The Lake Eyre Basin: A Modern Outcrop Reservoir Analogue of a Dryland Continental Interior Basin

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The Lake Eyre Basin (>1 Million km2) is a vast, internally-draining, low accommodation dryland fluvial-lacustrine basin, containing the World's fifth largest playa lake system (Lake Eyre). The northeastern rivers are characterised by extensive catchments and receive high precipitation from tropical cyclones in far-northern Australia. Rivers in the western part, on the other hand, have smaller catchments and comparatively little precipitation. These shorter western rivers terminate within Lake Eyre forming sandy terminal splay complexes. The larger northeastern rivers, however, dump most of the their coarse-grained sediment load in large floodouts 400 km inland from the playa margin. As a result mainly fine-grained sediments are transported to Lake Eyre. The floodouts are up to 300 km long and 100 km wide and comprise anabranching rivers separated by extensive floodplains. The floodplain and the lake plain is dominated by a broad Quaternary longitudinal and transverse aeolian dune complex that represents a significant sand storage area, ready to be reworked into fluvial systems in a future wet phase.

The Lake Eyre Basin, Central Australia, has been widely used as a modern day reservoir analogue for many non-marine dryland basins (eg. North Sea and North African Triassic, South Caspian Pliocene) even though a basin-scale facies model has not been published to date. The high variability of depositional elements at various scales within the basin emphasizes the care that needs to be taken when using the Lake Eyre Basin as an analogue for both regional and field scale palaeogeographic reconstructions.

Fractures in Formation MicroImager (FMI) Log Versus Outcrop Data: Reservoir Character of a Thick-Bedded Deepwater Miocene Sandstone, New Zealand

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The aims of this study are to assess the potential for hybrid reservoirs that offer both clastic and fracture storage and flow paths and to test whether outcrop analogue studies can provide realistic models for the subsurface.

The Middle Miocene Tunanui Formation comprises a range of deep water facies, notably including metre-thick turbidite sandstone units with thin mudstone interbeds. Fractures were studied using an 8.1 m long scanline along a 1.78 m thick bed of fine, soft, calcareous sandstone. This bed is interpreted to be a flow-stripped turbidite. Data are compared with those from a similar facies of the same formation using FMI logs from exploration well Tuhara-1A, 23 km to the west.

The main fracture strike in outcrop is NNE and these fractures are scaleable. NNE fractures dipping WNW (Set A1) have a power trendline of $y = 0.4391x^{-1.0927}$ and those dipping ESE (Set A2) have a trendline of $y = 0.274x^{-1.8063}$. Similar orientations are identified in the subsurface in Tuhara-1A using FMI logs and most apertures (from scaled resistivity data) and fracture spacing data plot within the aperture-frequency zone obtained from outcrop data. This suggests:

1. the outcrop data may be a good analogue for the subsurface for this formation; 2. there may be wider-aperture fractures in sets A1 & A2 missed by the vertical borehole; 3. this approach to predicting reservoir quality and character might be applicable for other deepwater sandstones in this basin, though power trendline formulae may differ in other formations.

The NNE-striking fractures are slightly oblique to the direction of principal horizontal shortening derived from first motion studies and to the main horizontal stress orientation as inferred from breakout directions observed on FMI logs. Cementation is variable but is insufficient to seal most fractures in either outcrop or the subsurface.

Comparison of Modeled Fracture Sets from Structure Analysis with Field Data from Oman

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Combination of structural analysis and Discrete Fracture Network has become a standard workflow used both in exploration and production of fractured reservoirs.

Two reservoirs analogues located in Oman (Natih Formation) have been heavily studied at outcrops scale. Those analogues consist in two classical trap structures: a salt dome and a Fault-Propagation-Fold. Fracture sets are studied from aerial to outcrop scale. Fracture maps (10 x 10 m.) are collected on structurally relevant locations on each structure. Spatial, statistical and connectivity analyses are performed on those fracture maps. Comparison of fracture maps at the different scales provides a framework of up-scaling properties for those two particular structures.

3D digital models, with similar geometric characteristics than the reservoir analogues, are schematically created from those three structures. Static analyses, like simple and gaussian curvature or dip analysis, are performed on the two digital models. Then each modelled structure is restored according to its own tectonic setting and forward modelled to capture the strain induced by the deformation. Discrete Fracture Networks are generating for each model using finite strain attributes to constrain fracture density. Orientation, spatial and connectivity analyses (connectivity degree and relative connectivity) are performed on the Discrete Fracture Networks.

Fracture sets digitally modelled are compared to the real data set.

Contrasting Styles of Fluvio-Aeolian Interaction: The Skeleton Coast Erg – a Modern-Day Dryland Reservoir Analogue

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The damming of river flow by aeolian landforms has been previously recognized as one of several principal types of fluvial-aeolian interaction. Our study on the Skeleton Coast ephemeral river systems is complementary in terms of considering variabilities of parameters within the fluvio-aeolian systems resulting in variable depositional sequences.

The Skeleton Coast forms part of the Atlantic coastline of northwest Namibia comprising several ephemeral rivers which

flow episodically west-southwest towards -and sometimes into- the Atlantic Ocean. This climatically hyper-arid area receives less than 50 mm average annual rainfall. However, the major catchment areas of the rivers are about 100-200 km farther inland in regions with relatively higher annual rainfall. The coastal plain in the river downstream area is characterized by the a prominent NNW trending 165 km long belt of 20-50 m high, locally compound, barchanoid and transverse dunes, termed Skeleton Coast Erg. As the SSE-NNW trending dune belt is oriented perpendicular to river flow, the erg dams and interacts with the WSW flowing ephemeral river systems.
Five ephemeral rivers were chosen for the purpose of this study. The southernmost river, the Koigab River, plays an important role providing sand for the southern end of the erg. In contrast, the Hoarusib flows sufficiently often to prevent a northward migration of the erg forming the northern boundary of the erg by flushing aeolian sand into the Atlantic Ocean. Between these two, the remaining rivers provide a spectrum of types of interaction with the Skeleton coast Erg.

Outcrop Gamma Ray and Rock Properties of the Tumblagooda Sandstone, Western Australia – a Fluvio-Deltaic Reservoir Analogue

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Outcrop of the Ordovician Tumblagooda Sandstone, Western Australia, shows internal heterogeneity typical of fluvial and deltaic systems. Gamma ray (GR) logs measured along a 50 m x 6.5 km coastal section reveal sandbody architectures at reservoir scale in these braided river and deltaic deposits. Reconnaissance spectral GR and rock property (core plug) data were gathered from a 30 m thick representative section to examine reservoir heterogeneity.
GR profiles for the braided river deposits are smooth to ratty and highly variable in shape, making lateral correlation difficult. The overbank/interdistributary deposits contain metre to sub-metre scale sheet-like interbeds of very-fine and coarser grained sandstones, which stack together as broadly coarsening-upward cycles; however their GR character allows lateral correlation for just a few hundred metres. Finer grained overbank/interdistributary deposits show high total counts and elevated K, U and Th values compared to crevasse-splay and distributary channels facies.
The helium porosity and Klinkenberg corrected permeability data range between 6–26% and 0.003–3726 mD, respectively. The braided river and distributary channel facies display the highest porosity (12–26%) and permeability values (50–3700 mD). Similar readings are found in the crevasse-splay and overbank sandstone facies, but these are more frequently well-cemented, reducing permeabilities to below 10 mD. Overbank/interdistributary bay fines are extremely poorly sorted, with porosities and permeabilities typically below 8% and 1 mD, respectively. Fine-grained sediments are commonly interbedded with overbank sandstones, and less commonly within fluvio-deltaic channel deposits. These essentially tight units represent significant baffles and barriers to fluid flow.

Extensive Carbonate Cementation of Outcropping Fluvial Successions, Upper Cretaceous, Book Cliffs, Utah: Implications for Prediction of Subsurface Cement Distribution

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Here we document an outcrop example where carbonate cementation of fluvial successions is intensive (cement bodies over 100 m) and extensive (occurring over distances of 10s of kms) with implications for modelling of sub-surface reservoirs. The Book Cliffs of Utah and Colorado, USA, exposes an extensive, 200 km, succession of Upper Cretaceous fluvial, coastal plain, shoreface and offshore strata. Cement bodies up to 100m long and 20m thick are present within the lowstand fluvial strata of the Desert Member and Castlegate Sandstone. These cement bodies are composed of early diagenetic ferroan dolomite (up to 3 mol% Fe), preserving minus-cement porosity of up to 40%, possessing δ13C values of +3.4 to -3.9 per mil VPDB and δ18O values of -8.5 to -12.5 per mil VPDB. In addition to cemented units, whitecaps, up to 10m thick, are present beneath coals, having formed from the early diagenetic leaching of detrital dolomite. Field mapping of cement body distribution reveals that cement bodies are present in amalgamated fluvial lowstand units and in amalgamated lowstand/highstand sand bodies. The source for the cements was detrital dolomite remobilised by meteoric fluids from up-dip whitecap units, an interpretation supported by field observations, and δ13C and δ18O data. We propose that at times of relative sea-level fall these lowstand and lowstand/highstand sand bodies acted as confined aquifers. At these times basinward meteoric fluid migration remobilised diagenetically leached detrital dolomite from up-dip, leading to extensive dolomite cementation in down-dip portions of the fluvial succession.

WODAD – a Web-Based Outcrop Digital Analog Database of Carbonate Platform Margins

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WODAD (Web-Based Outcrop Digital Analog Database) is a public, searchable database that is a serious attempt to make outcrop information more readily available to earth scientists. Such analogs can help industry earth scientists to conceptualize stratigraphic, facies and diagenetic relationships that develop reservoirs and traps while it may provide academics with a tool to compare and contrast information across geological time and space.
WODAD will cover the Phanerozoic and include carbonates initially, but later clastics as well as mixed systems. The database consists of a series of chapters, each focusing on a specific outcrop. Each chapter contains a summary page with search items, a few (2-3) pages of descriptive information, and a short reference list. A section of each summary page contains the items that will eventually guide the search. The primary search items will be age, system type (for carbonate, platform type), rock properties (lithology, texture), overprint (recrystallization, fracture, karst), and geographical location.

The database will offer unique and unsurpassed opportunities for comparative research, many of which will be only discovered once the database is available. WODAD “carbonates” is currently operational thanks to start-up funding provided by Chevron. Outcrop contributions from academia and industry are invited through submission of an abstract as well as through personal invitations (see wodad.org for information and instructions). It is anticipated that by 2007 the database will be published as a digital publication.