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Basin and Petroleum System Modeling of the Lake Edward Basin, Albertine Graben, Uganda

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Inspite of the significant petroleum exploration that has been undertaken to date in the Lake Edward Basin, no commercial discoveries have been made. However, hydrocarbon shows in the Ngaji-1 well demonstrate the presence of an effective petroleum system.
Therefore, the study majorly aimed at evaluating the thermal and burial history including modelling of the petroleum system criticals. Specifically, it served to determine the tectonic history, reconstruct the depositional history, define operating petroleum systems through modeling and determine hydrocarbon volumes available for entrapment.

Seismic interpretation using Petrel aided an understanding of the structural framework. Paleowater depth was estimated from the sea-level curves of Haq et al. (1987) due to lack of paleobathymetry data for the Albertine Graben.
Depositional history was based on analyses of samples from Ngaji-1 and geological reports. Reconstruction of ancient environments was aided by analysis of stratigraphic record in Ngaji-1 from which facies were interpolated by applying Walther's Law. The facies maps and ancient environments were refined by applying the concepts of sequence stratigraphy and drainage styles associated with rift systems.
The petroleum systems elements were inferred from well log interpretation. Source rock analysis involved evaluating the total organic carbon and Rock-Eval pyrolysis. Facies boundaries and maps were estimated from PetroMod and were construed based on the guiding principles of facies models. Determination of kerogen type from Rock-Eval pyrolysis and organic petrology studies was the basis for assigning appropriate petroleum generation kinetics from a list of kinetics of PetroMod.
The Mackenzie crustal model in PetroMod was used to determine heat flow and this was calibrated using temperature and vitrinite reflectance measurements from Ngaji-1. Sediment-water interface temperature, SWIT was auto tracked using Wygrala (1989) plot of PetroMod. Forward models were used to simulate the burial history, generation, migration and accumulation of petroleum within the model through time.

The study reveals that the subsidence history has 3 main episodes that correspond to episodes of rifting, with a major rifting occurring between 3Ma and 2Ma. Analysis of burial and subsidence history suggests that traps formed during period of highest rate of subsidence between 3Ma and 2Ma and during the period of uplift between 2Ma to present. Traps under category 1 mainly developed as a result of generation of high tilt angles potentially creating closures. Trap under category 2 are more common and appear as horst blocks.
The basin is endowed with well-developed petroleum systems elements, including reservoirs, traps, seals and potential source rocks. However, sediments are poorly consolidated. Although positive to reservoir potential in terms of high porosity development, it is detrimental to sealing and production in such reservoirs is anticipated to be problematic.
Thermal and maturity modeling indicates that no generation has occurred in the basin. Maturity modeling using a heat flow of 66mWm-2 corresponding with a geothermal gradient of 41.80C/Km

indicates that the source rock, Ishasa is at vitrinite reflectance of 0.45%, and therefore immature with respect to petroleum generation. However, given that the basin extends into Congo (not modeled), where it is significantly deeper, and therefore likely to be mature, it is possible that hydrocarbons could have been generated. Nevertheless, modelling estimates upto 79Bbbls and upto 57 tcf of oil and gas potential respectively.

This presentation will discuss the key aspects of the petroleum systems associated with rift systems in reference to the Albertine Graben, East African Rift System. In addition, the paper will demonstrate a modern workflow employed in evaluating the dynamics of sedimentary basins and their associated fluids to establish if past conditions were suitable for hydrocarbons to accumulate in potential reservoirs and be preserved there.

References

Allen, P.A. and Allen, J.R.2005, Basin Analysis: Principles and Applications, Wiley-Blackwell (2nd Edition) 560pp.

Blakely, R.C., 2008, Paleogeography and geologic evolution of North America, Department of Geology, Northern Arizona University, Web accessed 2nd June, 2014, http://www.geology.nau.edu

Bohacs, K. M., A. R. Carroll, J. E. Neal, P. J. Mankiewicz, 2000, Lake-basin type, source potential, and hydrocarbon character: an integrated-sequence-stratigraphic geochemical framework, in E. H. Gierlowski-Kordesch and K. R. Kelts, eds., Lake basins through space and time: AAPG Studies in Geology 46, p. 3-34.

Carroll, A. R., and Bohacs, K. M., 2001, Lake-type controls on petroleum source rock potential in nonmarine basins, AAPG Bulletin, v. 85, p. 1033–1053.

Cohen, A.S., 1990, Tectono-stratigraphic model for sedimentation in Lake Tanganyika, Africa, AAPG Memoir 50.

CoreLab, 2013, East African Reservoirs and Seals, Phase-III, Albertine Graben, Uganda

Curtis, J. B., 2002, Fractured shale gas systems: AAPG Bulletin, 86, 1921-1938.

Demaison, G., and B. J. Huizinga, 1991, Genetic classification of petroleum systems: AAPG Bulletin, v.75, p. 1626-1643

Dow, W. G., 1977, Kerogen studies and geological interpretations: Journal of Geochemical Exploration, v. 7, p. 77-79.

Hantschel, T., and Kauerauf, A.I., 2009, Fundamentals of Basin and Petroleum Systems Modeling, Springler-Verlag, Germany.

Haq, B.U., J. Hardenbol and P. Vail, 1987, Chronology of fluctuating sea levels since the Triassic, Science, v. 235, p. 1156-1167.

Haq, B. U., and S. R. Schutter, 2008, A chronology of Paleozoic sea-level changes; Science, v. 322, p. 64-68.

Karp, T., Scholz, C.A. and McGlue, M.M., 2012, Structure and stratigraphy of the Lake Albert Rift, East Africa: Observations from seismic reflection and gravity data, in O.W. Baganz, Y. Bartov, K. Bohacs, and D. Nummeda, eds., Lacustrine sandtone reservoirs and hydrocarbon systems,: AAPG Memoir 95, p. 299-318.

Kasande, R., and Abeinomugisha, D., 2009, Tectonic control on hydrocarbon accumulation in intracontinental Albertine Graben of the East African Rift System, in (Gao, ed.), Tectonics and Sedimentation: implications for petroleum systems, AAPG Memoir 100, p. 209-228.

Katz, B.J., 1990, Controls on distribution of lacustrine source rocks through time and space; In B.J. Katz, ed., Lacustrine basin exploration-Case studies and modern analogues: American Association of Petroleum Geologists Memoir 50, p. 61-76.

Magoon, L. B., and W. G. Dow, 1994, The petroleum system, in L. B. Magoon and, W. G. Dow eds. The Petroleum System: From Source to Trap: AAPG Memoir 60, p. 3-24.

Morley, C.K., 1989, Extension, detachments and sedimentation in continental rifts (with particular reference to East Africa): Tectonics, 8, p. 1175-1192.

Olsen, P.E., Tectonic, climatic, and biotic modulation of lacustrine ecosystems-examples from Newark supergroup of Eastern North America; In B.J. Katz, ed., Lacustrine basin exploration-Case studies and modern analogues: American Association of Petroleum Geologists Memoir 50, p. 209-224.

Pedersen T.F., and Calvert S.E., 1990, Anoxia vs. productivity; what controls the formation of organic carbon rich sediments and sedimentary rocks: American Association of Petroleum Geologists Bulletin, v. 74, p. 454-466.

Peters, K., Schenk, O., and Wygrala, B. Exploration paradigm shift: the dynamic petroleum system concept, Swiss Bull. Angew. Geol., v. 14, p. 65-71.

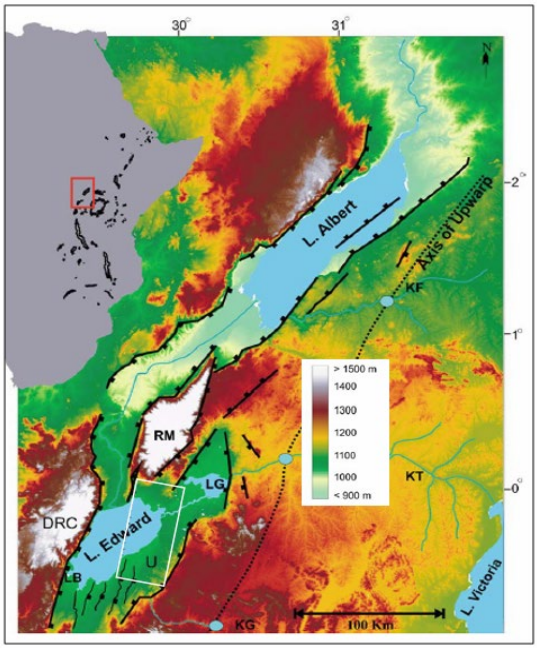
Sweeney, J. J. and A. K. Burnham, 1990, Evaluation of a simple model of vitrinite reflectance based on chemical kinetics, AAPG Bulletin, v. 74, p. 1559-1570.

Tiercelin, J., Cohen, A.S., Soreghan, M. J., and Lezzar, K., 1994, Plesitocene-Modern of the Lake Tanganyika rift basin, East Africa, A modern analogue for Lacustrine source rocks and reservoirs, SEPB Special publication, AAPG meeting, Denver p. 37-59.

Tugume F.A., and Nyblade, A.A., 2009, The Depth distribution of seismicity at the northern end of the Rwenzori Mountains: implications for heat flow in the western branch of the East African Rift System in Uganda, South African Journal of Geology, v. 112, p. 261-276.

Van Wagoner, J.C., Mitchum Jr., R.M., Campion, K.M., Rahmanian, V.D., 1990, Siliciclastic sequence stratigraphy in well logs, core, and outcrops: Concepts for High-Resolution Correlation of Time and Facies. In: American Association of Petroleum Geologists, Methods in Exploration Series 7, p. 55.

Wygrala, B. P. 1989, An integrated study of an oil field in the southern Po Basin, Northern Italy. PhD Thesis, University of Cologne, Germany.



Modified from McGlue et al., 2006