GEOLOGICAL ANALYSIS OF OIL SANDS CORES
ZONE VI BEMOLANGA OIL SANDS

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ABSTRACT

The province of Alberta – Canada owns the biggest non conventional hydrocarbon fossils in the world. Named the Athabasca oil sand deposit, Canada may be self sufficient in petroleum consumption with oil crude from Alberta. The reserve assessment as well as the mining production, bitumen extraction process using the hot water process is well developed for the Athabasca oil sands since 1970.

Bemolanga deposit has been estimated to more than 250 km². Geological and mining study was mainly carried out by the French Petroleum Company (SPM) since 1950 in the zone VI of about 6 km². This zone VI with its DRIEZ quarry seems the most interesting zone because of its high bitumen content (up to 12% by weight).

The probable bitumen reserve was estimated for 3 billion tons for the entire zone and on 1960, feasibility study for producing non conventional crude was undertaken by the SPM using hot water process but the project didn't get through and replaced by the Tamatave refinery which imported crude from everywhere (Algeria, USSR, etc.), starting to process light crude from middle east to end up with medium crude from Russia. Since that time, Madagascar have always imported his crude oil to be treated in that refinery and self sufficient in white products such as gasoline, gasoil, jet fuel and heavy products (fuel oil and bitumen). The excess heavy products such as fuel oil were sold to La Reunion, to Mauritius and to Comoros.

On 1980, the Malagasy government decided to undertake for his own the Bemolanga project in the aim of producing crude from tar sand bitumen. The studies were focused on the zone VI and concern the geological, geochemical and the mining aspect for the future exploitation.

All the analyses were carried out at the High School of Polytechnic in Antananarivo, at OMNIS and at the Alberta Research Council-Canada laboratories in Edmonton.

Thus this paper is related to geological and geochemical assessment of the four wells drilled into the zone VI to understand the source rocks behavior and to get better knowledge of the geology of the bituminous sands deposit within the Bemolanga area.

Cores from four wells drilled in zone VI of Bemolanga oil sands deposit are described on lithologs which one example is attached in this paper.

The average oil saturation (w/w) from the four wells is as follows:

- ANK 140 bis : 5,32 %
- ACD 141 bis : 7,79 %
- SACD 142 bis : 6,43 %
- NPA 143 : 6,87 %

None of the wells penetrated the entire thickness of the oil saturated section. The bitumen is contained in predominantly fine to medium gained, cross-bedded, lithified sandstones of the basal ***Isalo II*** sandstones.

Palynological examination of two shale beds indicates an ***upper Triassic*** (Rheatic) age for the sandstones. In the cores and outcrops examined, the predominant cementing agent are calcite and carbonate in the large modules and

small patches; clay minerals in small paths and/or as a general cement binding the rock together; and silica, mainly in the form of quartz overgrowths on sand grains.

NNW-SSE trending dykes cut through the oil sands. These dykes post-date the emplacement of the oil in the sandstones. .

It is thought that the Isalo II sandstone were deposited in a fluviatil sandstone, which by its very nature produces a complex facies pattern that is characterized by a lack of lateral continuity of individual sands on shale unit.

None of the sand bodies found in the core could be correlated from one well to another. Because of the nature of depositional environment of the Isalo II sandstones, delineation drilling for future mine exploitation as to be carried out on smaller grid pattern.

Based on the overall study we have carried out, followings are suggestions for the future prospection on Bemolanga oils sand deposit:

- 4 to 5 km grid in essential non explored areas, mainly in the northern of the deposit
- 2 km grid in the areas known to be underlain by oil sands
- 150 m grid for main planning and ore body delineation.
- All cores should be fully cored and logged with geophysical well logs.
- A detailed depositional model should be established for the Isalo II sandstones.
- A detailed mapping program should be undertaken to map the dykes that cut the oil sands.
- Further geological and geochemical study should be undertaken on the available cores to get better knowledge of the geology of the Bemolanga oil sands and Tsimiroro deposits.

Key words: geological, geochemical, mining, Zone VI, Driez quarry, bitumen, dykes, Isalo, Karroo, sandstones, lithologs.

INTRODUCTION

This paper summarizes geological investigations of four wells sand cores from wells drilled in the zone VI of Bemolanga oil sands deposit.

These cores are from the following wells (figure 1):

ANK 140 bis
ACD 141 bis
SACD 142 bis
NPA 143

Some of outcrops of Bemolanga oil sands in the near zone VI were also examined for the familiarization of lateral variability of the oil sands.

An example of observational data on the geology aspect as well as lithologs on the cores is attached in this paper.

The main focus of this paper is the confirmation of the age and the depositional mode of the Bemolanga tar sands deposit and the recommendations for the future works to be undertaken prior to the exploitation of the resource.

Almost of the cores are consumed for the chemical and geochemical analysis in the Laboratories, nevertheless news cores should be taken for future investigations on geology, geochemistry and chemistry study as well.

We may notice that the use of the term « Oil sand » in the paper would not be correct and it should be rather called « Oil- sandstones » because the oil occurs in the consolidate rocks, which, when the oil is extracted, retains its texture. The term « Oil sands » is retained because as cumbersome as « oil sandstone »;

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A. *GEOLOGY*

Very few of published papers exist on geology of Bemolanga oil sands. Some of them which were cited in the references are very old and gave just an overview of the oil sands deposit and the general geology of the surrounding areas. Prior to 1990 non published specific geological papers would exist but there are some reports specifying about or have sections on some general aspect of geology of western Madagascar and may include descriptions of oil sands deposit. Some non published reports address themselves specifically to the Bemolanga oil sands deposits, its geology and development and are the most useful background material we used for. Some of them are kept by their owners as non published and confidential reports

Most of geological information in these reports can be classified as general matter and of a reconnaissance nature. Before the resources of the Bemolanga area can be exploited, more detailed geological work will have to be done.

General geology [1], [2], [3], [4]

The Bemolanga oil sands are found in the upper sandstones of the ***Isalo II*** formations and are of ***Upper Triassic(Rhéatic)*** age.

The sequence in the Bemolanga area correlates with the ***Karroo*** sequence of Africa. On a regional scale, the Bemolanga area is located on an arch or hinge line, which separates the Majunga Basin in the south.

The basement rocks in western Madagascar consist mainly of gneisses' and migmatites of ***Precambrian*** age. In the Bemolanga area these are overlain by 450 to 550 meters of ***Permo-Triassic*** sandstones and shale of the ***Sakamena*** formation. An unconformity separates the ***Sakamena*** beds from the ***Isalo I and II*** formations. The Isalo beds consist of sandstones and shale and are up to 900 meters thick in the Bemolanga general area.

Overlying the ***Isalo*** in the ***Middle to upper Jurassic Folakara*** series which also consist of interbedded sandstones and shale.

Two episodes of faulting have affected the Bemolanga area. The first was ***pre-Isalo*** and only affected the ***Sakamena*** beds. The second probably the ***late Cretaceous*** age (approximately 83 years ago affected all the strata currently exposed in the Bemolanga area.

These second generation faults trend primarily NW-SE and in the ***Isalo II*** beds where most of bitumen is found. The maximum displacement is in the order of a few tens of meters. The other structural feature is in a gentle dome, which appears to have been the controlling factor in the accumulation of the bitumen.

In addition to the faults, which will affect the extraction of the resource, the Bemolanga oil sands are cut by NNW-SSE **trending dolerite dykes**. These dykes of ***low cretaceous*** age are near vertical, vary in thickness from a few decimeters to several meters and can be several kilometers in length. [5]

Intrusion of the dyke was post oil emplacement, because the bitumen has been coked along the contact with the dykes up to several dyke-widths away from the dykes.

The exact location of these dykes and the coked zone adjacent to the dykes will have to be mapped in great detail before the ne plans and ore body reserves can be established.

The dykes and the coked bitumen represent waste zone and complicate the mining of oil sands. In that selective mining techniques will have to be used. Also, because the dolorite dykes are harder than the oil sands, different mining equipment and/or techniques may have to be used to remove them.

geology of oil sands

In the review that follows references are made to core photographs, a complete suite of which is submitted to this paper. Referral to these photographs is by well name depth or depth range e.g. (ANK 13.0 - 13.5m) .

Isalo I [6]

Only a small portion of the total resource of Bemolanga oil sands is found in the ***uppermost sandstone of Isalo I*** formation. Some outcrops of Isalo I was seen at some places of Bemolanga such as on the Bekolosa River near the village of Ambararatabe where three meters of poorly saturated sandstone were exposed.

The sandstone is variable in grain size but predominantly medium to coarse grained and argillaceous. Sedimentary structure was difficult to discern, but the outcrops appears to be horizontally to very low angle cross-bedded. The outcrop is cut by a dyke approximately 1.5m wide. This dyke is badly weathered and actually softer than the adjacent sandstone. Coking of the oil sand does not appear to have more than 0.5 m from the dyke margin.

Basal clays

Uncomfortably overlaying the ***Isalo I*** sandstone are the basal clays of ***Isalo II***. These are black lignitic clays with interbeds of lenticular siltstone and very fine sandstone.

There is some calcareous horizon in these clays and beneath the upper one globular presumed to be calcified lithisted sponge remains have been found. In the upper part of the clays, the color changes to green and the clays grade to the Isalo II sandstone. This clay horizon varies in thickness from 0 to 50 m, thickening from east to west. [7]

None of the well we drilled penetrates the basal clays; however, the SACD 142 bis well (25.0 to 25.3 m) may have reached the transition between the basal clays and the ***Isalo II*** sandstones.

Isalo II [3, 6]

The basal Isalo II sandstones form the main reservoir body for the Bemolanga oil sands deposit.

During the coring program, only part of the lower oil saturated sandstone unit of the ***Isalo II*** was penetrated. Above these sandstones unit there is shale bed, which in turn is overlain by oil saturated sandstone.

The upper saturated sandstone was not cored or examined in the outcrop. Consequently the remarks made about ***Isalo II*** from this, point on and will only refer to the lower saturated sandstone.

The basal ***Isalo II*** sandstone contact with the basal clays is gradational over an interval of 2 m. This gradational contact is exposed in a little gully going into the Ambararata River approximately 150 m south of Bemolanga camp.

The basal clay grade upward into interbedded siltstone and shale, very fine to fine laminated sandstone, and then into the typical cross-bedded ***Isalo II sandstone***.

The main body of basal Isalo II sandstone varies in thickness from 30 to 80 m . The sandstone is primarily fine to medium grained with some medium to coarse grained bed (ANK 140 bis 27.62 m – 36.50 m).

At the base, shale clasts and coarse and very coarse grains are common and the sandstone appears to have a bimodal distribution.

Cross-bedding is the dominant sedimentary structure throughout the impregnated sandstones. Most cross-bedding is low angle. However high angle cross-bedding is not uncommon. [8]

Ripple marks are another rare sedimentary structure with the best examples found in NPA 143 (9.8 m - 10.25 m).

Two shale beds were found n the core ANK 140bis (12.92 -13.06 m). They were examined for their micro faunal and micro floral content. Only micro flora was found indicating an ***Upper Triassic*** (Rheatic) age of a continental mode of deposition. Thus on the basis of grain size variations , sedimentary structure and the contained micro flora of the shale, a continental fluvial environment of deposition for the basal Isalo II sandstones is envisaged. At any one locality the sandstone may represent either an single fluvial cycle (the result of one river channel) or a series of stacked channels (the result of a series of superimposed river channels. The fluvial interpretation is strengthened by the lack of horizontal continuity between cored wells.

This absence of lateral continuity is a characteristic feature of fluvial deposited sediment sediments.

The establishment of a depositional model for the oil sands is important, in that it can guide the exploration and the delineation drilling by predicting where the main sand bodies occur. For example to the south of zone VI, the Isalo II becomes shalier and is not bitumen saturated. This can be explained by a fluvial depositional model, in that this area south of zone VI is outside of the main channel trend.

The basal Isalo II sandstone consists mainly of angular quartz and feldspar grains with minor mica. Three types of cement are found in two visible mode of occurrence. Cement occurs as scattered small paths (NPA 143, 27.00 m – 29.00 m) as a large nodules, which is core looks like cemented bed (ANK 140 bis, 32.8 m, SACD 142, 7.0 m, SACD 142 bis, 9.7 m, NPA 143, 10.0 m).

These nodules of cement were found in outcrop at only one locality (Mitsiotaka quarry).

The large nodules are invariably calcareous and differences in their appearance are the most likely the result of slight differences in micro porosity, or their argillaceous content (NPA 143, 10.0 m). [9]

The small scattered paths of cement, so well exemplified in the last 2.5 m of the NPA 143 core can be composed of calcareous cement, clay cement (predominantly kaolinite) or siliceous cement in the form of quartz overgrowths.

To these two visible modes of occurrence, another mode of diffuse cement occurs within these sandstones and is the cause of their lithification. This cement is believed to be predominantly clay cement of varying composition, but including kaolinite, illite, chlorite, montmorillonite and interlayer mixtures of these clays.

B- PALYNOLOGICAL STUDY [10]

To confirm the age of the strata encountered in the wells, some microfloras studies were carried out mainly along the SACD 142 bis cores and ANK 140 bis cores. We came up to the following conclusion that the typical ***Jurassic (Liassic)*** species are not present in this assemblage. The age of the strata inferred from the recorded species is ***Upper Triasssic (Rheatic).***

There is no marine micro plankton present in the samples. The large number of the megaspores present in the samples indicates a continental, possibly a fluviatile mode of deposition.

Hereunder are the detailed microfloras recorded during the study of ANK 140bis (13 m – 15 m).

- Annulispora sp. (M. Triassic to Jurassic)
- Guttulapollenites sp. (U. Permian to U. Triassic of Madagascar, Goubin, 1965)
- Ovalispollis sp. (L.M.U. Triassic)
- alskaisporites sp. (U. Triassic)
- Deplexisporites gyrates Playford and Dettman, 1965 (Rheato-Liassic of S. Australia)

For SACD 142 bis, 21.8 m, 22 m, 25.3 m

- Cordasporites sp. (L.M.U. Triassic)
- Verrucosisporites sp. (Permian and Triassic)
- Klausipolenites sp. U. Triassic)
- Samaropolenites sp. (U. Triassic of Madagascar, Goubin, 1965)
- Ovalipolis sp. (L.M.U. Triassic)
- Aratrisporites sp. (L.M.U. Triassic)
- Hortispoorites sp. (U. Triassic of Tasmania)
- Camerosporites socatus Leshik, 1965 (U. Triassic)
- Aratrisporites tenuispinosus Playford, 1965 (Triassic)

C- CONCLUSION

The Bemolanga oil sand deposit is from Upper Triassic (Rheatic) age with continental, possibly a fluviatile mode of deposition. It is recommended that a petrographic and digenetic study be undertaken for the Bemolanga oil sands as this can shed light on the occurrence of distribution of the cementing agents.

These cementing agents will in part dictate the mining plan as they directly affect the grindability of the oil sands. Therefore a thorough knowledge of the occurrence and distribution of these cements is essential of development of the resource.

A geochemical study of the oil, and the effects of the intrusion dolerite dykes have had on the oil sands, should also be done, in order to ascertain when the oil was trapped in the reservoir, in what form it was trapped (an immature oil or a mature light oil) and how it was degraded to its present form (water washing? biodegradation? thermal effect resulting from the dyke intrusions?.

These questions may rather seem academic; however, the results of above mentioned studies could influence the economics of the extraction plant.

APPENDIX

- Figure-1: Location map of Bemolanga oil sand deposit and location of the studied four wells
- SACD 142 bis Well description, an example for core lithologs.
- Stratigraphic scale

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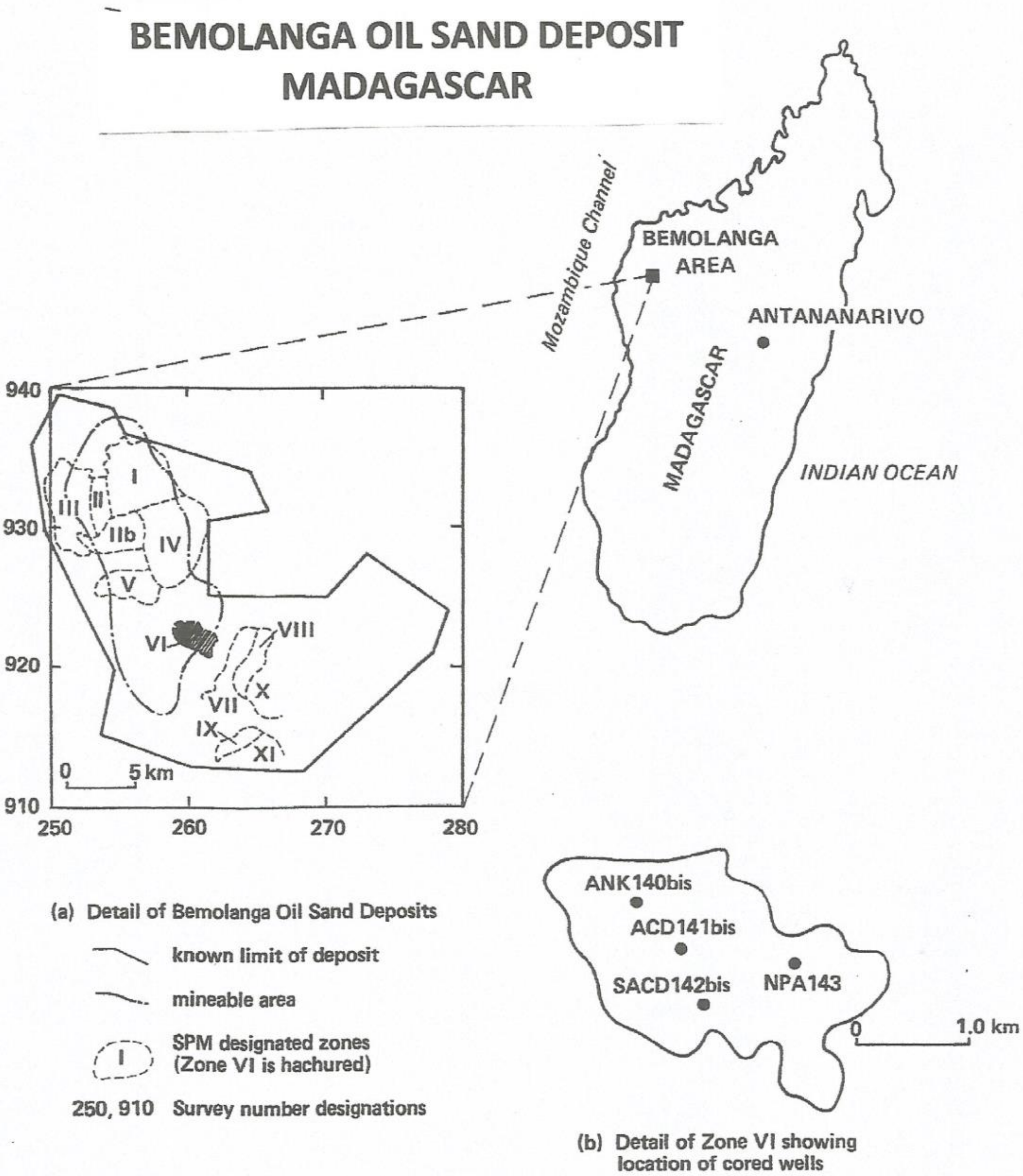
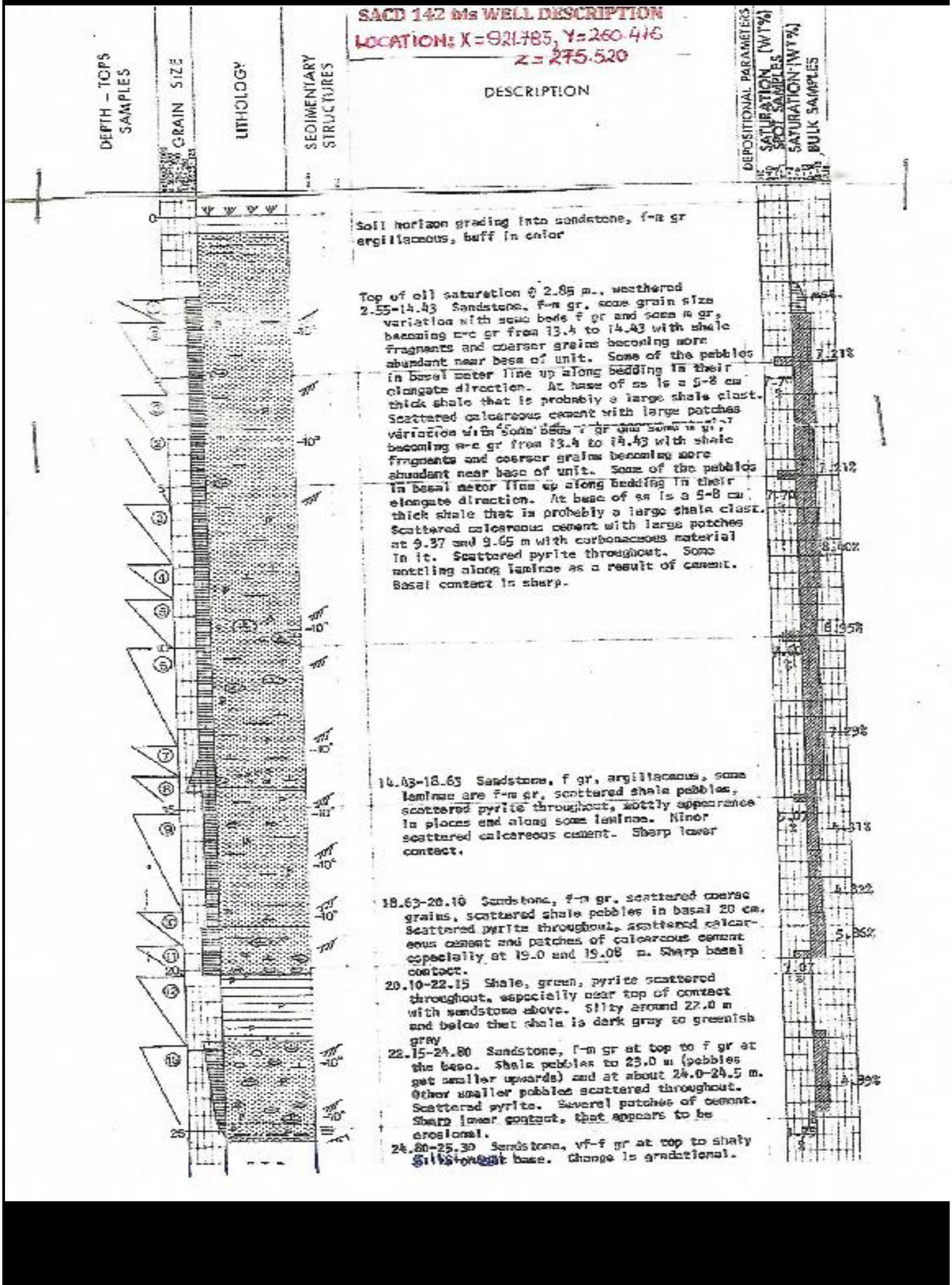
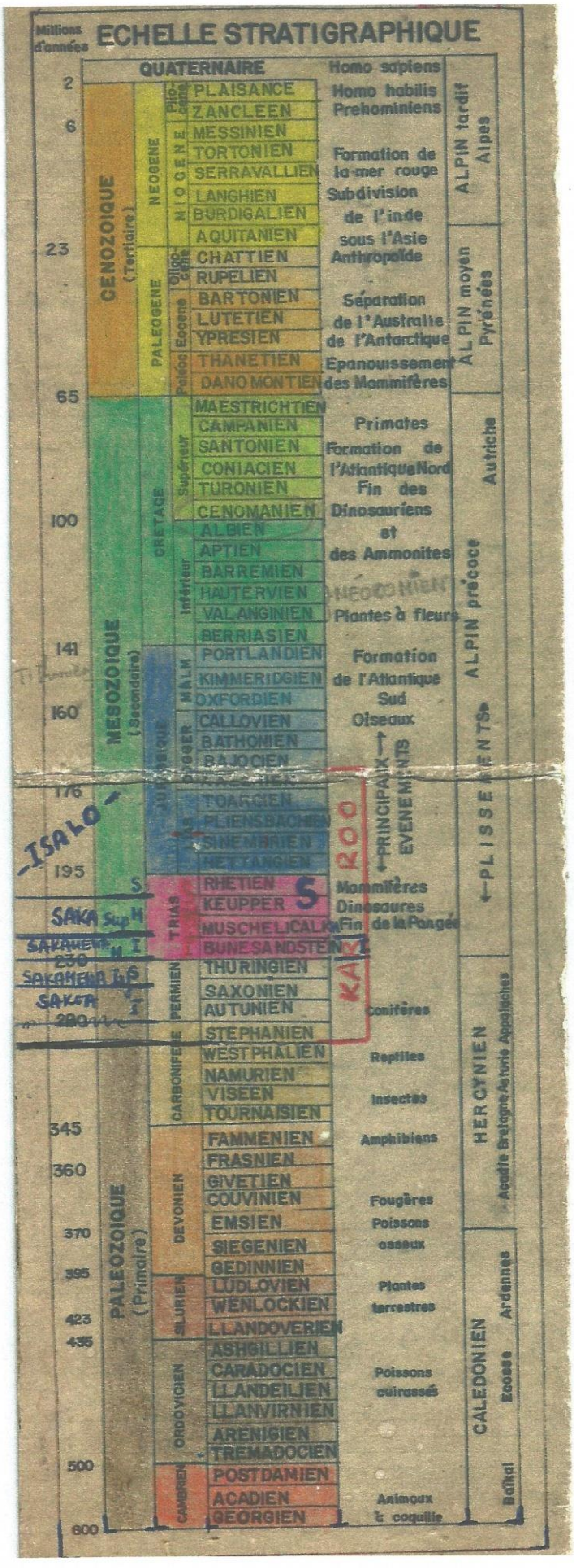


Figure-1 : LOCATION MAP OF BEMOLANGA OIL SAND DEPOSITS IN MADAGASCAR AND LOCATION OF CORED WELLS IN ZONE VI OF BEMOLANGA OIL SAND DEPOSITS


SACD 142 bis WELL DESCRIPTION
LOCATION: X=921.785, Y=260.416
Z=275.520
DEPTH – TOPS SAMPLES
GRAIN SIZE
LITHOLOGY
SEDIMENTARY STRUCTURES
DESCRIPTION
DEPOSITIONAL PARAMETERS
SATURATION SPOT SAMPLES (WT%)
SATURATION (WT%) BULK SAMPLES
Soil horizon grading into sandstone, f-m gr argillaceous, buff in color
Top of oil saturation @ 2.85 m., weathered
2.55-14.43 Sandstone, f-m gr, some grain size variation with some beds f gr and some m gr, becoming m-c gr from 13.4 to 14.43 with shale fragments and coarser grains becoming more abundant near base of unit. Some of the pebbles in basal meter line up along bedding in their elongate direction. At base of ss is a 5-8 cm thick shale that is probably a large shale clast. Scattered calcareous cement with large patches at 9.37 and 9.65 m with carbonaceous material in it. Scattered pyrite throughout. Some mottling along laminae as a result of cement. Basal contact is sharp.
14.43-18.63 Sandstone, f gr, argillaceous, some laminae are f-m gr, scattered shale pebbles, scattered pyrite throughout, mottly appearance in places and along some laminae. Minor scattered calcareous cement. Sharp lower contact.
18.63-20.10 Sandstone, f-m gr, scattered coarse grains, scattered shale pebbles in basal 20 cm. Scattered pyrite throughout, scattered calcareous cement and patches of calcareous cement especially at 19.0 and 19.08 m. Sharp basal contact.
20.10-22.15 Shale, green, pyrite scattered throughout, especially near top of contact with sandstone above. Silty around 22.0 m and below that shale is dark gray to greenish gray
22.15-24.80 Sandstone, f-m gr at top to f gr at the base. Shale pebbles to 23.0 m (pebbles get smaller upwards) and at about 24.0-24.5 m. Other smaller pebbles scattered throughout. Scattered pyrite. Several patches of cement. Sharp lower contact, that appears to be erosional.
24.80-25.30 Sandstone, vf-f gr at top to shaly siltstone at base. Change is gradational.
7.21%
7.21%
8.40%
8.95%
7.29%
4.31%
4.83%
5.85%
4.89%



Millions d'années
ECHELLE STRATIGRAPHIQUE
QUATERNAIRE
Homo sapiens
Homo habilis
Prehominiens
CENOZOIQUE (Tertiaire)
NEOGENE
PALEOGENE
PLAISANCE
ZANCLEEN
MESSINIEN
TORTONIEN
SERRAVALLIEN
LANGHIEN
BURDIGALIEN
AQUITANIEN
CHATTIEN
RUPELIEN
BARTONIEN
LUTETIEN
YPRESIEN
THANETIEN
DANO MONTIEN
Formation de la mer rouge
Subdivision de l'inde sous l'Asie
Anthropoïde
Séparation de l'Australie de l'Antarctique
Epanouissement des Mammifères
ALPIN tardif Alpes
ALPIN moyen Pyrénées
MESOZOIQUE (Secondaire)
CRETACE
MAESTRICHTIEN
CAMPANIEN
SANTONIEN
CONIACIEN
TURONIEN
CENOMANIEN
ALBIEN
APTIEN
BARREMIEN
HAUTERVIEN
VALANGINIEN
BERRIASIEN
Primates
Formation de l'Atlantique Nord
Fin des Dinosauriens et des Ammonites
NEOCOMIEN
Plantes à fleurs
Autriche
ALPIN précoce
PORTLANDIEN
KIMMERIDGIEN
OXFORDIEN
CALLOVIEN
BATHONIEN
BAJOCIEN
TOARCIEN
PLIENSBACHIEN
SINEMURIEN
HETTANGIEN
Formation de l'Atlantique Sud
Oiseaux
PRINCIPAUX EVENEMENTS
PLISSEMENTS
ISALO
KAROO
TRIAS
RHETIEN
KEUPPER
MUSCHELKALK
BUNTSANDSTEIN
Mammifères
Dinosaures
Fin de la Pangée
SAKA
SAKAMENA
PALEOZOIQUE (Primaire)
PERMIEN
THURINGIEN
SAXONIEN
AUTUNIEN
CARBONIFERE
STEPHANIEN
WESTPHALIEN
NAMURIEN
VISEEN
TOURNAISIEN
Conifères
Reptiles
Insectes
Amphibiens
DEVONIEN
FAMMENIEN
FRASNIEN
GIVETIEN
COUVINIEN
EMSIEN
SIEGENIEN
GEDINNIEN
Fougères
Poissons osseux
HERCYNIEN
Acadie Bretagne Asturie Appalaches
SILURIEN
LUDLOVIEN
WENLOCKIEN
LLANDOVERIEN
Plantes terrestres
ORDOVICIEN
ASHGILLIEN
CARADOCIEN
LLANDEILIEN
LLANVIRNIEN
ARENIGIEN
TREMADOCIEN
Poissons cuirassés
CALEDONIEN
Ardennes
Ecosse
CAMBRIEN
POSTDAMIEN
ACADIEN
GEORGIEN
Animaux à coquille
Baïkal