Tarsands & Bitumen
Exploration opportunities in Nigeria
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GEOLOGICAL SETTING

BENIN (DAHOMEY) BASIN
Tarsands occurrences in the Benin (Dahomey) Basin are restricted to the eastern portion of the basin (the Okitipupa structure) and are contained in generally Upper Cretaceous sediments. These sediments onlap on the crystalline basement complex rocks of Precambrian age. The Benin Basin constitutes part of a system of West African margin basin developed during a brief period of rifting in the late Jurassic to Early Cretaceous, associated with the Benin Trough Complex. It was accompanied by an extended period of thermally induced basin subsidence through the Middle to Upper Cretaceous to Tertiary times as the South American and African plate entered a drift phase. The onshore portion of the basin covers a broad arc-shaped profile approximately 2600km, attaining a maximum width of 65km at the basin axis along the Nigerian border with the Republic of Benin. It narrows to about 25km west and eastwards. It is along its north eastern fringe (the Okitipupa Structure) that a band of tarsand (oil sand) and bitumen seepage occurs.

THE CRETACEOUS STRATIGRAPHY
The interplay of sedimentation and eustatic sea level fluctuation of normal faulted graben and horst structures of the basin floor (goeblocks) have produced thick accumulations of sediments within the grabens accompanied by sediment bye-pass and extensive cut and fill structures at or near the shelf margins.

THE UPPER CRETACEOUS
These sediments are predominantly terrigenous clastics with clay/shale and sand intercalations. Bands of biogenic limestone and calcareous shaly beds developed on the highs. Sufficiently anoxic conditions prevailed leading to accumulations of dark-gray to bluish-green micaceous shales and clays containing glauconitic grains and biogenic pyrite.

THE LOWER CRETACEOUS
These sediments range from feldspatic sandstone with admixture of ferruginised conglomeratic sequence, comprising very coarse, sometimes pebbly to fine gritty clastic with partly weathered feldspar crystals. The sandstones are trough-cross bedded but sometimes massive, generally poor to poorly sorted. The claystones are very silty, micaceous and grayish. Thin bands of almost pure white kaolinitic clays occur. The entire cretaceous succession has been grouped into 3 formational units, the Ise Formation (Neocomian - Albian), Afowo Formation (Cenomanian - Coniacian) and Araromi Formation (Maasstrichtian - Danian).
BITUMINOUS OCCURRENCES

Surface Occurrences
Extensive bituminous seepages and sediments impregnated with tarry oil define a narrow band about 5-8km wide between latitude 60°37’N and 60°48’N, stretching from just East of Ijebu-Ode town (Ogun State) to the banks of the tributaries of the Siluko River at Ofosu Village in Edo State, an approximate distance of 110km. It is covered by the following Federal Survey sheets 280, 280A, 281, 281A, 282 and 283.

They occur in two (2) different forms:
- As seepages in farmlands (seen only on hot days) from the underlying sandstone reservoir. As surface and near surface impregnated sediments exposed along road cuts, cliff faces and river banks and at break of slopes.
- With the exception of road cut exposures, most of these seepages and surface/near surface impregnated sediments occur in geographic positions not easily accessible.

Sub-surface Occurrences
Sub-surface occurrences of bituminous sands and heavy oils are known from flows and shows in drilled and cored wells in the onshore, coastal and offshore areas of the basin. Most of these wells (now abandoned) penetrated horizons with highly viscous hydrocarbons at relatively shallow depths.
Two main horizons generally referred to in reports as Horizon x and y have been encountered within depths of 100m, along latitude 6°36’N.

General Borehole Sequence
There is significant variation in litho-facies types across the tarsand belt and in vertical thickness of sequences penetrated up to 130metres depth. Average stratigraphic profile shows the following:

Top Lateritic Layer
This unit varies in thickness from 1.5m to 8m with variation in thickness reflecting the composition of the original material. It may be overlain in places by a relatively thin layer of humic soil.

Upper Shale/Limestone Layer
Thickness varies from 3m to 55m (south of the outcrop zone).

Upper Bituminous Sediments - Horizon X
Thickness ranges between 9m and 22m, comprising varying lithofacies: coarse to medium to fine-grained sandstone with interbeds of sandy clays, (1-2m thick). Medium to fine-grained sediments tend to be fossiliferous.
**Shaly Unit**
This unit varies in thickness from 6m -15m with an average of 8m. Shale is dark-gray, fossiliferous, but may be silty in places and may be bituminous.

**Lower Bituminous Sediments Horizon Y**
Thickness varies from 3m eastwards to about 23m westwards. Litho-facies types are variable.

**Basal Sediments**
This sequence directly rests on weathered crystalline basement rocks. Litho-facies types may be conglomeratic, coarse-grained, arkosic, or gritty sandstone. Thickness varies from 1m to 2.5m. It is generally devoid of bitumen, and seem to be the main aquiferous horizon, which may be artesian to sub-artesian.
The significant differences in measured depth to crystalline basement and sediment thickness suggest faulting both along strike and dip of the basin floor.
Flash Point 89°F
Pour Point 20°F
Softening Point 47°F
Penetration Point 80 to 100

**Chemical**
- Saturates 22 - 24%
- Aromatics 12-19%
- Resins I & II 39 - 44%
- Asphaltene 9 - 18%
- Naphta (a) Olefins and Aromatics90%
- (b)Parafins and Naphthene
- Total Acid number 6.3-9.6
- Trace Metals Nickel 33 - 36ppm
- Vanadium 25 28ppm
- Sulphur 1.3%
- Mol Wt558 667
- Calorific Value 43,000KJ/Kg

Graphical display of grain sizes
Bituminous Sediments
Analysis of the bituminous bearing sediments show extreme lithofacies variation and bitumen concentrations, indicating that the singular control on bitumen saturation and distribution relate to facies changes as influenced by depositional condition. Bitumen saturation for successive oil foot interval range between 16wt % to as low as 2wt %.

Four (4) litho-facies types have been recognised within the outcrop band and to depths of 130m. Parameters for characterisation include: dominant grain size, clay percentage and degree of bitumen saturation.

These are:
  i) silty sands,
  ii) coarse to medium-grained sands,
  iii) clayey sands, and
  iv) arkosic sands.

Thus, litho-facies distribution maps are important in maximising mining and extraction technologies to be applied.

Physio-Chemical Properties
Physical
Bitumen Content Average 12wt %
API Gravity 14.6 to 5.3, Avg 9.4
Specific Gravity 0.204 to 1.837, Avg.0.968
Breaking Point (after Fraas) 10°C
Drip Point (after Ubbelohde) 58°C
Flash Point 89°F

Resource Potential
Exploration work on a 17sqkm area has allowed projection on possible resource volume.

- Estimated probable reserves of bitumen by open cast mining method within Ondo State in a 4.5km x 55km area is 16billion barrels.
- Estimated probable reserves of bitumen and heavy oil (open cast mining and In-situ technics) within Ondo State in a 4.5km x 55km area are 42billion barrels.
- Probable reserve of bitumen and heavy oil in the entire belt 110 x 4.3km is expected to double that expected for Ondo State.

Available Documentation
- Topographic Maps on scales of 1: 500,000; 1:250,000 and 1:50,000 on the basin.
Comparative Characteristics With Athabasca Oilsands And Heavy Oil Deposits

Both the Nigerian and Athabasca oilsands compare favourably on the following:

I) Water wet nature of the sand grains.
II) Textural parameters.
III) Oil saturation.
IV) General chemical properties. (However, the Nigerian tarsands are more asphaltenic (17.9 to 29.7wt % with lower aromatic and sulphur content).

The close similarities of these two deposits suggest that the Canadian experience can be used as a model for developing the Nigerian deposit.

In addition, there are significant advantages over the Canadian deposit that gives it added advantage, which include:

- Medium to good sorting of the sand grains
- Lower clay content and amount of fines.
- Higher bitumen content.
- Absence of tarsand stress due to deep incumbent loads.
- Manageable basal aquifer devoid of the need for depressurisation.
- Smaller volumes of gas that dissipates through the boreholes.
- Lower heavy metal content.

Thus, the Nigerian tarsands and bitumen have some potentials for easy development, namely:

- Amenability to gravity assistance.
- Potential for steam assistance.
- Amenability to open cast mining.
Market Prospect and Application

The only source of bitumen at present in Nigeria is the Kaduna Refinery which processes imported heavy crude. This is insufficient for domestic needs, thus, Nigeria imports bitumen to supplement her internal production. Extracted bitumen from the tarsand belt can be used as feedstock for the Kaduna Refinery; and for setting up other bitumen processing units to meet both domestic and West African sub-regional needs.

The bitumen is uniquely aromatic and naphthenic in composition, thus can be used for the manufacture of naphthenic base stocks for industries specializing in critical application products.

Heavy and extra-heavy crude can be extracted from the Nigerian tarsands. This can be upgraded to synthetic crude oil or syncrude specification tailored as feedstock to refineries. Sulphur and phenol can be derived from it.

Laboratory tests have shown that specification grade grease within NLGI classification number 3 and 2 (i.e. soap and clay based respectively) suitable as lubricants for plain and roller bearings, and as sealant can be made from the tarsand’s oil.

Project Possibilities

Three potential project types (PPT) are envisaged for the tarsand resources.

(i) Small Scale Project: Asphalt Concrete (Strip Mining)
- Suitable for small-size scale prospect, using specification bitumen as a major component for road asphalt.
- Short-term execution period of three (3) years using strip-mining techniques.
- Production level: 150,000 metric tons/year.
Bidders will obtain EPL and later Mining Lease (ML) or Quarrying Lease (QL).

ii) Medium-sized Project: Synthetic Crude production-(In-situ Mining)
- Mining at depths below 150m using enhanced oil recovery technique (EOR)
- Time frame: 5 years
- Suitable for companies having foreign partners with technological know-how.
- Successful bidders will be granted EPL
- Projected production: 10,000 bbls/day

iii) Large-size Project: Mega Mining Project (Open Mining)
- Focus on tarsands activity within 30-50m of overburden
- Open cast mining method
- Major experienced companies to invest in exploitation and full feasibility evaluation prior to commencement
- Requires periods of about 15 years to develop
- Expected to produce modules of 50,000 bpd of synthetic crude for export
- Processing by water/solvent extraction method.

Process Technology Options
The similarity in textural parameters and chemistry of the deposit to those of Athabasca make it easy to transfer process technologies with minor modifications to accommodate subtle differences.

Adaptable process options include:
- Cold water process (OSLO)
- Hot water process (Clark method)
- Solvent process
- Oil agglomeration process
- High temperature retorting (LR) process

There are several other technology options currently being experimented, including some combination of the above. All options are geared towards achieving cost effectiveness and environmental acceptability.

Environmental Considerations
Major environmental elements to be considered include:
- The general low topography, lush vegetation, high rainfall, high humidity and dense drainage.
- The coincidence of the tarsands belt with a belt favourable for vegetable oil and rubber tree cultivation.
- The high level of groundwater, low permeability of soil, localised flooding and swamps.
- Occurrence of localised pressured bottom waters below the tarsand horizons
Legal Regime
Tarsands and bitumen exploration and production in Nigeria is classified as Mineral Fuels, and governed by the Federal Government National Policy on Solid Minerals.

New Policy
A new mineral policy that will encourage greater private sector participation in an environment of orderly and sustainable development for the exploitation of solid minerals resources.

The focus of this new policy is to take full advantage of the increased international commodity prices and the global resurgences of exploration activities and:

- Achieve a substantial increase in GDP contribution by the minerals sector;
- Generate quality geoscience data;
- Formalise Artisanal and Small Scale Mining (ASM) operators;
- Achieve poverty reduction through ASM operations;
- Generate employment opportunities;
- Create wealth through value addition;
- Increase capacity of mineral based industries; Attract private investment capital;
- Facilitate capacity building opportunities in the solid mineral sector.

2. Signing into law of a new Minerals and Mining Act, 2007 to ensure security of tenure, competitive fiscal terms and the encouragement of an industry led by private investors

EMERGING PROSPECTS FOR INVESTMENT IN THE TAR SANDS RESOURCES

Previous attempts at attracting investors to the tar sand resource of Nigeria (1990s, 2002-2003, 2006) have either produced investors who lacked the technical capability and financial muzzle the types required for a subsector like the tar sand's or those who wanted the blocks for other purposes other than development.

The defunct Bitumen Project Implementation Committee between 2002 and 2005 drilled 16 coreholes in Blocks 1 and 2 of the belt. Out of the 16, 5 penetrated bituminous sands at depths varying from 60 to 94.83m. The average thickness of the pay zones was found to be 6m.

With the country’s return to democracy in 1999, Government commenced a major reform of the economy. A major focus of the reform was the privatization of most Government interests in all the sector of the economy. Importantly, the reform in the solid mineral’s subsector transformed the nature of Government participation from that of owner-operator to administrator-regulator.
With greater availability of data and in fulfillment of government’s privatization drive, the bitumen belt was delineated into six prospective blocks with an average of 600km² each in area extent.

To further generate more stratigraphical data, the BPIC between January 2006 and September 2007 drilled 33 core holes in Blocks 5 and 6. Ten of the wells penetrated various thicknesses of bituminous sands at depths varying from 6.4 to 81m. The average thickness of bituminous pay zones was found to be 7m. The other 23 sites were drilled in the southern fringes of the belt where bituminous sands are known to exist at depths beyond 150m, nearing those for heavy crude accumulation.

To date, four of the blocks (1, 2, 3 and 4) have been sold to investors. Two blocks 5 and 6 are to be placed for bidding in the immediate future.

Abundant investment opportunities abound in the subsector as some of those who won the four privatized blocks are desperately in need of partnering with reputable outfits having required technology and access to finance. Government is also reviewing the entire sales and purchase procedure for blocks to make participation easier and development achievable. Government has created a favourable climate for business and industries ventures. Infrastructures have improved, administrative and bureaucratic procedures are being streamlined while exchange control regulations have been liberalized to ensure a free flow of international finance. There is now unrestricted movement of investment capital.

Certain basic facilities favourable for conducting business exist in the country. These include

- A fairly developed infrastructure such as road network, deep ocean ports and jetties.
- A network of gas and oil pipelines
- Improved communication system
- Dynamic banking community
- Relaxed foreign exchange for capital raising
- Large local and sub-regional market for bitumen sales
- Existing joint venture opportunities
- A large community of geoscientists and engineers
- A commitment to privatisation

Above all, the government of Nigeria recognizes the fact that an enabling political environment must be put in place to attract foreign investment into the country. To this effect, Nigeria is continuously striving to improve on its political and economic stability, accountability in government spending, and divesting of government concerns under a democratic setting.
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