

# EUROPEAN REGION NEWSLETTER

*Unlocking the Future*



October 2015, Vol. 10

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### Instructions to authors

Editorial correspondence and material submitted for publication should be addressed to the Editor to [viki.oconnor@scarabus.co.uk](mailto:viki.oconnor@scarabus.co.uk). All materials should be sent by the 15<sup>th</sup> of the month before issue publication. All submissions are subject to editorial review and revision.

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## PRESIDENT'S MESSAGE



Dear Members,

It is a very great honour to have been elected to serve as the President of the AAPG Europe Region for 2015-2017. I succeed Keith Gerdes, who has done a superb job of leading the region for the past two years. Having served on the AAPG European Region Committee as President-Elect for the last two years, I

know how hard Keith has worked to raise the profile of the European Region within AAPG and I will do my best to build on the superb legacy that he has built. Fortunately, Keith will remain on the committee for another two years as the Past-President, so we will have good continuity and I will continue to benefit from his wise counsel.

These are, of course, 'dark times' again in our industry. The current low oil price has caused most E&P companies to make significant cuts in their exploration and development programmes in order to manage cash flow and maintain an appropriate level of 'capital discipline'. The amount of work available to Service Companies, Contractors and Consultants has reduced accordingly. Many of our friends and colleagues have already lost their jobs and the future for those of us who remain employed in industry is, at best, uncertain. It is in these difficult times that membership of the AAPG can be particularly valuable. It not only allows us to maintain our technical skills by providing access to the very latest geoscience knowledge and expertise through publications, conferences and the AAPG website, but also provides access to a vast worldwide network of fellow industry and academic professionals who can provide support, advice and - who knows - perhaps the route to a new job.

This is a particularly worrying time for students, who will find it a challenge to secure jobs in the near future when they have completed their courses or research projects as companies reduce their graduate recruitment programmes. Here again, AAPG membership can provide access to skills, knowledge and contacts that may provide 'an edge' in an increasingly competitive job market. The support and encouragement of the AAPG 'Student Chapters' and 'Young Professionals' across the European Region, will be one of the key priorities of my term as President.

For those of you looking to buy or sell prospects, or just to see what opportunities are available, a reminder that APPEX Regional 2015 is coming up in Nice on 5<sup>th</sup>-6<sup>th</sup> November. This event will focus on opportunities in Africa and the Atlantic margins. We currently have 16 keynote speakers and 10 prospect forum slots confirmed and the exhibition is nearly full with a range of companies represented, including Government Agencies and NOC's.

Courses are a particularly good way to keep up our knowledge and skills, so the AAPG is pleased to be starting a new series of one-day 'Basin Mastery' courses in collaboration with the PESGB. These courses will be held at the PESGB Training Facility in Croydon (less than 20 minutes by train from Central London) and provide 'state-of-the-art' knowledge of basin evolution, petroleum plays and prospects in some of the world's oil and gas hotspots. This new programme starts on the November 11<sup>th</sup> with 'An Overview of the Petroleum Geology of Myanmar', led by Andy Racey, co-author of the newly-released Geological Society Memoir 'Petroleum Geology of Myanmar'. This will be followed by courses on 'Greenland and Labrador' in January and 'Atlantic Equatorial Basins' in March. The registration fees are just £20 and the places are limited, so I encourage you to book your place as soon as possible.

Other AAPG Europe events to keep in mind for the rest of this year and the first half of next year include GTWs on 'Geochronology applied to petroleum exploration' in Geneva, Switzerland on the 23<sup>rd</sup>-25<sup>th</sup> November and on 'Exploring and Exploiting Carbonate Reservoirs' in Bari, Italy on the 26<sup>th</sup>-27<sup>th</sup> April 2016. Then there is APPEX Global in London on the 1<sup>st</sup>-3<sup>rd</sup> March 2016 and, of course, the AAPG European Regional Conference on 'Petroleum systems of Alpine-Mediterranean fold belts and basins' in Bucharest, Romania on the 19<sup>th</sup>-20<sup>th</sup> May 2016.

I hope to see you at one of these excellent events!

**Jonathan Craig**  
*AAPG Europe Region President 2015-2017 Vice President, Exploration and Global Strategy Advisor, Eni Upstream & Technical Services, Milan, Italy*

# Fluids Overpressures and Decollements in Source Rocks - Application of Thermo-mechanical Models to the Subalpine Chains

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## ABSTRACT

A key question with respect to the petroleum exploration of Fold and Thrust Belts (FTB) is to determine the calendar of the formation, the expulsion and the migration of the hydrocarbon products in relation with the development of structural traps. The geometry of the successive deformation steps from the restored geologic cross sections until the present-day cross section must be predicted taking into account the mechanical behavior of the sedimentary basin materials. A study case in the Subalpine Chartreuse FTB is documented. Hydrocarbon-related fluids generated in the source rock decollement could have influenced its propagation and the development of thrust-related folds. In order to better predict the Chartreuse FTB scenario of evolution and to study the impact of the fluids pressure, it is necessary to incorporate a formulation of rock mechanics in basin models. Several simple mechanical models performed with the code FLAMAR show that it is possible to provide useful data with thermo-mechanical models. The localization, activation and propagation of decollements in a simulated mechanical stratigraphy could be explained only by the variation on several key parameters such as the internal friction angle and the cohesion of decollement rocks.

## INTRODUCTION

Many petroleum exploration studies of fold-and-thrust belts (FTB) have shown that the source rock levels under the frontal-most folds are crossing the oil window maturity level (Roure & Sassi, 1995; Moretti et al, 1996; Grelaud et al, 2002; Faure et al, 2004; Deville & Sassi, 2006; Sassi et al, 2007). A key question for the geologist is to determine the calendar of the formation, the expulsion and the migration of the hydrocarbon products in relation with the development of these structural traps. To answer these questions it is necessary to reconstruct in detail the sequential geometries of the geologic system. The geometry of the successive deformation steps until the present-day geologic cross section must be predicted such as to determine the restored cross sections taking into account the mechanical behavior of the sedimentary basin materials.

Forward kinematic models integrating balanced cross sections principles combined with thermal and geochemical elements (Roure & Sassi, 1995; Sassi & Rudkiewicz, 2000) often show the progression of the frontal thrust synchronous to the generation of hydrocarbon within shale source rock decollements (e.g. Moretti et al, 1996; Faure et al, 2004; Deville & Sassi, 2006). The high fluids pressure generated during the source rock maturation could have facilitated the formation of thrust-related folds and the propagation of decollement levels, and therefore impact the tectonic deformations and the fold styles (Mourgues & Cobbald, 2006; Zanella et al., 2014;

Aydin & Engelder, 2014). Still, a major difficulty is that currently balanced cross sections are obtained with mathematical geometric models and not with mechanical models. In order to better predict the scenario of structural evolution and to study the impact of the fluids pressure, it is necessary to incorporate a formulation of the rock mechanics of the sediments in basin models.

The Chartreuse FTB in the Western Alps provides constraints on a geological system where the propagation of the decollement and the development of the structural style could have been facilitated by fluid pressure in the main source rock (Deville & Sassi, 2006). In order to introduce mechanical concepts in the scenario of structural evolution we use the thermo-mechanical code FLAMAR (Burov et al, 2014, and reference therein). We run a parametrical study to investigate the onset of thrust development and localization with boundary conditions close to that of the Chartreuse. Different rheological parameters are tested, along with the introduction of a simple mechanical stratigraphy.

## GEOLOGIC SETTINGS

The Chartreuse FTB is located in the external part of the Western Alps (Figure 1). The tectonic structures result from the last step of deformation of the Subalpine Chains during the Miocene (Bellahsen et al, 2014 and references therein). The Chartreuse FTB is formed by a narrow succession of thrust faults that root within a Liassic-Aalenian decollement level (Figure 1).

The thrusts ramp up from the Lias-Aalenian shale without employing the potential decollement of the Middle Jurassic "Terres Noires" shales and Berrasian marls (Figure 2). The decollement level is localized within the Toarcian-Aalenian black shales, interpreted as a good quality source rock in the Subalpine chains (Deville & Sassi, 2006). While petrophysics and geochemistry studies provide good knowledge on the type and distribution of organic content and on the stratigraphy of the Liassic organic-rich intervals, the precise localization of the decollement level with respect to the shale mineralogy and the organic content is still poorly described and understood (Figure 2). Questions remain on the thickness of the decollement level and the impact of fluids circulations within and out of limit of the shale organic rich formation.

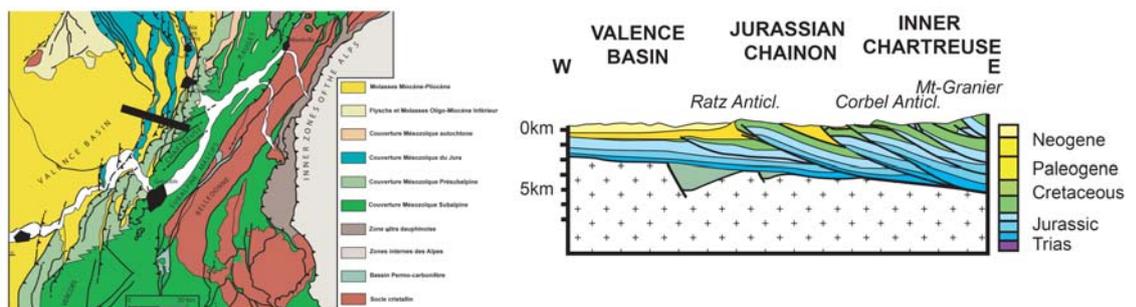


Figure 1- Location and cross section of the Chartreuse FTB.

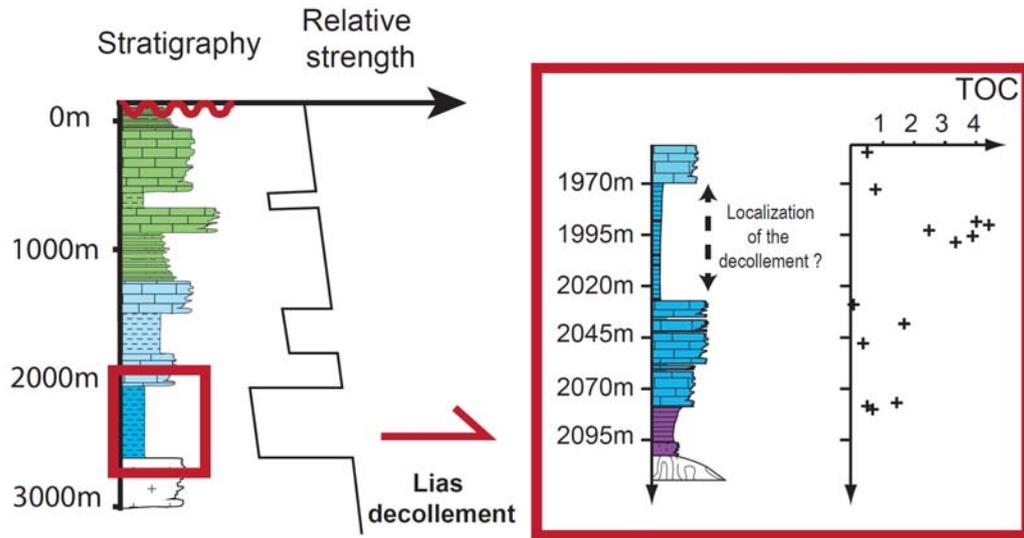


Figure 2- Stratigraphy of the Inner Chartreuse, with its relative strength. The zoom details the stratigraphy of the Lias and its TOC content, based on the Paladru well located west of the Ratz Anticline (Figure 1).

Thrustpack forward kinematic models (Sassi & Rudkiewicz, 2000) performed in the Chartreuse FTB propose that the timing of generation of hydrocarbons in the Lias is synchronous to the propagation of the decollement (Deville & Sassi, 2006). Moreover the Paladru well in the frontal-most thrust block evidenced hydrocarbon overpressures in the Toarcian, still in the oil-window in this area (Deville et al, 1994). Therefore several observations seem to indicate that hydrocarbon-related overpressure has a strong impact in the emplacement of the stacked thrust horses of the Chartreuse FTB. An integrated mechanical approach should in practice be used to explain the relationship between regional structural style differences as observed between the closely located Chartreuse FTB, Vercors FTB and Bauges FTB (Deville & Sassi, 2006; Bellahsen et al, 2014).

**INSIGHT FROM MECHANICAL MODELLING**

FLAMAR is a hybrid finite-element/finite difference code. It solves simultaneously Newtonian equations of motion in a Lagrangian formulation,

coupled with visco-elasto-plastic rheology, heat transport equations and state equation (see Burov et al, 2014 and reference therein). Several models are set according to a simple set-up (Figure 3), that respect the elastic and elasto-plastic solutions provided by previous analytical and numerical models (Sassi & Faure, 1997; Gerbault et al, 1998).

The point is to understand and constrain the onset of deformation with respect to specific boundary conditions supplied by the study of the Chartreuse FTB, in order to discuss and predict mechanical results. Sensitivity tests on physical parameters such as the internal friction angle and the basal friction of the material are performed (Figure 3). While only these basic mechanical rock properties are modified, important variations are observed on where the localization of the shear zone take place (Figure 3) and how the future faults geometry will lead to new structural blocks including their location and vergence (Figure 3).

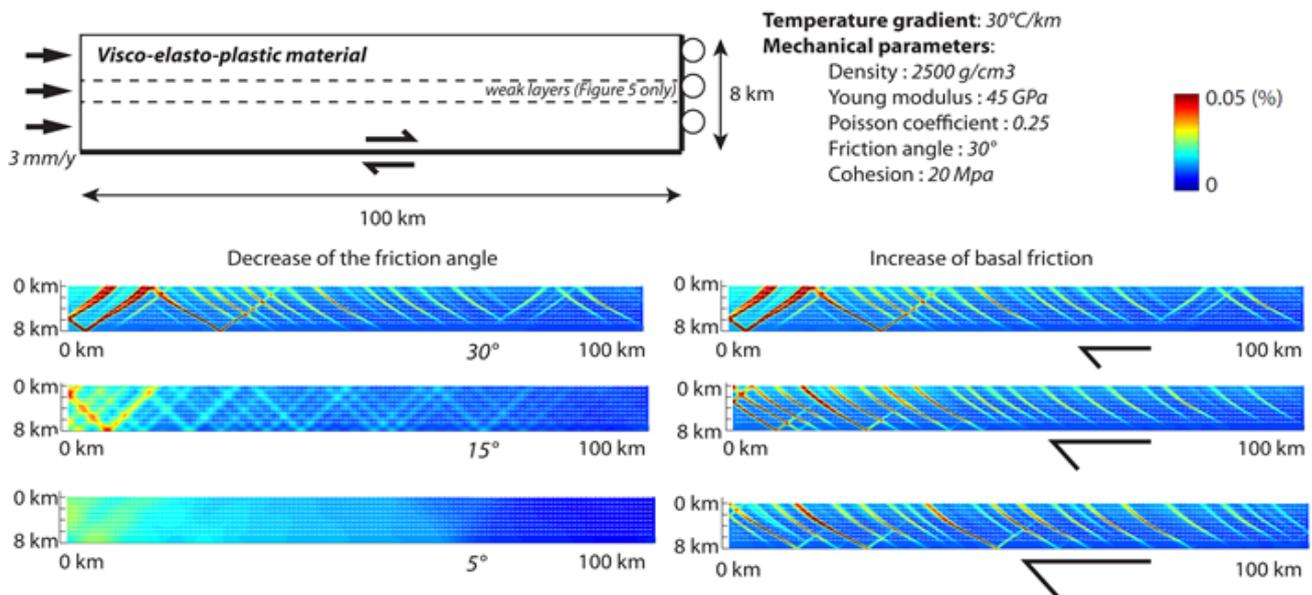


Figure 3- a) Set-up of the numerical experiments. The rheological laws are set according to Burov et al, 2014. b) Sensitive tests of the friction angle and the basal friction. Each picture represents the computed strain at 1km of shortening, with different friction angle and basal friction. Vectors indicate the orientation of the principal stress  $\sigma_1$ .

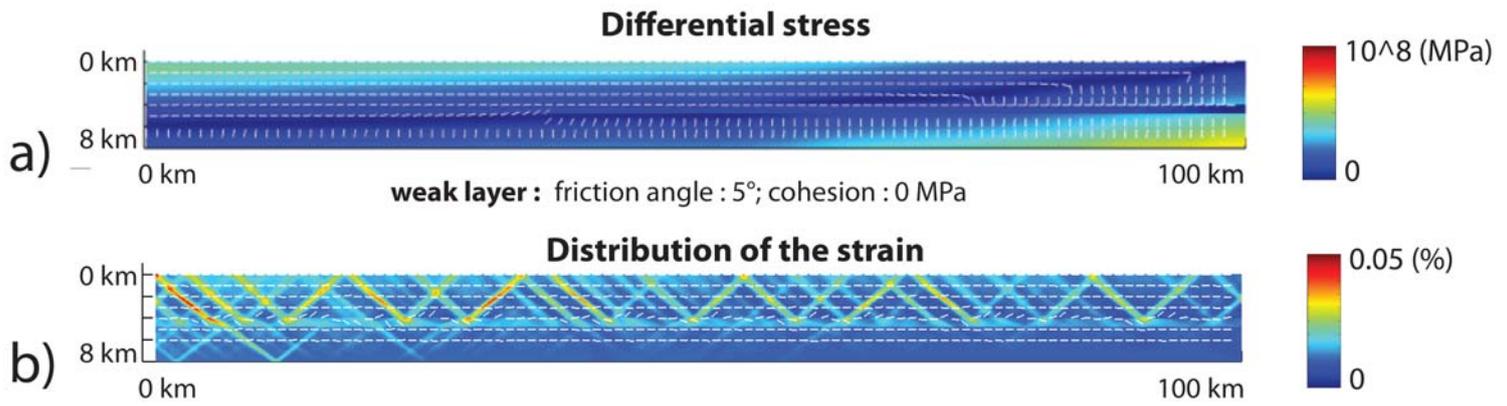


Figure 4 – Numerical results of the set-up with the introduction of mechanical stratigraphy. The picture represents the differential stresses at 100m of shortening (a) and the computed strain at 1km of shortening (b)

The introduction of a single weak layer in the model simulates a secondary decollement level that is able to modify both the stress field and the style of the deformation (Figure 4). These exercises of modified Hafner problem (Hafner, 1951) show that different mechanical answers can be displayed and an internal decollement can be developed using only simple hypotheses on the internal friction angle and the basal shear strength.

In further attempt to integrate more complexity in the exercises, several models are run with different mechanical stratigraphy (Figure 5a) and integrating a simple erosion/sedimentation law (Figure 5b). It is shown that a secondary decollement is activated only for a very low value of friction angle and cohesion (Figure 5a). When it does, the simulated fold adopt a geometry and kinematics close to that of a fault-bend fold (Suppe, 1983). However, for a value of friction angle and cohesion similar to that of natural shale, the secondary decollement is not activated (Figure 5a); the resulting geometry of the simulated fold is that of a fault propagation fold (Suppe & Medwedeff, 1984).

When a simple erosion/sedimentation law is integrated in the model, both stress and strain fields are deeply modified (Figure 5b). The decollement level activation is facilitated, leading to its progression toward the foreland, and a small transported piggy-back basin is formed in front of the main fault-related fold. Additional structural blocks are accounted in the frontal part of the model (Figure 5b).

**CONCLUSIONS**

A study case in the Chartreuse FTB is documented, where hydrocarbon-related fluids generated in a source rock decollement could have influenced its propagation and the development of thrust-related folds. However, currently the relation between source rock thermal maturation, fluids circulations and deformations cannot be considered in the building of a structural scenario of deformation, because no tools exist to provide

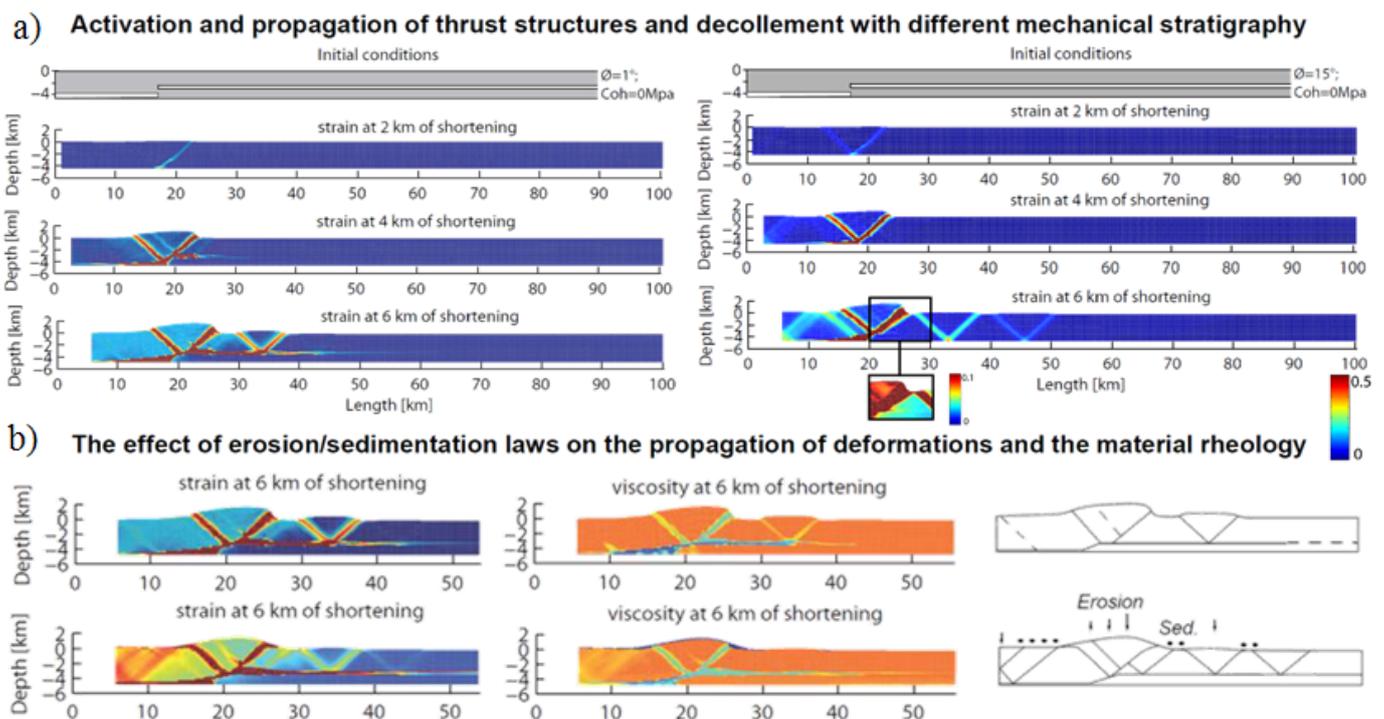


Figure 5 – a) Numerical results indicating the critical need of low friction angle and cohesion to activate and propagate a secondary decollement level. b) Effect of a simple erosion/sedimentation law on the strain distribution.

mechanical insight in basin models. Several simple mechanical models run with FLAMAR show that it is possible to provide useful data with thermo-mechanical model. The localization, activation and propagation of decollements in a mechanical stratigraphy can be explained only by the variation on several key parameters of the mechanical stratigraphy such as the internal friction angle and the cohesion of the decollement rocks. The critical values needed to activate a decollement in shale levels is shown to be very low, which may indicate the need for important fluids pressures to allow the development of such geologic structure. However, these critical values still need to be constrained with laboratory experiments. Also, external factors such as the erosion and the sedimentation strongly modify the distribution of the deformation in a mechanical stratigraphy, and therefore must be taken in those kind of modeling approach.

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## ACKNOWLEDGMENT

*It is with great regret that we dedicate this article to our colleague and friend Professor Burov, who sadly passed last week on a business trip to Santiago del Chili. Our thoughts and deepest condolences are with his family, friends and colleagues at this time, particularly in France and the Netherlands. Evgueni was an outstanding scientist, ever positive and highly regarded by all who worked with him. He will be sorely missed.*



## AAPG YP Aberdeen Chapter Ythan Estuary fieldtrip

*September 2015*

*Written by Peter Heath*

This September the Aberdeen AAPG Young Professionals chapter, in partnership with the PESGB went on a day-long fieldtrip to the Ythan Estuary. The locality is best known in the Aberdeen area as a place to see friendly seals but also offers geologists the chance to study modern estuarine and aeolian sediments analogous in part to some of the Carboniferous and Permian reservoirs in the Southern North Sea.

The group consisted of both young professional and student members with a variety of backgrounds, and was led by Doug Boyd from Integrated Sedimentology Ltd who generously offered his time and expertise. The trip was planned to take advantage of low tides, allowing the group excellent and safe access across the area.

First stop of the day was to look at sediments within the estuary margins, and the boundary between fluvial and terrestrial sediments. It quickly became apparent from the slipping and sliding around that the main channel in the estuary was filled with very fine grained materials, which was contrary to the group's expectations. Subsurface professionals commonly anticipate estuaries to be largely sand-dominated systems, particularly in highly energised central channels. Whilst this may often be true, the Ythan clearly demonstrates that estuaries can be dominated by mud-rich facies when the fluvial sediment supply is low. Failure to identify this in the subsurface clearly could have consequences during reservoir characterisation and modelling.

Moving downstream, the group turned their attention to the nearby sand dunes. Modern dunes were noted to be peculiar features, offering one of the few ways to deposit materials above mean sea level. Such topography means that dunes are generally short-lived, and present day dune environments may not be entirely analogous the stratigraphic record. Dunes are, however, interesting geomorphological features which can exhibit extraordinary sedimentation rates. It was at this point that Doug demonstrated the very latest chronostratigraphic method "litterology", trawling through a dune picking out disused food packets is used to date sediments. Although this method clearly contains a degree of uncertainty, the discovery of a 1970s crisp packet nearly a meter below ground level gives some idea of the rate at which sand dunes can build.

Having mapped the various facies discovered in the area, the group moved onto the second activity, a team exercise. Teams were issued with a 'top structure' map, and combined with their knowledge of the facies distributions were tasked to produce a field development plan for the fictional Ythan Estuary oilfield, with a \$50mm budget. Each team presented their findings, and the group discussed the impact that structural configuration can have on the field development concept.

Deciding to make the most of the miraculous weather, the group decided to spend the remaining afternoon exploring Northern side of the Ythan, taking time to see the seals that Newburgh is so famous for and finished off with a few drinks at a local watering hole.

Many thanks to Doug Boyd for leading this excellent trip, and to our sponsors Chevron and Maersk for making this trip possible.



*Student and YPs working in teams on the Ythan Estuary, looking out onto the North Sea*



*Thanks to the group for coming along, we hope to see you at the next AAPG field trip*



SAVE THE DATE!

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## Petroleum Systems of Alpine-Mediterranean Fold Belts and Basins

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AAPG Europe are pleased to be hosting the annual European Region Conference and Exhibition in this region which has a rich history of petroleum exploration.

### CALL FOR ABSTRACTS COMING SOON!

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