Exploration on the Frontier: Towards an Understanding of the Albert Basin*

Paul Logan[1], Steve Curd[1], Bob Downie[1], Janice Weston[2], and Dave Shaw[3]

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[1]Heritage Oil & Gas, London, UK (pl@heritageoilltd.com)
[2]RPS Timetrax, Woking, UK
[3]Biostratigraphic Associates (UK) Ltd., Stoke-on-Trent, UK (d.shaw@ecqc.com)

Introduction and Exploration History

Situated in the western arm of the East African Rift Valley, the Albert Basin has seen an upsurge in exploration drilling in the past two years with a number of successful exploration wells. At the time of this writing, some 12 wells have been drilled in Blocks 2 and 3 over the past two years, all of which have been successful in encountering hydrocarbons. The drilling of the Kingfisher-1 well on the shores of Lake Albert, and the subsequent acquisition of a 3D seismic survey over the Kingfisher structure, supported by extensive 2D data coverage on the Ugandan side of the lake, has enabled a start to be made on unravelling the history of this Neogene lacustrine/fluvial basin.

The Albert Basin forms part of the western arm of the East African Rift Valley (EARV), lying on the western border of landlocked Uganda some 200 km northwest of Kampala (Figure 1), the greater part of the basin being occupied by Lake Albert. The northeast–southwest-trending basin is about 40 km across and over 200 km in length, covering an area of some 9000 km^2 and is flanked on both sides by high- medium-grade metamorphic rocks which form the steep flanks of the basin, rising 300-400 metres on the Uganda side and over 1100 metres in the Blue Mountains on the DRC side. Along the base of the basin margin, oil seeps were known to local inhabitants long before they were first documented by visiting British geologists in 1920.

Heritage Oil & Gas operates two blocks in Uganda's Albert Basin; situated in the western arm of the EARV, Blocks 1 and 3A together comprise over 12,000 km^2 and lie at the northeastern and southwestern ends of the basin, respectively (Figure 2). Heritage's involvement in Uganda began in 1997 with the award of Block 3. Exploration began with the acquisition of seismic data in 1999 and 2001, focused on the Semliki Flats area, to the southwest of Lake Albert. Also in 2001, Energy Africa farmed-in for 50% of the licence. Drilling began in 2002 with Turaco-1, which drilled to a TD of almost 2500 metres and was abandoned after encountering mechanical difficulties without encountering significant hydrocarbon shows. 2003 saw exploration move onto the lake itself with a joint regional lake 2D seismic survey, operated by Hardman Petroleum, then operators of Block 2. Turaco-2 was spudded in 2003 and encountered hydrocarbon shows, but they could not be tested due to mechanical problems. A large 3D survey was then acquired over the Turaco area; this confirmed the presence of a sizable structure, followed by the drilling of Turaco-3, effectively a re-drill of Turaco-2. The well encountered good quality reservoirs of Late Pliocene – Pleistocene age, but when tested, it produced a gas comprising c. 95% carbon dioxide, the remainder being methane.

The decision was subsequently made to relinquish the southern part of Block 3 and to focus on the northern part of the block (now Block 3A) around the southern part of Lake Albert. An intensive programme of soil and lake bed sampling, together with related geological studies, was considered to have reduced the risk of encountering further carbon dioxide accumulations sufficiently to encourage the drilling of Kingfisher-1 on the southeastern shore of Lake Albert during 2006/07. Success in this well and its associated sidetrack wells, which together tested at a cumulative rate in excess of 14,000 bbls oil per day (BOPD), has been followed recently by the acquisition of a 3D seismic survey over Kingfisher and the adjacent Pelican prospect and, more recently, the drilling of the successful Kingfisher-2 appraisal well.

The Kingfisher wells encountered a late Miocene – Holocene sequence totalling approximately 3000 metres in thickness, comprising interbedded sandstones and shales of apparent fluvial and lacustrine origin. Kingfisher-1 encountered a c. 12-metre oil-bearing zone of early Pliocene age at a depth of c. 1800 metres true vertical depth (TVD), before penetrating the basin margin fault at c. 2000 metres TVD, while Kingfisher-1A, sidetracked to the northwest, encountered three oil-bearing zones of late Miocene – early Pliocene age between 2180 and 2285 metres TVD. All four zones tested c. 30^{o} API waxy crude oil with a low gas-oil ratio. At the time of this writing, Kingfisher-2 is believed to have encountered three oil-bearing zones thought to be equivalent to those found in Kingfisher-1A, and it is awaiting production testing.

In Block 2, Tullow Oil has drilled a number of successful wells along the basin margin, all of which are thought to have penetrated reservoirs of Plio-Pleistocene age.

Structural Setting

The Albert Basin is a frequently cited as an example of a classic extensional tectonic regime, consisting of horst and graben structures associated with supposed approximate east-west extension. Many research papers allude to the extensional nature of the basin whether they are focused on the lithospheric modelling of the area or the recent structural development of the basin. Few of these address the formation of the nearby Ruwenzori Mountains, Africa’s highest non-volcanic mountains, nor do they necessarily incorporate earthquake focal mechanisms or simple observations of neo-tectonic structure, easily visible on satellite data.

Recent seismic data acquired in this basin demonstrates that the basin contains structures inconsistent with the simple notion that the basin results from east-west extension. Numerous examples of fold structures, reverse faults and flower structures attest to a tectonic setting that is dominated by strike-slip and transpressional or transtensional movements. Earthquake focal mechanisms suggest that the neo-tectonic period is dominated by strike-slip movement. Regional satellite data also shows that horsetail structures are typical of terminations to the fault systems in the basin and that the linearity of these faults is also suggestive of a strike-slip origin to the basin.

The recent seismic reflection data within the basin in combination with readily accessible neo-tectonic data strongly point to the strike-slip origin of the basin. In the Albert Basin, the basin geometries are revealed by more than 1000km of 2D data and several 3D surveys. The Kingfisher structure is revealed as a substantial compressional feature formed against the basin margin (Figure 3). The Turaco prospect, drilled in 2003, is mapped as part of a series of flower structures forming the Makondo fault in the southern part of the basin.

At the northeastern end of the Albert Basin, the Pakwach sub-basin deviates from the northeasterly trend of the Albert Basin to a more northerly heading. Recent seismic surveys within this area demonstrate that within this sub-basin the structures exhibit a more extensional character with normal fault-bounded blocks being the dominant structural target for the area. The combination of structural styles seen in the Albert Basin and the Pakwach Sub-basin suggests a sinistral sense of strike-slip movement along the axis of the Albert Basin. It is interesting to note that recent research based on GPS data postulates the presence of microplates in the East African region, notably the Victoria Microplate, roughly coincident with the Kenya Dome, which is thought to show clockwise rotation with respect to the Nubian Plate, the latter constituting the larger part of the African continent to the west. This rotation is consistent with the observation of sinistral offset along the Albert Basin axis.

Various mechanisms have been postulated to explain the Ruwenzori Mountains. For example, localised underplating and isostatic uplift were suggested for these mountains that rise to some 5500m: 3500m above the “rift” shoulders of the basin. Implicit in the observation of clockwise rotation of the Victoria Microplate is that the Ruwenzori Mountains are then more easily explained as a substantial pop-up structure on a restraining bend in the western arm of the East African Rift.

Basin History

The use of high-resolution quantitative palynology, the first time that such techniques have been applied in this area, has proved vital in understanding the climatic and depositional history of the sequence. The basin-infill sequence has proved to be younger than originally thought, comprising predominantly latest Miocene through Holocene sediments, although seismic data has revealed hints of what may be an earlier Karoo Basin.

Quantitative palynological data collected from the Kingfisher and Turaco wells at the southern end of Lake Albert and from outcrop samples has enabled regional vegetation trends to be recognised and correlated to climatic cycles/changes, related to the effects of the northern hemisphere ice ages and more locally to the effects of doming in East Africa. This in turn has provided a basis to establish a robust chronostratigraphic framework for these sequences, enabling accurate correlation across the southern Lake Albert area. The data collected have been attributed to their parent plants in order to derive an understanding of the local and regional vegetation change through time at these well locations. The sequences penetrated in these wells represent deposition in markedly different depositional settings; the Turaco wells representing predominantly alluvial plain and delta plain deposition in the Semliki Flats area in the southern part of the lake, while the Kingfisher wells represent deposition on the southeastern flank of the rifted basin under mainly lacustrine conditions. These different depositional settings are evident within the different palynofloras recovered, although overall regional vegetation trends can be recognised and correlated to climatic cycles/changes. These can be related to the effects of the northern hemisphere ice ages and, more locally, to the effects of doming in East Africa, which, when calibrated using occurrences of age diagnostic pollen, provides a basis for a robust chronostratigraphic framework. This has enabled accurate correlation across the southern Lake Albert area. The palynofloral characteristics are summarized below and in Figure 4.

Late Pleistocene – defined by an abundance of high-mountain derived pollen, particularly the conifer *Podocarpus* spp.;
Early Pleistocene – characterised by an abundance of savannah and bushland pollen and spores, particularly grass pollen;
Late Pliocene – typically characterised by the highest occurrence of the miospore *Peregrinipollis nigericus*.
Early Pliocene – characterised by a sharp decrease in savannah and bushland pollen and spores (particularly grass pollen), and by an increase in tropical forest pollen.

Recent work on palaeo-drainage patterns in western Uganda suggests that the River Nile has followed its present course from Lake Victoria to the northeastern end of Lake Albert for as little as 400,000 years. Prior to that time, it drained into the nascent and subsequently developing Albert Basin at its southern end. Such a late Miocene – Pleistocene proto-Nile may well have provided the sediment source for the reservoirs found in the wells drilled to date.

Geochemical analysis of well samples and recovered oils indicates the possibility of multiple source rocks, although, due to the marginal location of the wells drilled to date, no suitable candidates have been found. It is likely that subsequent drilling farther out in the lake will encounter these source rocks, probably in the latest Miocene sequence, thought to be a time of wetter climatic conditions and therefore lake highstand. At some 9000 km^2 in area, the basin is thought to be large enough to have generated several billions of barrels of oil. Burial history analysis suggests that generation and migration is ongoing, as is supported by the many active oil seeps around the basin and the presence of proven oil accumulations.

Conclusion

At the time of this writing, 12 wells have been drilled in Blocks 2 and 3 over the past two years, all of which have been successful in encountering hydrocarbons. This astonishing success rate shows that the Albert Basin has the potential to be a world-class example of a petroleum province.

Figure 1. Location of Albert Basin.

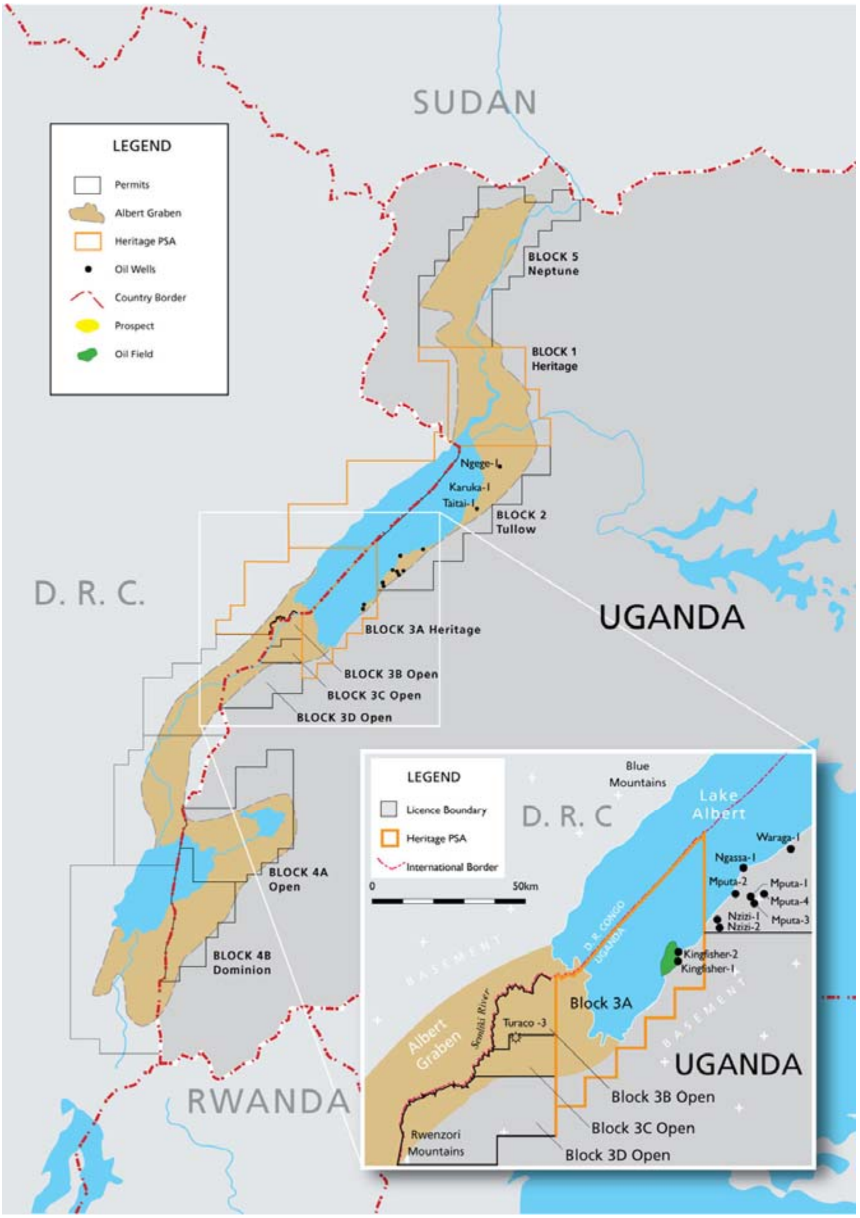

Figure 2. Location of Kingfisher discovery.

Figure 3. 3 D seismic line across the Kingfisher discovery.

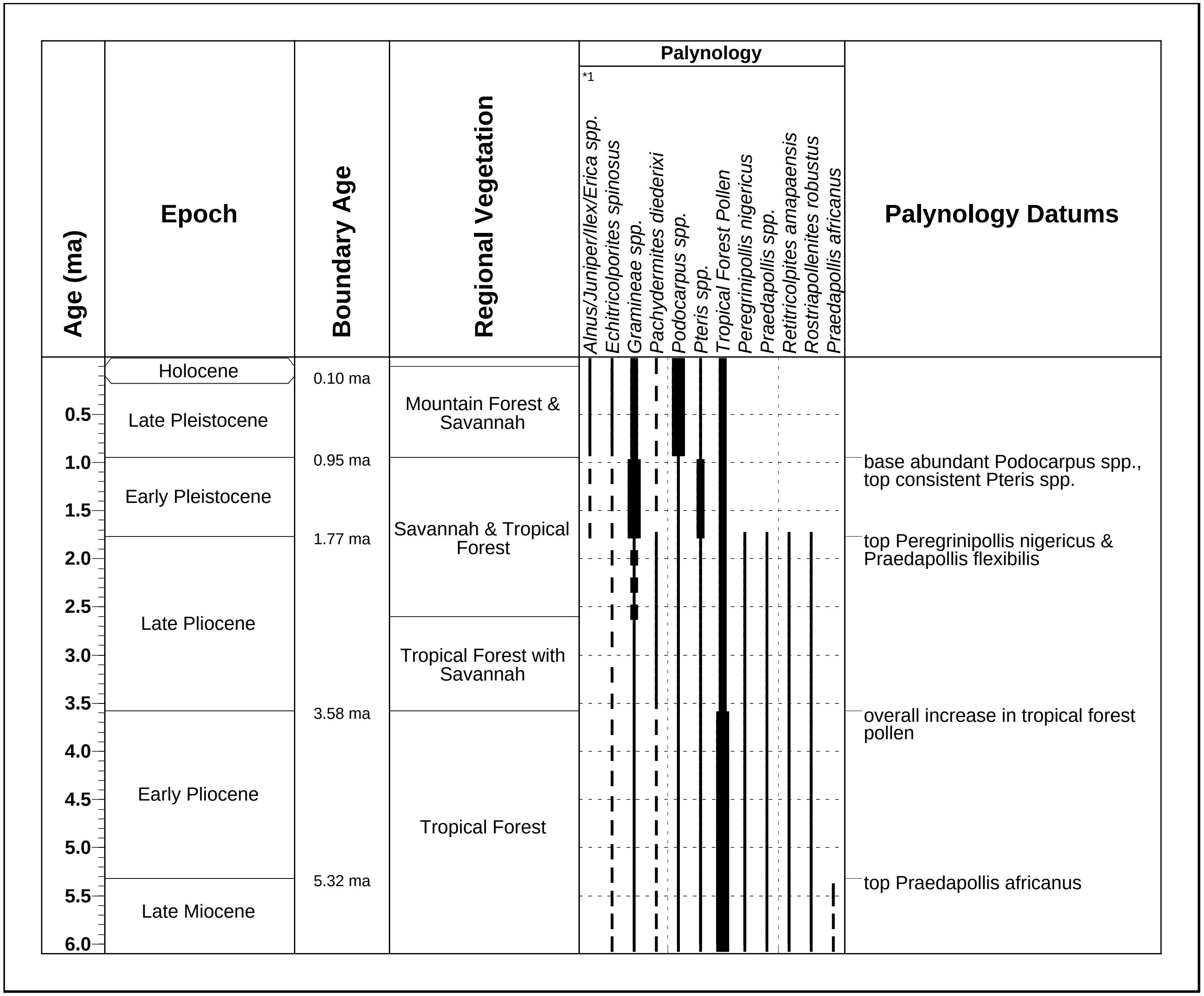

Figure 4. Principal palynology ranges and datums, and regional vegetation for the Late Neogene of the Lake Albert area.

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