

## Session 2

# Facies analysis and reconstruction of palaeoenvironments

7<sup>th</sup> International Congress on the Jurassic System,  
September 6-18, 2006, Kraków, Poland

## Storm deposits: evidence of event sedimentation in the Bajocian of the Central High Atlas, Morocco

Abdellah AIT ADDI

Cadi Ayyad University, Faculty of Sciences and Techniques, Earth Sciences Department,  
P.O.Box 549, Guéliz-Marrakech, Morocco; e-mail: aitaddi@fstg-marrakech.ac.ma

**Key-words:** Bajocian, High Atlas, Morocco, oscillatory currents, resedimentation, storm deposits.

During Bajocian time, the Central High Atlas of Morocco received several hundred meters of marls, shaly marls and carbonate deposits. These are spread out in two main domains: southern and northern platforms, situated N of Errachidia and S of Midelt cities, respectively, where shallow marine carbonates corresponding to the group of Bin El Ouidane formations dominate (Monbaron 1981); and central basin, presently forming the centre of High Atlas, where hemipelagic facies to shallow marine carbonates represent Agoudim (members II, III and IV) and Tazigzaout formations (Ait Addi 2000, Ait Addi 2002). The first evidence of event sedimentation in the Middle Jurassic of central High Atlas of Morocco has been provided by Ait Addi (2002). These deposits are Middle Jurassic (Bajocian) in age and are included in Agoudim and Tazigzaout formations in the central basin; and parts of Bin El Ouidane Group in the borders. The storm deposits are calcarenite beds of bioclastic packstone-grainstone character. These beds present symmetrical wave-ripples at their tops and show an internal structure with hummocky cross-stratification. The deposits are considered to be formed by tropical storms and hurricanes. The above characteristics are the effects of multiple reworking and winnowing of siliciclastic or bioclastic and/or carbonate material by oscillatory currents related to storm and to storm/tide currents interaction. Palaeobathymetric interpretation of related pelagic sediments indicates that the sedimentation occurred fairly deep, and that calcareous tempestites resulted from episodic resedimentation, mainly coincident with relative sea-level falls, in which major storm waves and tsunamis affected the sea bottom. This interpretation is in agreement with the regional palaeogeography and is further evidence of Jurassic storm-controlled sedimentation in adjacent Mediterranean basins.

### References:

- Ait Addi A. 2000. Les séries du Dogger moyen du Haut Atlas au Nord d'Errachidia (Maroc): Lithostratigraphie et sédimentologie d'une nouvelle formation, la formation Tazigzaout. *Revue de Géologie Méditerranéenne*, **27**, 1-2: 57-69.
- Ait Addi A. 2002. Les séries du Dogger du Haut Atlas marocain (Nord d'Errachidia/Boudenib): Lithostratigraphie, sédimentologie, stratigraphie séquentielle, cyclostratigraphie et évolution géodynamique. Thèse d'Etat, Univ. Ibn Tofail, Faculty of Sciences (Kénitra), 242 pp.
- Monbaron M. 1981. Sédimentation, tectonique synsédimentaire et magmatisme basique: l'évolution paléogéographique et structurale de l'Atlas de Beni-Mellal (Maroc) au cours du Mésozoïque; ses indices sur la tectonique tertiaire. *Eclogae geologicae Helvetiae*, **74**, 3: 625-638.

## Middle to Upper Jurassic stromatactis mud-mounds in the Pieniny Klippen Belt, Carpathians

Roman AUBRECHT<sup>1</sup>, Michał KROBICKI<sup>2</sup> and Ján SCHLÖGL<sup>1</sup>

<sup>1</sup>Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynská Dolina – G, SK-84215 Bratislava, Slovakia; e-mail: Aubrecht@nic.fns.uniba.sk, Schlogl@nic.fns.uniba.sk

<sup>2</sup>Department of General Geology and Environment Protection, Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Al. Mickiewicza 30, PL-30059 Kraków, Poland; e-mail: Krobicki@geol.agh.edu.pl

**Key-words:** mud-mounds, stromatactis, carbonate sedimentology, Jurassic, Pieniny Klippen Belt, Carpathians.

Stromatactis mud-mounds are structures still enigmatic, despite of many years of research. Recently, most authors consider stromatactis mud-mounds to be fossil microbial reefs. Particularly enigmatic is the origin of stromatactis structures that appear to be the main megascopic component of the mounds.

Stromatactis mud mounds occur since Neoproterozoic time and reach their maximum in Palaeozoic, especially in Carboniferous and Devonian. Mesozoic examples are rare. They were reported mostly from Jurassic; later examples are dobtfull. Our research concerns Jurassic stromatactis mud-mounds. To date, stromatactis structures were only reported from the Early Jurassic of the Upper Austroalpine of the Eastern Alps, Early Jurassic of Sicily, Oxfordian mud-mounds of southern Germany, offshore Nova Scotia, Oxfordian of Cracow Upland, Poland and Lower Kimmeridgian of southern Portugal. Recently, Middle- and Upper Jurassic stromatactis mud-mounds were found in the Czorsztyn Unit of the Pieniny Klippen Belt in Slovakia and Transcarpathian Ukraine: Slavnické Podhorie, Štepnická Skala, Babiná, Kyjov-Pusté Pole, Priborzhavskoe and Velyky Kamenets. Stratigraphic range of the mounds is Bajocian to Lower Tithonian. Geometry of the mounds could only be studied at Štepnická Skala, Priborzhavskoe and Velyky Kamenets, where flat mound shapes are revealed. Other outcrops show only fragments of the mounds or their shape is merged with the surrounding rocks. Rocks of the mounds are mostly micritic to micropeloidal mudstones, containing fauna of pelecypods, brachiopods, ammonites and crinoids.

All the occurrences are characterized by mass occurrence of stromatactis structures. In some of them (Slavnické Podhorie, Priborzhavskoe and Velyky Kamenets), the stromatactis cavities occur also in the crinoidal limestones underlying the mud-mounds which is an atypical feature.

Only three sites investigated by us involve considerable portion of sponge spicules in the mound matrix which contradicts to a theory favouring sponges as stromatactis builders. There was no discernible type of biota that might serve as being responsible for the stromatactis structures. Also biota itself is variable. The Bajocian to Callovian mounds contain more benthic biota, e.g. brachiopods, bivalves, sponges, agglutinated foraminifers *etc.*, although biota as a whole was dominated by planktonic representatives, as shells of *Bositra* bivalves. The Oxfordian and younger occurrences were fully dominated by planktonic biota, e.g. planktonic foraminifers *Globuligerina*, planktonic crinoids *Saccocoma*, ammonites, shells of *Bositra* or coccal algae *Globochaete alpina*. The latter type also lacks micropeloidal matrix which is ubiquitous in the first type. The micropeloidal to clotted structures are usually attributed to be typical for microbialites.

## Microbial mounds from the restricted-marine Sinemurian succession of S. Pedro de Moel (Lusitanian Basin, Portugal): preliminary palaeoecological interpretation

Ana C. AZERÊDO<sup>1</sup>, Luis V. DUARTE<sup>2</sup> and Maria C. CABRAL<sup>1</sup>

<sup>1</sup>Departamento de Geologia and Centro de Geologia, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, C6, 4<sup>o</sup>, 1749-016 Lisboa, Portugal; e-mail: acazeredo@fc.ul.pt, mccabral@fc.ul.pt

<sup>2</sup>Departamento de Ciências da Terra and Centro de Geociências, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, 3000-272 Coimbra, Portugal; e-mail: lduarte@dct.uc.pt

**Key-words:** microbial mounds, restricted-marine setting, palaeoecology, Sinemurian, Lusitanian Basin, Portugal.

In the Lusitanian Basin the Sinemurian corresponds to a marginal- to restricted-marine succession, representing the early stage of sea flooding in the recently formed basin, following a Late Triassic rifting event. Except for its topmost part, the Sinemurian succession belongs to the Coimbra Fm., composed of dolostones, dolomitic limestones and limestones. This unit is dominated by peritidal facies towards the eastern, more landward zone of the basin, whereas in the W (as at S. Pedro de Moel) more distal (though not quite deep) facies occur. At S. Pedro de Moel the Coimbra Fm. is well exposed and the section displays a succession mostly composed of argillaceous and/or dolomitic limestones and fossiliferous/skeletal limestones (bivalves, gastropods, ostracods), interbedded with a few marly levels. Although fossil remains are commonly present in variable amounts, some beds seem to be azoic, others exhibit rare, deformed burrows and very rare ostracods. Undulating, irregularly bounded, laminar levels are common and, locally, centimetre to decimetre-thick concentrated skeletal/fossil layers occur. However, towards the middle part of the section, well-preserved, dome-shaped stromatolites occur, in clear contrast with the under- and overlying bedded deposits. Towards the top of the succession, the calcareous/clay ratio increases. This section is still under study, so we only make a preliminary palaeoenvironmental approach here.

The microbial mounds have an average maximal thickness of 0.75 m and show different fabrics, sometimes within the same mound: laminated, stromatolitic crusts; clotted, peloidal micrite; micritic and sparitic threads; degraded, tuft-like filamentous structures; enhanced fenestral-like porosity; dense, slightly darker micrite. These features suggest that they were formed through hardening of calcified cyanobacterial and other microbial films, whose early disintegration also would have contributed with autochthonous mud for the mounds. However, a more detailed study is clearly needed. It is known from the literature that microbialites, as a whole, may form in a wide range of environmental conditions, though some associations or particular morphologies may give us more accurate ecological information. However, a crucial basic condition is a very low to low background sedimentation. In the present case, it is suggested that the stromatolites grew under low-energy, restricted water-circulation and low rate of mixed terrigenous and calcareous mud deposition. A likely nutrient-poor substrate, the existence of terrigenous material and, maybe, slight (?) hypersalinity would have inhibited a more significant development of epibenthic and heterotrophic organisms, favouring the microbial community. The low energy prevented physical erosion which, coupled with the absence of predators, allowed the development of the well-defined dome morphologies. In contrast, towards the top of the succession a more open setting prevailed, with better water-circulation, probably better oxygenation and somewhat higher sedimentation rate with dramatic decrease of clay material. Though most of the upper deposits are still low-energy ones (biomicrite mudstones and wackestones, with a few ostracods, gastropods, bivalves, rare hyaline forams), skeletal/intraclastic/peloidal packstones and rarer grainstones occur more frequently, attesting for the less protected environment. These conditions did not allow the continuation of microbial growth.

## Lithostratigraphy of Jurassic sedimentary rocks in Qayen area, eastern Iran

Seyed Ahmad BABAZADEH

Birjand Payam noor University, Birjand, Iran; e-mail: ababazadeh2001@yahoo.fr

**Key-words:** lithofacies, Jurassic sedimentary, Qayen area, Eastern Iran.

The Jurassic sedimentary rocks dominate the surface exposure of western Qayen. They are extensively located at Doust-abad region. The focus of this study is on the lithofacies analysis of the sediments. The Jurassic rocks consist of the shale-limestone unit with intercalation of sandstone followed by massive limestone and is topped by limestone-argillaceous limestone with thin parallel lamination of shale. Three patterns of facies dominate the formation. Gray to black shale-mudstone facies in the lower part, biointrasparite/biopelsparite in the middle part and gray micritic limestone/argillaceous limestone. The main marine fauna include *Lenticulina* aff. *quenstedti*, *Nodosaria* cf. *striatojuensis*, *Lingulina nodosaria*, *Haurania* aff. *amiji*, miliolids, corals, crinoids, ammonites and echinoids.

## Integrated studies of Late Jurassic neptunian dykes from central Poland

Marcin BARSKI and Szymon OSTROWSKI

Institute of Geology, Faculty of Geology, Warsaw University, Al. Żwirki i Wigury 93, PL-02089 Warszawa, Poland; e-mail: marbar@uw.edu.pl, Szymon.Ostrowski@uw.edu.pl

**Key-words:** neptunian dyke, dinocyst stratigraphy, fluid inclusion.

Steeply dipping clastic dykes cutting through the Middle Jurassic clays with ironstone nodules have been exposed in three localities at Wieluń, Częstochowa and Zawiercie in central Poland.

The dykes are grey calcareous, structureless sandstones, 5 to 10 cm wide running roughly along the NE-SW direction which corresponds approximately to system of faults in the area.

Palynological analysis of the internal sediment from the dykes revealed mixed assemblages of the Middle (Bajocian-Bathonian), and the Upper Jurassic (Oxfordian – Lower Kimmeridgian) Dinoflagellate cyst taxa. The latter consist of *Systematophora areolata*, *Ctenidodinium ornatum*, *Gonyaulacysta jurassica jurassica*, *Endoscrinium luridum*, *Endoscrinium galeritum*, *Leptodinium subtile* and *Scriniodinium crystallinum*.

Rich hydrothermal calcite mineralization occurs mainly where dykes cut ironstone nodules. Hydrothermal mineralization is composed of coarse palisadic crystals ranging from 2.5 to 6 mm in length. Cement of sandstones is also composed of hydrothermal calcite. Fluid inclusion analysis of palisadic crystals (performed by Prof. Andrzej Kozłowski) yielded homogenisation temperatures in range of 53 up to 72°C. Gradual decreasing of homogenisation point and change in composition of fluids from hydrothermal to more marine fluids is observed from dyke walls, toward the centre of the dyke. Fluid inclusion analysis confirms mixed, hydrothermal-neptunian genesis of dykes with stages postulated on the basis of thin section observations.

Presented work demonstrates necessity of integrated geological studies to improve sedimentological and tectonic reconstructions.

The origin of the dykes was related with synsedimentary tectonics during Late Jurassic (Oxfordian – Early Kimmeridgian) which controlled the facies distribution within the sponge megafacies of the Polish Jura Chain area.

### **The Torrecilla Reef Complex (Early Kimmeridgian, N Spain): an example of tectonically forced regression**

Maria I. BENITO and Ramón MAS

Departamento de Estratigrafía, U.E.I. de Correlaciones Estratigráficas, Facultad C.C. Geológicas,  
Universidad Complutense de Madrid, CSIC, 28040 Madrid, Spain;  
e-mail: mibenito@geo.ucm.es, ramonmas@geo.ucm.es

**Key-words:** carbonate platform, coral reef, forced regression, tectonism, Early Kimmeridgian, Iberian Basin.

Palaeontological, sedimentological, palaeoecological and/or depositional aspects of most Late Jurassic reefs, specifically coral reefs, have been studied in detail (e.g. see references in Flügel & Flügel-Kahler 1992; Leinfelder *et al.* 1996; Insalaco *et al.* 1997; Dupraz & Strasser 2002; among others), but only a few papers deal with their depositional architecture and response to tectonics and/or sea-level change. For example, Leinfelder *et al.* (1994, 1996) conclude that both eustatic and tectonic changes were important in controlling platform geometry and evolutionary trends in Upper Jurassic reefs.

The Early Kimmeridgian Torrecilla Reef Complex in the northern Iberian Basin of Spain consists of a fringing reef composed of eight accretionary units (Alonso *et al.* 1986-1987; Mas *et al.* 1997; Benito & Mas 2002, 2006). The first four were deposited along a steep margin. They display down-lapping and off-lapping geometries, and are characterized by poor reef-framework development, large volumes of reworked corals and transported sediment, and limited growth of micro-encrusters. In contrast, deposition of the fifth and younger accretionary units occurred on a shallow platform without a pronounced slope where coral reefs grew in a shallow protected environment (Benito & Mas 2006). The main features of these reefs are: an absence of reef-slope facies, a high proportion of preserved framework elements, relatively low volumes of intrareef sediment, high proportions of terrigenous material, and abundant micro-encrusters and microbialites. These reefs were protected from storm waves by long-shore sand bars, which also protected a very shallow lagoon during the last stage of sedimentation.

The Early Kimmeridgian was a period of rising global sea level (Haq *et al.* 1988; Hallam 2001), a trend apparent across other portions of the Iberian Basin. However, geometry and sedimentary evolution of the Torrecilla Reef Complex is consistent with those of off-lapping reefs that develop during sea-level fall. Thus, we conclude that down-stepping geometries and evolution to progressively shallower environments within the Torrecilla Reef Complex occurred as a result of a tectonically forced regression.

#### **References:**

- Alonso A., Mas J. R. and Meléndez N. 1986-1987. Los arrecifes coralinos del Malm en la Sierra de los Cameros (La Rioja, España). *Acta Geologica Hispanica*, **21-22**: 296-306.
- Benito M. I. and Mas R. 2002. Evolución sedimentaria y diagenética de los complejos arrecifales kimmeridgienses de la Cuenca de Cameros. La Rioja-Soria. *Zubía*, **14**: 121-142.

- Benito M. I. and Mas R. 2006. Sedimentary evolution of the Torrecilla Reef Complex in response to tectonically forced regression (Early Kimmeridgian, Northern Spain). *Sedimentary Geology*, **183**: 31-49.
- Dupraz C. and Strasser A. 2002. Nutritional modes in coral-microbialite reefs (Jurassic, Oxfordian, Switzerland): Evolution of trophic structure as a response to environmental change. *Palaios*, **17**: 449-471.
- Flügel E. and Flügel-Kahler E. 1992. Phanerozoic reef evolution: basic questions and data base. *Facies*, **26**: 167-278.
- Insalaco E., Hallam A. and Rosen B. 1997. Oxfordian (Upper Jurassic) coral reefs in Western Europe: reef types and conceptual depositional model. *Sedimentology*, **44**: 707-734.
- Hallam A. 2001. A review of the broad pattern of Jurassic sea-level changes and their possible causes in the light of current knowledge. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **167**: 23-37.
- Haq B. U., Hardenbol J. and Vail P. R. 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: Wilgus C. K., Hastings B. S., Kendall C. G. St. C., Posamentier H. W., Ross C. A. and van Wagoner J. C. (Eds). Sea-level changes – an integrated approach. *SEPM Special Publication*, **42**: 71-108.
- Leinfelder R. R., Kreutter M., Laternser R., Nose M., Schmid D. U., Schweigert G., Werner W., Keupp H., Brugger H., Herrman R., Rehfeld-Kiefer U., Schroeder J. H., Reinhold C., Koch R., Zeiss A., Schweizer V., Christmann H., Menges G. and Luterbacher H. 1994. The origin of Jurassic reefs: current research developments and results. *Facies*, **31**: 1-56.
- Leinfelder R. R., Werner W., Nose M., Schmid D. U., Krautter M., Laternser R., Takacs M. and Hartman D. 1996. Paleocology, growth parameters and dynamics of coral, sponge and microbialite reefs from the Late Jurassic. In: Reitner J., Neuweiler F. and Gunkel F. (Eds). Global and regional controls on biogenic sedimentation. I. Reef evolution. *Research Reports. Göttinger Arbeiten zur Geologie und Paläontologie*, **2**: 227-248.
- Mas J. R., Alonso A. and Benito M. I. 1997. Depositional and diagenetic evolution of late Jurassic coral reefs in Northern Iberian Ranges (North Spain). *Boletín Real Sociedad Española de Historia Natural (Sección Geología)*, **92**, 1-4: 143-160.

## **Lower Hettangian in the Holy Cross Mountains region – an example of tectonically-controlled sedimentation in the epicontinental basin of Poland**

Paweł BRAŃSKI

Polish Geological Institute, ul. Rakowiecka 4, PL-00975 Warszawa, Poland; e-mail: pawel.branski@pgi.gov.pl

**Key-words:** Hettangian, Holy Cross Mts. margin, thickness, lithofacies, syndepositional faults, subsidence.

Origin of the Early Jurassic depositional sequences in the epicontinental basin of Poland is mainly related to the successive super-regional pulses of sea-level with relatively lesser role of tectonic activity (Pieńkowski 2004). Development of sedimentary infill of Hettangian basin in the Holy Cross Mts. region was determined by both tectonic and eustatic factors. In earliest Jurassic times, a short-term tectonic event led to the pronounced subsidence acceleration in the southern part of the Mid-Polish Trough. It followed period of a low subsidence rate during the Rhaetian times. Geometry of the Holy Cross Mts. segment of the Mid-Polish Trough with its framing crustal fractures, rapid facies changes and shifting of depocenter indicate a strike-slip regime of tectonic reactivation,

in agreement with the earlier suggestions of some authors (Hakenberg & Świdrowska 1997; Poprawa 1997). Based on the thickness changes, lithofacies and palaeoenvironment distribution, sequence correlation, as well as on the subsidence curves interpretation, two main stages of Hettangian basin evolution were identified. Accumulation of the basin-fill in Early Hettangian (Zagaje Fm.) was strongly related to the block-faulted structure of the basement and synsedimentary tectonics, controlling differential subsidence. After the transtensional (strike-slip) reactivation of the trough and local coarse-grained fluvial deposition, the extensional basin widening prevailed. It was coeval with a base-level rise (transgression), which continued through the Planorbis times (Pieńkowski 2004). Dip-slip motions of the faults became dominant and acceleration of the subsidence was very rapid. As a result of tectonic and eustatic processes, a large-scale fining-upward basin-fill succession was generated in a short time. The retrogradational, alluvial-lacustrine stacking pattern deviates from some traditional models of a progradational, coarsening-upward basin-fill in the strike-slip basins. It possibly reflects some temporal changes in magnitude of the strike-slip *vs.* dip-slip displacements and the rise of the base-level. After brackish-marine flooding, the nearshore and marginal-marine successions of Skłoby Fm. and Przysucha Ore-bearing Fm. were deposited in Middle-Late Hettangian time (Pieńkowski 2004). With exception of the Nowe Miasto-Itża Fault, a synsedimentary activity of tectonic discontinuities ceased and the subsidence became much weaker. Cyclicity of sedimentation was then controlled mainly by sea-level changes. The subsidence pulse at Triassic/Jurassic boundary offers an explanation for the accumulation of anomalous thickness of the continental Lower Hettangian followed by brackish deposits of marine transgression.

#### References:

- Hakenberg M. and Świdrowska J. 1997. Propagation of the south-eastern segment of the Polish Trough connected with bounding fault zones (from the Permian to the Late Jurassic). *Comptes Rendus de l'Académie des Sciences, Series IIA, Earth and Planetary Science*, **324**: 793-803.
- Pieńkowski G. 2004. The epicontinental Lower Jurassic of Poland. *Polish Geological Institute Special Papers*, **12**: 1-154.
- Poprawa P. 1997. Late Permian to Tertiary dynamics of the Polish Trough. Europrobe-Tesz-Meeting, Potsdam. *Terra Nostra*, **97**, 11: 104-109.

## **Architecture and dynamics of a Triassic/Jurassic carbonate platform-basin transition in the Sciacca area, South Central Sicily: implications for the Neogene accretion of the Maghrebien orogen**

Maria S. CACCIATORE and Pietro DI STEFANO

University of Palermo, Dipartimento di Geologia e Geodesia, Via Archirafi 22, 90123 Palermo, Italy;  
e-mail: simocaccia@virgilio.it, pdistefa@unipa.it

**Key-words:** Sicily, Triassic, Jurassic, paleotectonics, reefs.

The Sciacca area, in Southwestern Sicily, belongs to the external zone of the Neogene Maghrebien thrust and fold belt. Two different groups of south-verging thrust sheets crop out in this area: the so called "Saccense" units that consist of thick Mesozoic neritic and pelagic platform carbonates;

the “Sicanian” units made of Permian to Cenozoic deeper-water sediments. The tectonic boundary between Saccense and Sicanian units runs NW-SE from Monte Genuardo to Caltabellotta. This boundary is orthogonal to the main thrust fronts and nearly parallel to the direction of thrust propagation. Thrust-top-basin deposits of Pliocene age obscure the tectonic relationships along this alignment leaving different solutions open for its structural interpretation and for the palinspastic restorations between platform and basin-derived units.

Recent sedimentological and stratigraphical studies focused in this zone document the presence of Upper Triassic reef limestones in the Saccense units (Pizzo Telegrafo unit), close to the tectonic alignment. The macro and microfacies analysis reveal a typical *Dachstein*-type reef composition of these deposits. As consequence they can be interpreted as markers of platform edges facing high-energy, open marine basins. The collected data are thus consistent with the presence of a Late Triassic platform-basin transition close to the present-day tectonic boundary.

An intense Jurassic paleotectonic activity along this margin is proved by in situ brecciation and the presence of large polyphase neptunian dykes crosscutting the reef deposits and the overlying Lower Jurassic platform limestones (Inici Formation). The dykes are filled up by Middle to Upper Jurassic *Rosso Ammonitico* type condensed limestones. Basaltic pillow lavas occur as thick wedges intercalated to the Jurassic pelagic limestones. They indicate repeated episodes of (trans)tensional stresses along the paleomargin. An anomalous thin Cretaceous to Miocene sedimentary cover (Scaglia type calcilitites and glauconitic sandstones) is punctuated by deep erosional truncations and megabreccias. These sediments fill up later generations of neptunian dykes confirming the paleotectonic activity in this zone throughout the Jurassic-Miocene times.

In the Sicanian basinal units flanking the tectonic alignment the influence of the platform paleomargin is recorded by extensive Lower Jurassic carbonate aprons interbedded to cherty calcilitites. Upper Triassic reef-derived elements are common constituents of these clastics as recently documented at Campofiorito and Monte Triona.

Looking at the present day structural relationships in the studied area we can conclude that the Triassic/Jurassic paleomargin has played an important role as major transpressional dextral escape during the Neogene Sicanian mountain building.

## Lower Jurassic carbonate platform-to-basin transition at Mt. Rumija (Montenegro)

Alenka E. ČRNE<sup>1</sup>, Spela GORICAN<sup>1</sup> and Damjan CADJENOVIC<sup>2</sup>

<sup>1</sup>Ivan Rakovec Institute of Palaeontology, ZRC SAZU, Novi trg 2, SI-1000 Ljubljana, Slovenia;  
e-mail: acrne@zrc-sazu.si, spela@zrc-sazu.si

<sup>2</sup>Geological Survey of Montenegro, Krusevac bb, 81000 Podgorica, Serbia and Montenegro

**Key-words:** Early Jurassic, External Dinarides, Montenegro, High Karst Carbonate Platform, Budva Basin.

Mount Rumija, Montenegro represents one of the best-preserved Lower Jurassic platform-to-basin transitions in the Dinarides. Mt. Rumija is located in the High Karst Zone, overthrust on the Budva Zone. In the Mesozoic the High Karst Zone was a part of the Adriatic-Dinaric Carbonate Platform (ADCP), whereas the Budva Zone was a deeper basin. We describe two complete Lower Jurassic sections (Tejani and Livari) and a complementary Pliensbachian-Toarcian section (Seoce). The successions exhibit great facies differences across short distances and provide important new data for the reconstruction of the Lower Jurassic platform-to-basin system.

At Tejani and Livari, the Upper Triassic *Dachstein* Limestone is overlain by micritic limestone, which begins with a few beds of fine- to medium-grained calcarenites. At Tejani, 100 m of thick-bedded coarse-grained oolitic limestone follow, at places displaying cross-stratification. Laterally, at Livari, the correlative succession is 180 m thick and consists of three calcareous turbidite packages. The first and the third package are lithologically identical: fine- to medium-grained calcarenites, which contain 50% replacement chert layers and nodules; the calcarenites contain pellets, echinoderm fragments, foraminifers, ooids and sponge spicules. The second package is an oolitic limestone that lacks chert. The overlying lithostratigraphic unit is common to both sections and aids in correlation. It consists of a 30 m thick succession of marly limestone and marl overlain by 30 m of medium-bedded bioclastic limestone. The marly limestone contains foraminifers, ostracodes, sponge spicules and rare radiolarians, while the bioclastic limestone contains abundant brachiopod shells, echinoderm fragments and several Fe-Mn crusts. The bioclastic limestone is overlain by oolitic limestone. The base of the Seoce section starts with a thick-bedded *Lithiotis* limestone. A nodular micritic limestone follows, containing mostly pellets and rare bioclasts – fragments of echinoderms, ostracodes and brachiopods. The succession ends with oolitic limestone.

In the Budva Basin, the Upper Triassic *Halobia* limestone (pelagic lime mudstone with replacement chert) is overlain by *Passée Jaspeuse* (bedded calcareous chert). The overlying Bar Limestone (calcareous turbidites) was deposited beginning in the Late Sinemurian – Early(?) Pliensbachian. It is composed of Lower and Upper Member, divided by a marly horizon, probably Toarcian in age.

The lateral transition from the lagoonal environment (Seoce) to the platform edge (Tejani) and deeper water environment (Livari) can be observed at Mt. Rumija. Vertically, two abrupt facies changes occur. The first one is the beginning of the micritic limestone sedimentation above the *Dachstein* limestone. The second change is observed both in the shallow-water environment (nodular limestone overlying *Lithiotis* limestone) and on the platform-to-basin transition (sedimentation of marly limestone with open-marine biota). Two abrupt facies changes on the carbonate platform are correlated to facies changes in the Budva Basin (*Halobia* limestone – *Passée Jaspeuse*, Lower Bar Limestone Member – marl, respectively). The facies changes correspond to two drowning events: at T/J boundary and at Late Pliensbachian – Upper Toarcian.

## **Late Jurassic biofacies characteristics of Jubaila-Arab formational contact, Saudi Arabia**

Abdullah J. AL-DHUBAIB

Postgraduate Unit of Micropalaeontology, Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT, UK; e-mail: [abdullah.dhubeeb@aramco.com](mailto:abdullah.dhubeeb@aramco.com)

**Key-words:** biofacies, micropalaeontological analysis, Late Jurassic, Jubaila and Arab Formations, Riyadh, Saudi Arabia.

The lithostratigraphic relationship between the Jubaila and Arab Formations is not fully understood and is often misinterpreted in the subsurface. Since the type section of the Jubaila is in the outcrop and that of the Arab is subsurface, there is no common feature to easily define the contact in subsurface. The highly productive Arab-D reservoir spans the Jubaila and Arab Formations. One reservoir layer

		1939-1964 standart sub-surface	1958 Steineke <i>et al.</i> type section	1962 Powers	1964 and later standard sub-surface published and unpublished	
Fm	Lithology	Member	Member	Member	Reservoir	Member
Hith						
		Arab-A	"A"	Arab-A	Arab-A	Arab-A
Arab		Arab-B	"B"	Arab-B	Arab-B	Arab-B
		Arab-C	"C"	Arab-C	Arab-C	Arab-C
		Arab-D	"D"	C-D Anhydrite		Arab-D
				upper	Arab-D	
	middle					
	Jubaila	Arab-D	lower	Arab-D	correlative with Arab-Jubaila contact on outcrop	
Jubaila						

	- micritic limestones and calcarenites		- anhydrite
	- calcarenites		- dolomite

Fig. 1. Review of historical evolution of Arab and Jubaila formations, lithostratigraphical nomenclature in the Late Jurassic of central and eastern Saudi Arabia.

in Ghawar field (at the top of reservoir zone 2B) is considered in previous studies to possibly equate with the Jubaila-Arab formational boundary, and it is confirmed in this study (Fig. 1).

Using semi-quantitative micropalaeontological analysis of thin sections from three localities in Riyadh area where the Jubaila and lower Arab Formations are exposed enables recognition of this boundary in eight wells from eight fields in the east of Saudi Arabia.

In this study, the Arab-D reservoir has been divided into nine biofacies that characterize the Jubaila and Arab Formations and the nature of the Jubaila-Arab formational contact. Calibration of the wireline logs with these biofacies will assist in the recognition of this event in uncored wells, and assist in regional Arab-D reservoir layering. Such information will also contribute to improve the understanding of intra-Arab-D reservoir sequence stratigraphy, palaeoenvironmental and sedimentological variations and unexpected production behavior of the reservoir.

## The Jurassic section of Ras Sharwayn (Southern Yemen): stratigraphic analysis

Milvio FAZZUOLI<sup>1</sup>, Marco MORELLI<sup>2</sup> and Giulio PAVIA<sup>3</sup>

<sup>1</sup>Dipartimento di Scienze della Terra, via La Pira 4, 50121 Firenze, Italy; e-mail: milvio@dicea.unifi.it

<sup>2</sup>Fondazione Prato Ricerche, Via Galcianese 20/11, 59100 Prato, Italy; e-mail: morelli@geo.unifi.it

<sup>3</sup>Dipartimento di Scienze della Terra, via Accademia delle Scienze 5, 10123 Torino, Italy; e-mail: giulio.pavia@unito.it

**Key-words:** Jurassic, Southern Yemen, carbonate ramp, unconformity surface.

The present study was performed at Ras Sharwayn, about 250 km east of Al-Mukalla along the Gulf of Aden coast. Four Jurassic stratigraphic units have been distinguished.

The Kohlan Formation (60 m) overlies unconformably the crystalline basement. Its lower and middle part consist of fluviatile sandstone and conglomerate. The upper part is made up of transitional coarse- and fine-grained sandstones and siltstones. Shallow marine fine-grained sandstones close the sequence. Fossils are present in the bioclastic storm layers of the top unit.

The Shuqra Formation (71 m) is divisible into two members. The basal Calcareous-marly Member (45 m) consists of grey calcilutites alternating with fine calcarenites and subordinate nodular marls (inner to mid ramp). At the base, a very rich fossil palaeocommunity of muddy outer shelf occurs, characterized by Anomalodesmata pelecypods, less common brachiopods of orders Rhynchonellida (*Somalirhynchia africana*) and Terebratulida (*Kutchithyris* sp.), early, possibly new forms of infaunal Atelostomata echinoids (*Mepygurus* sp., *Bothriopneustes*(?) sp.). Among pelecypods, common taxa are *Modiolus* cf. *subangustissimus*, *Bucardiomya* cf. *protei*, *Ceratomya* sp., *Gresslya* sp., *Procardia* cf. *latissima*. The age, by benthic foraminifers and the nautiloid *Paracenoceras giganteum*, is Late Oxfordian. The Carbonate Member (26 m) changes from basal reddish marly calcilutites (mid ramp) to thick beds of red-brown, coarsely crystalline limestones and dolomites (inner ramp). The top beds contain fossils of colonial organisms, essentially stromatoporoids. The age, by stratigraphic frame and microfossils, is Late Oxfordian and possibly earliest Kimmeridgian.

The Madbi Formation, (30 m) consists of yellowish marls alternating with marly calcilutite and bioclastic calcarenite (coquinas) corresponding to storm layers (mid to outer ramp). The very basal bed contains an oligotypical palaeocommunity dominated by large-sized brachiopods (*Somalirhynchia* n. sp.) with scattered *Exogyra* sp. and *Alectryonia* cf. *pulligera*. The rich brachiopod assemblage indicates a muddy bottom where oyster shells offered a semi-rigid ground on which the rhynchonellid palaeocommunity was growing. As to the age, a specimen of ammonoid, *Orthosphinctes* sp., collected at some seven metres above the base, undoubtedly refers to as Early Kimmeridgian. The Madbi Formation ends with an unconformity surface.

The informal Clastic Unit (56 m) consists, from the bottom, of: red-brown dolomite; grey calcarenite with quartz grains; massive, white conglomerate with well rounded clasts of limestones, quartz and bioclasts (e.g. colonial organisms). The calcarenite and the conglomerate are gravity flow deposits, accumulated at the base of a scarp of possibly tectonic origin. The onset of the clastic sedimentation is connected with the tectonic phase that strongly deformed the Jurassic sedimentary basins, and formed horst and graben topography approximately at the Jurassic/Cretaceous boundary.

Main advances of the present research in regard to the previous studies (Beydoun 1964) are: a detailed lithological and sedimentological analysis, new biostratigraphical data and some variations on the lithostratigraphical subdivision and nomenclature.

### References:

Beydoun Z. R. 1964. The stratigraphy and structure of the Eastern Aden Protectorate. *Overseas Geology and Mineral Resources, Bulletin supplements*, 5: 1-107.

## Sedimentary environments of the Middle Jurassic epicontinental deposits from the central part of the Polish Basin (Kuiavian Region)

Anna FELDMAN-OLSZEWSKA

Polish Geological Institute, ul. Rakowiecka 4, PL-00975 Warszawa, Poland;  
e-mail: anna.feldman-olszewska@pgi.gov.pl

**Key-words:** Middle Jurassic, sedimentary environments, offshore, shoreface, foreshore, black shales, heteroliths, sandstones, trace fossils.

The Polish Basin was the eastern part of the Jurassic European epicontinental basin. The zone of maximum thickness of the Middle Jurassic deposits runs along the so called Mid-Polish Trough which extends from the West Pomerania (NW) to the Holy Cross Mountains (SE), generally along the Teisseyre-Tornquist Zone. The complete lithological profile of the Middle Jurassic deposits exceeds 1100 m in the depocentre of the Mid-Polish Trough (in the Kuiavian Region). Sediments are represented by sandstones, mudstones, heteroliths and claystones with intercalations of siderites, dolomites and coquina beds. Subordinately, crinoidal limestones, arenaceous limestones, gaizes and oolitic ironstones occur.

Sedimentological studies were based on investigation of cores from ten deep boreholes. Nineteen lithofacies were distinguished: black shales, massive mudstones, bioturbated mudstones, lenticular bedded mudstones, heteroliths, wavy bedded sandstones, flaser bedded sandstones, sandstones with clay drapes, structureless sandstones (massive and bioturbated), parallel bedded sandstones, cross bedded sandstones, HCS (hummocky cross stratification) cross bedded sandstones, ripple bedded sandstones, herringbone cross bedded sandstones, chamosite sandstones, calcareous sandstones and arenaceous limestones, crinoidal limestones, conglomerates, condensed bed.

Additionally, 15 ichnogenera of trace fossils: *Asterosoma* isp., *Bergaueria* isp., *Chondrites* isp., *Diplocraterion* isp., *Gyrochorte* isp., *Lockeia* isp., *Ophiomorpha* isp., *Palaeophycus* isp., *Planolites* isp., *Rosselia* isp., *Skolithos* isp., (?)*Spongeliomorpha* isp., *Teichichnus* isp., *Terebellina* isp. and *Thalassinoides* isp. were recognized in the Middle Jurassic deposits of Kuiavian Region. They point to sedimentation in the transition zone – foreshore environments.

Based on the geochemical and palaeoecological investigations, four biofacies connected with different oxygenation of the bottom waters during sedimentation of the black shales have been proposed. The Upper Aalenian – Lower Bajocian deposits represent clayey sedimentation which occurred in dysoxic to anoxic environment. On the other hand, the Upper Bajocian – Lower Bathonian deposits represent dysoxic to oxic conditions.

Sedimentation of the Middle Jurassic deposits in the central part of the Polish Basin took place in the shallow epicontinental sea, in environment spanning offshore to foreshore zones of a shallow siliciclastic shelf. Precise sedimentological studies point that the Middle Jurassic succession can be divided into 8 transgressive-regressive cycles. The oldest (Lower Aalenian) one begins with estuarine/foreshore sediments, sharply covered with offshore black shale facies. The Upper Aalenian, Bajocian and Lower Bathonian cycles are built of the transgressive offshore black shales and progradational regressive successions composed of mudstones and heteroliths and topped by shallow or middle shoreface sandstones. The Middle and Upper Bathonian cycles begin with transition zone sediments or lower shoreface deposits. The uppermost part of these cycles are built of sandstones and limestones representing the upper shoreface, foreshore and lagoon environments. The transgressive part of the last (Callovian) cycle is documented by carbonate-siliciclastic shoreface deposits which pass upwards into limestones of the Upper Jurassic. At the boundary between the Middle and the Upper Jurassic a condensed bed occurs.

## Upper Jurassic – Lower Cretaceous platform to basin transition of the Northern Calcareous Alps

Alois FENNINGER<sup>1</sup> and Michael W. RASSER<sup>2</sup>

<sup>1</sup>Karl-Franzens-Universität Graz, Institut für Erdwissenschaften, Bereich Geologie und Paläontologie, Heinrichstrasse 26, A-8010 Graz; e-mail: alois.fenninger@uni-graz.at

<sup>2</sup>Staatliches Museum für Naturkunde Stuttgart, Rosenstein 1, D-70191 Stuttgart; e-mail: michael.rasser@paleoweb.net

**Key-words:** Northern Calcareous Alps, Upper Jurassic/Lower Cretaceous, platform to basin transition.

Tectonic events in the Upper Triassic caused the break of carbonate platforms in the Northern Calcareous Alps (NCA). Drawing and synsedimentary faulting stipulated a highly structured seafloor topography with sedimentation of crinoidal limestones, cherty limestones as well as cephalopod limestones on top of the Triassic platforms. This mainly pelagic development lasted until the Oxfordian with deposition of radiolarites and siliceous limestones.

The Upper Jurassic to Lower Cretaceous development is linked to the opening of the Northern Atlantic and the Penninic Ocean and led to the break up of Pangea and the Austroalpine units. They became independent from the European Plate and are considered as microplate north of the Apulian Plate.

Basin sediments of the central part of the NCA are represented by radiolarites and cherty limestones overlain by Tithonian to Valangian micritic sediments with intercalations of allodapic limestones. Carbonate breccias together with variagated nodular limestones and periplatform ooze are interpreted as slope deposits.

Platform environments are represented by large carbonate mud areas with local patch reefs. Other reefal areas of the platform are dominated by “stromatoporids”, “chaetodids”, scleractinians and microincrusters binding reef rubble. Inner platform environments are dominated by “stromatoporids” while corals are subordinate. In open platform environments secondary framework builders can bind reef rubble.

The Jurassic Alpine reefs reflect trends to coral adapted oligotrophic high-energy conditions, representing ancestors of modern reefs.

Beside the typical reef guild organisms, gastropods (nerineids) and patches of dasycladales are typical for low energy environments.

## Depositional sequences and ammonite fossilization on deep carbonate platform environments (Upper Oxfordian, Iberian Range, Spain)

Sixto R. FERNÁNDEZ-LÓPEZ<sup>1</sup> and Guillermo MELÉNDEZ<sup>2</sup>

<sup>1</sup>Departamento y UEI Paleontología, Facultad Ciencias Geológicas e Instituto Geología Económica, (CSIC-UCM), 28040 Madrid, Spain; e-mail: sixto@geo.ucm.es

<sup>2</sup>Departamento de Geología (Paleontología), Universidad de Zaragoza, 50009 Zaragoza, Spain; e-mail: gmelende@posta.unizar.es

**Key-words:** taphonomy, stratigraphic condensation, sedimentary condensation.

The uppermost deposits of the Yatova Formation in the Riela area represent a condensed section, 1.5 m thick, developed during the Semimammatum and Berrense subchronozones. This interval is composed

of grey-reddish wackestone to packstone and boundstone beds alternating with marly intervals, bearing common sponges, ammonites and bioturbation textures. Terebratulid and rhynchonellid brachiopods, belemnites, bivalves, gastropods, serpulids, bryozoans, crinoids and echinoids are very scarce. Small sponge mud mounds, some few metres wide and less than 50 cm high, are locally developed. Limestone beds, 10 to 40 cm thick, show sharp base, but gradual size-increase or inverse grading of fossils and gradational upper boundary. Marly intervals, under 40 cm thick, display planar fabric, being normal grading of fossils more common than inverse grading. Hardground surfaces, ferruginous crusts and glauconite grains are common on the limestone beds. In contrast, hardground surfaces are not developed within marly intervals, although reworked concretions and remobilization surfaces are common, often capping the underlying argillaceous sediments. Parasequences show a less distinct development than in underlying intervals. Thickening and coarsening upwards sequences of metric thickness are common. Thinning and fining upwards sequences are scarce, generally developed between the last sponge mounds and associated with the thickest intervals of condensed deposits.

This condensed interval is interpreted as formed in an open marine, moderately deep carbonate platform, below effective wave base, showing generally low-energy conditions with extremely low rates of carbonate and terrigenous sedimentation. Marly deposits represent background sedimentation, with very low rates of sediment accumulation, which may be due to sedimentary starving as well as to winnowing action on the seafloor. In contrast, limestone beds correspond to event sedimentation, with relatively high rates of sediment accumulation, probably distal tempestites. Lasting episodes of background sedimentation give rise to clay deposits showing no evidence of basal discontinuity, whereas brief events of turbulence lead to carbonate deposits with sharp base. The low diversity of the benthic fauna, scarce development of sponge bioherms and microbial crusts, as well as ammonite populations inhabiting the platform are all palaeobiological criteria confirming these deep and distal palaeoenvironments. Taphonomic features of ammonite assemblages indicative of sedimentary starving are the occurrence of: 1 – high concentrations of reworked ammonites showing very low values of taphonomic condensation; 2 – taphonic populations of type-2; 3 – predominant internal moulds of phragmocones completely filled with homogeneous sediment up to the innermost whorls; and 4 – reworked fossils bearing no signs of abrasion, bioerosion or dense encrusting.

These condensed deposits characterize the last phase of a deepening half-cycle, attaining the maximum deepening environments during Upper Jurassic, within a 3<sup>rd</sup> order deepening/shallowing cycle developed in the Iberian platform system.

## **Aalenian-Bajocian iron-coated grains: evolutionary stages, sequence distribution and genetic significance (Iberian Basin, Spain)**

Alejandra GARCÍA-FRANK<sup>1</sup>, Soledad URETA<sup>1</sup> and Ramón MAS<sup>2</sup>

<sup>1</sup>Departamento y UEI de Paleontología, Facultad C. C. Geológicas e Instituto de Geología Económica, (CSIC-UCM), 28040 Madrid, Spain; e-mail: agfrank@geo.ucm.es, solureta@geo.ucm.es

<sup>2</sup>Departamento y UEI de Estratigrafía, Facultad C. C. Geológicas e Instituto de Geología Económica, (CSIC-UCM), 28040 Madrid, Spain; e-mail: ramonmas@geo.ucm.es

**Key-words:** coated grains, iron, stratigraphical sequences, Early-Middle Jurassic, Iberian Basin, Spain.

The study area is situated in the northwestern extreme of the Iberian Range (northern Spain). Some sections ranging from uppermost Toarcian to Bajocian have been studied for the analysis of the iron rich particles. Petránek & Van Houten (1997) documented about 550 well-known Phanerozoic ooidal

ironstone outcrops, showing that in the Jurassic of Europe, ironstones occur mainly in the Lower-Middle Jurassic and in the Middle-Upper Jurassic transitional beds. The main minerals forming these particles are berthierine, chamosite and goethite.

The particles recorded from the Iberian Range, according to Flügel's (2004) classification, consist on iron-skeletal grains, iron-coated grains (cortoids, ooids and oncoids) and iron-grain aggregates, mostly composed of the ferrous Fe-phyllsilicate berthierine, and in a less amount goethite. Five stages of increasing complexity in the habit of these particles are documented in the Aalenian/Bajocian boundary, which are correlated with a more condensed sedimentary record in the stratigraphical succession. A trend ranging from iron cortoids (stage 1) in the lower part of the series, passing to small-sized iron ooids and oncoids (stage 2), and finally, more complex iron-grain aggregates and larger iron ooid-oncoid mixed particles (stage 3). In condensed sediments, a rim of berthierine can be developed around any of the previously documented particles (stage 4), or even, a total dissolution of the particle can occur (stage 5).

A relationship between these stages and the main stratigraphical discontinuities affecting the sequences is acknowledged. Stages 1 and 2 appear in the lower sequences (Lower Aalenian), in which, each individual discontinuity, represent a sedimentary gap equivalent at least to one ammonoid subzone. Stages 3 to 5, occur in the upper part of the succession, and as previously mentioned, related with more condensed sediments, and where, discontinuities represent more extent temporal gaps.

The active tectonic context of the basin, might be associated with the Fe-mineralogy of the particles by exhalative sources. The rare earth elements (REE) distribution of the particles and samples of the coeval volcanism documented in the Iberian Range, shows similar patterns. It is therefore probable to situate the studied area in an active tectonic framework within the Aalenian-Bajocian, where the source of iron could be associated with exhalative events.

#### References:

- Flügel E. 2004. Microfacies of carbonate rocks. Analysis, interpretation and application, 1-976. Springer, Berlin.
- Petránek J. and Van Houten F. B. 1997. Phanerozoic ooidal ironstones. *Czech Geological Survey Special Papers*, 7: 1-71.

## Biofacies and palaeoenvironments of the Jurassic Shaqra Group of Saudi Arabia

Geraint W. G. HUGHES

Saudi Aramco, Geological Technical Services Division, Dhahran 31311, Saudi Arabia;  
e-mail: geraint.hughes@aramco.com

**Key-words:** Saudi Arabia, Jurassic, Shaqra Group, micropalaeontology, biostratigraphy, sequence stratigraphy, palaeoenvironments.

The Jurassic succession in Saudi Arabia consist of eight formations, of which most are carbonate and some are partly evaporitic, and is of economic importance because it hosts twelve hydrocarbon reservoirs, including the Arab-D reservoir within the world's largest oilfield at Ghawar. The Minjur-Marrat formational boundary marks the Triassic/Jurassic boundary, of which the Marrat is dated as Toarcian. A significant unconformity separates the overlying Dhruma Formation, of Bajocian to Bathonian age. The Tuwaiq Mountain Formation, of Callovian age, overlies the Dhruma Formation, with reduced unconformity duration. The Hanifa Formation, of Oxfordian age, is separated from the Tuwaiq Mountain Formation by a minor unconformity, as are the successive Jubaila, Arab and Hith formations,

of Kimmeridgian to Tithonian age. The Jurassic/Cretaceous boundary is currently placed at the Hith-Sulaiy formational contact.

Intensive analyses of the carbonates reveals variably rich micropalaeontological biofacies that contain foraminiferal species of potential palaeoenvironmental significance, especially when applied to cored mudstone to grainstone repeated successions of which the hierarchy is often difficult to elucidate. A combination of semi-quantitative micropalaeontological and macropalaeontological analysis of closely-spaced thin sections from these carbonates reveals clearly defined microbiofacies cycles. Their stacking order provides clearly defined palaeoenvironmental trends that subdivide the succession into potential parasequences, transgressive and highstand systems tracts.

The Shaqra Group spans at least 38 Ma, and qualifies as a second order depositional sequence, within which the lithostratigraphic units of formation identity fall into third order sequences. The extensive duration of unconformities spanning the Hettangian-Sinemurian and the Aalenian-Bajocian need explaining, especially when compared to the relatively minimal interformational unconformities that characterize the Bajocian-Tithonian succession. Eustatic sea-level data indicates that the Hettangian to Early Pliensbachian is characterized by a relatively insignificant sea level variation when compared with the gradual rise from the Late Bajocian to the Kimmeridgian. The mid Bajocian event approximates with the global increase in percent dolomite in abiotic muds, and may be associated with a transitional icehouse-greenhouse phase, for which post Bajocian eustatic falls would be expected to display increasing greenhouse affinity. Preservation of calcitic ooids within the Middle and Late Jurassic carbonate reservoirs within Saudi Arabia, together with excellent intergranular porosity testify to the calcitic oceanic conditions associated with greenhouse times.

The biofacies approach to elucidating palaeoenvironmental variations of the Shaqra Group provides significant insights to the Jurassic history of the Arabian Plate, as well as serving to explain the origin and stratigraphic location of hydrocarbon reservoirs.

## Oxfordian palaeoenvironments of Saudi Arabia

Geraint W. G. HUGHES<sup>1</sup>, Mokhtar AL-KHALED<sup>1</sup>, Osman VAROL<sup>2</sup> and David BACCHUS<sup>1</sup>

<sup>1</sup>Saudi Aramco, Geological Technical Services Division, Dhahran 31311, Saudi Arabia;  
e-mail: geraint.hughes@aramco.com

<sup>2</sup>Varol Research, Rhos On Sea, Conwy, N. Wales, United Kingdom; e-mail: osman@varol.com

**Key-words:** Saudi Arabia, Oxfordian, Hanifa Formation, palaeogeography, Foraminifera, nannofossils, *Clypeina*, *Cladocoropsis*.

The Hanifa Formation in Saudi Arabia consists of a succession of carbonates, over 90 m thick that were deposited during the Late Jurassic, Oxfordian. It consists of a lower Hawtah Member and an upper Ulayyah Member. A Late Oxfordian age is based on the first appearance of the benthonic foraminifera *Alveosepta jaccardi* and, within the upper part of the underlying Hawtah Member, the local extinctions of the calcareous nannofossil species *Watznaueria manivittiae* and *Stephanolithion bigotii* together with an influx of *Ellipsagelosphaera britannica*.

A detailed study of the micropalaeontology, nannopalaeontology, biofacies, sedimentology and wireline log character of the uppermost parts of 35 cored wells distributed across the Kingdom has revealed a variety of depositional environments. The late highstand succession of the Formation displays a variety of biofacies and lithotextures, of which the grainiest host the Hanifa Reservoir. These are associated with stromatoporoid banks that developed on the flanks of intrashelf basins, although grain-dominated shoals within the lagoons also present reservoir potential.

A range of palaeoenvironments has been determined, based on integrated biofacies and lithofacies that include shallow lagoon packstones and foraminiferal dominated grainstones, deep lagoon wackestones and packstones with *Clypeina/Pseudoclypeina* dasyclad algae, stromatoporoid back bank packstones and grainstones with the branched stromatoporoid *Cladocoropsis mirabilis*, bank crest grainstones with encrusting and domed stromatoporoids and intrashelf basin flank mudstones and wackestones containing sponge spicules, deep marine foraminifera and coccoliths.

This study has assisted delimitation of an intrashelf basin with an irregular margin situated in the East Central part of the Saudi Arabian portion of the Arabian Plate palaeoenvironments during the Late Oxfordian. The basin is flanked by a belt of stromatoporoid banks that pass laterally into a back-bank facies before developing into a lagoon facies. There is no evidence for the shoreline of this basin, although the presence of rare charophytes in the northwest testifies to possible proximity of fluvial input.

The grainstone margin presents good hydrocarbon reservoir facies and its juxtaposition to intrashelf basinal sediments with potential source rock character provides exciting new prospects in areas hitherto uninvestigated for hydrocarbon reservoirs.

## Post-evaporitic carbonates of the Saudi Arabian Late Jurassic

Geraint W. G. HUGHES, Nasir NAJI, Mokhtar AL-KHALED, Tom HARLAND and David BACCHUS

Saudi Aramco, Geological Technical Services Division, Dhahran 31311, Saudi Arabia;  
e-mail: geraint.hughes@aramco.com

**Key-words:** Saudi Arabia, Tithonian, Hith Formation, carbonates.

The Hith Formation forms the latest lithostratigraphic unit of the Jurassic Shaqra Group, and was deposited during the Tithonian. The Formation outcrops in central Saudi Arabia, but has been studied in detail in subsurface eastern Saudi Arabia where the upper carbonate member hosts an important hydrocarbon reservoir called the Manifa reservoir. Chronostratigraphic control is absent, and the Tithonian age is based on stratigraphic position between the underlying Kimmeridgian Arab Formation, and the overlying Sulaiy Formation, of Berriasian age.

The lower anhydrite-dominated member is un-named, and considered to represent subaqueous deposition representing the transgressive systems tract of the Manifa sequence. A transitional unit, consisting of interbedded anhydrites and carbonates, approximates with the maximum flooding zone, and the overlying carbonates are considered to represent the results of a prograding shallow marine succession related to the highstand systems tract.

The carbonates of the Manifa reservoir consist of five parasequences, each of which represents a shoaling-upwards cycle that commences with a stromatolitic, microfaunally-barren unit that is followed by fine-grained grainstones with a monospecific but abundant ostracod biofacies. A succession of coarse peloidal grainstones with rare Foraminifera, including *Redmondoides lugeoni*, *Trocholina alpina* and miliolids, then follows, that passes vertically into coarse ooid grainstones that form the uppermost part of each parasequence.

The Hith Formation represents the culmination of a succession of hypersaline and euryhaline cycles that characterise the Late Jurassic of Saudi Arabia, and provides an insight to the palaeoenvironmental conditions that existed across the Arabian Plate at the end of the Jurassic.

## Upper Jurassic carbonate buildups in the Carpathian foreland in Poland: geological and geophysical setting

Halina JĘDRZEJOWSKA-TYCKOWSKA<sup>1</sup>, Jan GOLONKA<sup>2</sup>, Piotr MISIARZ<sup>1</sup>, Michał KROBICKI<sup>2</sup>, Jacek MATYSZKIEWICZ<sup>2</sup>, Barbara OLSZEWSKA<sup>3</sup>, Anna PRZEJCZOWSKA<sup>4</sup> and Nestor OSZCZYPKO<sup>4</sup>

<sup>1</sup>Polish Oil and Gas Institute, ul. Lubicz 25a, PL-31503 Kraków, Poland; e-mail: znzwincz@cyf-kr.edu.pl, misiarz@idea.net.pl

<sup>2</sup>Department of General Geology and Environment Protection, Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Al. Mickiewicza 30, PL-30059 Kraków, Poland; e-mail: jan\_golonka@yahoo.com, krobicki@geol.agh.edu.pl, jamat@geol.agh.edu.pl

<sup>3</sup>Polish Geological Institute, ul. Skrzatów 1, PL-31560 Kraków, Poland; e-mail: Barbara.Olszewska@pgi.gov.pl

<sup>4</sup>Jagiellonian University, ul. Oleandry 2a, PL-30063 Kraków, Poland; e-mail: przejcowska@onet.pl, nestor@ing.uj.edu.pl

**Key-words:** Upper Jurassic, Carpathian foreland, Poland, carbonates, seismic modeling.

The Upper Jurassic carbonate sediments in the Carpathian foreland in Poland are exposed in the Polish Jura Chain and covered by the Outer Carpathian thrust and Neogene sediments of the Carpathian Foredeep. The thickness of marine Jurassic-Cretaceous carbonate series exceeds 1000 m in southern Poland and Ukraine covering the North European Platform. The lithology of the Upper Jurassic and Lower Cretaceous deposits reflects the main stages of sedimentation on the European Platform caused by eustatic changes of sea-level as well as local tectonics. Two megasequences could be distinguished here (Golonka & Kiessling 2002). Lower Zuni II, began with the Middle Jurassic transgression and ended with Early Tithonian regression. Lower Zuni III lasted from Early Tithonian to the general Early Valanginian regression. There is a gap between Lower and Upper Cretaceous deposits in the whole Carpathian Foredeep area.

The Lower Zuni II starts with sandstone-gaize series passing upward to the Callovian nodular limestones covered by Lower Oxfordian calcareous sponge deposits (Golonka 1978; Olszewska 2001). The carbonate buildups of thickness from few dozens to few hundreds meters are common within the calcareous sponge series. They form hills in the Polish Jura Chain between Kraków and Częstochowa (Matyszkiewicz 1997), in the SW margin of the Holy Cross Mountains and have been recognized in the numerous 2-D and 3-D seismic subcrop sections.

Interpretation of the 3D seismic data in the central part of the Carpathian foreland resulted in the recognition of several large Lower Oxfordian biohermal buildups exceeding 1 km in diameter (Misiarz 2004). Comparison with the outcrop data and seismic velocity models allows to propose new facies architecture model. The large bodies seen on the 2D seismic lines represent the clusters of small buildups. Similar clusters exist in the Jurassic outcrops in the Polish Jura Chain in the Ogrodzieniec and Olsztyn areas. The Ogrodzieniec hill was a subject of the synthetic seismic modeling of the outcrop. The impedance was calculated from the petrophysical studies of rock samples. Impedance inversion velocities were used to construct simple velocity model of a selected biohermal object and a synthetic seismic profile. Explaining internal heterogeneity of bioherms is crucial for treating them not as a single prospect but as a complex of drilling targets.

*This research has been partly supported financially by the Polish Committee for Scientific Research (KBN) - grant 5 T12B 013 23 and AGH grants 11.11.140.159 and 11.11.140.888.*

### References:

- Golonka J. 1978. Upper Jurassic microfacies in the Carpathians foreland. *Biuletyn Instytutu Geologicznego*, **310**: 1-37.
- Golonka J. and Kiessling W. 2002. Phanerozoic time scale and definition of time slices. *In*: Kiessling W., Flügel E. and Golonka J. (Eds). Phanerozoic reef patterns. *SEPM Special Publication*, **72**: 11-20.

- Matyszkiewicz J. 1997. Microfacies, sedimentation and some aspects of diagenesis of Upper Jurassic sediments from the elevated part of the Northern peri-Tethyan Shelf: a comparative study on the Lochen area (Schwäbische Alb) and the Cracow area (Cracow-Wieluń Upland, Polen). *Berliner Geowissenschaftliche Abhandlungen*, **21**: 1-111.
- Misiarz P. 2004. Oxfordian bioherms from the central part of the Carpathian foreland (Poland) – seismic modeling results. *AAPG Regional Conference with GSA, October 10-13, 2004, Prague, Official Program and Abstract Book*, 94.
- Olszewska B. 2001. Stratygrafia malmu i neokomu podłoża Karpat fliszowych i zapadliska w świetle nowych danych mikropaleontologicznych. *Przegląd Geologiczny*, **49**: 451.

## Clasts of the Liassic gravels (the Polish Uplands) – where do they come from?

Małgorzata KOZŁOWSKA-DEUSZKIEWICZ

Faculty of Geology, Warsaw University, Al. Żwirki i Wigury 93, PL-02089 Warszawa, Poland;  
e-mail: Malgorzata.Deuzskiewicz@uw.edu.pl

**Key-words:** clasts of vein quartz, quartzites, lydites and jaspers, Liassic gravels, Polish Uplands, Połomia Beds, Snochowice Beds.

The investigated gravels occur in the western part of the Mesozoic margin of the Holy Cross Mountains (MHCM) and in the northeastern part of the Mesozoic margin of the Silesia Upland (MSU), in central and southern Poland. The investigated deposits represent two informal lithostratigraphic units: the Snochowice Beds (in MHCM) – SnB and the Połomia Beds (in MSU) – PmB. The investigated gravels, in both cases, represent the bottom part of the profile of the Early Jurassic deposits.

The problem is: where are the source area and the source rocks? Did clasts from MHCM and from MSU Liassic gravels come from the same source rocks or not?

Both in SnB and in PmB cases mainly clasts of vein quartz, the quartzites, lydites and jaspers are recognized. Unfortunately the main components of the Liassic gravels are represented by the rocks which are insufficient as source indicators. The petrographical analyses have permitted to compare similar rocks from SnB and PmB clasts. The differences between the main groups of similar rocks from PmB and SnB are considerable, especially in the fabric and in the grade of metamorphism of the quartzites. Only few types of rocks – mainly quartz arenites (among the clasts from SnB and PmB) have got similar textural features which were confirmed in the CL analyses. Besides, the author has affirmed that the lithological differentiation of all PmB clastic material is greater than in SnB. Fortunately, but only in PmB, fragments of polymictic conglomerates, metamorphic schists, meta-subarcoses, silicified limestones, silicified woods and volcanites were distinguished.

Near the southern margins of the Mid-Polish Trough there were 3 areas which could yield clastic material: the Upper Silesia Coal Basin (USCB), the Brno-Upper Silesia Massif (BUSM) and the hypothetical Precarpathian Land. Among the clastic material of PmB and SnB the author hasn't recognized:

- any fragments of typical epimetamorphic rocks and Palaeozoic sedimentary rocks which could enable to recognize the BUSM succession (Buła 2000),
- any typical clastic material known from the Namurian and Wetphalian conglomerates such as fragments of the gneisses, granitoids, meta-volcanites (Paszkowski *et al.* 1995; Świerczewska 1995),
- any fragments of the black coals and other rocks which could be treated as good indicators for the Carboniferous succession of the USCB.

In the author's opinion only the Precarpathian Land, constituting the Western Outer Carpathian (WOC) basement (Poprawa *et al.* 2004), could be a source area for the Liassic gravels. This hypothetical land was situated somewhere on the south and consisted of the crystalline basement, covered by a thick succession of the epimetamorphic rocks. During the Early Jurassic these epimetamorphic rocks were the main source of the clastic material for the deposits in the Mid-Polish Trough. Probably since the Callovian, but certainly since the Early Cretaceous, the clastic material deriving from the sea-cordilleras, which were built mainly of epimetamorphic rocks, was deposited in WOC sedimentary basins. Henceforth, the same fragments of rocks (called "exotics") are known from the Liassic gravels in MSU and from the Mesozoic-Palaeogene succession of WOC, especially from the Silesian Unit. In addition, the differences between the SnB and PmB gravels are the effect of some differentiation of source rocks in the Precarpathian Land. The main source rocks for the PmB were metaquartzites with veins of quartz, meta-subarcoses, some detrital limestones, partly silicified and probably a succession of polymictic sandstones and conglomerates, which have got the same components as in PmB. The main source rocks for SnB were only metaquartzites with veins of quartz, but different than in PmB's source. The lydites, jaspers, some quartz arenites which are known from SnB and PmB all come from the same source rocks, and have been eroded during the Early Jurassic time.

#### References:

- Buła Z. 2000. Dolny paleozoik Górnego Śląska i zachodniej Małopolski. *Prace Państwowego Instytutu Geologicznego*, **171**: 1-89.
- Paszowski M., Jachowicz M., Michalik M., Teller L., Uchman A. and Urbanek Z. 1995. Composition, age and provenance of gravel-sized clastics from the Upper Carboniferous of Upper Silesia Coal Basin (Poland). *Studia Geologica Polonica*, **108**: 45-127.
- Poprawa P., Malata T., Pecskey Z., Banaś M., Skulich J., Paszowski M. and Kusiak M. 2004. Geochronology of crystalline basement of the Western Outer Carpathians' sediment source areas – preliminary data. *In: Karwowski Ł. and Ciesieleczuk J. (Eds). Mineralogical Society - Special Papers*, **24**: 329-332.
- Świerczewska, A. 1995. Composition and provenance of Carboniferous sandstones from the Upper Silesia Coal Basin (Poland). *Studia Geologica Polonica*, **108**: 27-43.

## Diagenetic history of the Upper Jurassic sediments in easternmost part of the Kopet-Dagh Basin, NE Iran

Asadollah MAHBOUBI<sup>1</sup>, Reza MOUSSAVI-HARAMI<sup>1</sup> and Scott J. CARPENTER<sup>2</sup>

<sup>1</sup>Department of Geology, Faculty of Science, Ferdowsi University of Mashhad, Mashhad 91775-1436, Iran;  
e-mail: amahboubi@science1.um.ac.ir, amahboobi2001@yahoo.com

<sup>2</sup>Department of Geoscience, University of Iowa, Iowa City, IA 52242-1379 USA

**Key-words:** Iran, Kopet-Dagh, Mozduran Formation, diagenetic history.

The Kopet-Dagh Basin is located in northeastern Iran and southwestern Turkmenistan. It is believed that this basin may provide a significant petroleum reserves in the 21<sup>st</sup> century. The Upper Jurassic Mozduran Formation (Oxfordian-Kimmeridgian) is the most important gas-bearing reservoir in this basin and is mainly composed of limestone, dolomite and several calcareous shale and gypsum interbeds. Eight measured stratigraphic sections and petrography studies of 800 thin sections showed that the carbonate sediments of this interval have been deposited in a platform of ramp type including open marine,

shoal, lagoon and tidal flat environments. The petrographic analysis also indicates that the Mozduran Formation carbonates have undergone a complex diagenetic history which includes compaction, cementation, micritization, dissolution, silicification, dolomitization, neomorphism and fracturing. Carbon and oxygen isotopes as well as trace elemental (Mn, Na, Fe, Sr) analysis of 30 samples are also used for interpretation of diagenetic processes.  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values in Mozduran Formation limestones in the study area range between -1.50 to -11.86 PDB and 5.56 to -5.04 PDB, respectively. These variations are interpreted to reflect meteoric and burial diagenetic processes. Variations in trace elements concentration (Fe and Mn increased while Na decreased) also indicate the meteoric flushing. The paragenetic sequence indicates that the primary porosity decreased during early stages of diagenesis, while the secondary porosity was subsequently created and improved the reservoir quality of the carbonate rocks of the Mozduran Formation.

## Origin of Middle Jurassic siderite rocks from Central Poland

Anna MALISZEWSKA, Aleksandra KOZŁOWSKA and Marta KUBERSKA

Polish Geological Institute, ul. Rakowiecka 4, PL-00975 Warszawa, Poland;  
e-mail: Anna.Maliszewska@pgi.gov.pl, Aleksandra.Kozlowska@pgi.gov.pl, Marta.Kuberska@pgi.gov.pl

**Key-words:** siderite rocks, petrological studies, Middle Jurassic sediments, Poland.

Siderite rocks in the Middle Jurassic marine deposits in Central Poland occur from Aalenian to Upper Bathonian in form of intercalations and concretions. Most frequently, they are clayey siderites composed of siderite and sideroplesite, being accompanied by illite, kaolinite, pyrite, quartz, sometimes also chamosite. Some layers contain also the chamositic and chamosite-sideritic ooids and fine bioclasts.

Selected samples of the clayey siderites were isotopically analyzed in the Institute of Physics of UMCS in Lublin. It appears that  $\delta^{18}\text{O}$  values fall into the interval from -2.66 to 0.58‰ PDB. It was calculated, adopting a water temperature in the Middle Jurassic basin Central Poland between 18 and 24°C (Coleman *et al.* 1997), that the siderites crystallized mainly from the marine mixed with meteoric water of  $\delta^{18}\text{O}$  in the limits between -7 and -1‰ SMOW. The  $\delta^{13}\text{C}$  values oscillate between +11.78 and +5.67‰ PDB. That points to the origin of the carbon present in the crystallization waters from the organic matter altered in the zone of microbiological metanogenesis (Mc Kay *et al.* 1995). The abundance of pyrite is an evidence for strong reduction conditions of sedimentation and diagenesis of the siderite formation. Sulphide minerals and micas accumulated in the Aalenian and Bajocian dark bottom muds, further altered in the marine waters, were the most probable iron source.

Layers of siderite coquinas also occur in the deposits under description. They contain numerous bioclasts built of calcite or ankerite, sideritic, sideroplesitic and ankeritic spars, less frequently – euhedral pistomesite crystals and pyrite. The chamosite, kaolinite, phosphates and detrital quartz are subordinate.

According to present knowledge, the formation of the coquinas resulted from the intraformational alteration of the deposits connected with the Middle Jurassic salt tectonics and mobilization of the Zechstein saline waters rich in ions of metals. The results of chemical analyses of zonal siderites and sideroplesites point to the progressive increase of magnesium content in the pore solutions in the Jurassic deposits.

*These researches have been financially supported by Committee for Scientific Researches (KBN), project no. 2 PO4D 008 27.*

**References:**

- Coleman M. L., Feldman-Olszewska A., Gaździcka E. and Gruszczyński M. 1997. Sekwencje depozycyjne a zapis izotopowo-geochemiczny wybranych odcinków czasowych jury środkowej i górnej w centralnej części Niżu Polskiego. *Materiały konferencyjne, VI Krajowe Spotkanie Sedymetologów, Lewin Kłodzki, 4-6.*
- Mc Kay J. L., Longstaffe F. J. and Plint A. G. 1995. Early diagenesis and its relationship to depositional environment and relative sea – level fluctuations (Upper Cretaceous) Marshybank Formation, Alberta and British Columbia. *Sedimentology*, **42**, 1: 161-190.

### **Petrological studies of the Early Jurassic siderites from Western Pomerania (Poland)**

Anna MALISZEWSKA, Aleksandra KOZŁOWSKA and Marta KUBERSKA

Polish Geological Institute, ul. Rakowiecka 4, PL-00975 Warszawa, Poland;  
e-mail: Anna.Maliszewska@pgi.gov.pl, Aleksandra.Kozłowska@pgi.gov.pl, Marta.Kuberska@pgi.gov.pl

**Key-words:** siderite, chamosite, brakish shelf facies, Early Jurassic, Western Poland.

Petrological studies of siderite layers and concretions occurring in the Early Jurassic periodically marine deposits, described as the brackish shelf facies (Feldman-Olszewska 1997), were conducted. The analyzed rocks are mainly built of the sideroplesite, while siderite and pistomesite occur sporadically. Two generations of the sideroplesite were distinguished, that essentially differ due to the size of the rhombohedra. The older generation forms micritic concretions and micritic layers of the clayey siderites. The younger generation either represents a groundmass of the sparry siderites or cements of the sideritic sandstones. Some layers of siderites contain ooids and aggregates of the chamosite and phosphates, chamosite intraclasts, pyrite, detrital quartz and micas. Numerous shells of foraminifers and occasionally molluscs are present, too.

Nine samples of the clayish siderites from the Mechowo IG1 borehole were isotopically analyzed aiming at oxygen and carbon ratios. The recognition of  $\delta^{18}\text{O}$  of crystallization waters responsible for the siderite formation was the final aim of the studies. A formula given by Carothers *et al.* (1998) as well as the results of studies on the siderites of Baker *et al.* (1995) were applied. It results from the calculations that the  $\delta^{18}\text{O}$  of the crystallization water oscillated between -12 and -3‰ SMOW in the Late Sinemurian, while in the Early Pliensbachian and the Early Toarcian it changed from -10 to +2‰ SMOW. That points to the meteoric waters gradually enriched in the  $^{18}\text{O}$  isotope.

The  $\delta^{13}\text{C}$  values in the siderite samples oscillate from -0.85 to -10.57‰ PDB. That suggests that the pore waters were enriched in carbon formed in the microbiological zone of the metanogenesis due to the alteration of the organic matter (Longstaffe & Ayalon 1997). The whole petrological analysis of the siderites points to their origin as the product of the diagenetic processes which operated in the bottom mud of the shallow brackish basins in the anoxic conditions with the influence of the meteoritic waters.

*These researches have been financially supported by Committee for Scientific Researches (KBN), project no. 2 PO4D 008 27.*

**References:**

- Baker J. C., Kassan J. and Hamilton P. J. 1995. Early diagenetic siderite as indicator of depositional environment in the Triassic Rewan Group, Southern Bowen basin, eastern Australia. *Sedimentology*, **43**, 1: 77-88.
- Carothers W. W., Adami L. H. and Rosenbauer R. J. 1988. Experimental oxygen isotope fractionation between siderite – water and phosphoric acid liberated CO<sub>2</sub> – siderite. *Geochimica et Cosmochimica Acta*, **52**, 10: 2445-2450.
- Feldman-Olszewska A. 1997. Depositional systems and cyclicity in the intracratonic Early Jurassic basin in Poland. *Geological Quarterly*, **41**, 4: 475-490.
- Longstaffe F. J. and Ayalon A. 1997. Oxygen-isotope studies of clastic diagenesis in the Lower Cretaceous Viking Formation, Alberta: implications for the role of meteoric water. *Geological Society Special Publication*, **36**: 277-296.

### **Stratigraphy and architecture of the extensional basins in the eastern Southern Alps (N Italy)**

Daniele MASETTI<sup>1</sup>, Roberto FANTONI<sup>2</sup>, Roberta ROMANO<sup>3</sup>, Dario SARTORIO<sup>2</sup>,  
Enrico TREVISANI<sup>4</sup> and Sandro VENTURINI<sup>2</sup>

<sup>1</sup>Dipartimento Scienze Geologiche, Marine ed Ambientali, Università di Trieste, via Weiss 2, 34123 Trieste, Italy; e-mail: masetti@units.it

<sup>2</sup>ENI E and P Division, Milano, Italy; e-mail: roberto.fantoni@agip.it, sartorio@agip.it, sandro.venturini@agip.it

<sup>3</sup>Dipartimento Scienze Geologiche, Marine ed Ambientali, Università di Trieste, via Weiss 2, 34123, Trieste, Italy; e-mail: robroman@unina.it

<sup>4</sup>Museo di Storia Naturale di Ferrara, via Filippo de Pisis 24, I-44100 Ferrara, Italy; e-mail: consgeol@comune.fe.it

**Key-words:** Southern Alps, extensional basin, palaeogeography, Lower Jurassic.

The Southern Alps represent a well-preserved section of the southern continental margin of the Mesozoic Tethys, characterized by horst and graben structures inherited from the rifting associated with the opening of the central North Atlantic. In their eastern sector Southern Alps are composed of three palaeogeographic-structural units. These are, from east to west:

- a carbonate platform persistent in its southern area from Jurassic until the Cretaceous (Friuli Platform),
- a basin formed in the Early Liassic (Belluno Basin),
- a wide ridge (Trento Platform/Plateaux), subdivided in a puzzle of blocks drowned in different times from Sinemurian until Aalenian when the Trento Platform area evolved in a pelagic plateau covered by condensed sedimentation during the Late Jurassic.

In the subsurface areas (Veneto Plain and Adriatic Sea) a new paleogeographic-structural unit has been recognized informally called North Adriatic Basin. This new unit is characterized by the superposition of Pliensbachian deep-water units, similar to those outcropping in the Belluno Basin, on the top of the Hettangian-Sinemurian peritidal platform.

The integrated valuation of surface and subsurface data performed through the stratigraphic revision of the well stratigraphy and the interpretation of seismic lines acquired by means of the CROP projects (Crop Mare and Transalp) and the ENI hydrocarbon exploration in the Venetian Plain and of the Adriatic Sea, led to the distinction of a new three dimensional model pertaining to the Mesozoic extensional architecture of the eastern Southern Alps and the their Veneto foreland.

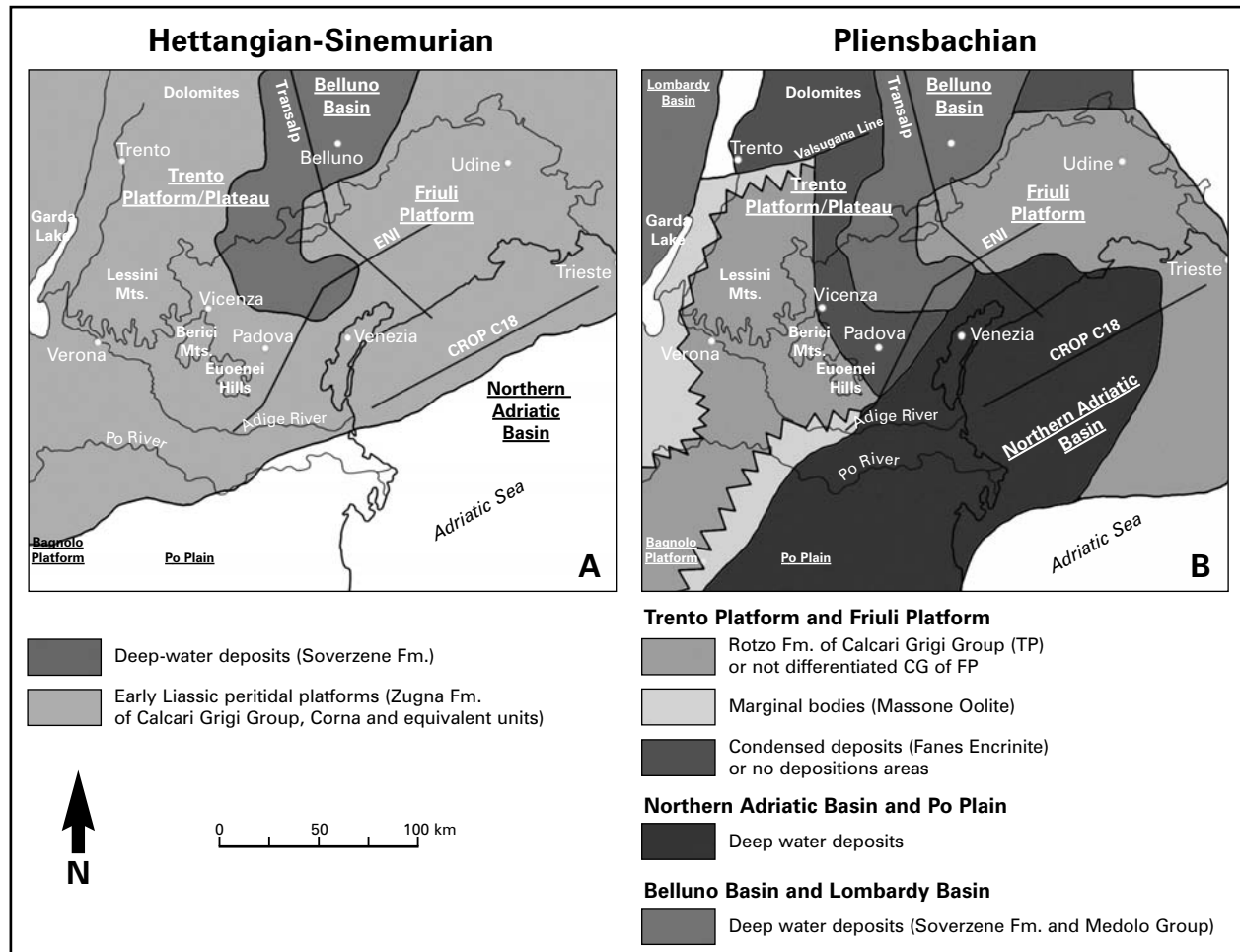


Fig. 1. A – The palaeogeographic scenario at the Early Liassic time was dominated by a widespread peritidal carbonate platform lying on the most part of the Southern Alps, on the Po Plain and on the Veneto foreland. This flat palaeogeography was only interrupted by a narrow trough, the Belluno Basin. B – In comparison with the Early Liassic palaeogeography the highlights deep reorganization of the entire Eastern Southern Alps occurred at the Early/Middle Liassic boundary.

According to this model, the recognized extensional pattern is the result of the following two main tectonic phases:

At the Triassic/Jurassic boundary this region experienced a strong extensional tectonics with the debut of a deep asymmetrical trough, the Belluno Basin, filled by cherty deposits (Soverzene Fm.), closed to the south and bounded to the west by the Trento Platform and to the east by the Friuli Platform. In the other sectors of the Southern Alps and of the Veneto foreland, and elsewhere, peritidal sedimentation persisted (M. Zugna Formation) (Fig. 1A).

At the Sinemurian/Pliensbachian boundary, a new extensional phase, seemingly interactive with a decrease in carbonate productivity, produced a widespread drowning of the platforms and the deep reorganization of the Lower Jurassic palaeogeography (Fig. 1B). The northern and the eastern sector of the Trento Platform and the northern area of the Friuli Platform were drowned and became plateaus on which crinoidal sand waves accumulated (Fanes encrinites). To the south the Northern Adriatic Basin opened with a structural style far from the Belluno Basin; compared with this last mentioned palaeogeographic unit, the Northern Adriatic Basin is wider, nearly asymmetric and less subsiding. The Northern Adriatic Basin debut pushed the margin of the Trento and Friuli platforms respectively to the west and to the east, thus leading to a zigzag geometry of the structural units formerly interpreted as the interfering between the main, NNW-SSE extensional faults and a ENE-WSW, transcurrent system.

## Jurassic – Early Cretaceous succession in Ab-Band area, High Zagros (SW Iran)

Javad MOGHADDASI<sup>1</sup> and Seyed Ahmad BABAZADEH<sup>2</sup>

<sup>1</sup>Payame Noor University, Department of Geology, P.O. Box 12345-1232, Tehran, Iran

<sup>2</sup>Birjand Payam noor University, Birjand, Iran; e-mail: ababazadeh2001@yahoo.fr

**Key-words:** High Zargos, Iran, radiolarian cherts, Radiolaria fauna.

The Jurassic – Early Cretaceous sedimentary rocks of Ab-Band area are located in the High Zagros, southwest Iran. Two sections are examined in this region. They are consisting of two units: Chert and Turbidites Unites. Chert Unit consists of red radiolarian chert with 50% Radiolaria, calcareous chert, white and grey radiolarian chert and argillaceous chert. The best preserved radiolarian fauna occurs in this unit. Turbidite Unit is composed of calcarenite, pelbiomicrosparite with nodular radiolarian chert and argillaceous limestone bearing benthic foraminifera. Two size radiolarian fauna are reported in thin sections. The larger forms are found in lower part of section AÁ and the smaller forms are occurring in the radiolarian chert at section CĆ in the Chert Unit. The benthic marine fauna include *Pseudocyclamina* sp., *Pseudocrysalidina* sp., *Lenticulina* aff. *quenstedti*, miliolids and echinoids.

## Functional morphology and ethology gathered by *Thalassinoides* branched burrows in Mesozoic shallow water environments

Paolo MONACO and Alice GIANNETTI

Dipartimento di Scienze della Terra, piazza dell'Università, 06100 Perugia, Italy;

e-mail: pmonaco@unipg.it, alice\_giannetti@yahoo.it

**Key-words:** ichnology, *Thalassinoides*, Mesozoic, shallow-water.

Each part of a crustacean burrow has an important and specific function within the ecology and trophism of the burrower. It goes from the oxygenation and irrigation of tunnels to the protection of the organism and the storing of organic material for feeding (also predation, e.g. carnivorous crustaceans such as stomatopods). Considering modern thalassinoidian burrows (*Thalassinoides*), the most important characteristics are the presence of surficial mounds, vertical shafts, tunnels and horizontal galleries, turning chambers, organic debris within burrows, Y- or U-shaped burrows and the number and type of apertures on the seafloor.

Analysis of the Pliensbachian, lagoonal deposits of the Calcari Grigi Formation (Trento Carbonate Platform, Southern Alps, Italy) and of the Albian outer shelf deposits of the Sácaras Formation (Serra Gelada, Southeastern Spain) gave rise to individuate different specimens of *Thalassinoides suevicus* trace fossils. They are well preserved in three-dimensions and therefore are useful to gather the trophism of the ancient burrowers in shallow-water environments. These Y-shaped, branched traces were studied observing and measuring diameter of tunnels, enlargement at the bifurcation point, development of the vertical burrow and coarse-grained skeletal debris infilling. Within the studied sections, abundance and dimensions of trace fossils vary, developing repetitive “burrow-decreasing upward” parasequences (BDUP), 2.3-2.9 m thick (Giannetti & Monaco 2004). They represents a useful record of functional morphology of crustacean decapods in shelf environments. We have hypothesized that

the regular mazes of Mesozoic crustaceans were mainly developed on horizontal planes (commonly few centimetres inside the substratum), while vertical shaft were rudimentary or lacking, differing from those largely developed by modern crustaceans. The presence of tubular tempestites proves the existence of apertures on the seafloor, even if only the horizontal part of the filled burrows is generally preserved.

According to the scheme proposed by Nickell & Atkinson (1995), we observe that the main function of *Thalassinoides* was the nutritional strategies through the sediment processing and storage of material for maintenance purposes. The sediment processing was supported by the storage of nutritional material (chambered burrows filled by organic detritus). The composition of organic detritus varies from coarse-grained to fine-grained crashed bioclasts, indicative either of biogenic sorting or of the storage of debris coming from the seafloor and fallen down into the burrow. The concentration of coarse-grained fragmented shells close to other free tunnels was probably due to the motion strategy of the crustaceans, as in actual cases. Proofs of irrigation of burrows and entrance from the seafloor are rare and can be deduced from few findings, closely similar to the burrows of modern crustaceans. In the category of the vertical elements, we have considered inhalant and exhalant shafts, but these vertical elements are rare and poorly developed. Anyway, they indicate the presence of suspension feeders (whose primary nutritional source is the water column) and of deposit feeders. According the scheme proposed by Nickell and Atkinson, all the studied *Thalassinoides* testify the presence of organisms belonging to the category of the deposit feeders (looking for food within the substratum) and to that of the omnivorous scavengers, which eat organic debris present on the seafloor and deriving from algae and other animals.

#### References:

- Giannetti A. and Monaco P. 2004. Burrow decreasing-upward parasequence (BDUP): a case study from the Lower Jurassic of the Trento carbonate platform (southern Alps), Italy. *Rivista Italiana di Paleontologia e Stratigrafia, Milano*, **110**, 1: 77-85.
- Nickell L. A. and Atkinson R. J. A. 1995. Functional morphology of burrows and trophic modes of three thalassinidean shrimp species, and a new approach to the classification of thalassinidean burrow morphology. *Marine Ecology Progress Series*, **128**: 181-197.

## Microbial grains – a way of spreading of microbial bioherms

Szymon OSTROWSKI

University of Warsaw, Faculty of Geology, Al. Żwirki i Wigury 93, PL-02089 Warszawa, Poland;  
e-mail: Szymon.Ostrowski@uw.edu.pl

**Key-words:** microbial bioherm, detritic limestone.

Most of the Upper Jurassic microbial-sponge bioherms known from Poland formed prominent elevations on sea bottom and were surrounded by thick sequences (up to 100 m) of detritic limestones composed of small round to elliptical dense micritic grains of clotted texture, 0.5-2 mm in diameter. Typically they are packstones with grain content between 40-50% of rock volume. Elongated micritic grains are often deformed or partly torn which shows that they were deposited as plastic fragments. Grains, bigger than 2 or 3 mm, are hardly present. Many micritic grains are covered by microbial structures on the upper surface. Microbial structures on grains form irregular layers and small bulbous forms characterized by occurrence of clotted texture. Continuous transition from microbial structures covering individual micrite grain to microbial structures spreading on few neighbouring grains and bigger structures

can be observed. Small metre-scale microbial bioherms within sections of circum-biohermal detritic limestones, or thick sequences of massive, microbial limestones directly above detritic limestones are often observed. It can be assumed that microbial structures developed on substratum composed of micritic grains due to activity of microorganisms present within the grains. Grains are not lithoclasts, but fragments of microbial structures containing live cells, delivered from bioherm by slight water movement or currents. Such grains can be treated as “seeds” of microbial structures.

It is suggested that the existence of thick sediments of detritic limestones is caused by emerging of tops of microbial-sponge bioherms above normal or storm wave base depth. When concerning composition of discussed rocks – size of grains and their relative monotonous composition – a low energy model of sedimentation of detritic limestones seems to be more appropriate.

Proposed model of “sowing” or contaminating areas around bioherms with microorganisms forming microbial structures had an important role in development of Upper Jurassic bioherms.

## **Callovian crinoidal sandstone from North East Świętokrzyskie Mts. (Central Poland)**

Szymon OSTROWSKI

University of Warsaw, Faculty of Geology, Al. Żwirki i Wigury 93, PL-02089 Warszawa, Poland;  
e-mail: Szymon.Ostrowski@uw.edu.pl

**Key-words:** Callovian, synsedimentary tectonics, crinoids.

Monotonous calcareous sandstones outcropping on the northern slopes of Kamienna River North East Świętokrzyskie Mts. (Holy Cross Mts.) are recognized as Callovian mostly on the basis of superposition (Samsonowicz 1932) and scarce occurrence of ammonites *Macrocephalites* and belemnites. Although the rocks are exploited for over 200 years, there is no complete sedimentological study available.

Outcropping rocks are yellow and brown, quartz-calcareous sandstones, poorly horizontally bedded. Cross-bedding, horizontal laminations and ripplemark laminations are scarce in the sequence. Grains are well sorted, bigger fragments can be found only in lower parts of some beds. Bigger grains are exclusively fragments of crinoids.

Typically rocks are composed of quartz grains and crinoid ossicles of 0.1-0.2 mm in diameter. The proportion of these components is close to equal. Quartz grains are well rounded, mostly monocrystalline. Fragments of crinoids are broken, but marks of noticeable corrosion are lacking. Grains are cemented by blocky calcite, forming syntaxial overgrowth (*sensu* Bathurst 1975) on crinoids.

Statistic comparison of diameter of quartz grains and fragments of crinoids revealed that crinoids are about 10% bigger in diameter. However statistic parameters of grain diameters calculated separately for quartz and crinoids are similar in individual samples, and fractionation of diameter for both grain types are close to normal.

Differences of mean diameter of both grain types can be attributed to crinoid porosity (resultant lower density).

Quartz grains and fragments of crinoids were brought together to sedimentation area by currents. The second ones did not experience long transport – porous fragments of crinoids are prone to destruction (abrasion). The large quantity of crinoids suggests that the area where they flourished was placed nearby.

Areas of intensive crinoid growth can be often found on distinctive submarine slopes (Maliszewska 1998; Ostrowski 2003). Tectonically active Radom-Kraśnik Fault zone (Gutowski *et al.* 2003) could represent the area of development of crinoids in question.

#### References:

- Bathurst R. G. C. 1975. Carbonate sediments and their diagenesis. 1-658. Elsevier, New York.
- Gutowski J., Krzywiec P., Walaszczyk I. and Pożaryski W. 2003. Od ekstensji do inwersji – zapis aktywności północno-wschodniej brzeżnej strefy uskokowej świętokrzyskiego segmentu bruzdy śródpolskiej w osadach jury górnej i kredy na podstawie interpretacji danych sejsmiki refleksyjnej. *Tomy Jurajskie*, 1: 124-125.
- Ostrowski S. 2003. Krawędzie bioherm mikrobialitowo-gąbkowych miejscem znacznego nagromadzenia płytek szkarłupni. *Tomy Jurajskie*, 1: 59-62.
- Samsonowicz J. 1932. Ogólna mapa geologiczna Polski w skali 1:100000, arkusz Opatów. Państwowy Instytut Geologiczny.
- Maliszewska A. 1998. Petrografia skał budujących skałkę w Leśnej koło Żywca. *Biuletyn Państwowego Instytutu Geologicznego*, 384: 37-52.

## Palynofacies of the epicontinental Lower Jurassic deposits of Poland: their distribution in different sedimentary environments

Grzegorz PIENKOWSKI and Marta WAKSMUNDZKA

Department of Regional and Petroleum Geology, Polish Geological Institute, ul. Rakowiecka 4, PL-00975 Warszawa, Poland; e-mail: grzegorz.pienkowski@pgi.gov.pl, marta.waksmundzka@pgi.gov.pl

**Key-words:** palynofacies, palaeoenvironments, palynofacies inversions.

Diversified continental, marginal-marine and marine epicontinental deposits in Poland of Early Jurassic age yielded unusually rich palynofacies. 210 samples from 6 selected boreholes have been studied in order to determine distribution of palynomorphs and other kerogen particles in various depositional systems, prior determined by detailed sedimentological studies. Several palynofacies parameters, like content of terrestrial phytoclasts, their type and degree of oxygenation, spore/bisaccate pollen ratio, presence of tetrads and sporangia, presence of amorphous organic matter – AOM (both of terrestrial – AOMT and aquatic – AOMA origin), presence of acritarchs and dinoflagellate cysts were collectively found as indicative of certain palynofacies. Generally, six main palynofacies linked to certain depositional systems have been distinguished:

1. alluvial plain – very abundant palynological matter, varied frequency of sporomorphs, varied bisaccate pollens/spores ratio (depending on a local vegetation), very abundant dark-brown to opaque phytoclasts or AOMT (amorphous organic matter of terrestrial derivation);
2. delta plain – abundant dark to opaque phytoclasts (or AOMT) and cuticle, abundant sporomorphs (spores dominate over bisaccate pollens), sporadic presence of dinoflagellate cysts and acritarchs;
3. delta front-lagoon – abundant sporomorphs, varied bisaccate pollens/spores ratio (usually spores and pollens are in approximate ballance, but sometimes huge number of spores accompanied by tetrads and sporangia occurs in “hydrodynamic traps”), moderate amount of phytoclasts – mostly cuticle, relatively rare dark phytoclasts, rare dinoflagellate cysts and acritarchs;

4. shoreface-foreshore – dispersed and rounded fragments of black, opaque phytoclasts or AOMT, rare to moderate sporomorphs (bisaccate pollens and spores in ballance or slight dominance of spores), sporomorphs often mechanically destroyed, rare dinoflagellate cysts and acritarchs;
5. offshore brackish marine – rare translucent AOMA (amorphous organic matter of aquatic derivation), very rare small and rounded fragments of opaque phytoclasts or AOMT, rare sporomorphs (bisaccate pollens dominate over spores), occurrence of dinoflagellate cysts and acritarchs;
6. offshore marine – translucent AOMA (amorphous organic matter of aquatic derivation), rare bisaccate pollens, spores absent or very rare, occurrence of dinoflagellate cysts and acritarchs.

Transitional palynofacies between these main types can be also distinguished, but it must be coupled with sedimentological data. Some abnormal composition of palynofacies have been observed and they are defined as palynofacies inversions. The first type (type I) of inversion represents coexistence in one sample of palynomorphs of the same geological age but of drastically different colours, which is explained by darkening of some palynomorphs by intraformational oxidation processes. The second type (II) of inversion occurs when characteristic alluvial/deltaic palynofacies elements (like sporangia, tetrads, large phytoclasts) are found together with obviously offshore elements (light AOMA, dinocysts, accompanied by ammonites and open shelf organisms). This inversion is explain by a storm resuspension processes. Abnormally high number of spores observed in few samples of an interdistributary lagoon origin is explained by hydrodynamic entrapment of spores. Some regular fluctuations of palynofacies characteristic within lagoonal/lacustrine laminites are described as a result of seasonal changes. Collectively, palynofacies can be regarded as useful tool for recognition of palaeoenvironments. However, palynofacies studies should be coupled with sedimentological investigations.

## **Palaeogeographic evolution of the eastern Iberian carbonate ramp during the Middle Oxfordian**

Javier RAMAJO<sup>1</sup>, Julia BELLO<sup>2</sup>, Guillermo MELÉNDEZ<sup>2</sup> and Kevin N. PAGE<sup>3</sup>

<sup>1</sup>Departamento de Geología (Estratigrafía), Univ. Zaragoza, Zaragoza 50009, Spain; e-mail: ramajo@unizar.es

<sup>2</sup>Departamento de Geología (Paleontología), Univ. Zaragoza, Zaragoza 50009, Spain;  
e-mail: jbello@unizar.es, gmelende@unizar.es

<sup>3</sup>School of Earth, Ocean and Environmental Science, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK;  
e-mail: kpage@plymouth.ac.uk

**Key-words:** facies analysis, ammonites, taphonomy, environment reconstruction.

Sedimentation on the East Iberian carbonate platform during the Middle and early Late Oxfordian represents the onset of subtidal marine conditions after a long period (Middle Callovian – Early Oxfordian) where extremely shallow to temporarily emerged environments predominated, favouring the development of condensed deposits. A progressive deepening during the Middle Oxfordian led to the development of sponge and microbiolite buildups alternating with biostromes. Levels with inverted or fragmented sponges and bioclastic storm deposits mark the most energetic events. Ammonite assemblages comprise mainly drifted shells from open-marine areas with only short-lived episodes of colonisation. Five stages are distinguished in this Middle Oxfordian sequence.

1. Parandieri Subchronozone – Middle Oxfordian deepening begins. In deeper areas to the NW, carbonate sediments contain abundant, well-preserved sponges occasionally in upright position. In shallower distal areas (SE) across a palaeogeographic swell, sedimentation is limited to thin, condensed levels of iron-oolite limestones and sponge spicules.

2. *Luciaeformis-Schilli* Subchronozone interval – a widespread deepening event leads to the development of sponge limestone facies throughout the platform. Sponge biostromes and buildups are developed in the NW, and in distal areas (SE) biostromic levels with inverted sponges and tempestite levels with broken sponges are common. A brief ammonite colonisation event took place in the NW during the middle *Schilli* Subchronozone.
3. *Rotoides* Subchronozone – lower part forms a condensed sequence (representing a storm deposit interval) formed by bioclastic limestones with sponge fragments and ammonite internal moulds. In the SE this interval is represented by a centrimetic level of bioclastic and ferruginous peloids, which grade laterally into layers with fragmented sponges and pellets. The upper, *Wartae* Horizon, is represented in NW areas by a more expanded sequence of well-bedded micritic sponge limestones.
4. *Stenocycloides* Subchronozone – a micritic limestone sequence containing fragmented and broken sponges occasionally in upright position develops in the NW. In the SE more condensed, pelloidal, glauconitic limestones with packed, inverted sponge fossils are present. Ammonite assemblages comprise mainly reelaborated moulds.
5. *Grossouvrei* Subchronozone – the lower part in the NW forms a homogeneous interbedding of micritic limestones and marls with an increasing quartz content upwards; sponges are generally inverted or fragmented. In the SE, pelloidal and glauconitic limestones are dominant. Facies analysis and taphonomic features of ammonites indicate that maximum depths were reached at around the *Grossouvrei-Hypselum* zone boundary.

## **Drowning of a carbonate platform and reflection on adjacent basinal sedimentation: a Jurassic successions from the Julian Alps (NW Slovenia)**

Boštjan ROŽIČ and Andrej ŠMUC

University of Ljubljana, Faculty of Natural Sciences and Engineering, Geology Department,  
Privoz 11, 1000 Ljubljana, Slovenia; e-mail: rozicb@yahoo.com, andrej.smuc@yahoo.com

**Key-words:** Jurassic, drowning, Julian Carbonate Platform, Slovenian Basin, transitional area.

The Julian Alps are located in northwestern Slovenia and extend to the west into northeastern Italy. Structurally they belong to the Julian and Tolmin Nappes that together form eastern continuation of the Southern Alps. In the Jurassic the investigated area was a part of the southern Tethyan passive continental margin and experienced extensional faulting due to the rifting. From the latest Triassic to Early Jurassic NW Slovenia belonged to the Julian Carbonate Platform bordered towards the south by deeper the Slovenian Basin. In the early Early Jurassic the platform was marked by sedimentation of tidal flat, lagoonal and ooidal limestone. Slovenian Basin was at that time characterized by abundant resedimented carbonates (*Krikov* Formation) shaded from marginal parts of the platform.

In the *Pliensbachian*, shallow-water sedimentation on the Julian Carbonate Platform ended due to an extensional tectonic phase. At that time platform was dissected into blocks with different subsidence rates. Inner parts of the platform were probably emerged, while marginal parts were drowned and distal shelf limestone rich in sponge spicules and juvenile ammonites of *Sedlo* Formation deposited. The change of sedimentation style is also recorded in the Slovenian Basin, where resedimented carbonates of the *Krikov* Formation are abruptly overlain by marls, mudstones and siliceous limestone of the *Perbla* Formation.

In the basin the pelagic sedimentation continued in Middle Jurassic, while on the area of the former Julian Carbonate Platform there is no sedimentary record from the *Toarcian* to the *Bajocian*.

The accelerated subsidence in the Bajocian caused further deepening of the investigated area. In the basin this event corresponded to the sedimentation switch from shaly Perbla Formation to radiolarian cherts (radiolarites s.s.). Additionally the emerged area of the former Julian Platform was drowned and became a pelagic plateau named Julian High, with condensed sedimentation of *ammonitico rosso* type (Prehodavci Formation). Transitional zone forming the physical link between the plateau and the basin is characterized by onlap of radiolarites s.s. on the Pliensbachian Sedlo Formation. At the end of Jurassic the sea bottom morphology had become predominantly leveled as evidenced by monotonous sedimentation of the *Biancone* limestone.

## Stratigraphy and depositional environments of the Upper Bajocian-Bathonian Kashafrud Formation (NE Iran)

Jafar TAHERI, Franz T. FÜRSICH and Markus WILMSEN

Institut für Paläontologie der Universität Würzburg, Pleicherwall 1, D-97070 Würzburg, Germany;  
e-mail: jafar.taheri@mail.uni-wuerzburg.de

**Key-words:** Iran, Bajocian-Bathonian, Kashafrud Formation, bio- and lithostratigraphy, facies analysis.

The Upper Bajocian-Bathonian Kashafrud Formation is a thick (>2 km), siliciclastic sedimentary unit, distributed in a NW-SE-trending, 200 km long and 80 km wide outcrop belt in the area between the Koppeh Dagh and the Binalud Mountains (NE Iran). It was deposited in a strongly subsiding rift basin developing between the Iran Plate and Eurasia (Turan Plate) in response to Middle Jurassic crustal extension following the Mid-Cimmerian tectonic movements. The Kashafrud Basin is a southeastern prolongation of the South Caspian Basin, opening along the ocean suture which has been formed by the Late Triassic closure of the Palaeotethys (so-called Early Cimmerian orogeny). The stratigraphy and depositional environments of the Kashafrud Formation are the scope of this integrated analysis.

Ten sections of the Kashafrud Formation were logged in detail and sampled for lithology, macro- and trace fossils, and facies analysis. At several localities, ammonites occur near the base of the formation, in every case providing a Late Bajocian age. Within the middle and upper parts of the Kashafrud Formation, ammonites are rare. However, in its uppermost part and at the base of the overlying unit (marls of the Chaman Bid Formation), ammonites of the genus *Macrocephalites* indicate an Early Callovian age. Thus, the Kashafrud Formation can be mainly assigned to the Upper Bajocian-Bathonian.

Commonly, the Kashafrud Formation rests with angular unconformity on rocks affected by the Early Cimmerian orogeny. Based on thicknesses and principal facies development, two NW-SE-striking (basin-axis-parallel) zones can be differentiated, i.e., a more proximal one close to the Binalud Mountains in the SW and a distal one towards the Koppeh Dagh in the NE. Basal conglomerates tend to be thickest and coarsest in the proximal zone, at the southwestern basin margin. Rapid lateral thickness changes indicate a fault-controlled deposition (proximal alluvial fans or rockfalls). Up-section, the conglomerates are replaced by highly immature arcose sandstones and pebbly sandstones of a short-headed braided river system grading into marine fan delta deposits. Rapid deposition and subsidence are indicated by the lack of significant maturation of the sediments even in settings above the fair-weather wave base. In some sections, basal conglomerates are thin and fluvial sediments missing, and the Kashafrud Formation directly starts with coarse-grained marine fan delta deposits. In all cases, a distinct fining-upward indicates a significant deepening trend. In the distal zone, basal conglomerates are thin and commonly marine as indicated by marine fossils. They are vertically replaced by basin plain (dark shales with rare ammonites)

and intercalated submarine fan deposits (including coarse upper fan feeder channels, mid-fan leveed channel and inter-channel deposits, and well bedded shale-sandstone outer fan intercalations). Bioturbation is common in turbidite sequences and a deeper marine environment is indicated by rare graphoglyptids of the *Nereites* ichnofacies. Also in the distal part, a general fining- and thinning-upward trend indicates a deepening.

All the observations can be integrated into a rift basin model for the Kashafrud Formation. The basin axis trend was roughly NW-SE and the stratigraphic and sedimentologic data indicate a main sediment input from the southwestern basin margin (Binalud). The northeastern basin margin is inferred below the Koppeh Dagh.

## **Onset of erg sedimentation during the Early Jurassic on the Colorado Plateau, southwestern U.S.A.: climatic, eustatic and tectonic controls**

Lawrence H. TANNER<sup>1</sup> and Spencer G. LUCAS<sup>2</sup>

<sup>1</sup>Department of Biological Sciences, Le Moyne College, 1419 Salt Springs Road, Syracuse, New York 13214, USA; e-mail: tannerlh@lemoyne.edu

<sup>2</sup>New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104-1375, USA; e-mail: slucas@nmmnh.state.nm.us

**Key-words:** Wingate, Moenave, erg, eolian, Early Jurassic.

Deposition of the Moenave and Wingate formations took place during the latest Triassic to Early Jurassic in a mosaic of terrestrial subenvironments including fluvial, lacustrine, and eolian. Fluvial-lacustrine processes dominated Moenave deposition, which included channelized flow in ephemeral to perennial streams, unconfined flow (sheetwash) in interchannel areas, ephemeral lakes (playas), and perennial lakes that were subject to episodic desiccation. The Moenave terminal floodplain, which was dotted by broad, shallow lakes, interfingered with the Wingate erg, where eolian processes dominated. The Moenave-Wingate outcrop belt exposes a north-south lithofacies gradient from distal (erg margin) to proximal (erg interior) as dominantly fluvial-lacustrine lithofacies in the north are replaced by mainly eolian dune and interdune deposits to the south, recording encroachment of the Wingate erg.

The prevalence of ephemeral stream and eolian environments during deposition of these strata indicates a seasonally arid climate during the latest Triassic to earliest Jurassic. We see no sedimentologic evidence for significant climate change at the Triassic/Jurassic boundary, or at any time encompassed by this sedimentary succession. The growth and incursion of the Wingate erg into the Moenave fluvial system may have been driven by the availability of sediment in the up-wind source area, the coastal plain and coastline to which the Moenave streams delivered sediment. We interpret a eustatic signal as responsible for formation of this erg as long-term regression during the Rhaetian and continued Hettangian low-stand exposed a broader area of shallow marine sediments to eolian reworking. Preservation of the erg deposits may have been enhanced by tectonically controlled accommodation space as continental shortening led to crustal flexure during the Early Jurassic.

## New data on the Jurassic evolution of the Panormide Carbonate Platform (Sicily)

Giuseppe ZARCONE<sup>1</sup>, Andrea MINDSZENTY<sup>2</sup> and Pietro DI STEFANO<sup>1</sup>

<sup>1</sup>University of Palermo, Dipartimento di Geologia e Geodesia, Via Archirafi, 22, 90123 Palermo, Italy;  
e-mail: pdistefa@unipa.it, geozarcone@libero.it

<sup>2</sup>Eötvös L. University, Department Applied and Environmental Geology, Pázmány Psètàny 1/c,  
1117 Budapest, Hungary; e-mail: andrea@iris.geobio.elte.hu

**Key-words:** discontinuities, bauxites, hardground, Panormide Carbonate Platform, Sicily.

The Jurassic of the Panormide Carbonate Platform records several discontinuity surfaces reflecting a complex sedimentary dynamics at a time of general extension in the western Tethyan realm. Previous studies documented subaerial exposure with karst bauxites between Upper Triassic and Upper Jurassic in the internal sector of the platform. On the contrary, at same time the marginal sectors of the platform record *Rosso Ammonitico* type sedimentation and the subsequent progradation of a new, Upper Jurassic platform. Latest sedimentological and stratigraphical studies added new data on these discontinuity surfaces in the Palermo Mountains. The succession of Mt. Castellaccio is characterized by Upper Triassic peritidal dolostones crosscut by various generations of neptunian dykes filled by pelagic limestones with crinoids, brachiopods, ammonites and filaments (Pliensbachian to Middle Jurassic). They are covered by red sediments rich in ferric ooids and lithoclasts enclosed in a red, argillaceous matrix. Petrographics and X-ray analyses have confirmed the presence of boehmite, kaolinite and hematite in these rocks, on the basis of which they may be qualified as low-grade bauxites. Above, with an angular unconformity, there follow Kimmeridgian loferitic limestones interbedded to bioclastic grainstone/packstone with *Clypeina sulcata* (Alth).

At Punta Raisi, a stratigraphically equivalent, but sedimentologically different succession has been studied. The Upper Triassic peritidal dolostones are overlain by Lower Jurassic cyclic peritidal limestone with very poor microfauna. It is repeatedly interrupted by yellow to brownish paleosol levels. The top of this succession is red-coloured and is marked by a complex dissolution surface, with pinnacles and grooves. It is capped by a thick Fe-Mn crust with Foraminifera, small ammonites and filaments [Bajocian-Callovian(?)]. Based on preliminary petrographical and geochemical analyses a brief subaerial event may be hypothesized. However, the very same petrographic analyses revealed the effects of undoubtedly submarine bioerosion (action of sponge, fungi and bacteria), too. So even if we accept the idea of a transient subaerial phase, a strong submarine overprint during subsequent drowning, possibly contributing to the development of the pinnacle-and-groove topography can not be excluded, either. The Fe-Mn-crust is overlain by pelagic sediments displaying a coarsening upward trend and gradually passing into bioclastic grainstones/packstones with abundant carbonate platform elements (Kimmeridgian). This work is intended to add new arguments to the stratigraphic evolution and, consequently, to the subsidence history of the Panormide Carbonate Platform. Results are as follows:

- evidence for an Early Jurassic shallow water depositional environment;
- restriction of the size of the hiatus between Lower and Middle Jurassic;
- verification of the presence of a submarine dissolution surface analogous to that of the Trapanese Platform;
- increase of the areal extension of bauxites on the Panormide Platform;
- confirmation of the synchronicity of the re-establishment of the shallow-water carbonate sedimentation during the Late Jurassic.

This data moreover allow a better paleogeographic reconstruction and a key to understand the combined effects of sea-level changes, tectonics and thermal (?) updoming at the time of an overall extensional regime.