intensely burrowed and covered with a fossiliferous phosphatic conglomerate (*Poudingue de la Malogne*). This hardground plays an important role in maintaining the stability of the roof of the galleries, which have a square cross section. Laterally, its thickness may be considerably reduced and the cemented horizon is no longer continuous but nodular (firmground). Then the cross section of the galleries must have an ogival profile in order to be self-supporting as it is the case in other nearby underground quarries.

Fossils are abundant and besides the great diversity in invertebrates, the Ciply-Malogne Fm yielded spectacular vertebrates such as large reptiles (*Hainausaurus bernadi* Dollo, 15 m long, excavated from a nearby open pit quarry, *Mosasaurus*, chelonids, etc.) Cretaceous fossils are also abundant, but reworked, in the La Malogne Conglomerate (Danian), which is found topping the hardground.

The formations overlying the Ciply-Malogne Fm are the Saint-Symphorien (Maastrichtian, not visible here) and Ciply calcarenites (Danian). The Ciply calcarenite with its flint band is exposed along the entrance gallery and where the roof collapsed. No K/T boundary is observed because the Uppermost Maastrichtian and lowermost Danian are missing.

Glauconitic sand of Thanetian age (Hannut Fm) can be observed in places where the gallery cuts cryptokarsts.

The Mons Basin has recorded a multistage tectonic history, which can be observed in La Malogne underground quarry (fig. 4).

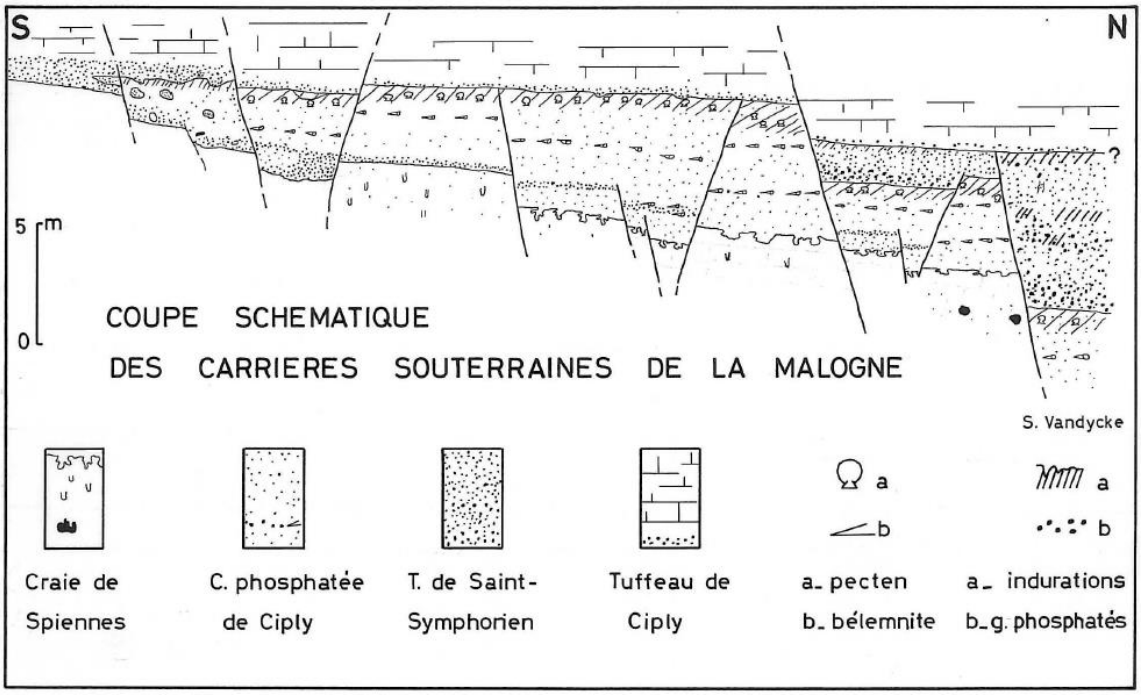

Figure 4. Typical fault pattern in La Malogne underground quarry (after Vandycke et al., 1991).

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