AAPG HEDBERG CONFERENCE
"MICROBIAL CARBONATE RESERVOIR CHARACTERIZATION"
June 4-8, 2012 – Houston, Texas

Evidence for the Microbial Origin of the Tengiz Unit I Boundstone Slopes, (Pricaspian Basin, The Republic of Kazakhstan)

Miriam S. Andres[1], Tomaso R.R. Bontongnali[2], Jeroen M. Kenter[1], Paul (Mitch) Harris[1], Crisogono Vasconcelos[2], Judith A. McKenzie[2], Ruslan Manakhayev[3] and Steve D. Jenkins[3]

[1]Chevron Energy Technology Company, San Ramon, California, USA
[2]Geomicrobiology Laboratory, Department of Earth Sciences, ETH Zurich, Zurich, Switzerland
[3]TengizChevroil (TCO), Atyrau, Kazakhstan

The supergiant Tengiz oil field of the Pricaspian Basin is a steep-sided isolated carbonate platform deposited during the Devonian through Carboniferous. Microbial-dominated and well-cemented boundstone slopes form one of the dominant reservoir facies, primarily due to localized fracturing in the upper to middle slope. This latest-Visean to Serpukhovian slope interval is characterized by up to 600 m of *in situ* microbial boundstone, massive boundstone breccia and mixed breccia and allochthonous platform- and slope-derived grainy carbonates. Based on the sedimentary features identified in core and thin sections the Tengiz microbial boundstone is of three different types: A = peloidal-micritic (massive) boundstone; B = laminar-cemented (accretionary) boundstone; C = skeletal-micritic boundstone (Collins et al. 2006). Boundstone types A and B occur on the upper slope whereas type C is restricted to the deeper outer platform (see also Della Porta *et al.,* 2003; Kenter *et al*., 2005). Apart from basic morphological descriptions in core and thin sections and habitat on the slope profile, however, key questions such as fossil evidence of microbial activity and products, and if present their texture, mineralogy, isotopic composition are not well understood.

In contrast to macroscopic metazoans, microbes usually exhibit simple morphologies, lack skeletal components and are embedded in a generally recrystallized and altered sediment matrix. This makes the identification and the interpretation of their fossil counterparts a challenge. Beyond the traditional techniques analyzing the microbial cell (i.e. macro- and microtextures, stable isotopes) research is increasingly focusing on analyzing the microbial products i.e. exopolymeric substances (EPS) and minerals that excrete and precipitate in association with microbial activity. Twelve Tengiz core samples selected from various slope locations covering the three different microbial boundstone types offered an opportunity to investigate the presence of physical and chemical evidence of microbial activity at the right spatial, micrometer scale (Fig. 1).

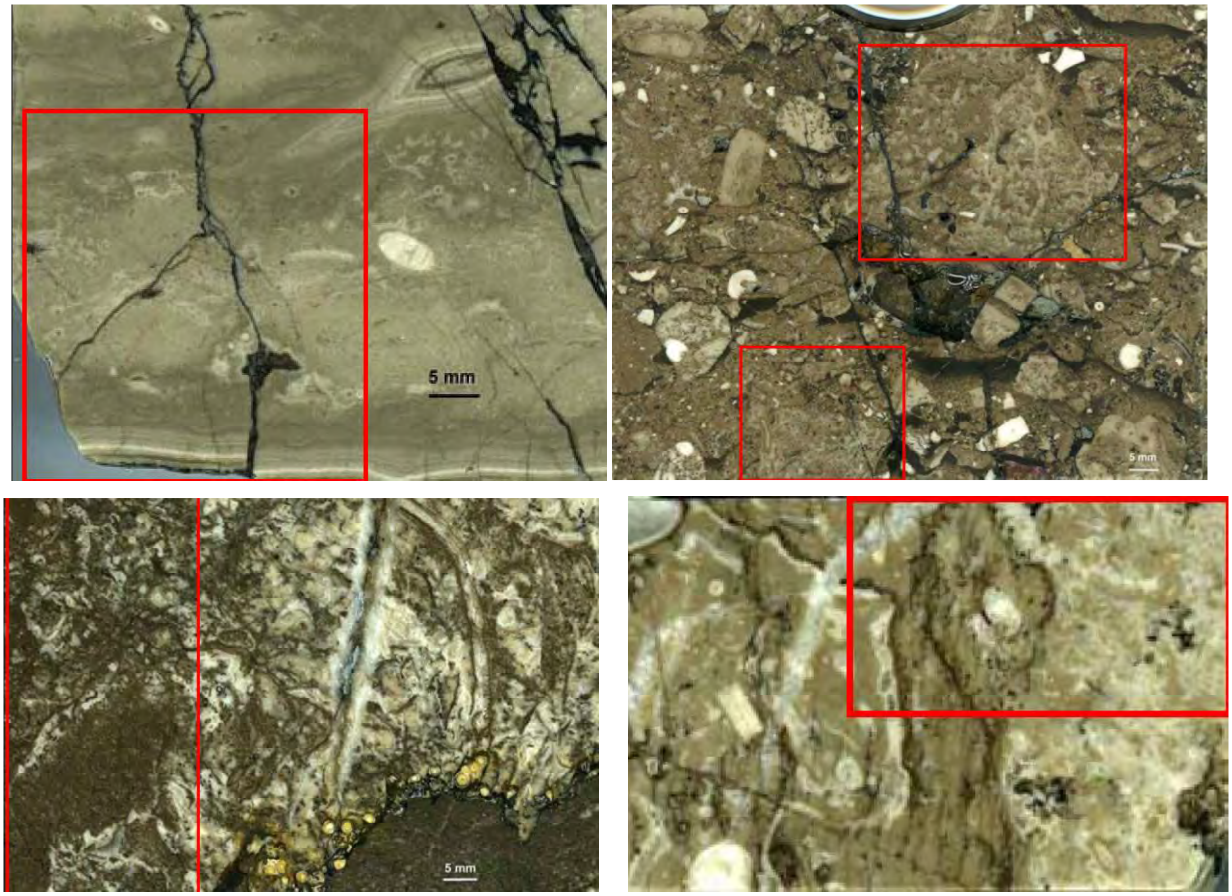

Figure 1: Microbial boundstone examples used in this study range from the deeper outer platform to slope environments of deposition. Top left: well T-7450 at 4326.00 m is in-situ boundstone from the transitional deeper outer platform to uppermost slope; top right: well T-463 at 456.7m is bounstone breccia from middle to lower slope; bottom left: well T-6337 at 4948.60 m is boundstone breccia from lower slope to toe of slope; and bottom right: well T-5963 at 4796.39m is boundstone breccia from lower slope to toe of slope.

Representative polished thin sections were platinum-coated for scanning electron microscope (SEM) analysis coupled with an energy dispersive X-ray spectrometer (EDAX) for elemental analysis, and stable carbon and oxygen isotope analysis were performed on the same micro-dilled thin section.

SEM observations revealed the presence of sub-µm to µm scale filaments, nanoglobules and grainy textures in 9 of the 12 studied samples (Fig. 2). Carbonate precipitation occurring within an EPS matrix results in a characteristic mineral habit which differs from that of abiotic precipitates. The viscosity of the organic matrix affects the crystal morphology such that they tend to form spherical shapes that lack cleavage and angular surfaces (Braissant *et al.,* 2003; Chafetz and Guidry, 1999). In an experimental EPS matrix, early stage carbonate precipitates form as nanoglobules (~20-200 nm) which merge together to form larger bodies exhibiting a grainy texture, which is also documented in several modern carbonate settings (Bontognali *et al*., 2008; Vasconcelos and McKenzie, 1997). The most noteworthy SEM image of the Tengiz samples suggests the fossil imprint of EPS alveolar microstructures! EDAX analysis of filaments, nanoglobules and grainy texture confirmed their carbon-oxygen-calcium-sulfur composition.

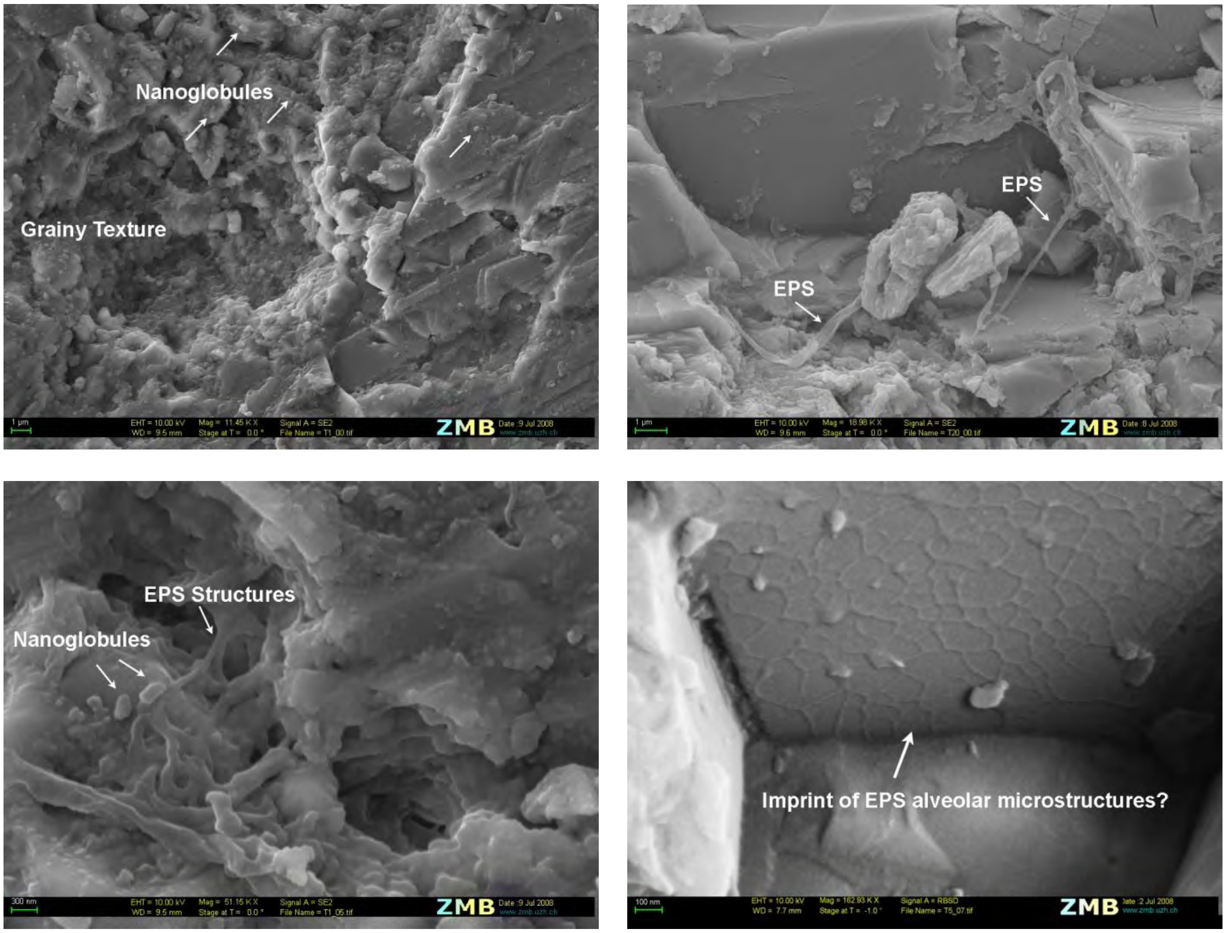

Figure 2: Examples of microsedimentary textures observed in scanning electron microscopy (SEM) imaging from Tengiz samples. Top left: Micro-sized nanoglobules and the resulting grainy texture with the merger of nanoglobules. Top right: EPS filaments. Bottom left: nanoglobules and EPS structure. Bottom right: putative fossil EPS honeycomb microstructure.

Stable isotope values range from -1.0 to 3.5 ‰ for ∂13C and from -7.5 to -0.3 ‰ for ∂18O where values refer to the standard ∂ notation with respect to the VPDB standard. Data in an oxygen vs. carbon cross-plot the cluster according to their sample location (i.e. well) and vary systematically suggesting variable diagenetic conditions during cementation and/or subsequent early diagenesis and/or burial.

The Tengiz microbial boundstone samples contain very typical nanoglobules and grainy textures evidencing a distinctive microbial origin. Although the presence of such micro textures is not unexpected, their exquisite preservation considering their ~320 Ma age is. This suggests very early, if not instantaneous mineralization and thus stabilization of the slope environment and lack of later destructive re-mineralization. The early cementation likely formed the basis for subsequent preferred fracturing of the slope, oil-emplacement and vertical permeability critical for production today. Furthermore, the lack of sedimentary bedding features and hence the isotropic nature of the slope, are in part responsible for their typical transparent seismic character.

References:

Bontognali, T.R.R., Vasconcelos, C., Warthmann, R.J., Dupraz, C., Bernasconi, S., and McKenzie, J.A., 2008, Microbes produce nanobacteria-like structures, avoiding cell entombment: Geology, v. 36, p. 663-666.

Braissant, O., Cailleau, G., Dupraz, C., and Verrecchia, E.P., 2003, Bacterially Induced Mineralization of Calcium Carbonate in Terrestrial Environments: The Role of Exopolysaccharides and Amino Acids: Journal of Sedimentary Research, v. 73, p. 485-490.

Chafetz, H.S., and Guidry, S.A., 1999, Bacterial shrubs, crystal shrubs, and ray-crystal shrubs: bacterial vs. abiotic precipitation: Sedimentary Geology, v. 126, p. 57-74.

Collins, J.F., Kenter, J.A.M., Harris, P.M., Kuanysheva, G., Fischer D. J., and Steffen, K.L., 2006, Facies and reservoir-quality variations in the late Visean to Bashkirian outer platform, rim, and flank of the Tengiz buildup, Precaspian Basin, Kazakhstan, in P. M. Harris and L. J. Weber, eds., Giant hydrocarbon reservoirs of the world: From rocks to reservoir characterization and modeling: AAPG Memoir 88/SEPM Special Publication, p. 55–95.

Della Porta, G., Kenter, J.A.M, Bahamonde, J.R., Immenhauser, A., and Villa, E., 2003, Microbial boundstone dominated carbonate slope (Upper Carboniferous, N Spain): Microfacies, lithofacies distribution and stratal geometry: Facies, v. 49, p. 175-208.

Kenter, J.A.M., Harris, P.M., and Della Porta, G., 2005, Steep microbial bounstone-dominated platform margins – Examples and implications: Sedimentary Geology, v.178, p. 5-30.

Schaudinn, C., Stoodley, P., Kainovic, A., O'Keeffe, T., Costerton, B., Robinson, D., Baum, M., Ehrlich, G., and Webster, P., 2007, Bacterial biofilms, other structures seen as mainstream concepts: Microbe, v. 2.

Vasconcelos, C., and McKenzie, J.A., 1997, Microbial mediation of modern dolomite precipitation and diagenesis under anoxic conditions (Lagoa Vermelha, Rio de Janeiro, Brazil): Journal of Sedimentary Research, v. 67, p. 378-390.

AAPG Search and Discovery Article #90153©2012 AAPG Hedberg Conference Microbial Carbonate Reservoir Characterization, Houston, Texas, 3-8 June 2012.