

# **The Oil Migration Pathway and Hydrocarbon Charging History of Petroleum Systems in Termit Basin, Eastern Niger\***

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Search and Discovery Article #80560 (2016)\*\*

Posted November 28, 2016

\*Adapted from poster presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 16-22, 2016

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## **Abstract**

Termit Basin, located in southeastern Niger, is a Mesozoic-Cenozoic continental rift basin in West and Central Africa Rift System. Little commercial oil has been discovered, except on the Paleogene Dinga faulted terrace in Termit Basin during about forty years from 1970. The position of hydrocarbon kitchen, the oil migration pathway, the hydrocarbon-charging history of petroleum systems in Termit Basin is urgent issues for further exploration outside the Paleogene Dinga faulted terrace. To figure out these problems, oil-source correlation based on biomarker parameters of special polycyclic aromatic hydrocarbons were used to confirm the constituents of petroleum systems. Homogenization temperatures of fluid inclusions combined with burial-thermal history of individual well were taken to define the hydrocarbon charging time of reservoirs, and 2,4-/1,4-dimethyl-dibenzothiophene with other oil migration tracers were used to trace the oil migration pathway and the location of hydrocarbon kitchen of petroleum systems. Results show that oil samples in the Termit Basin can be divided into two oil families; the first family mainly comes from the source rocks of Yogou Formation, and the second family is from source rocks of Sokor Formation. Reservoirs of Sokor Formation from well Agida-2 and Goumeri-2 and Yogou Formation from well Koulele D-1 have been charged once during 8~2Ma and 4~0Ma, respectively. The absolute content of the methyl-dibenzothiophene decreases gradually with the migration distance increasing. In conclusion, petroleum systems in Termit Basin include Sokor-Yogou(!) and Sokor-Sokor(!). The oil charging of petroleum systems occurred in late Miocene to late Pliocene(8~2Ma) and early Pliocene-Quaternary(4~0Ma). The 2,4-/1,4-DMDBT can be used as an effective geochemistry parameter for tracing oil-charging pathway to predict the location of hydrocarbon kitchen. The general orientation of oil filling is from the southeast part of Moul sag to its surrounding. Therefore, it can be predicted that the source kitchen of Termit Basin should be in the southeast part of Moul sag.

## **Introduction**

Termit Basin is a Mesozoic-Cenozoic continental rift basin in West and Central Africa Rift System ([Figure 1](#)). Only a little commercial oil was discovered, except on the Paleogene Dinga faulted terrace in Termit Basin since 1970.

On the basis of the interpretations structures on the top of Paleogene Sokor1 Member and differences in tectonic features, Termit Basin can be divided into six secondary structural units Dinga fault-terrace, Dinga sag, Araga graben, Fana low-uplift , west-Yogou slope and Moul sag.

Main source rocks for oil accumulation discovered in this basin are marine mudstones of Upper Cretaceous Yogou Formation ([Figure 2](#)). The majority of lacustrine source rocks from Sokor Formation is in immature stages. The majority of oils discovered in the Termit Basin were derived from marine mudstones of the Upper Cretaceous, and three sets of reservoir-forming assemblage were vertically developed in this basin. They are the Lower Cretaceous, the Upper Cretaceous, and the Paleogene assemblages. Some oils were derived from lacustrine source rocks of Paleogene Sokor Formation.

### Division of Oil Populations

Termit Basin has 4 distribution patterns of n-alkanes. The gas chromatograms of saturate hydrocarbon of the crude oils can reflect the distribution patterns of n-alkanes and the acyclic isoprenoids ( primary pristane and phytane ) ([Figure 3](#)). The distribution of *Acyclic isoprenoids*, *Hopane series*, *Sterane series*, *Triaromatic dinosteroids*, and *methyl-triaromatic steroids*. *TAS* are used as indicator of source deposition environment and make oil-to-oil correlation. The distribution patterns of tricyclic and tetracyclic terpanes ([Figure 4](#)), and the distribution of gammaceranes ([Figure 5](#)) can be used for oil-to-oil correlation.

### Oil Migration Pathway and Hydrocarbon-Charging History of Termit Basin

Five pay zones in Sokor 1 are E1~E5 from top to bottom. 2,4-/1,4-dimethyl-dibenzothiophene (2,4-/1,4- DMDBT), and maturity parameter  $T_m/(T_m+T_s)$  are selected to trace the oil migration pathway of Termit Basin. ([Figures 5](#) and [6](#)). [Figure 7](#) is diagram of PH/Pr-GA/C<sub>30</sub> in Termit Basin crude oils.

#### 2,4-/1,4- DMDBT ([Figures 8](#) and [9](#))

Based on the thermodynamic stability and hydrogen bond mechanisms, alkyl-dibenzothiophene molecular ratios, 4-/1-MDBT, 2,4-/1,4- and 4,6-/1,4-DMDBT, are used to characterize organic maturity and oil migration, which can act as molecular tracers for the filling orientation and pathway in oil reservoir. Dimethyldibenzothiophene has 3 dimethyldibenzothiophene isomers (DMDBTs); i.e., 1,4-, 2,4- and 4,6-DMDBTs and can also be used as effective maturity indicators.

A DBT molecule is composed of two benzene rings with one five-membered thiophene ring. According to molecular thermodynamic stability, methyldibenzothiophene isomers, which have substituent groups in different carbon potential in benzene ring, show difference in thermostability-- descending order: C-4>C-2>C-3>C-1. As the maturity increases, alkyl DBTs parameter 4-/1-DMDBT, 2,4-/1,4- DMDBT and 4,6-/1,4-DMDBT are with the maturity increasing .

## **Ts/(Ts+Tm)**

The oil-charging pathway can be confirmed by the direction of parameter values  $T_s/(T_s+T_m)$  decrease progressively. When many isolines intersected parallel, the inflection point which projected forwards indicate the preferential migration passage.

### **The Timing and Episodes of Oil Filling ([Figures 10](#) and [11](#))**

### **Reconstruction of Burial History and Thermal History ([Figures 12](#) and [13](#))**

The reconstructed burial and thermal history of individual well are key factors in converting reservoir-forming temperature to hydrocarbon accumulation geological age. Using Basin Mod-1D basin modeling software, the burial and thermal history of well A-2, Gou-2, K-2 can be reconstructed.

Fluid-inclusion observation, combined with stratigraphic burial and thermal history of single well can confirm the timing and episodes of oil filling and entrapment. The measured vitrinite reflectance can constraint and correct Burial and thermal history, and make sure the stratigraphic burial history and thermal history is relatively accurate, then get the more reliable accumulation time

## **Conclusion**

### **(1) Oil classification**

Oils in Termit Basin can be divided into two oil families. The majority of the oils belong to Group I, and the oils of this group are mainly derived from the source rocks of Cretaceous Yogou Formation, whereas oils in Group II mainly include the oils from wells DD-2 (Sokor), D-1 (E0) and T-1 (E0), and derived from Paleogene Sokor Formation.

### **(2) Oil-charging pathway**

Filling points are close to well GE (E1), well GSE (E2, E3), well DD-1 (E4~5). Filling point 1: Oil migrated along GE→GO one-line dominant migrating pathway. Filling point 2: Regard well GSE regarded as a center to form a circle, oil migrated to the surrounding area. Filling point 3: Well DD-1 regarded as a center to form a circle, oil migrated to the surrounding area. The potential source kitchen is located on the middle and southeastern part of Dinga sag.

### **(3) Oil-filling and entrapment timing**

Based on the homogenization temperature data of fluid inclusions, combined with burial-thermal history for individual wells, this study concluded that oil reservoirs of Sokor Formation from wells Agadi-2 and Goumeri-2 in the Termit Basin has been once charged. The oil filling and entrapment event occurred at 8~2Ma, equivalent to late Miocene to late Pliocene. The oil reservoir of Yogou Formation from Well Koulele D-1 has been also once charged. The oil-charging event occurred at 4~0Ma, corresponding to early Pliocene to Quaternary.

### **Selected References**

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Wan, L., J. Liu, f. Mao, and B. Liu, 2014, The petroleum geochemistry of the Termit Basin, Eastern Niger: *Marine and Petroleum Geology*, v. 51, p. 167-183.

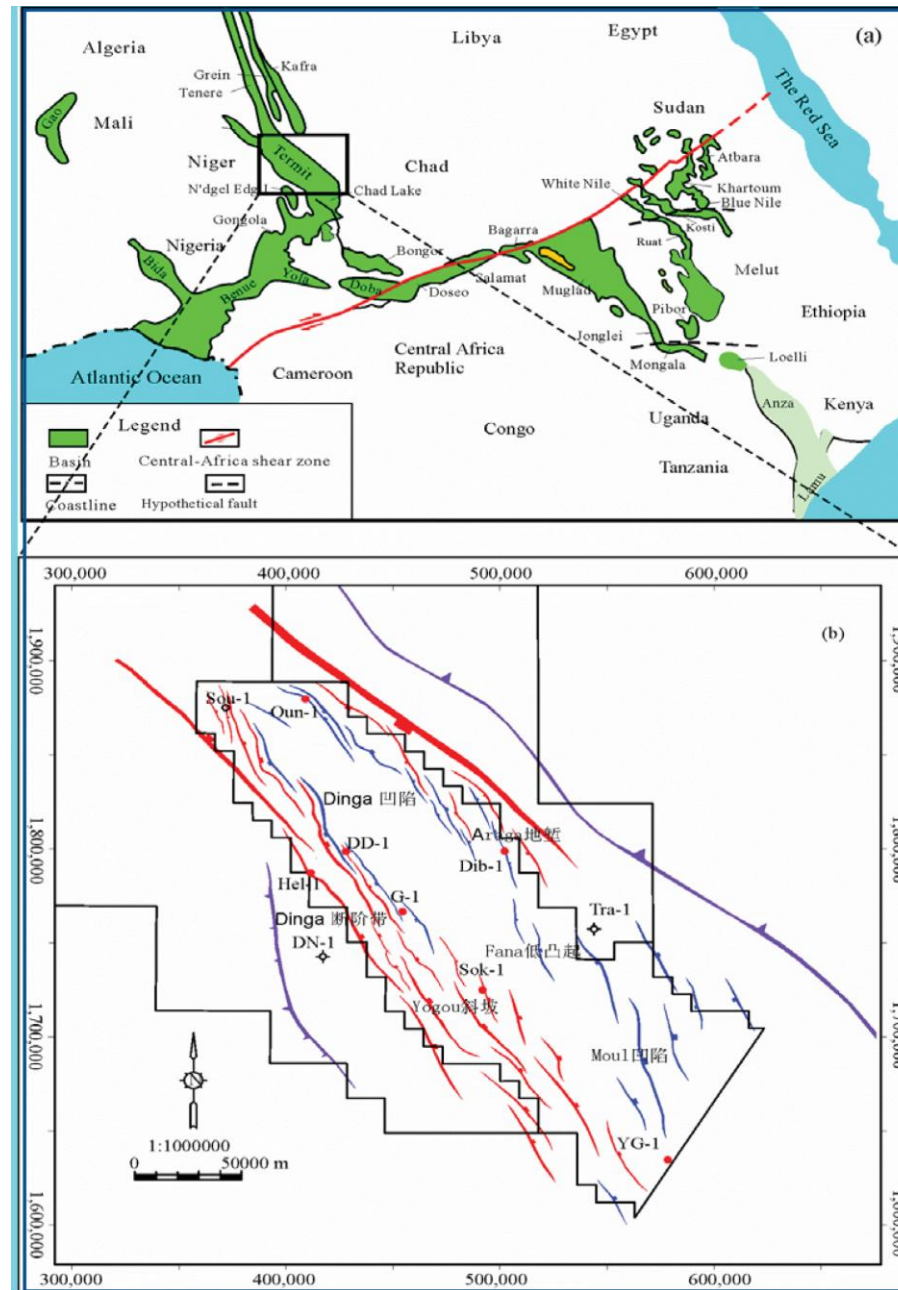


Figure 1. Generalized geological map showing (a) the location, and (b) outline of sedimentary basin architecture and schematic structures of the Termit Basin, Niger (after Wan et al., 2014).

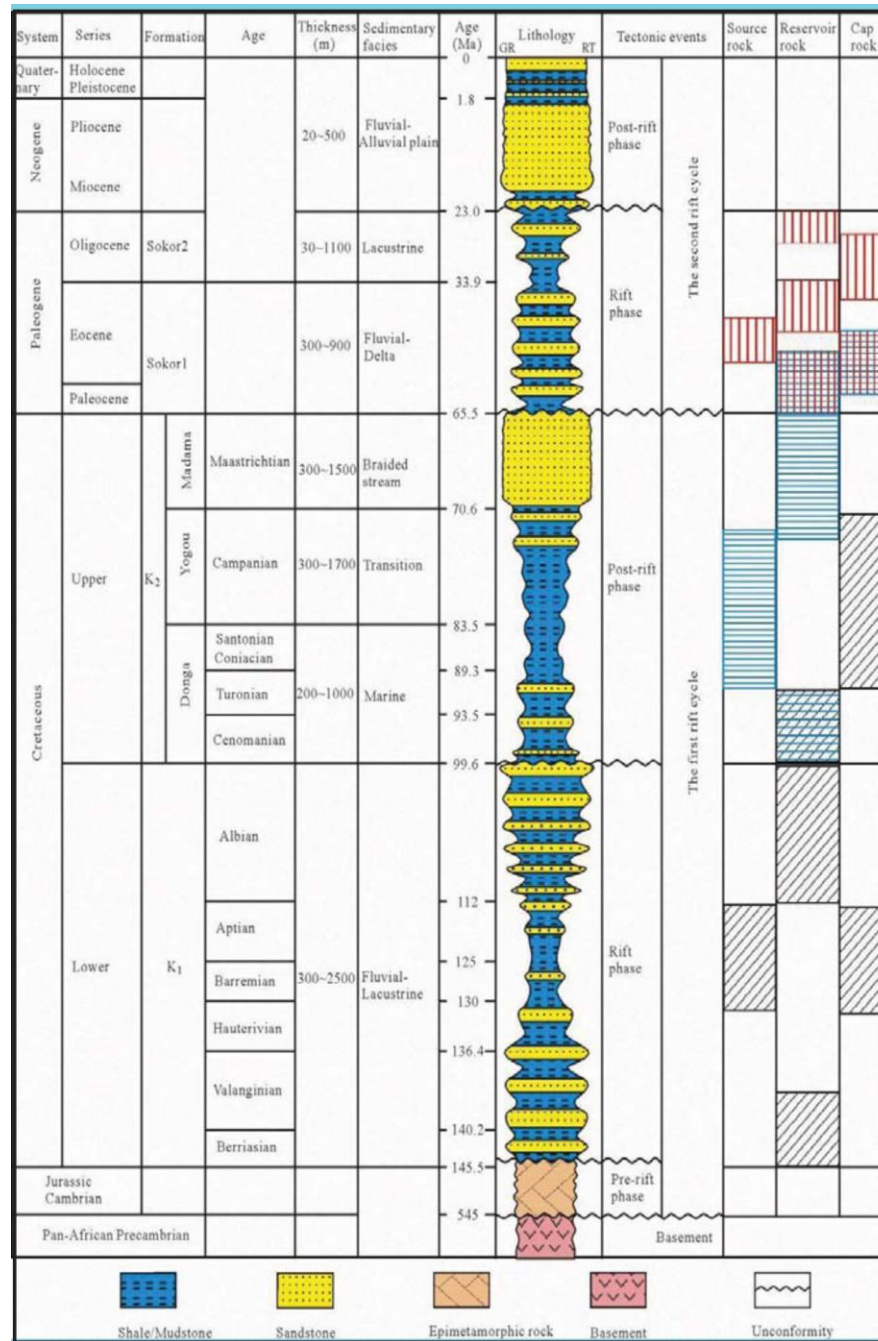


Figure 2. Generalized stratigraphy and tectonic events and source-reservoir-cap assemblage of the Termit Basin, Niger.

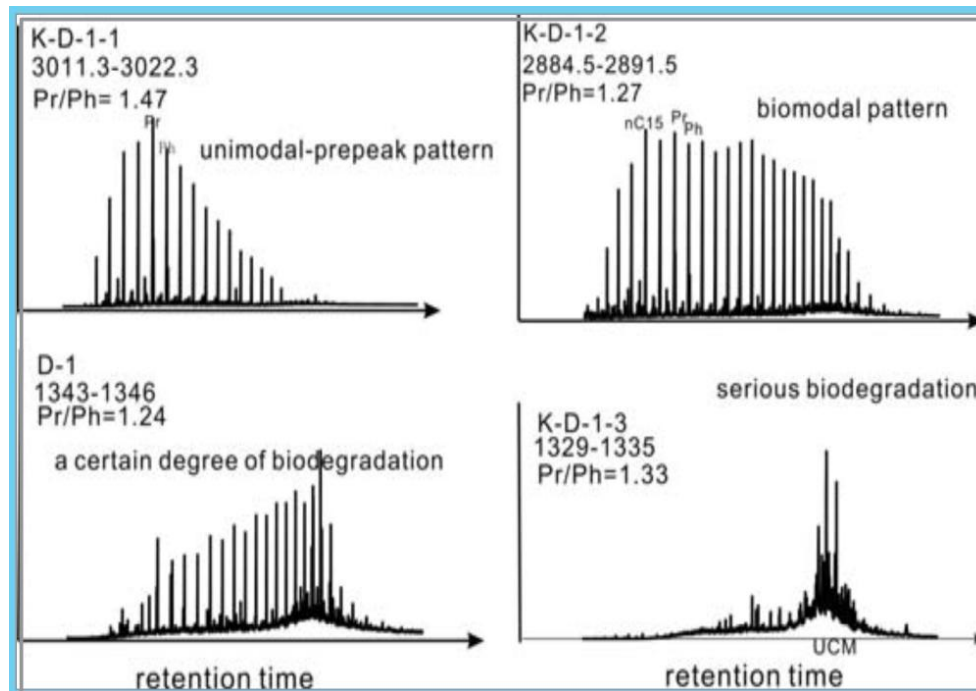
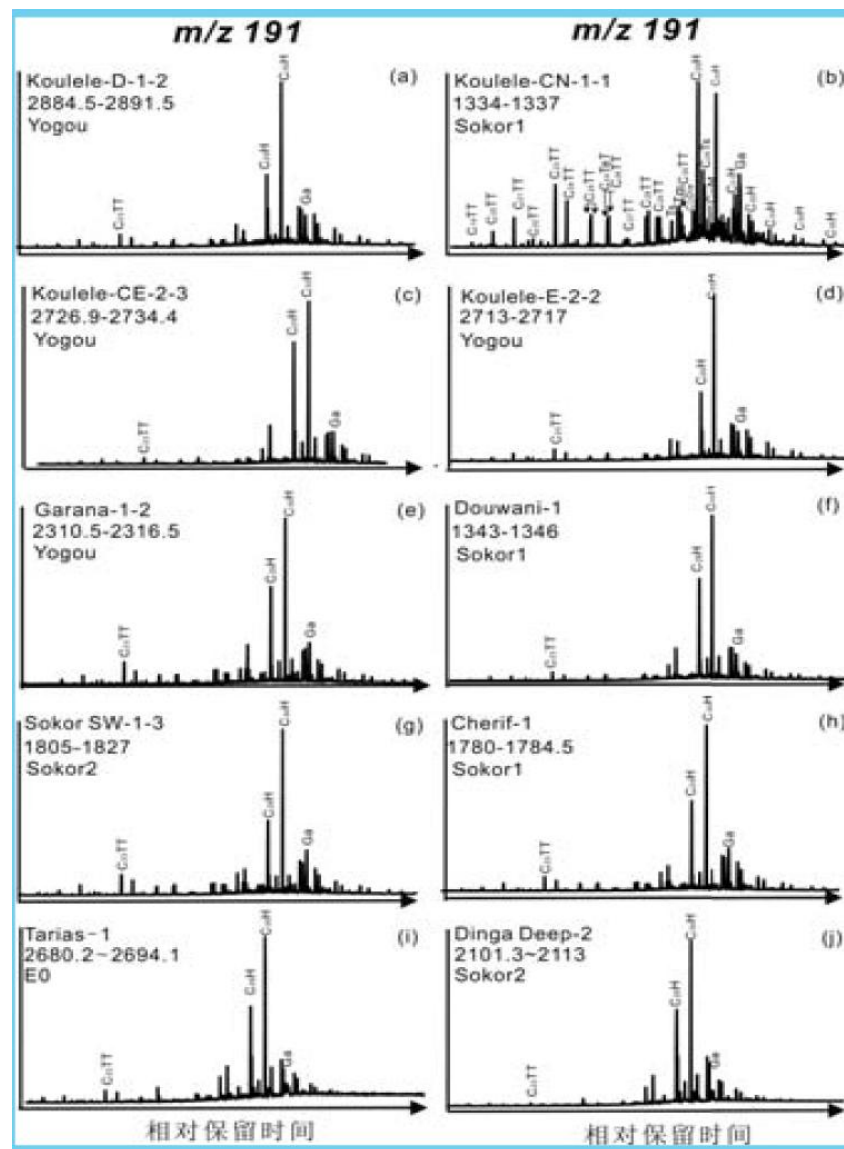


Figure 3. Chromatogram of saturated hydrocarbons of crude oils from Termit Basin.



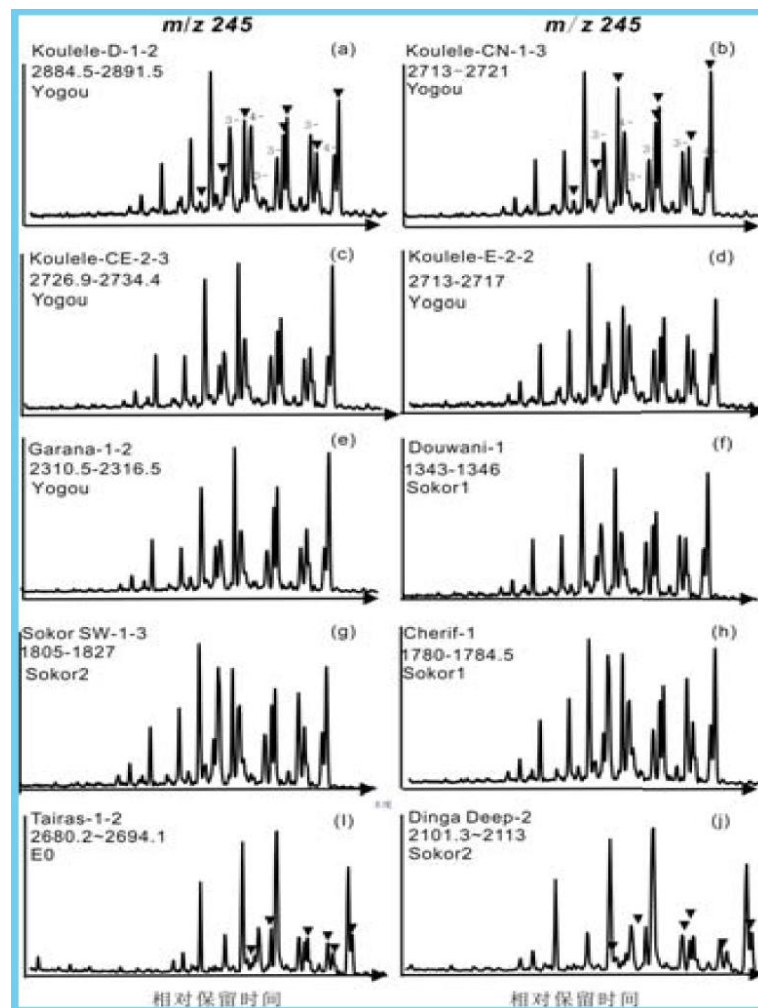


Figure 5. Triaromatic dinosteroids and methyl-triaromatic steroids distributive characteristics of crude oils from Termit Basin ( $m/z$  245).

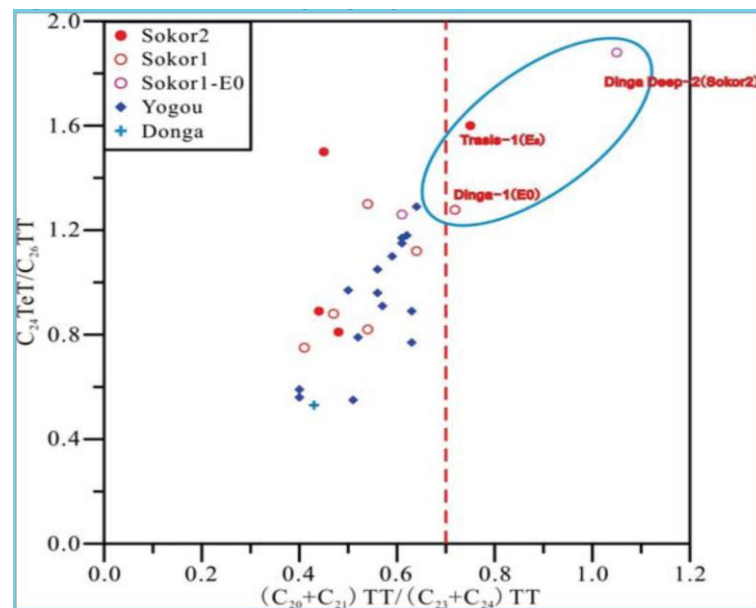


Figure 6.  $C_{24}TeT/C_{26}TT - ((C_{20}+C_{21})TT)/((C_{23}+C_{24})TT)$  diagram of crude oils from Termit Basin. Note: TT: tricyclic terpane, TeT: tetracyclic terpane.

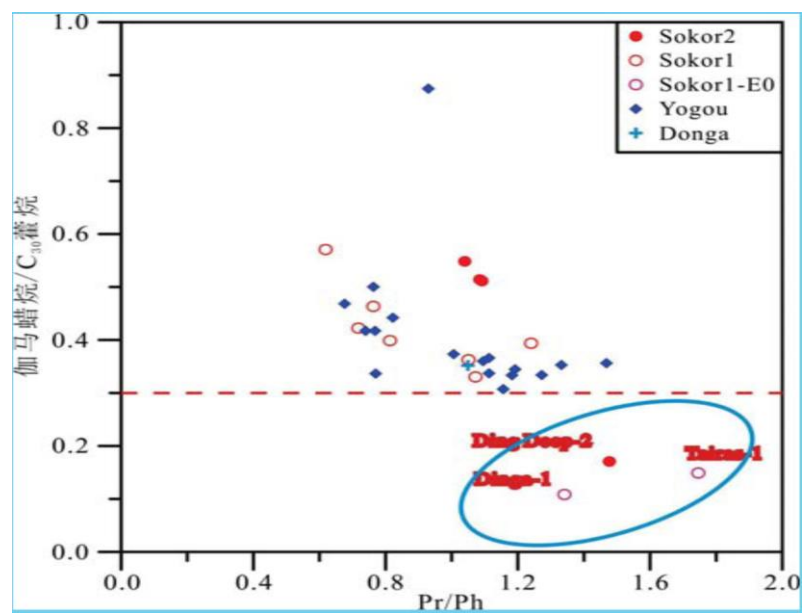


Figure 7.  $Ph/Pr-Ga/C_{30}$  diagram of crude oils from Termit Basin.

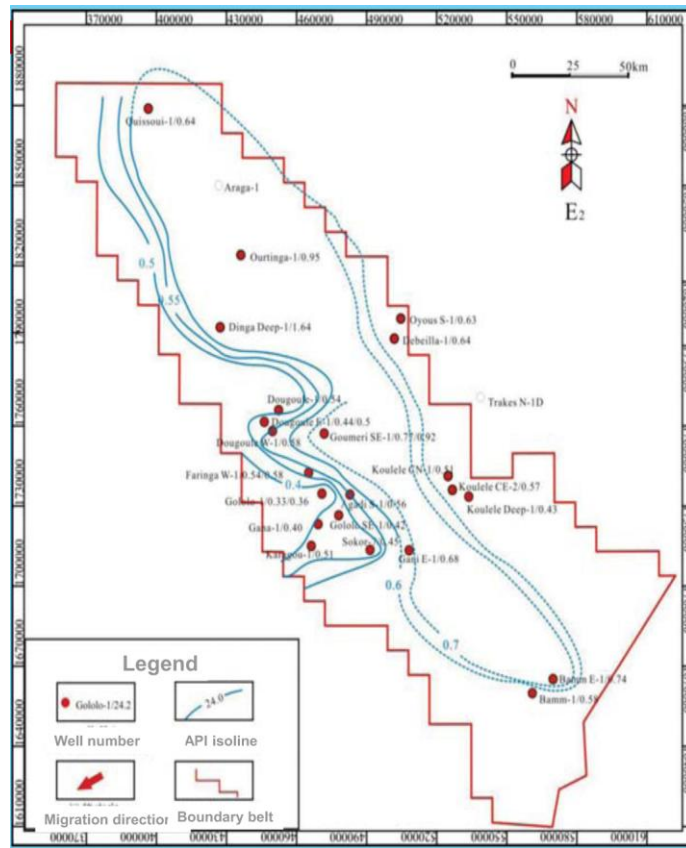


Figure 8. Contour map of the 2,4-/1,4-DMDBT ratio, tracing oil-filling pathway in Sokor (E<sub>2</sub>), Termit Basin.



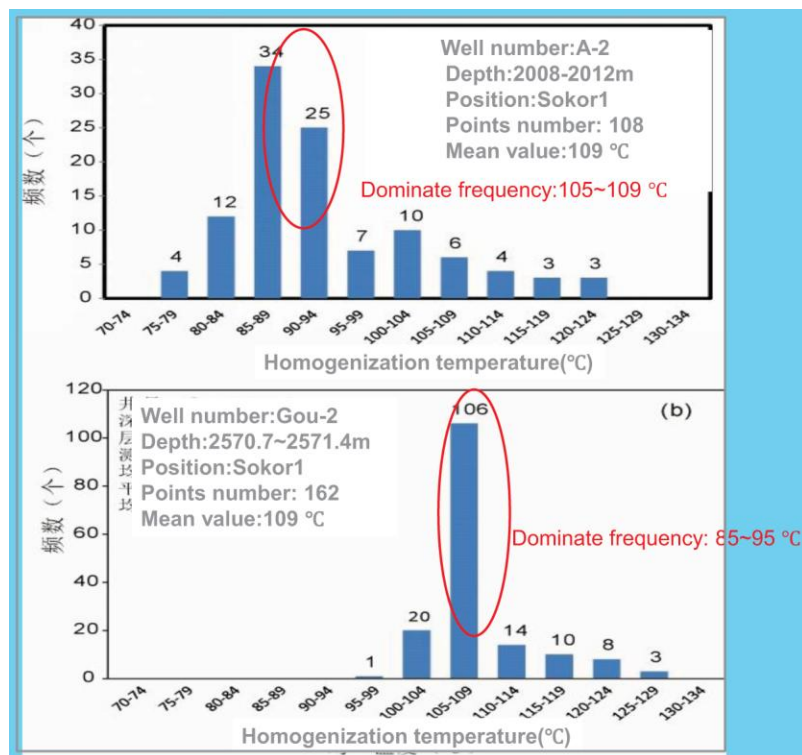


Figure 10. Histogram of homogenization temperature of reservoir fluid inclusions from wells A-2 and Gou-2.

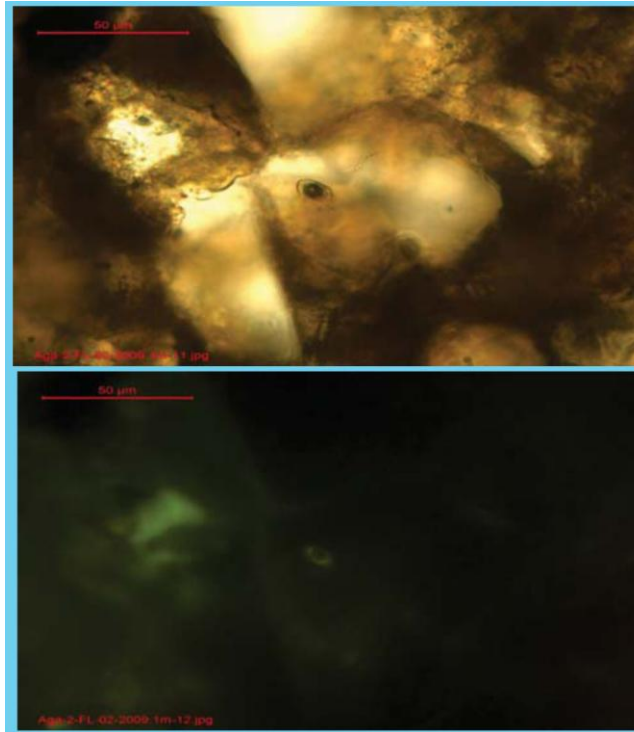


Figure 11. Polarized light and fluorescence microscopic photographs of reservoir fluid inclusions.

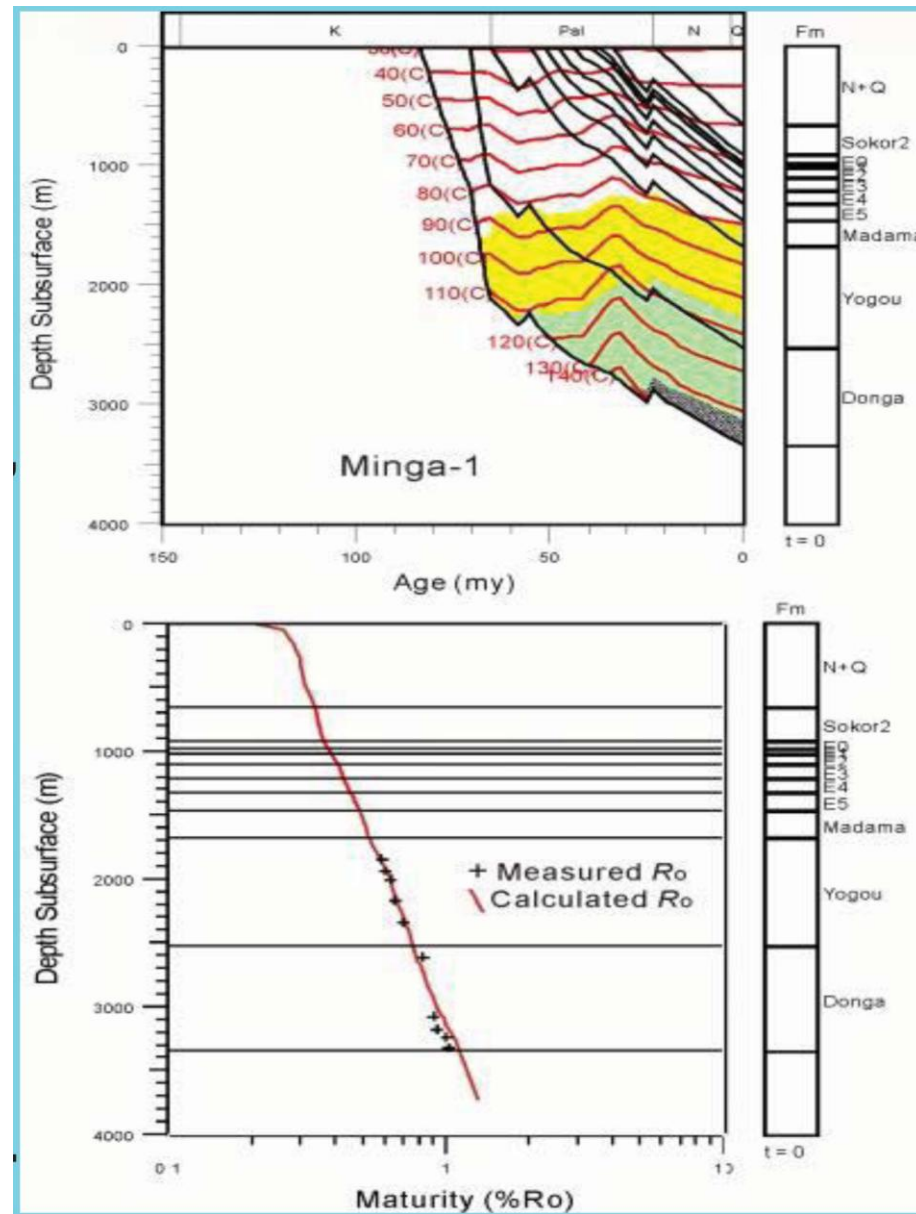


Figure 12. Comparison of the measured maturity profile and modeled maturity profile, the stratigraphic burial history for Well Minga-1 in the Termi Basin.

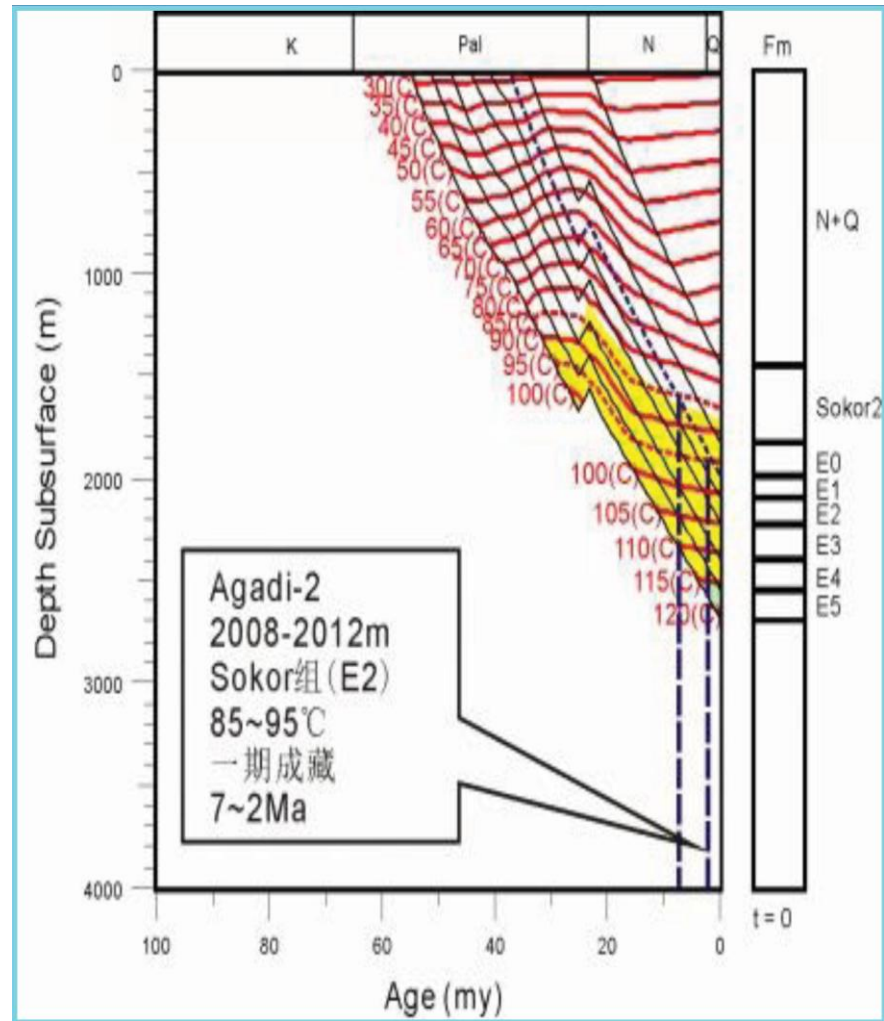


Figure 13. Stratigraphic burial history of Agida-2 and determination of the period of oil and gas accumulation in Sokor formation.