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11717 The Arabian Plate and the IGC Programme 572 (Permian–Triassic extinction and recovery): Results from the Muscat - Gutech (German University of Technology) field meeting (February 2010).

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The Permian–Triassic transition has been surveyed in the Oman Mountains and new detailed sections have been presented (Baud and Bernecker, 2010), from autochthonous shallow-water units (Saih Hatat and Al Jabal al-Akhdar) to slope deposits in the Jabal Sumeini area (Wadi Maqam units), from distal tilted block (Wadi Wasit) to oceanic deep-water deposits (Buday'ah).

Middle Permian Transgression
At the dawn of the Wordian (Middle Permian), the "Fusulinid Sea" transgressed over most of Oman with the exception of Jabal Ja'alan and the Huqf-Dhofar High. This transgression enabled the establishment of a vast carbonate platform in Al Jabal al-Akhdar, a 700 m-thick succession of cyclic shallow-marine carbonate, the Saiq Formation (Middle and Late Permian, basal Triassic (Baud et al., 2001a, b, 2005; Richoz et al., 2005; Richoz, 2006). A similar succession occurs in Saih Hatat (Le Métour, 1988; Weidlich and Bernecker, 2003; Chauvet, 2007), in the Musandam (Bih Formation, Maurer et al., 2009), as well as in the Interior Oman and in the Haushi area (Khuff Formation, Angiolini et al. 1998, 2003). Clearly, for us, this transgression was the result of the break-up of the Neo-Tethyan rift and the associated thermal subsidence.

Following the peak of the thermal subsidence in the Wordian–Capitanian, a stable carbonate platform became established on the Arabian Peninsula. The Saiq, Khuff and Hagil formations show a strong regressive tendency at the end of the Guadalupian (Middle Permian), with restricted environment facies and a reduced biophase, mainly associated with a global fall in sea level at this time and climate changes (Isozaki, 2009). During the Lopingian (Late Permian), the subsidence as recorded in the Saiq mega-cycle B (up to 300 m of shallowing upward cycles) was still well active.

The most striking effect of the climax of the Neo-Tethyan extension was the formation of a continental slope (Sumeini) and a basin (Hawasina) that constituted with the adjacent Arabian Platform, the southern continental passive margin of the Neo-Tethys Ocean. Furthermore early-rifted blocks detached from the edge of the Arabian Shield formed isolated proximal platforms along the continental slope (later they were incorporated in the Hawasina Nappes). The continental margin slope deposits are clearly identified (with slumps and intra-formational breccia) in the northwestern part of the Oman Mountains (Jabal Sumeini), where they form the basal part of the Maqam Formation dated as Roadian (Middle Permian).

The distal isolated platform identified as nappes in Baid and Jabal Qamar areas by Béchennec (1988), Béchennec et al. (1992), Pillevuit (1993) and Pillevuit et al. (1997) are mainly made of Middle–Late Permian open-shelf carbonates. The Jabal Qamar unit includes a fragment of the pre-Middle Permian Basement (Rann, Ayim and Asfar formations, Pillevuit, 1993) overlain in unconformity by the late Early to early Middle Permian shallow-marine carbonate Qamar Formation with its quartz-sandstone basal member. The Baid unit is truncated at the base and is made of about 100 m of the Middle–Late Permian (Capitanian–Wuchiapingian) shallow-marine carbonate (Baid Formation, Béchennec, 1988; Pillevuit, 1993; Pillevuit et al., 1997; Baud et al., 2001b). The distal paleogeographic position of these Permian tilted blocks in regard with the Arabian Platform is documented by: (1) the differences in terms of facies (open marine with ammonoids) with those restricted to the others parts of the Oman Mountains (Al Jabal al-Akhdar, Saih Hatat and Musandam); and (2) the presence of reworked boulders originating from these isolated platforms in the calcirudites of the proximal units of the basinal Hawasina Nappes.

Basinal facies of the Middle Permian are present in the Hawasina Nappes at the base of numerous tectonics units, made up of formations from the Hamrat Duru Group. These successions generally start with thick volcanic sequences (Al Jil and Buday'ah formations). These volcanic rocks are either of MORB type or alkali basalt-related (Maury et al., 2003; Lapierre et al., 2004). The volcanic succession is filled and overlain by red ammonoid limestones dated as Middle Permian (Capitanian) followed by radiolarian chert and shales newly dated as Lopingian in Buday'ah. In the Wadi Wasit area, the volcanic series is capped by red cephalopods-bearing carbonate, dated Middle Permian (Wordian, Blendinger et al., 1992; Pillevuit et al., 1997; Baud et al., 2001b), by shales and breccia with reworked blocks of Middle Permian to basal Triassic platform carbonate (Béchennec et al., 1992b; Pillevuit, 1993; Pillevuit et al., 1997; Krystyn et al., 2003; Weidlich and Bernecker, 2007).

Near Nahkl the volcanic series includes blocks of Middle Permian shallow-marine carbonate and is overlain by pelagic limestone (Weidlich, 2007). In the Rustaq area the volcanic succession is also capped by a condensed carbonate sequence (Hallstatt facies type) dated as Middle Permian (Wordian, Blendinger et al., 1992; Pillevuit et al., 1997; Baud et al. 2001b; Richoz et al., 2005).

Different types of deep-water black limestones are also identified in the basinal units of the Batain Plain (southeastern part of the Oman Mountains), the "Qarari Limestone" with a base dated as Roadian (Middle Permian, Immenhauser et al., 1998) and the top as Changhsingian.

From the Permian/Triassic Transition to the Basal Triassic (Figure 1)
At the end of the Permian (top of KS3 sequence of Koehrer et al., 2010), regressive conditions up locally to emersion (?) are recorded as well on the Arabian carbonate platform (Al Jabal al-Akhdar, Saih Hatat and Musandam). On the slope of the continental margin, we observe a shallowing in the Sumeini unit deposits.

Shallow tidal influenced carbonate platform is the main component of the Induan dolomitized deposit in the Al Jabal al-Akhdar (Units C1 to C4 of the Saiq Formation in Baud and Bernecker, 2010, correlated with Khuff sequences KS2–KS1) that is now dated by conodonts. During the Dienerian, part of the margin was affected by a renewed extensional regime, tilting and drowning resulting in erosive deposition and accumulation of carbonate breccia (Unit C2 of the Saiq Formation) followed in the Al Jabal al-Akhdar by high-energy, partly oolitic dolomitized shallow-water deposits, Dienerian in age (Unit C3) and renewed breccias (Unit C4). The Saiq-Mahil transition (correlated with the Khuff-Sudair transition) is probably of late Induan age (chemostratigraphical correlations, Richoz, 2006).

On the slope of the continental margin, a continuous carbonate deposition and shale has been recently precisely dated from Changsingian to Spathian. Overlying the Wuchiapingian–Changhsingian, deep-water chert and dolostone (upper Member B of the Maqam Formation), we note the deposition of upper Changsingian shallowing siliceous strongly bioturbated lime mudstones. A major facies change occurs with the Griesbachian papery, laminated calcimicrobial mudstone overlying the boundary clay (base of C1c Member of the Maqam Formation). The calcarenite, calcirudite turbidites and avalanches with shallow water upper Permian lime clasts start in the Dienerian (instability period). The incredible thickness of the Smithian deposits (platy limestones, shales and megabreccia up to 900 m of thickness, middle and upper Member C of the Maqam Formation) indicate high carbonate productivity on the platform and a very active subsidence at the base of slope (Watts, 1985; Baud et al., 2001b; Richoz et al., 2005; Richoz, 2006).

On the Baid Exotic block, after karstification of part of the tilted Permian carbonate platform and the Dienerian drowning event, the Dienerian-Smithian deep-water red ammonoid limestone is filling fissures and cavities (Hallstatt breccia) and is deposited over the Permian limestones (Tozer and Calon, 1990; Pillevuit, 1993; Pillevuit et al., 1997; Baud et al., 2001a; Richoz, 2006; Wood and Baud, 2008).

In the proximal deep-water basin (Wadi Wasit units) the Lopingian allodapic limestones are partly eroded by a submarine avalanche breccia (Dienerian) containing Permian to basal Triassic mega-blocks. One of these blocks with a unique Permian–basal Triassic record has been analyzed in Krystyn et al. (2003). Upper Dienerian–Smithian deep-water platy limestone overlay the Lower Dienerian mega-block breccia.

In the distal Hawasina basin (Buday'ah), the Upper Permian radiolarian chert deposits are overlain by Changhsingian siliceous shales and calcareous shales followed by Griebachian laminated platy limestones and shales and Dienerian–Smithian papery limestones.

Conclusions

The Neo-Tethys Ocean opened with the northward drifting of the Iran/Mega-Lhasa microcontinent followed a rifting extensional phase in the Roadian–Wordian. Thermal subsidence, with the development of the continental margin, is well recorded in the Wordian–Capitanian carbonate succession and continued during the Lopingian. Tectonic instability of the margin, with block tilting, platform drowning and (fault) breccia deposits started at the dawn of the Triassic with the main climax during the Dienerian and the Smithian.

References

Angiolini, L., A. Nicora, H. Bucher, D. Vachard, A. Pillevuit, J. Platel, J. Roger, A. Baud, J. Broutin, H.A. Hashmi and J. Marcoux 1998. Evidence of a Guadalupian age for the Khuff Formation of southeastern Oman: preliminary report. Rivista Italiana di Paleontologia e Stratigrafia, 104, p. 329-340.

Angiolini, L., M. Balini, E. Garzanti, A. Nicora, A. Tintori, S. Crasquin-Soleau and G. Muttoni 2003. Permian climatic and paleogeographic changes in Northern Gondwana: the Khuff Formation of Interior Oman. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 191, nos. 3-4, p. 269-300.

Baud, A., F. Béchennec, F. Cordey, L. Krystyn, J. Le Métour, J. Marcoux, R. Maury and S. Richoz 2001a. Permo-Triassic Deposits: from the Platform to the Basin and Seamounts, Conference on the Geology of Oman, Field guidebook, Excursion A01: Muscat, Oman, p. 1-54.

Baud, A., F. Béchennec, F. Cordey, J. Le Métour, J. Marcoux, R. Maury and S. Richoz 2001b. Permo-Triassic Deposits: from shallow water to base of slope, Conference on the Geology of Oman, Field guidebook, Excursion B01, Muscat, Oman, 40 p.

Baud , A. and M. Bernecker, (Eds.) 2010. The Permian-Triassic transition in the Oman Mountains, IGCP 572 Field Guide Book. GUtech, Muscat, p. 1-109.

Béchennec, F. 1988. Géologie des nappes d'Hawasina dans les parties orientales et centrales des montagnes d'Oman., Documents du Bureau de Recherches Géologiques et Minières, 128, p. 1-474.

Béchennec, F., J. Roger, J. Le Métour and R. Wyns 1992. Explanatory notes to the Geological map of Seeb, Sheet NF40-03. Muscat, Oman Ministry of Petroleum and Minerals, 104 p.

Blendinger, W. 1988. Permian to Jurassic deep water sediments of the Eastern Oman Mountains: Their significance for the evolution of the Arabia margin of south Tethys. Facies, v. 19, p. 1-32.

Blendinger, W., W.M. Furnish and B.F. Glenister 1992. Permian cephalopod limestones, Oman Mountains: evidence for a Permian seaway along the northern margin of Gondwana. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 93, p. 13-20.

Chauvet, F. 2007. La marge continentale sud-téthysienne en Oman: structure et volcanisme au Permien et au Trias. Thesis, Grenoble I University, p. 1-362.

Immenhauser, A., G. Schreurs, T. Peters, A. Matter, M. Hauser and P. Dumitrica 1998. Stratigraphy, sedimentology and depositional environments of the Permian to uppermost Cretaceous Batain Group, eastern Oman. Eclogae geologicae Helvetiae, v. 91, no. 2, p. 217-235.

Isozaki, Y. 2009. Illawarra Reversal: The fingerprint of a superplume that triggered Pangean breakup and the end-Guadalupian (Permian) mass extinction. Gondwana Research, 15, p. 421-432.

Koehrer, B., M. Zeller, T. Aigner, M. Poeppelreiter, P. Milroy, H. Forke and S. Al-Kindi 2010. Facies and stratigraphic framework of a Khuff outcrop equivalent: Saiq and Mahil formations, Al Jabal al-Akhdar, Sultanate of Oman. GeoArabia, v. 15, no. 2, p. 91-156.

Krystyn, L., S. Richoz, A. Baud and R.J. Twitchett 2003. A unique Permian-Triassic boundary section from the Neotethyan Hawasina Basin, Central Oman Mountains. *Palaeogeography Palaeoclimatology Palaeoecology*, 191, p. 329-344.

Lapierre, H., A. Samper, D. Bosch, R.C. Maury, F. Bechennec, J. Cotten, A. Demant, P. Brunet, F. Keller and J. Marcoux 2004. The Tethyan plume: geochemical diversity of Middle Permian basalts from the Oman rifted margin. *Lithos*, 74, p. 167-198.

Le Métour, J., 1988, Géologie de l'Autochtone des Montagnes d'Oman: la fenêtre du Saih Hatat, *Documents du Bureau de Recherches Géologiques et Minières,* Orléans, 129, 430p.

Maurer, F., R. Martini, R. Rettori, H. Hillgärtner and S. Cirilli 2009. The geology of Khuff outcrop analogues in the Musandam Peninsula, United Arab Emirates and Oman. *GeoArabia*, v. 14, no. 3, p. 125-158.

Maury, R.C., F. Bechennec, J. Cotten, M. Caroff, F. Cordey and J. Marcoux 2003. Middle Permian plume-related magmatism of the Hawasina Nappes and the Arabian Platform. Implications on the evolution of the Neotethyan margin in Oman. *Tectonics*, v. 22, no. 6, p. 12-1 - 12-13.

Pillevuit, A. 1993. Les Blocs Exotiques du Sultanat d'Oman. Evolution paléogéographique d'une marge passive flexurale. *Mémoires de Géologie*, Lausanne, v. 17, 1-249.

Pillevuit, A., J. Marcoux, G. Stampfli and A. Baud 1997. The Oman Exotics: a key to the understanding of the Neotethyan geodynamic evolution. *Geodinamica Acta*, Paris, v. 10, p. 209-238.

Richoz, S. 2006. Stratigraphie et variations isotopiques du carbone dans le Permien supérieur et le Trias inférieur de la Néotéthys (Turquie, Oman et Iran). *Mémoires de Géologie*, Lausanne, v. 46. p. 1-264.

Richoz, S., A. Baud, L. Krystyn, R. Twitchett and J. Marcoux 2005. Permo-Triassic Deposits of the Oman Mountains from Basin and Slope to the shallow Platform, in *24th IAS regional Meeting, Post-Conference Excursion A13*. Muscat, Oman, 1-57.

Watts, K.F., 1987. Triassic carbonate submarine fans bounding the Arabian carbonate margin, Sumeini Group, Oman. *Sedimentology*, v. 34, p. 43-71.

Weidlich, O. and M. Bernecker 2003. Supersequence and composite sequence carbonate platform growth. Permian and Triassic outcrop data of the Arabian platform and Neo - Tethys. *Sedimentary Geology*, v. 158, p. 87-116.

Weidlich, O. and M. Bernecker 2007. Differential severity of Permian-Triassic environmental changes on Tethyan shallow-water carbonate platforms. *Global and Planetary Change*, v. 55, p. 209-235.

Woods, A.D. and A. Baud 2008. Anachronistic facies from a drowned Lower Triassic carbonate platform: Lower member of the Alwa Formation (Ba'id Exotic), Oman Mountains. Sedimentary Geology, v. 209, p. 1-14.

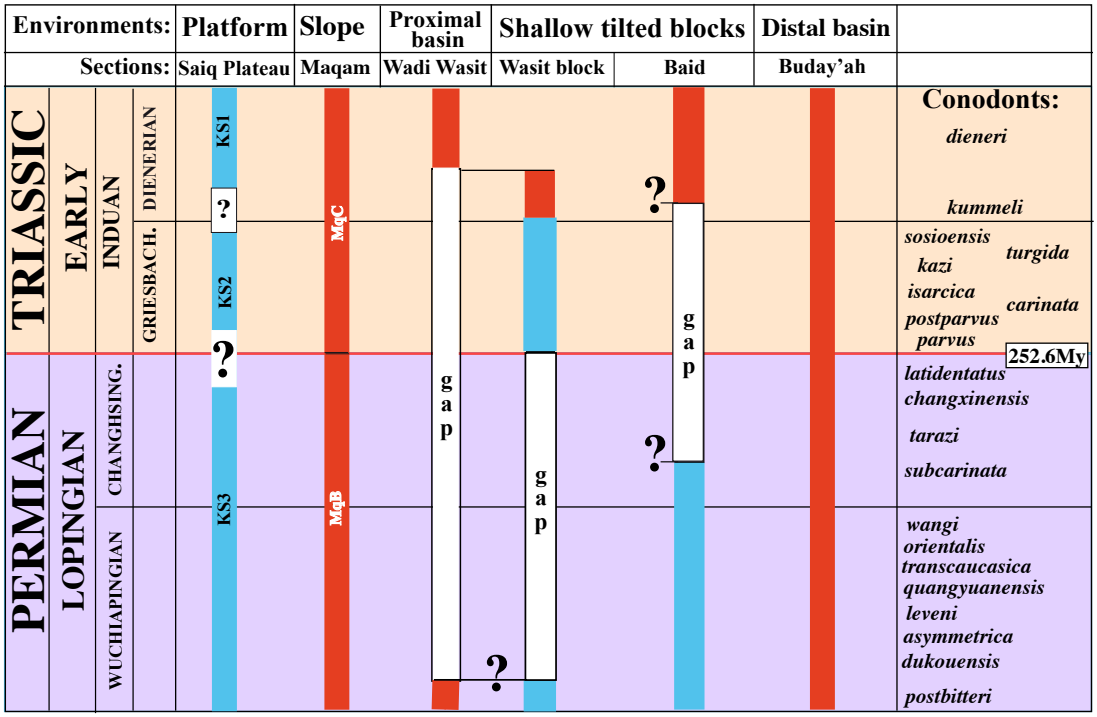

Figure 1: Recorded sedimentation and gaps of the main Permian–Triassic sections. Shallow-water deposits in light blue and open to deep marine deposits in red.