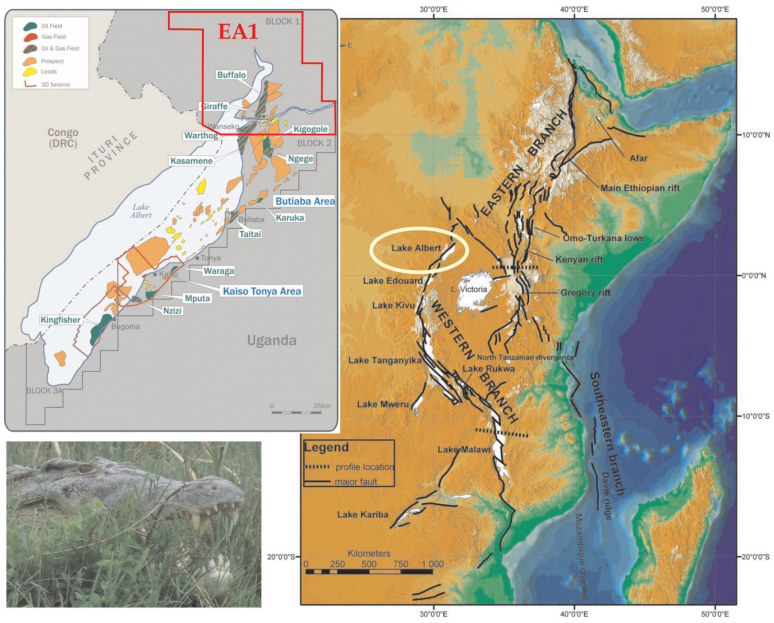
Anatomy of Early Continental Rifting: An Integrated Pedofacies, Spectral Gamma and Palaeomagnetic Approach

Almahdi Alshawib & Chris Nicholas

alshawia@tcd.ie nicholyj@tcd.ie

Department of Geology, School of Natural Sciences, Trinity College, The University of Dublin, Dublin 2, Republic of Ireland

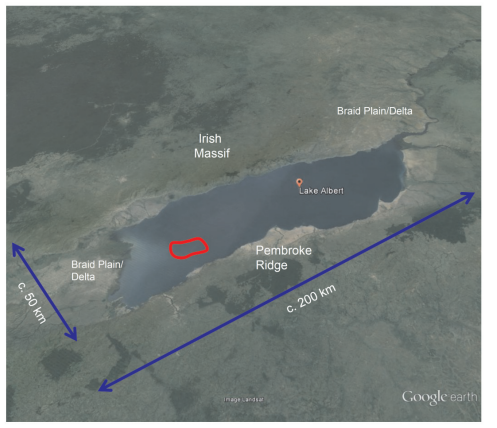


The East African Rift System showing the location of Lake Albert (from Chorowicz, 2005) and insets; Lake Albert exploration blocks, prospects & leads with EA1 highlighted (from Tullow Oil website, March, 2009) plus a 3m long, one tonne, Nile crocodile on the Victoria Nile during surveying

Hydrocarbon exploration in offshore 'Atlantic Ireland' rift basins carries significant risk for a number of different reasons and currently remains overly-dependent upon seismic surveys and their interpretation.

Finding and documenting high-resolution, onshore analogue examples of continental syn-rift sedimentary lithofacies architecture and depositional styles will potentially help de-risk exploration in these basins in the future.

The Lake Albert rift basin of the East African Rift System (EARS) exhibits all the classic tectonic, sedimentary, geomorphological and hydrological features of the early stages of continental rifting and has been used by exploration companies in the past as a direct recent analogue for the central North Celtic Sea Basin; it is of a similar structural size and style to Lake Albert, but with a fluvio-lacustrine fill from Upper Jurassic - Cretaceous.



The Ballyroe field and elements of the North Celtic Sea Basin overlain on a Google Satellite image of modern day Lake Albert (Providence Oil, 2014)

AIMS

The PI undertook the first ever detailed geological survey and mapping of Exploration Area (EA) 1; northern Lake Albert (Murchison Falls National Park) for Tullow Oil from 2011-2013.

This project, which started in September 2016, will build on the results of that Lake Albert survey to dissect the high-resolution sedimentary fluvio-lacustrine pedofacies and their spectral gamma ray response, developed during early continental rifting, and calibrate them against a palaeomagnetic polarity timescale. These data will then be used directly to reinterpret subsurface wells in the North Celtic Sea Basin.

1 PEDOFACIES

CHARACTERISTICS	CLIMATE, HYDROLOGY & BASE LEVEL INTERPRETATION
Widely spaced, reasonably well-developed ichnofabric consisting of: • Termite nests - network of galleries and chambers • Other more simple burrows • Developed in well-sorted, friable 'clean' sands • Usually in thick, massive sand body • Deep, oxidised Fe-staining in sediment common	**DRY SAND - LOW WATER TABLE** • Paleosol development during long period of low water table in well-drained sands • Dry season, or prolonged dry/arid period • Reactivation of channel system only during brief wet seasons
ORIGINAL DEPOSITIONAL ENVIRONMENT(S)	
• ABANDONED FLUVIAL CHANNEL • CHANNEL BAR • CREVASSE SPLAY	

CHARACTERISTICS	CLIMATE, HYDROLOGY & BASE LEVEL INTERPRETATION
Pervasive, highly bioturbated 'stirred' ichnofabric consisting of: • Complete destruction of any pre-existing sedimentary structures • Poorly defined, extensive, large root networks (possibly some large burrows), with dark yellowish orange weathering infill • Indistinct mottled oxidation pathcoes • Developed in interbedded massive f-m and c-vc quartz sandy clays • May contain brecciated Fe-hardground horizons	**WET CLAY - HIGH WATER TABLE** • Permanently high water table • Extensive colonisation by shrubs and lush tree vegetation • Long wet seasons - prolonged humid/wet phase • And/or permanently flooded during high lake-level stand
ORIGINAL DEPOSITIONAL ENVIRONMENT(S)	
• MARGINAL LACUSTRINE SWAMP • LATERALLY EXTENSIVE AND WELL-ESTABLISHED FLOODBASIN SWAMP	

Examples of Pedofacies descriptions in the field

Fluvio-deltaic Pedogenic Facies (or, 'Pedofacies') Analysis is a field-based technique developed by the PI in Lake Albert in order to make sense of the various mottled textures, paleosols and Fe-hardgrounds seen in exposures, by recognising a specific, characteristic paleosol development and its associated rhizo- and ichno-fabrics.

Recognition and description of lithofacies and varying ichno- and rhizo-fabrics provides direct local evidence of sedimentological / hydrological (water table rise or fall) conditions during deposition and early burial, and thereby on a larger scale, what the rift tectonic subsidence rates or climatic glacial / inter-glacial conditions were at that time. This provides the field observational background and support to feed into the interpretation of spectral gamma ray (SGR) analyses.

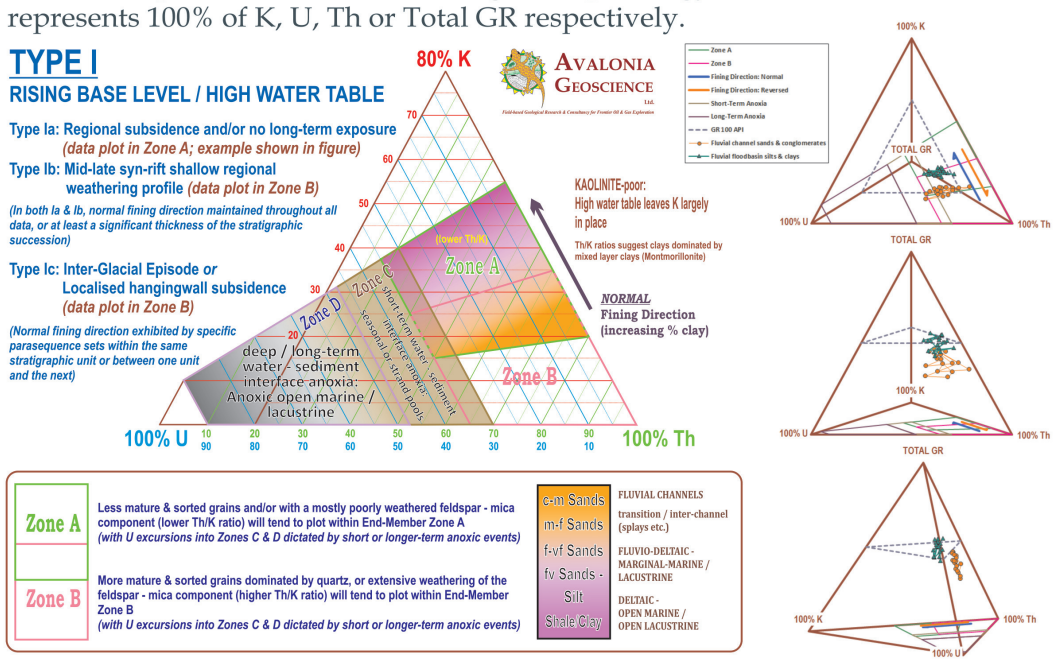
2 SPECTRAL GAMMA RAY (SGR)

The use of gamma ray spectrometry as a petroleum exploration tool is based on the recognition that certain component minerals and organic matter in rocks are naturally radioactive and emit gamma radiation. Hand-held Spectral Gamma Ray (SGR) analysis counts gamma rays being emitted from the decay of Potassium, Uranium and Thorium, and calculates the concentration of each in a sample or *in situ* assay.

SGR TERNARY & TETRAPLOTS

This is a completely new way to visualise and interpret SGR data. If the total gamma ray (Total GR) value of a sample is assumed to represent 100% of the detected radioactivity of the sample (and so is only due to the presence of K, U, and Th), then the proportional contributions of K, U and Th to the Total GR value can be calculated and expressed as a percentage of Total GR, and thus compared directly.

These data can then be shown in relation to each other on a standard ternary or tetrahedral plot, such as that used in igneous petrology, where each end member represents 100% of K, U, Th or Total GR respectively.



3-D Tetraplot of 'Type Ib' fluvial channel conglomerates and floodbasin silts & clays from the Holocene Tangi River, EA1; the SGR tetrahedron can be freely rotated in the original Excel file

The *SGR Tetraplot* method is still experimental and will be field-tested during July 2017 in northern Lake Albert. However, early results suggest that its importance lies in the fact that it appears to be able to identify potential reservoir sands (Type IIb), and even reservoir quality, in wells based only on interpretation of the SGR response.

3 PALAEOMAGNETIC POLARITY

Accurate age dating in the Lake Albert basin is notoriously difficult. Palynology only dates outcrop to 'Plio-Pleistocene or Holocene' in age, and there are no tuffs. A potential alternative is to use palaeomagnetic reversals recorded as remanent magnetism in rift sediments. Field testing is currently underway on a method to measure palaeo-polarity in sediments *in situ* within hand augered holes using a small fluxgate magnetometer housed in a tube fitted with an Fe-Ni-Cr alloy magnetic shield.

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