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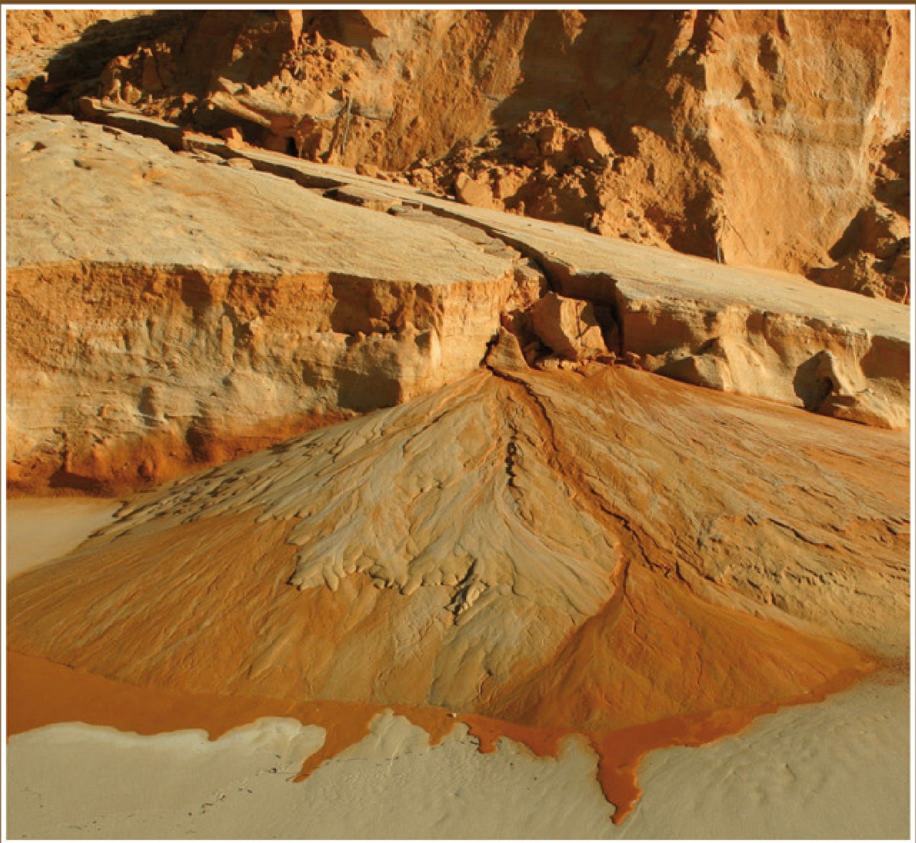

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EDITORIAL

Newsletter 251 opens with the announcement of the launch of a new IAS Open Source Journal: The Depositional Record. A new volume of the IAS Special Publication N. 46 will available by the end of the summer.

In the Student Corner, Balázs Törõ reports how he has used the allocated IAS grant, and Daniel Ariztegui informs on the pre-ISC conference student field trip.

Please note that the guidelines for the Student Grant applications have been updated. Allocated grants (1st Session 2014) and the IAS Financial Statement is reported at the end of the Newsletter.

I would like to remind all IAS members that:

- the IAS Newsletter 251 is published on-line and is available at: http://www.sedimentologists.org/publications/newsletter
- the next IAS Meeting will be held in 2014 in Geneva (CH). For details, please check: http://www.sedimentologists.org/meetings/isc
- IAS will be present at the AGU Conference (December, 2014, San Francisco - USA); please visit: http://fallmeeting.agu.org/2014/

The Electronic Newsletter (ENIAS), started in November 2011, continues to bring information to members. For info on ENIAS contact Nina Smeyers at nina.smeyers@ugent.be

Check the new Announcements and Calendar. Meetings and events shown in **CAPITAL LETTERS** and/or with * are fully or partially sponsored by IAS. For all of these meetings, IAS Student Member travel grants are available. Students can apply through the IAS web site. To receive the travel grant, potential candidates must present the abstract of the sedimentological research they will present at the conference. More info @ www.sedimentologists.org

Vincenzo Pascucci
(IAS General Secretary)

ANNOUNCEMENT

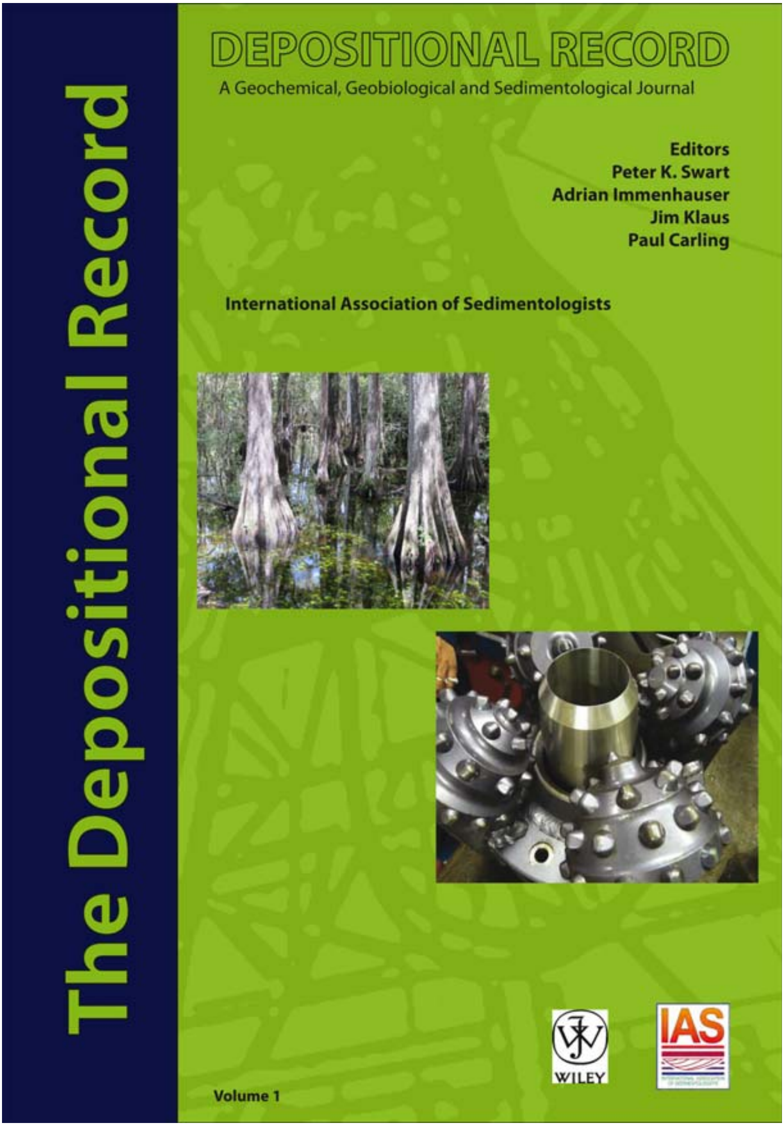
A new journal for IAS

From January 2015 there will be a new journal for the rapid publication of your geochemical, geobiological and sedimentological papers: **«The Depositional Record**”. In order to encourage high quality submissions and achieve a good impact factor, publication charges for all papers over the first two years will be paid by the IAS. As the journal will be online only papers will appear in issues soon aÔer they are finally accepted.

The journal will emphasize the application of sedimentary processes to the study of paleoclimate, changes of the chemical environment throughout deep time (such as changes in the composition of seawater oxygen isotopic composition and Mg/Ca ratios, ocean acidification etc.), modern studies on ocean acidification, extraterrestrial sedimentology, application of genetic methods to understanding sedimentological processes, such as using genetic probes to understand processes, interaction between the biological and geological systems such as calcification in carbonate secreting organisms, the role of microbes in the formation of carbonate minerals, the use of novel geochemical methods such as clumped isotopes, the application of non-mass dependent fractionation of systems involving more than two stable isotopes, as well as normal sedimentary processes.

The journal would cover all time scales from the Modern to the Ancient Earth. Hence we would include experimental studies on modern organisms and sedimentary systems as well as the application of such results to the oldest sediments on Earth and periods in between.

The journal will be overseen by a team of four experienced editors, Peter Swart, Paul Carling, Adrian Immenhauser, and Jim Klaus, the intended themes for the new journal (Geochemistry, Geobiology, and Sedimentology). For further information please contact one of the editors or visit the IAS (http://www.sedimentologists.org/) or Wiley websites (hp://onlinelibrary.wiley.com/).



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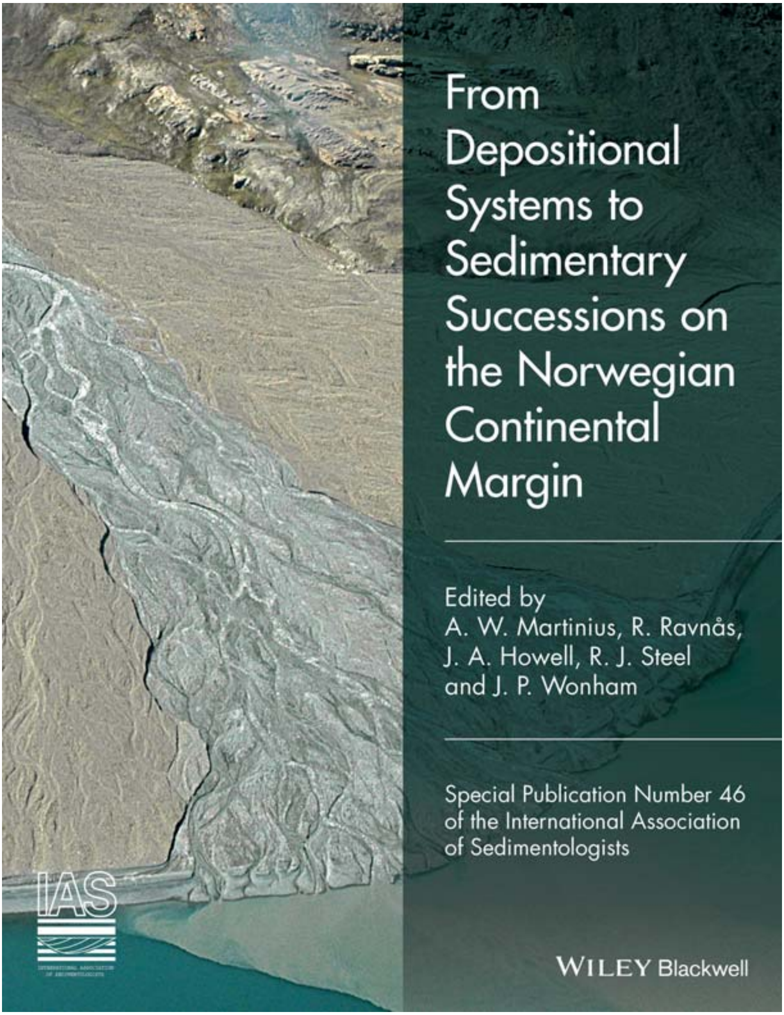
Advance preview of forthcoming IAS Special Publication 46, to be published September 2014: From Depositional Systems to Sedimentary Successions on the Norwegian Continental Margin. All Special Publications are colour throughout, have no page limits, and are indexed in Wed of Science. We invite proposal submissions for future volumes. All submissions are now entirely processed online through the ScholarOne website. Please contact Thomas Stevens for more information - thomas.stevens@rhul.ac.uk



STUDENT CORNER

IAS Postgraduate Grant Scheme Report (1st Session, 2013)

CHARACTERISTICS AND IMPLICATIONS OF EARTHQUAKE-INDUCED SOFT-SEDIMENT DEFORMATION FEATURES (SEISMITES) IN LACUSTRINE SEDIMENTS OF THE GREEN RIVER FORMATION (EOCENE, USA)

1.Project Description

Introduction

Soft-sediment deformation features occur in unconsolidated sediments with low or zero shear resistance reached by thixotropic behavior, liquefaction and/or fluidization (liquidization) (Owen, 1987). Liquidization can be triggered by several processes (e.g. overloading, storm waves, earthquakes). However the final morphology and size of the deformed structure depends on the driving force system (e.g. density contrast, unequal loading) and the areal extent and thickness of the rheologically susceptible sediment (Owen, 2003). Accordingly, recognition of the trigger mechanism is complex, many commonly used criteria are unreliable, non-diagnostic, or difficult to apply, and the determination of the trigger mechanism relies on criteria that are not yet well established (Sims, 1975; Jones & Omoto, 2000; Montenat *et al.*, 2007; Owen *et al.*, 2011).

As sand-rich sediments are often considered to have the highest liquefaction susceptibility, deformation

features are commonly reported from siliciclastic depositional environment. Soft-sediment deformation features in carbonates and mudstones (marine or lacustrine) are less common, and the effects of fines (silt and clay sized particles, lime mud, organics) are poorly understood.

Sediments deposited in lacustrine environments have great potential to study the formation and implications of seismically induced soft-sediment deformation structures (seismites – sensu Seilacher, 1984) (Rodríguez-Pasqua *et al.*, 2000; Moretti & Sabato, 2007). Their heterolithic nature gives them high susceptibility to deformation owing to their variable rheological properties. The low-gradient, quiet-water environment tends to eliminate other triggering mechanisms of synsedimentary deformation (e.g. overloading, storm

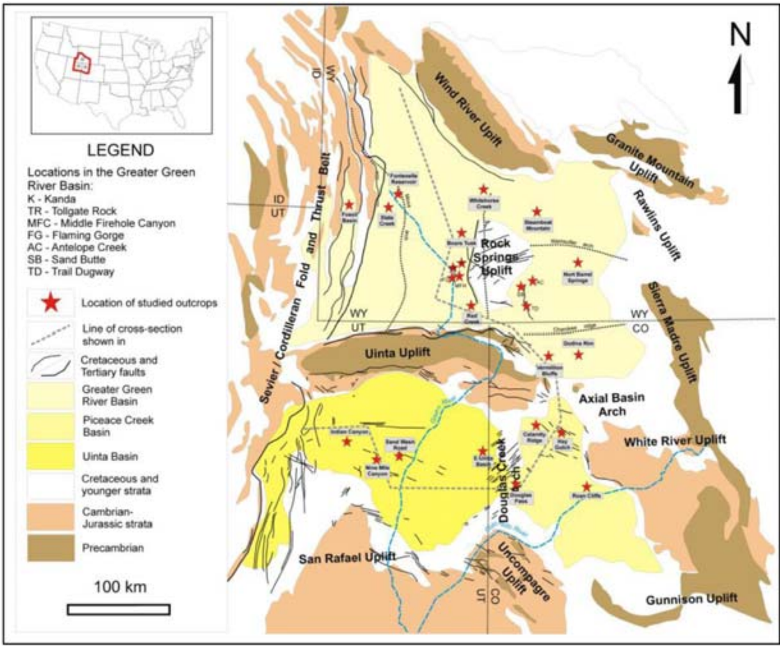


Figure 1. Map of the Green River Basins of SW Wyoming, NW Colorado and NE Utah (modified after Smith et al., 2008), showing all the studied locations and main structural elements (uplifts, and faults)

waves), and increases the potential for preservation (Renaut & Gierlowski-Kordesch, 2010). As soft-sediment deformation features induced by earthquakes are indicative of synsedimentary tectonism, these features can provide information about the location, timing, and intensity of the movements of structural elements in the study area (e.g. Weidlich & Bernecker, 2004; El Taki & Pratt, 2012). Tectonic events, in turn, may have induced changes in the paleohydrology of an area.

- Geological Background

Lacustrine sediments of the Green River Formation were deposited in interconnected foreland basins east of the Cordilleran fold and thrust belt in the central Rocky Mountain region during the early to middle Eocene (53 Ma – 45 Ma) (Dickinson *et al*., 1988; Smith *et al*. 2008). The Green River Formation represents one of the best-documented ancient lake systems and has long been a type example for understanding lacustrine depositional systems (Bradley, 1929; Eugster & Surdam, 1973; Carroll & Bohacs, 1999). Sediments comprise siliciclastic, evaporitic and carbonate lake-margin and profundal lacustrine strata almost 2 km thick in southwest Wyoming, northeast Utah and northwest Colorado, USA (e.g., Bradley, 1964; Roehler, 1993;

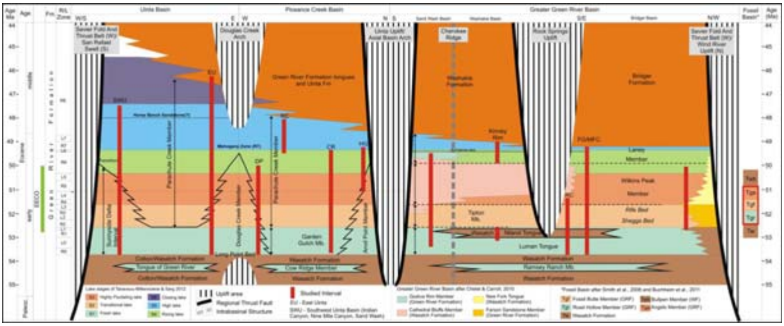


Figure 2. Main structural elements, simplified stratigraphy and correlation of the Greater Green River, Piceanc e Creek and Uinta basins (modified after Smith et al., 2008; Chetel & Carrol, 2010; Tänavsuu-Milkeviciene and Sarg, 2011), with the studied locations/stratigraphic intervals.

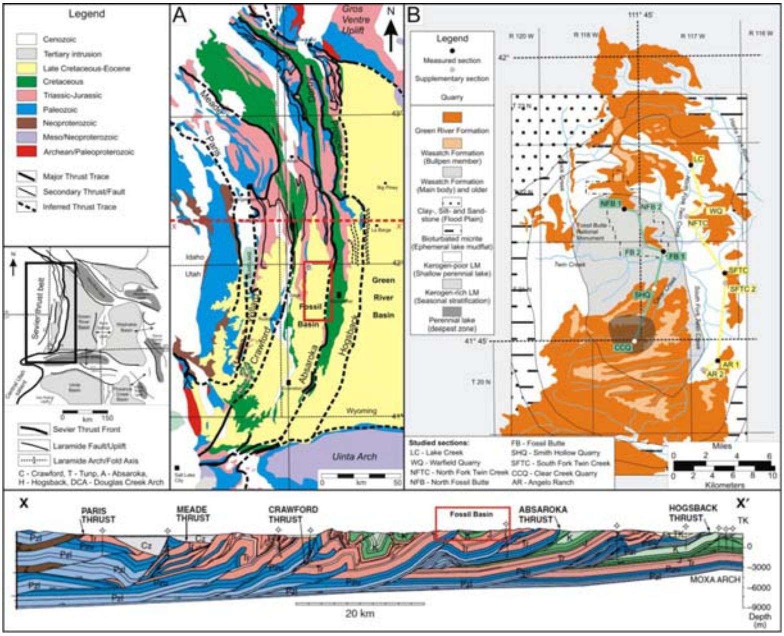


Figure 3. Geological map of the Sevier Thrust Belt (A) and cross-section (C) across the northern part of the Fossil Basin (modified after Yonkee & Weil, 2010); B. Studied locations and paleoenvironments of Fossil Lake during the lower part of the Fossil Butte Member (after Buchheim & Eugster, 1998)

Smith *et al.*, 2008). Sediments were deposited in three, temporarily connected lakes, the «Lake Gosuite» (greater Green River Basin, SW Wyoming and NW Colorado), «Fossil Lake» (Fossil Basin, SW Wyoming), and «Lake Uinta» (Piceance Creek Basin, NW Colorado and Uinta Basin, NE Utah) (Fig. 1). The Green River lake basins have been interpreted as permanent and stratified lakes (e.g., Bradley 1964; Bradley and

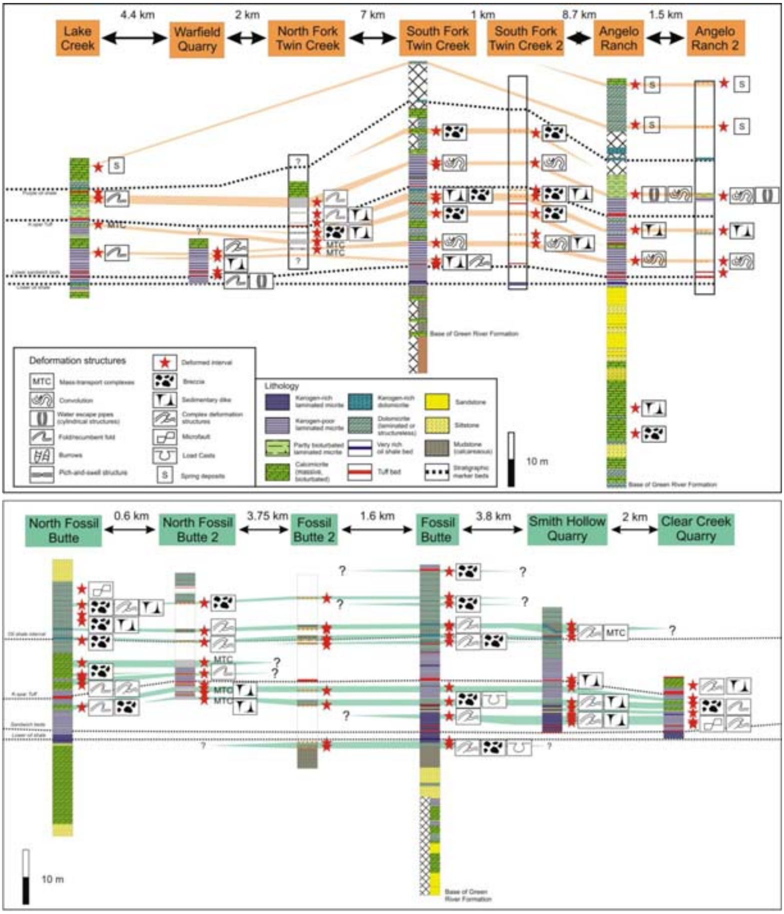


Figure 4. A - B. Preliminary correlation of deformed horizons between the studied locations showed on Fig 3 (stratigraphic sections N-Fossil Butte, Fossil Butte, Clear Creek Quarry, Angelo Ranch, and Lake Creek are based on Buchheim & Eugster, 1998; Buchheim et al., 2011). Note: distance between 'North Fossil Butte' and 'North Fossil Butte 2' locations is not to scale.

Eugster 1969; Desborough, 1978; Johnson, 1981) or playa lakes (e.g., Eugster and Surdam, 1973; Eugster and Hardie, 1975; Lundell and Surdam, 1975; Cole & Picard, 1978; Moncure & Surdam,

1980); others have noted that both may be applicable but at different times (e.g., Eugster and Surdam 1973; Boyer

1982; Moncure & Surdam, 1980; Smith *et al.*, 2008; Davis *et al.*, 2009). These lake basins are surrouned and separated from one another by chains of anticlinal basement-cored uplifts and arches that formed during the Laramide orogeny, which were variably active from the Cretaceous through Eocene (Beck *et al.*, 1988; Dickinson *et al.*, 1988; De Celles, 2004; Mederos et al., 2005; Bader, 2008, 2009). The tectonic movements along these structures in and around the lake basins influenced the basin shape, gradients and the sedimentation of the Green River Formation (Roehler, 1992b; Pietras & Carroll, 2006; Smith *et al.*, 2008). Despite the known syndepositional tectonic activity along the structures in and around the basins, and the large number of geological studies devoted to the stratigraphy, deformation features linked specifically to tectonic movements have not previously been identified.

Soft-sediment deformation structures are well known in profundal sediments ('oil shales') of the Green River Formation (e.g. the brecciated/ soft-sediment deformed beds and dewatering structures of Tänavsuu-Milkeviciene and Sarg, 2012). Chaotically deformed intervals in laminated oli shale deposits generally show contorted breccias («streaked-and-blebby» oil shale), disrupted bedding, with soft-sediment folds, microfaults and sedimentary dikes. However, the origin of these beds is still unclear, as these features can be described as the results of mass-movement processes (slumps, trubidites) of unlithified sediments (e.g. Dyni and Hawkins, 1981), or in-situ soft- sediment deformation of the beds (e.g. intrastratal hydroplastic flow structures of Buchheim, 1982). The occurrenceand study of such deposits in an otherwise low-energy profundal lacustrine environment with low slope gradients can be important for the interpretation of the sedimentological record.

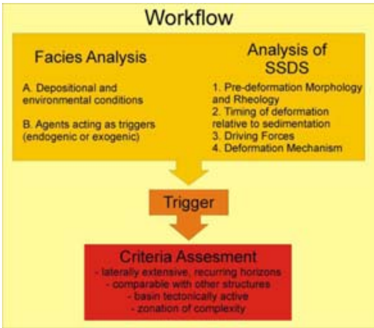
- Previous Work in 2012

During the Summer of 2012 a 7-week fieldwork was conducted to study several outcrops, the regional geology and facies relationships of the Green River Formation in all the sub-basins, in Wyoming, Colorado and Utah (USA). Pervasive horizons of soft-sediment deformation structures were identified and sampled. Many of the deformation features I identified have been mostly overlooked in the literature, or not described in detail. Deformed layers have been found in deposits ranging from paludal (coal and sand) to profundal (oil shale) and deformation structures

were classified based on their descriptive geometric characteristics.

- Research Methods and Goals

As proposed by Owen *et al* (2011), the recognition of potential trigger agents has to be based on the relationship between the occurrence of soft-sediment deformation structures and the sedimentary facies of the successions in which the deformed layers occur. The aim of this approach is to sort out internal and ordinary processes in the sedimentary



environment, which are able to induce the observed deformation feature (autokinetic triggers), and to deduce an earthquake origin on reliable way.

After the regional mapping and reconnaissance of deformation features in 2012, well-defined stratigraphic intervals were chosen for further, detailed studies, which are easy to correlate over long distances. Detailed

sedimentological fieldwork has been carried out at key locations to determine the depositional environment, and to make further observations on the sedimentology and stratigraphy of the outcrops and on the frequency and distribution of the deformed horizons. Furthermore, the genetic description and classification of soft-sediment deformation structures can give an insight into the governing factors of deformation and the implications of seismites. Moreover, as seismically induced structures indicative of synsedimentary tectonic movements, their stratigraphic and geographic distribution can provide data on their temporal and spatial occurrence, and the paleotectonic history of nearby fault systems and uplifts can be refined.

2. Project results

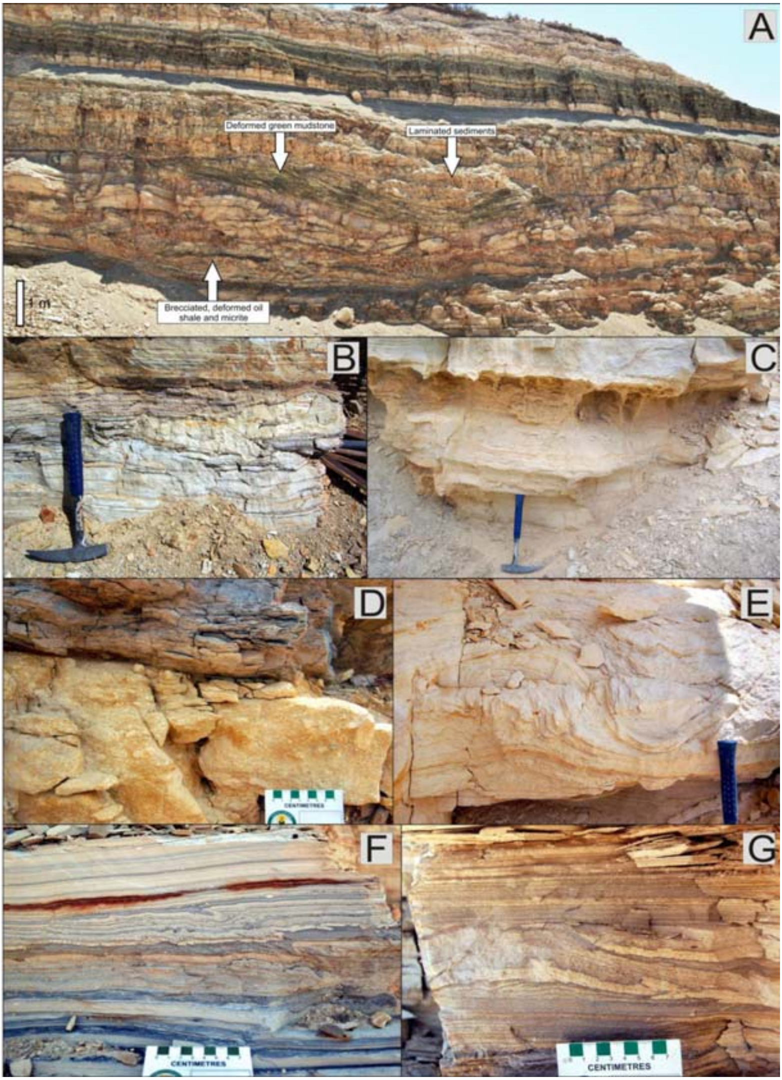
The fieldwork in 2013 focused on 5 main locations/stratigraphic levels within the whole Green River Formation: (1) the Fossil Basin (WY); (2) the boundary of the Tipton Shale –

Figure 5. Examples of deformation features is the Fossil Basin, WY. A. Mass transport complex and chute filled by deformed green mudstone and laminated carbonate mudstone above. The base of the cut is a resistant, brecciated pinkish oil shale bed. The oil shale bed, the laminated carbonate mudstones and tuff (dark orange interbeds) show complex plastic/brittle deformation in a 2 m thick zone below the cut with thrusted blocks, folding and sedimentary injections. The same interval can be traced for more than 10 km/6 miles across the centre of the former lake basin; B. Bulbous sedimentary dike filled with carbonate mud in organic rich oil shale, formed by segregation during seismic shaking and dewatering; C. Sedimentary dikes filled with calcareous silt and sand are penetrating downward from an irregular discontinuity surface; D. Inverse graded brecciated lime mudstone bed (mass transport deposit) with large (> 15 cm) clasts on the top. The layer is capped by deformed organic rich oil shale bed; E. Convoluted profundal laminated lime mudstone; F. Deformation related to the combination of microfaulting, folding and loading in oil shale. Folding is more general in the blue, organic-rich intervals, with continuous lamination, while the white, organic-lean parts show fragmentation, thrusting. G. Deformed interval in laminated micrites with fragmentation and folding. Sharp, erosive top indicates deformation after shallow burial.

Wilkins Peak Members in the eastern Bridger Basin (WY); (3) the 'lower' Laney Member along the Kinney Rim, western Washakie Basin (WY); (4) the Mahogany Oil Shale Zone (MOSZ) in the Piceance Creek and Uinta basins and (5) the boundary of the Green River and Uinta Formations in the eastern Uinta Basin (UT) (Fig. 1 & 2).

- *General observation*

In general, deformation features have a wide range of morphology, size, and deformation response is ranging



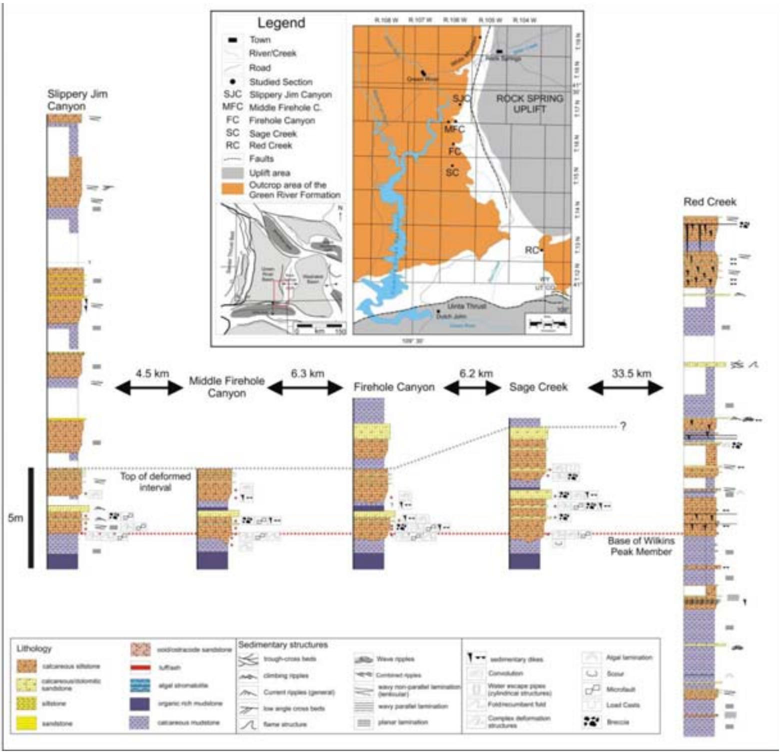


Figure 6. Studied locations, Eocene faults and measured sections from the eastern margin of the Bridger Basin, Wyoming.

from brittle (dislocated, fractured and/ or fragmented laminites, synsedimentary faults) to plastic (convolution, folding, load and flame features), to sedimentary injection into dikes and cracks. Some injection features show multiple deformations, indicating that more than one event induced failure of the sediments (cf. Pratt, 1998).

The style of deformation was controlled by the rheological properties of the host sediment. Grain size and morphology, abundance of organic matter (which influences ductility) and degree of diagenesis (compaction, cementation) all influenced the deformation structures. The variation in size, morphology and areal extent of the deformation features can be explained by the thickness changes and/or lateral facies variations and by the nature of the driving force.

In most cases, deformed layers are bound above and below by undeformed beds of similar facies with

horizontal bedding plane surfaces. This implies short-lived, recurring events that affected only sediments with a susceptible rheological state at the time. Furthermore, this indicates

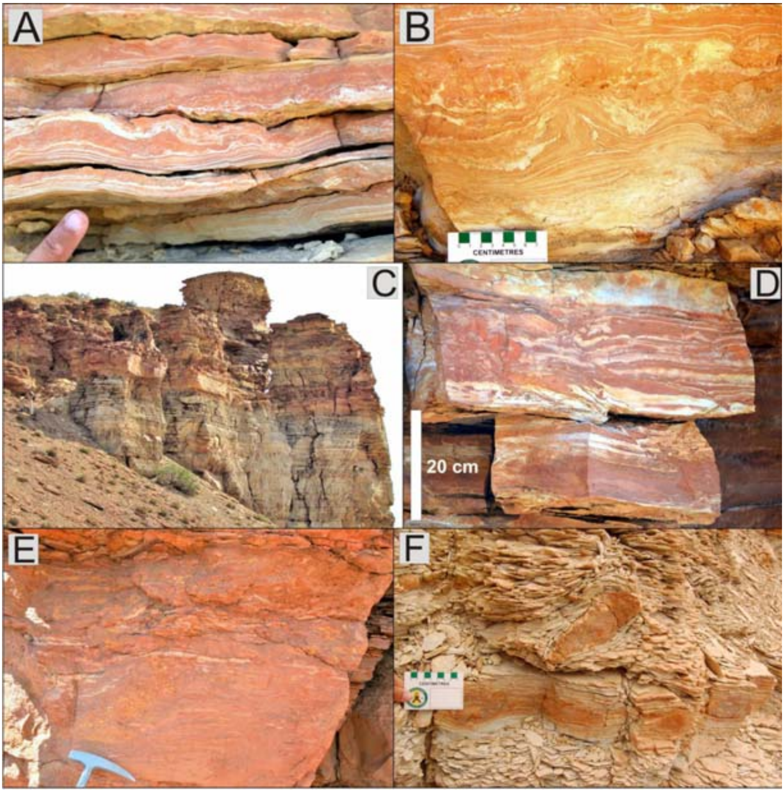


Figure 7. A. Lowermost deformed interval at Slipper Jim Canyon with plastic features indicating liquefaction and microfault. B. Lowermost deformed interval at Middle Firehole Canyon, showing complex deformation (fault related folds) in a mixed layer; C. Outcrop of the Tipton Shale-Wilkins Peak boundary at Firehole Canyon, with two coarsening upward cycles; D. Brittle-ductile deformation in the second deformed interval, with thrusts, brecciation (upper left & lower right), slight folding and sedimentary injections (on the left); E. Deformed interval 3 indicates a series of event (a) brecciation - (b) shearing and (c) injection of brecciated material (Sage Creek); F. Large isolated crack filled with silicified brecciated material (Red Creek). Note the smaller horizontal sill on the left.

that (1) the deformed zones were at (or close to) the sediment-water interface when deformation occurred, or (2) the deformation occurred in a confined interval. The presence of the undeformed beds is also useful to discard possible autokinetic trigger mechanisms, such as internal and ordinary sedimentary and/or erosive processes.

- *1. Fossil Basin (WY)*

The Fossil Basin is a small intermontane, axial basin in SW Wyoming and surrounded by the Sevier fold and thrust belt, which were active during the deposition of the Green River Formation in the basin (Rubey *et al*., 1975; Lamerson, 1982; Dickinson *et al*., 1988; Buchheim *et al*., 2011). The lacustrine deposits of the Fossil Basin offer a great opportunity to study and correlate deformed horizons within longer distances (up to 25 km). The thickness of lacustrine sediments deposited in the Fossil Lake is only 120 m and as a result of the deposition in a small and relatively shallow lake, the thickness and depositional facies of the Green River Formation change rapidly within short distances (Buchheim & Eugster, 1998). These facies transitions are better exposed and easier to study than in other basins of the Green River Formation. Correlation of extensive deformed intervals is aimed by the presence of numerous stratigraphic marker beds. Laterally extensive deformation features were also described by several authors (e.g. Buchheim *et al*., 2011), however they were not linked to tectonic events.

Lacustrine sediments of the Fossil Basin host a large variety of sedimentary deformation features, from large convolution structures to sedimentary dikes and mass transport deposits (Fig. 4 & 5). Many of these deformed horizons could be correlated across the basin. Synsedimentary tectonic activity at this area is documented by several authors (e.g. Dorr & Gingerich, 1980; Coogan, 1992). As a result, these extensive deformed intervals are interpreted to be the result of late stage tectonic movements along the nearby Absaroka and Hogsback thrusts (Fig. 3).

2. Boundary of the Tipton Shale and Wilkins Peak Members, eastern Bridger Basin (WY)

The boundary of the Tipton Shale and Wilkins Peak Member (Fig. 2) contains at least 5 well defined deformed intervals in two coarsening upward cycles of sublittoral sandy calcareous siltstone/silty mudstone deposits (Fig. 6,

7). Each interval could be traced for more than 20 km. In general the lower 3 deformed intervals show mainly

plastic or brittle-plastic deformation. Up section the brittle behavior is dominant. In some of the cases deformed intervals merge and overlap and couldn't be separated. Coarsening upward sedimentary cycles with similar depositional environment higher in the sections showed no deformation, indicating an allokinetic trigger.

Further to the north, by White Mountain, deformation structures could not be observed as a result of facies changes into recessive sediments with a lack of good exposure. At the Red Creek area, closer to the Uinta Fault system, the Tipton Shale Member change facies, as sediments were deposited closer to the former lake margin and the boundary between the two members is less obvious. The boundary was placed by the first appearance of extensive and large-scale sedimentary dikes.

- *3. Laney Member, Washakie Basin (WY)*

Outcrops of the Laney Member of the Green River Formation have been studied at four locations along the western and northern part of the Washakie Basin, Wyoming (Fig. 1). Sedimentary dikes identified at three

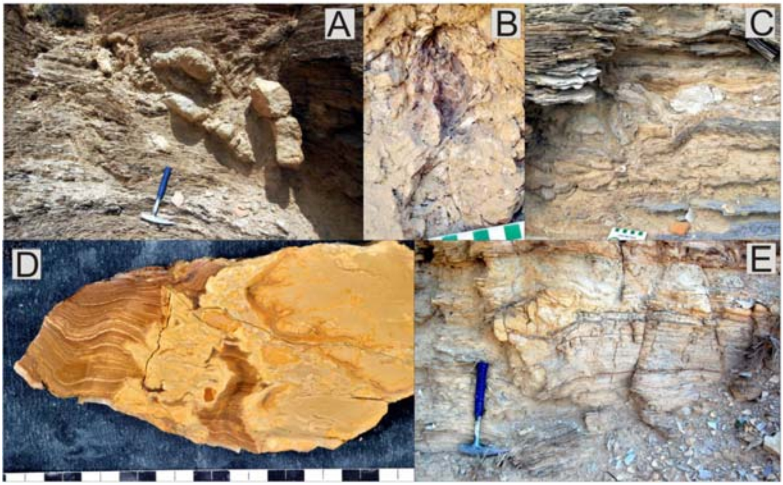


Figure 8. Characteristics of sedimentary dikes in organic rich and lean laminated lime mudstone deposits of the Laney Member, Washakie Basin: A. Dike at the base of the Buff Marker Bed filled with fragmented material showing multiple filling (AC); B. Dike with a central conduit filled with laminated chert (SB); C. Weathered sedimentary sill indicates intrastratal, horizontal injection (SB); D. Sample with multiple filling indicating more than one fluidization event (TD); E. Dike filled with carbonate mud and silt. Note the thin analcime-tuff layer with long cracks at its base (SB).

locations (Antelope Creek, Sand Butte, Trail Dugway) are up to 1,5 m long and several cm wide, filled with homogeneous mudstone or a mixture of fragmented material of mud, silt, sand, massive or laminated chert, fragments of lacustrine sedimentary rocks and tuff material (Fig. 8). The crack-fill is generally silicified, and many times a central conduit can be observed, occasionally filled with massive or laminated chert/calcite. The source of the crack fill is frequently a brecciated/rip-up layer or massive silty mudstone. Cracks show moderate sinuosity, branching, multiple fillings, brecciated internal structure, and their overall width decreasing downward and/or upward in laminated oil-shales or micritic mudstones. In many cases the cracks are represented by isolated bulbs or horizontal sills.

Rhodes *et al.* (2007) interpreted these cracks as the result of desiccation that occurred after a regional tectonic event which caused the modification of the regional drainage system. However the overall morphology and the infill of the cracks (with a central conduit) indicate fluid migration and sediment remobilization. Cracks are more frequent and larger in size at the base of a regional marker bed, the Buff Marker Bed. Their morphological characteristics are similar to the ones, found in several other stratigraphic levels in the Laney Member, which suggests a common, tectonic origin.

- 4. Mahogany Oil Shale Zone, Piceance Creek and Uinta Basins (UT, CO)

Pervasive deformation features were investigated across the Uinta and Piceance Creek Basin in the Mahogany Oil Shale Zone (MOSZ), an extensive stratigraphic marker in the Green River Basins of Colorado and Utah, which contains several organic rich shale beds (Fig. 9). Deformation style ranges from brittle (fragmented/faulted beds) to plastic (convolution/folding), to sedimentary injections into cm- to m-scale dikes. In general, the style of deformation was governed by the rheological properties of the sediment, trough the amount of organic matter.

- At **Indian Canyon** two prominent deformation zones were identified (Fig. 10A-B), with sedimentaty dikes in profundal and sublittoral lacustrine sediments. Extensional joints, and oriented injection features indicated E-W extension; sheared beds showed N/NNE movement/compression.

- Deformation features at **Gate Canyon** are characterized by (1) horizons with mud-filled carbonate injection

features («dewatering structures») in the oil-shales; (2) 0.1 - 2 m long sedimentary dikes filled with silicified carbonate mud and silt; (3) sheared oil shale (the Mahogany bed), showing en-echelon fabric, shear related propagation folds, kink and sheat folds, shear duplexes and thrusting (Fig. 10C). Small scale oriented cracks and the shear fabric indicated top to left (North) shear/compression, and perpendicular (~ 170) extension, with extensional joints (strike ~120).

- At **North Franks Canyon** Deformation structures are dominated by remobilized non-calcareous/silicified

mudstones at multiple detachment surfaces, forming large-and small-scale dikes and sills 0-3 m below the Mahogany Bed (Fig. 10D). Sheared layers within the interval indicated N-ward displacement, while small duplexes within the dikes showed S-ward movement. N-S oriented joints, and oriented small-scale «shrinkage-cracks» in silty mudstone deposits in the succession indicated E-W extension.

- At the **Sand Wash** area the Mahogany Oil Shale Zone hosts a 4-10m thick chaotic interval with complex deformation features, showing characteristics of a mass transport complex (MTC) (Fig. 11A-C). The interval has a sharp, erosional lower boundary on the top of horizontally bedded lake sediments, with smaller scale deformations and silicified sedimentary injections (up to 3 m long). The source of these dikes either the base of the MTC, or horizons within the deformed lake sediments. At many places a distinct, rich oil shale bed forms the basal boundary (e.g. 1), which is in turn brecciated or disrupted by the MTC. Internally the MTC shows two distinct lithofacies: (a) sandy-silty matrix, with sand-/silt-/ mudstone and oil shale clasts, or (b) massive/ laminated, blocky brown-dark brown siliceous mudstone with clasts of oil shale. In both cases chaotic

deformation, sheared fabric, or large-scale recumbent folded intervals are general. Large, tilted rafts of brecciated oil shale can be found at the top of the MTC. This upper oil shale is considered to be the Mahogany Bed. In places it seems continuous and intact, however even at those places it shows brecciation and small-scale disruption. Locally the upper oil shale bed is overlain by irregular, lens shaped lacustrine succession and/or orange tuff layer, mixed with organic-rich and lean oil shale and tuffaceous sediments, showing brittle-plastic deformation. This upper lacustrine succession is overlain by an undeformed (ledge-forming) wavy-bedded tuffaceous sand- and siltstone. The MTC indicates a large-scale slumping event and the instability of profundal to sublittoral sediments, which might have related to tectonic activity along the Sand Wash Fault Zone.

- In the Eastern Uinta basin, at **Evacuation Creek**, the MOSZ was studied in the box cut of the Enefit American Oil company. ~1.5 m below the Mahogany Bed an irregular horizon was identified, with en-echelon shear structures, folding, and thrusting (Fig. 11D). However deformation dies out quickly within a NE- SW direction. Structures indicate shear/slump towards SW (~230). A second, 10- 25 cm thick sheared zone was also found on the top of the Mahogany Bed (Fig. 11E), with similar structures and stratigraphic position as at Gate Canyon 100 km West.

- At **Hells Hole Canyon** several well defined, and traceable brecciated and/or plastically deformed horizons were found (Fig. 11F). Sheat folds with clear indication of the stress field showed shear/compression to WSW (~245).

- Recumbent folded intervals and sedimentary dikes were also identified at **Roan Cliffs**, Colorado (Fig. 11G)

- The great lateral extent of the deformation features, both in Utah and Colorado, and the confinement to a thin (20-30 m), well-defined stratigraphic level indicates a regional tectonic event, which caused dewatering, hydrofracturing and slope instability/slumping at different parts of the basin.

-5. Green River – Uinta Formation boundary, eastern Uinta Basin (UT)

The contact between the Green River and the overlying fluvial-deltaic Uinta Formation was studied at several locations between Bitter Creek and the Evacuation Creek, Utah (Fig.). In most

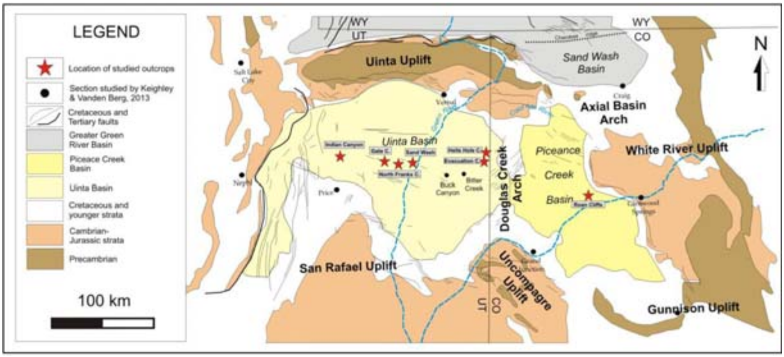


Figure 9. Generalized geological map of NW Colorado and NE Utah (after Smith et al. 2008) and the locations where the Mahogany Oil Shale Zone (MOSZ) have been studied.

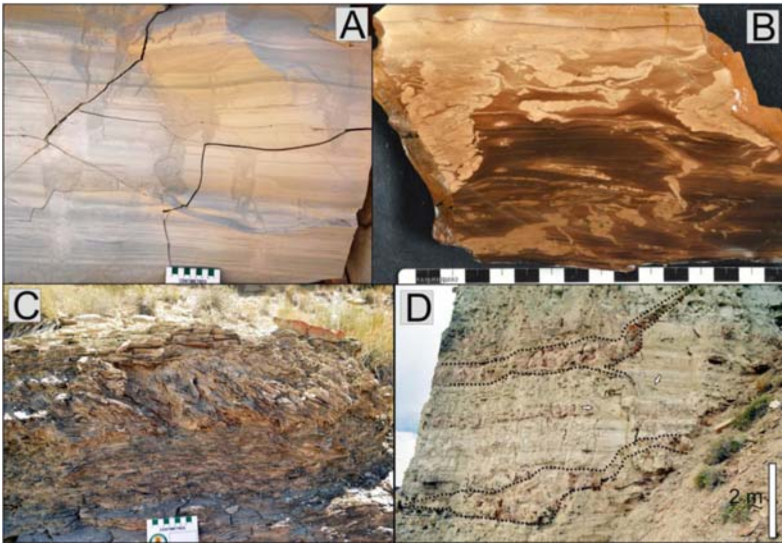


Figure 10. A. Sedimentary injections in sublittoral silty lime mudstones showing multiple fluidization events and hydrofracturing, Indian Canyon; B. Sedimentary injections («dewatering sturctures»), filled with carbonate mud, in profundal rich oil shales, Indian Canyon. The source is an organic-poor, massive carbonate mudstone layer. Injections form bulbous oriented dikes and irregular sills. In many cases these structures are isolated without a well defined source; C. Sheared fabric in the Mahogany Bed at Gate Canyon, showing en-echelon fabric, shear related propagation folds, kink and sheat folds, shear duplexes, and thrusting; D. Sedimentary injection features at North Franks Canyon (dikes and sills) filled with silicified mudstone.

cases large, cross-bedded sandstone blocks foundered into deformed or undeformed, laminated lacustrine sediments in form an irregular upper boundary on the top of the Green River Formation (Fig. 9). The same features have been mentioned by Cashion (1967), however their origin was not explained.

The sand blocks are intact or plastically deformed, with sharp, erosive lower boundary. In places the blocks are separated by large diapirs of lacustrine sediments. At other places the boundary marked by large-scale liquidization (ball-and-pillow) structures and hydroplaning of the glided sandstone blocks. Deformation/shear structures indicate S-ward displacement of the exotic sandstone blocks. Seismicity along the Douglas Creek Arch and related fault systems (Bader, 2009) might have caused emplacement of (semi) lithified deltaic sand bodies on the N/NE. Similar features are also present in northern Colorado (at the base of Uinta Formation), and in Wyoming (base of Sand Butte Bed in the eastern Bridger Basin) (Johnson, 1981; Chetel & Carroll, 2010).

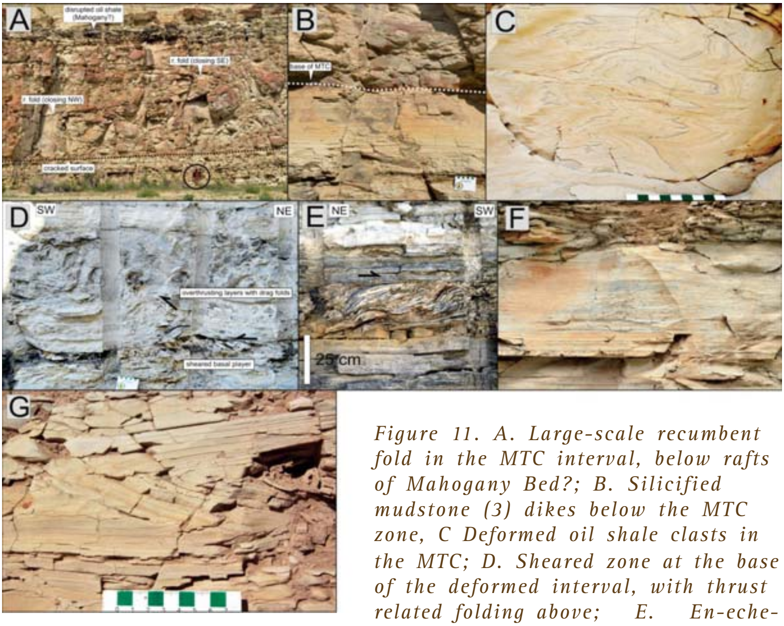


Figure 11. A. Large-scale recumbent fold in the MTC interval, below rafts of Mahogany Bed?; B. Silicified mudstone (3) dikes below the MTC zone, C Deformed oil shale clasts in the MTC; D. Sheared zone at the base of the deformed interval, with thrust related folding above; E. En-echelon structure in the sheared layer of the Mahogany Bed. F. Brecciated oil shale bed (40 cm thick) with recombent folded intraclast(?) at the top at Hells Hole Canyon, G. Recumbent folded oil shale in the Mahogany zone, Roan Cliff, Colorado

Conclusions

Pervasive horizons of seismically induced deformation structures were identified in the profundal lacustrine sediments of the Eocene Green River Formation, USA. Deformation is represented by brittle and plastic behaviour, as well as sediment injection and mass transport. The deformed layers are confined by undeformed beds which implies sporadic short-lived events that affected only near-surface sediments with susceptible rheological state at the time.

Based on: (1) the tectonic setting of the lacustrine basins; (2) the sedimentary environment and sedimentological characteristics of the successions in which the deformed layers occur; (3) their lateral extent and proximity to known active fault systems during the time of the deposition of host sediments; (4) their recurrence at different stratigraphic levels, intervals showing large-scale sedimentary deformation structures are interpreted as result of in-situ loss of shear strength, formed by increased pore pressure and vertical or horizontal stress induced by seismic activity.

Features previously described as the result of desiccation are reinterpreted as seismically induced sedimentary deformation and/or fluid flow. Silicified sedimentary injection features («dewatering structures») indicate segregation of fine grained

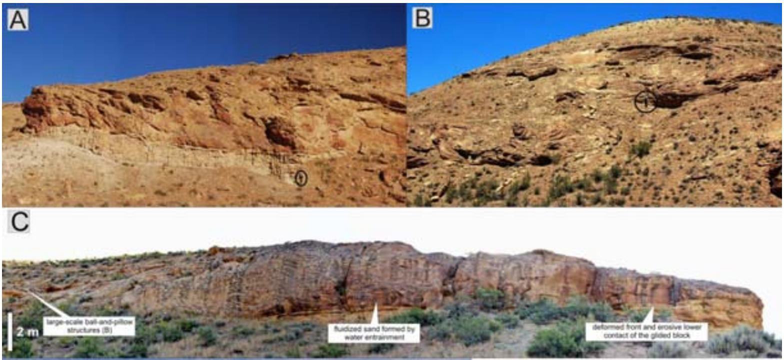


Figure 12. A. Large-scale cross-bedded sandstone block with angular lower contact, above the laminated silty lime mudstones of the Green River Formation; B Large-scale ball-and-pillow structures, near Watson; C. Outcrop shows the hydroplaning and fluidization of semi-lithified glided sandstone block.; D. Sandstone blocks on the top of lacustrine mudstone deposits. The lower blocks show plastic deformation and bending of the original bedding. The upper blocks are imbricated, and divided by dome-like intrusions of the sandy/silty lime mudstone or by shear planes.

sediments, dewatering and remobilization of the sediment. These features also acted as conduits of silica-rich brines. Mass transport complexes formed due to seismicity induced instability of the sediments on a flat or gently dipping slope. Oversteepening, loading and slumping of the sedimentary slope are also possible triggers of mass movements. However, the morphology of the slope existing in the basins during the time of deposition was unknown and information on the slope gradient in the basin center varies in the literature (0.2 to 0.6 m/km to 1-2° (17-35 m/km); e.g. Dyni, 1981). Features in the MOSZ indicate a basin-wide tectonic event in both the Piceance Creek and Uinta Basin.

As soft-sediment deformation features induced by earthquakes are indicative of synsedimentary tectonism, these deposits can provide information about the location and timing of the tectonic movements along nearby fault systems in the lake sub-basins. Small-and large-scale deformation features and deformed oil shale intervals may have significant effects on the horizontal and vertical permeability and connectivity of the oil shale beds. Moreover, large scale clastic dikes may affect local and regional hydrology of an area.

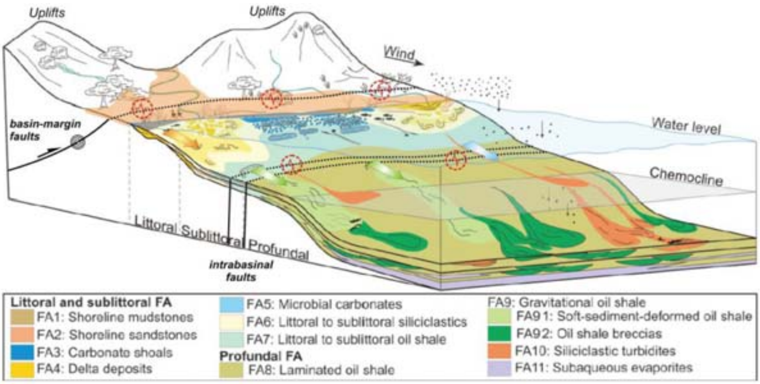


Figure 13. Proposed concept illustrating the origin of mass movement deposits and other sedimentary deformation features, triggered by earthquakes (depositional model modified after Tänavsuu-Milkeviciene and Sarg, 2012).

Future work

Collected samples will be studied in thin sections and under the electron microscope to provide information on the mineralogy, the deformation mechanism, the timing of deformation in relation to shallow burial, and the rheology of the sediments during deformation. As the clay content and the type of clay minerals present in the sediments have a great influence on the rheology (presence or absence of swelling clays), clay mineralogy will be identified by X-ray diffraction. These detailed studies on the samples will also help to understand the role of fine- grained particles in the deformation processes and their control on the rheological properties of the sediments.

Cores will be examined at the USGS Core Research Center in Denver in December 2013, to increase the stratigraphic and areal coverage in all the subbasins. The stratigraphic and geographic distribution of deformation structures will be plotted to provide data on their temporal and spatial occurrence, and to provide information on the paleotectonic history of the study area.

Acknowledgments

It has been a great honour for me to receive the Postgraduate Grant financial support from the International Association of Sedimentologists'. The work which was funded by this grant covers a significant part of my PhD study.

We are also thankful to Enefit American Oil for giving permission to study their box cut at Evacuation Creek/Park Canyon. We are grateful to Eli Wiens (University of Saskatchewan), Sudipta Dasgupta (University of Saskatchewan) and Jennifer J. Scott (Mount Royal University) for assisting during field work and for their helpful discussions, and to Alan Carroll, Arvid Aase, Kati Tänavsuu-Milkeviciene, Michael Vanden Berg, John R. Dyni, and Paul Buchheim for their help in organizing the field work. David Keighley contributed helpful discussions and kindly provided details of field locations & stratigraphic sections in Utah. This work is partly funded through NSERC-Discovery Grants awarded to Brian R. Pratt and Robin W. Renaut.

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ISC STUDENT PRE-STUDENTS FIELD TRIP

Following the successful student fieldtrip at the 18th ISC in Mendoza, organized first time, the Geneva ISC organizers are now preparing the Geneva edition. This will be organized and leaded by Arnoud Slootmann one of Geneva University PhD students. The field trip aims to gather IAS student members prior to the Congress. It will provide the opportunity to meet other PhD students and to share experiences, skills and ideas in the field in a friendly atmosphere. It will not be a classic 'show-and-tell' excursion as participants are expected to actively contribute to the

observation and interpretation of the field data. Moreover, to meet student demands, the excursion will encompass three important aspects: it will be instructive, low cost, and have a social evening program!

In his Introduction to Geology (1813) Robert Bakewell stated «If any readers of this volume should visit Geneva, I would recommend them to devote a day to visiting the mountain called the Salève, in the immediate vicinity of that city.» Two hundred years later we will follow his advice and set out for the summit of the Mont Salève (1379 m) on Saturday 16, prior to the Congress. After reaching the lower station by public transport, participants will make the breath-taking ride to the top by cable car to observe the mountain's geographic setting between the Jura mountains, the Prealps, the Subalpine chains and, most notably, the Mont-Blanc massif. Then the Upper Jurassic to Lower Cretaceous stratigraphic succession will be examined. This is predominantly composed of a variety of limestones with local intercalations of marl and coal. The itinerary will also bring students to some spectacular (paleo) karst structures and faults. Sitting on erratic boulders at the end of the day, we will work out the geological history of the Salève and its regional significance as we summarize the observations together with Prof. Pascal Kindler, a specialist in the geology of the Geneva region.

Daniel Ariztegui

Special IAS Grants or 'Institutional IAS Grants'

Special IAS Grants or Institutional IAS Grants are meant for capacity building in 3rd world countries. There exists a list of 'Least Developed Countries' (LDC) by the UN. This list categorizes countries according to income per capita and is yearly updated.

Grants are allocated to allow Geology Departments in LDC to acquire durable sedimentological equipment for teaching and research (like sieves, calcimeters, auger drilling tools, etc.) or tools that can be used by all geology students (like general geology/sedimentology textbooks, IAS Special Publications (SP), memory sticks with back issues of Sedimentology or SP, etc). Therefore the grant application should clearly demonstrate to increase the recipient's capacity to teach sedimentology at the undergraduate level (Bachelor) in a durable way. It should also indicate in what way it would enable to support sedimentological research at the graduate level (Master).

Applicants should have a permanent position at their University and should be IAS members. Applications should provide the following information (not exhaustive list):

- the mission statement of the University/Geology Department
- the approval of the University Authorities to accept the grant
- a list of permanent teaching and technical staff members of the Geology Department (with indication of their area of research)
- the structure of the geology undergraduate and graduate courses (Bachelor/Master programme with indication of courses and theoretical and practical lecture hours)
- the number of geology students
- the actual facilities for geology/sedimentology students
- a motivation of application
- a budget with justification
- the CV of the applicant, including a sedimentology research plan

The institutional grant scheme consists each year of 2 sessions of 1 grant of 10.000 Euro. Applications run in parallel with the PhD research grant scheme (same deadline for application and recipient notification). The IAS Grant Committee will seek recommendations from relevant National Correspondents and Council Members (eventually including visitation) before advising the IAS Bureau for final decision. Additional funds made available by the recipient's University are considered as a plus.

Items listed in the application will be bought through the Office of the IAS Treasurer and shipped to the successful applicant. By no means will money be transferred to the grant recipient.

IAS STUDENT GRANT APPLICATION GUIDELINES

Application

The application should be concise and informative, and contains the following information (limit your application to 1250 words max.):

- Research proposal (including Introduction, Proposal, Motivation and Methods, Facilities) – max. 750 words
- Bibliography – max. 125 words
- Budget – max. 125 words
- Curriculum Vitae – max. 250 words

Your research proposal must be submitted via the Postgraduate Grant Scheme application form on the IAS website before the application deadline. The form contains additional assistance details for completing the request. Please read carefully all instructions before completing and submitting your application. Prepare your application in 'Word' and use 'Word count' before pasting your application in the appropriate fields.

Recommendation letter (by e-mail) from the PhD supervisor supporting the applicant is mandatory, as well as recommendation letter (by e-mail also) from the Head of Department/ Laboratory of guest institution in case of laboratory visit.

Please make sure to adequately answer all questions.

Deadlines and notifications

Application deadline 1st session: 31 March.

Application deadline 2nd session: 30 September.

Recipient notification 1st session: before 30 June.

Recipient notification 2nd session: before 31 December.

NOTE: Students who got a grant in a past session need to wait 2 sessions (1 year) before submitting a Postgraduate Grant Scheme grant application again. Students whose application was rejected in one session can apply again after the notification deadline of the rejected grant application

Guidelines for recommendation letter from supervisor:

The recommendation letter from the supervisor should provide an evaluation of the capability of the applicant to carry out the proposed research, the significance and necessity of the research, and reasonableness of the budget request.

The recommendation letter must be sent directly to the Treasurer of the IAS by e-mail, and before the application deadline.

It is the responsibility of the applicant to make sure that his/her supervisor submits the recommendation letter in time. No reminders will be sent by IAS, neither to the applicant, nor to the supervisor. Applications without letter of support will be rejected.

Application Form

Research Proposal (max. 750 words)

Title: ....

Introduction (max. 250 words): .....

Introduce briefly the subject of your PhD and provide relevant background information; summarise previous work by you or others (provide max. 5 relevant references, to be detailed in the 'Bibliography' field). Provide the context for your PhD study in terms of geography, geology, and/or scientific discipline.

Proposal (max. 250 words): ...

Describe clearly your researchproposal and indicate in what way your proposal will contribute to the successful achievement of your PhD. Your application should have a clearly written hypothesis or a well-explained research problem of geologic significance. It should explain why it is important. Simply collecting data without an objective is not considered wise use of resources.

Methods (max. 125 words): ....

Outline the research strategy (methods) that you plan to use to solve the problem in the field and/or in the laboratory. Please include information on data collection, data analyses, and data interpretation. Justify why you need to undertake this research.

Facilities (max. 125 words): ....

Briefly list research and study facilities available to you, such as field and laboratory equipment, computers, library.

Bibliography (max. 125 words)

Provide a list of 5 key publications that are relevant to your proposed research, listed in your 'Introduction'. The list should show that you have done adequate background research on your project and are assured that your methodology is solid and the project has not been done already. Limit your bibliography to the essential references. Each publication should be preceded by a '*'-character (e.g. *Surlyk et al., Sedimentology 42, 323-354, 1995).

Budget (max. 125 words)

Provide a brief summary of the total cost of the research. Clearly indicate the amount (in Euro) being requested. State specifically what the IAS grant funds will be used for. Please list only expenses to be covered by the IAS grant.

The IAS will support field activities (to collect data and samples, etc.) and laboratory activities/analyses. Laboratory activities/analyses that consist of training by performing the activities/analyses yourself will be considered a plus for your application as they will contribute to your formation and to the capacity building of your home institution. In this case, the agreement of the Head of your Guest Department/Laboratory will be solicited by automated e-mail.

Curriculum Vitae (max. 250 words)

Name, postal address, e-mail address, university education (degrees & dates), work experience, awards and scholarships (max. 5, considered to be representative), independent research projects, citations of your abstracts and publications (max. 5, considered to be representative).

Advise of Supervisor and Head of Guest Department/Laboratory

When you apply for a grant, your PhD supervisor will receive an automated e-mail with a request to send the IAS a letter of recommendation by e-mail. You should, however, check with your supervisor everything is carried out the way it should be. It will be considered as a plus for your application if your PhD supervisor is also a member of IAS.

Supervisor's name: ....

Supervisor's e-mail: ....

If you apply for laboratory analyses/activities, please carefully check analysis prices and compare charges of various academic and private laboratories as prices per unit might differ considerably. Please first check whether analyses can be performed within your own University. If your University is not in a position to provide you with the adequate analysis tools, visiting another lab to conduct the analyses yourself strengthens your application considerably as it contributes to your formation and to capacity building of your home University. Please check with the Head of Department/Laboratory of your guest lab to assure its assistance during your visit. You should fill in his/her name and e-mail address to solicit his/her advise about your visit.

Name of Head of guest Department/Laboratory: ....

E-mail address of Head of Guest Department/Laboratory: ....

Finally, before submitting your application, you will be asked to answer a few informative questions by ticking the appropriate boxes.

- is your supervisor a member of IAS
- was this application your own initiative
- did you discuss your application with your Supervisor
- did you already had contact in the past with the Head of the Guest Department/Laboratory (if appropriate)

FOR THE 1ST SESSIONS 2014 THE FOLLOWING STUDENTS ARE GRANTED:

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FINANCIAL REPORT

INTERNATIONAL ASSOCIATION OF SEDIMENTOLOGISTS (IAS)

Financial statements - June 30, 2013

1. BALANCE SHEET

	Note	As at June 30, 2013 EUR	EUR	As at June 30, 2012 EUR	EUR
ASSETS					
NON-CURRENT ASSETS					
Property, plant and equipment	4		5 945.90		6 032.74
CURRENT ASSETS					
Inventories	5		45 538.10		40 456.38
Receivables	6				
Prepayments		2 970.00		2 970.00	
Other receivables		112 260.59		20 924.82	
			115 230.59		23 894.82
Cash and cash equivalents	7		3 291 406.39		3 271 016.61
TOTAL ASSETS			3 458 120.98		3 341 400.55

		As at June 30, 2013 EUR	EUR	As at June 30, 2012 EUR	EUR
EQUITY					
Reserves		3 044 475.21		2 895 464.61	
Surplus for the year		34 574.74		149 010.60	
			3 079 049.95		3 044 475.21
CURRENT LIABILITIES					
Other debts and prepayments received	8		379 071.03		296 925.34
TOTAL EQUITY AND LIABILITIES			3 458 120.98		3 341 400.55

CALENDAR

Central European Meeting of Sedimentary Geology*

9th-13th June 2014
Olomouc, Czech Republic

Ondrej Babék
babek@prfnw.upol.cz
www.sedgeol.upol.cz

Sedimentary Provenance Analysis (SPA) Short Course*

23rd-25th June 2014
Gottingen Germany

Guido Meihold
guido.meinhold@geo.uni-goettingen.de

2nd Workshop - Working Group on Sediment Generation (WGSG)*

25th -27th June 2014
Göttingen Germany;

Ines Ringel
ines.ringel@geo.uni-goettingen.de
www.sediment.uni-goettingen.de/WGSG/

Short course in Chemostratigraphy to be taught by Hugh Jenkyns (Oxford University)

30th June – 3rd July 2014
Ferrara, Italy

Chiara Ciampaglia
convegni@unife.it
www.consorziofermeraricerche.it

Inaugural Workshop on West African Sedimentology and Sedimentary Basins*

27th July – 2nd August 2014
Ibadan
Nigeria

Izuchukwu Mike Akaegbobi
izumike1970@gmail.com

19th International Sedimentological Congress*

18th -24th August 2014
Geneva, Switzerland

Daniel Ariztegui
Daniel.Ariztegui@unge.ch,
http://www.sedimentologists.org/meetings/isc

XIV Argentinian Meeting of Sedimentology (RAS)*

1st-5th September 2014
Puerto Madryn (Patagonia)
Argentina

J. Marcelo Krause
mkrause@mef.org.ar
www.xivras2014.ar

Geological Society of Italy*

10th-12th September 2014
Milano
Italy

Giovanna Della Porta
giovanna.dellaporta@unimi.it
www. geoscienze2014.it

7th International Meeting on Taphonomy and Fossilization

10th -13th September 2014
Ferrara
Italy

convegni@unife.it
www.consorzioferrararicerche.it

2nd Deep-Water Circulation Conference*

10th-12th September 2014
Ghent
Belgium

David Van Rooij
david.vanrooij@ugent.be
www.2DWC.ugent.be.

6th International Symposium on Lithographic Limestone and Plattenkalk*

15th-19th September 2014
Museo del Desierto,
Saltillo,
Mexico

Christina Ifrim
ISLLP2014@geow.uni-heidelberg.de
http://isllpsaltillo.uni-hd.de

«Are there limits to evolution?»

25th -26th September
Cambridge
UK

http://wserv4.esc.cam.ac.uk/atle/

Interim Colloquium of the Regional Committee of Neogene Stratigraphy (RCMNS)*

25th-28th September 2014
Torino
Italy

Francesco De La Pierre
Francesco.delapierre@unito.it
www.rcmns-turin2014.weebly.com

Workshop - Field Trip «Sedimentary carbonate and reservoir systems»*

26th -29th September 2014
Tirana
Albania

Rudy Swennen
Rudy.Swennen@ees.kuleuven.be
www.cbga2014.org/workshops.html

4th International Palaeontological Congress (Mendoza, Argentina)*

28th September-3rd October
2014
Mendoza
Argentina,

Cecilia Benavente
cebenavente@gmail.com
www.ipc4mendoza2014.org.ar

Applied Ichnology and Sedimentology Short Course

29th September – 1st
October
2014
Utrecht
The Netherlands

Herman Darman
Herman.Darman@shell.com
http://www.kngmg.nl/evenementen/2014aapg-ichnology-course.pdf

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5th International MAAR Conference*

17th -21st November
2014
Querétaro
Mexico

Gerardo Carrasco Nuñez
gerardoc@dragon.geociencias.unam.mx

Quadrennial International Limnogeology Congress (ILIC6)*

15th -19th June
2015
Reno
Nevada

Michael Rosen
mrosen@usgs.gov

First International Congress on Continental Ichnology (ICCI-2015)*

21th – 27th April
2015
El Jadida
Morocco

Abdelouahed Lagnaoui
abdelouahedlagnaoui@yahoo.fr

Bathurst Meeting*

*Bathurst Meeting**
13th -16th July
2015
Edinburgh
UK

Rachel Wood
Rachel.Wood@ed.ac.uk

5th International Conference on Alluvial Fans*

29th November – 4th December
2015
Christchurch
New Zealand

James Driscoll
james.driscoll@monash.edu

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