PETROLEUM GEOCHEMISTRY OF EARLY CRETACEOUS LACUSTRINE SEQUENCES OF BIMA FORMATION, NORTHERN BENUE TROUGH, NIGERIA

BABANGIDA M. SARKI YANDOKA and M.B. ABUBAKAR

Department of Geology, Faculty of Earth and Environmental Sciences, Bayero University Kano
&
National Centre for Petroleum Research and Development, A.T.B.U Bauchi

PRESENTATION FORMAT

1. Introduction

2. Geologic setting

3. Problem statements and objectives

4. Materials and methods

5. Results and discussions

6. Conclusions

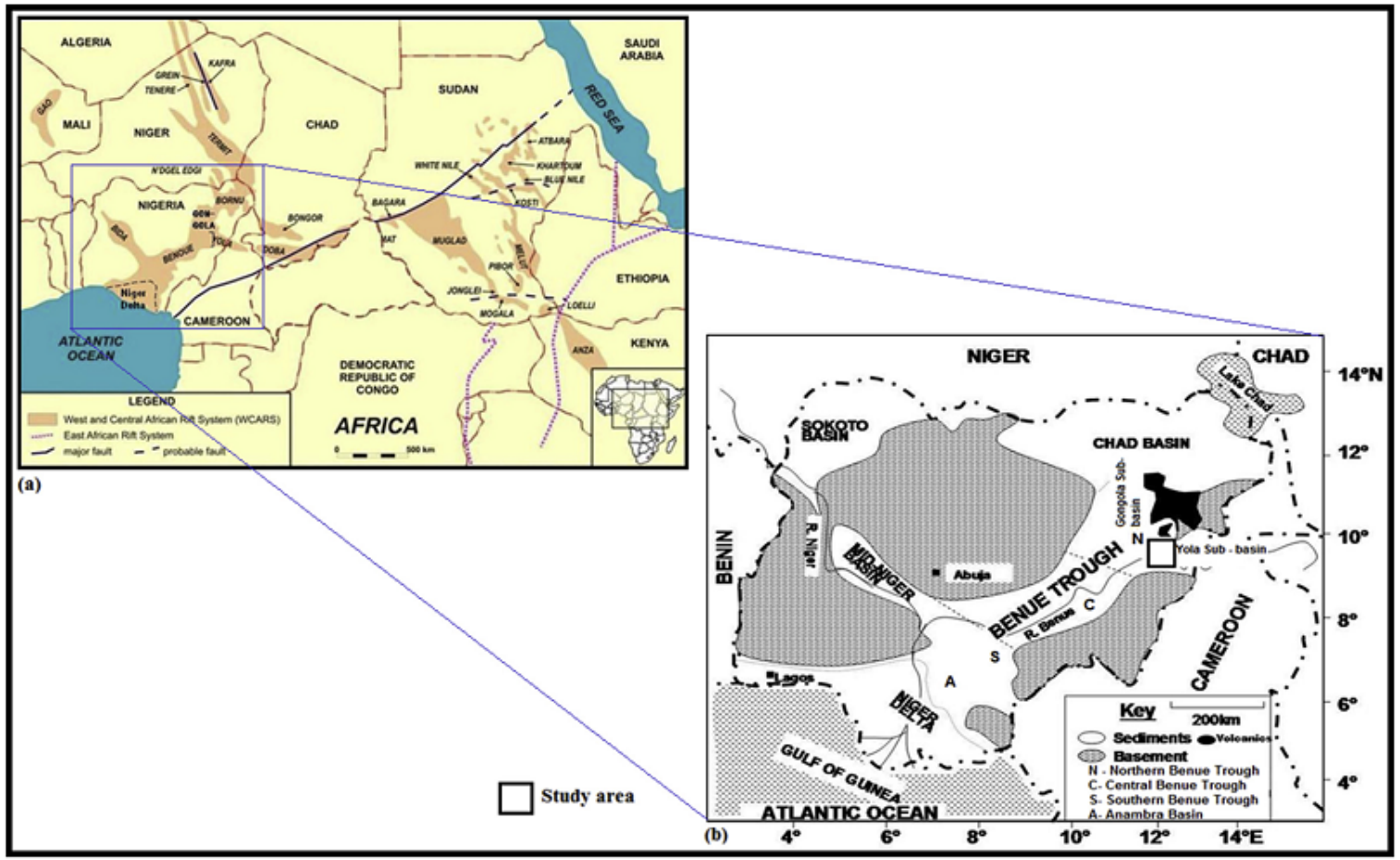


Figure 1: Geological Maps of WCARS and Nigeria showing the study area (After Sarki Yandoka, 2015)

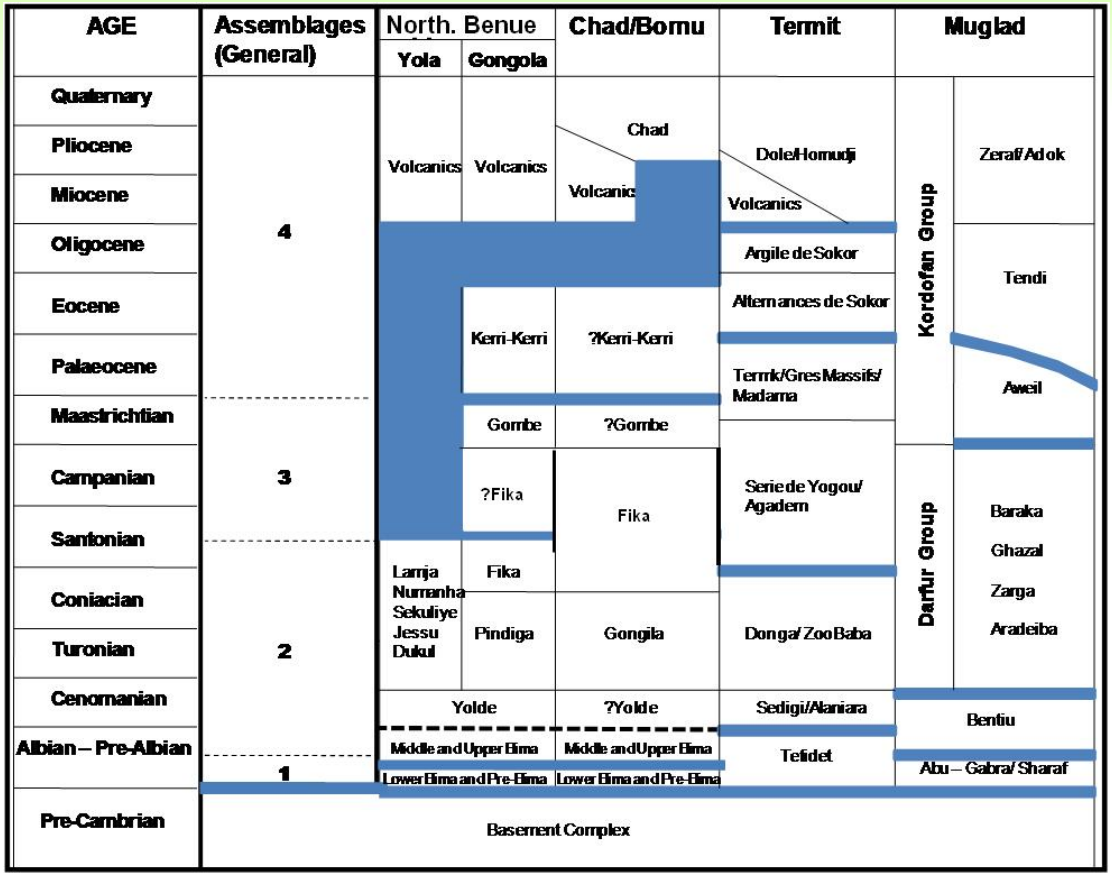
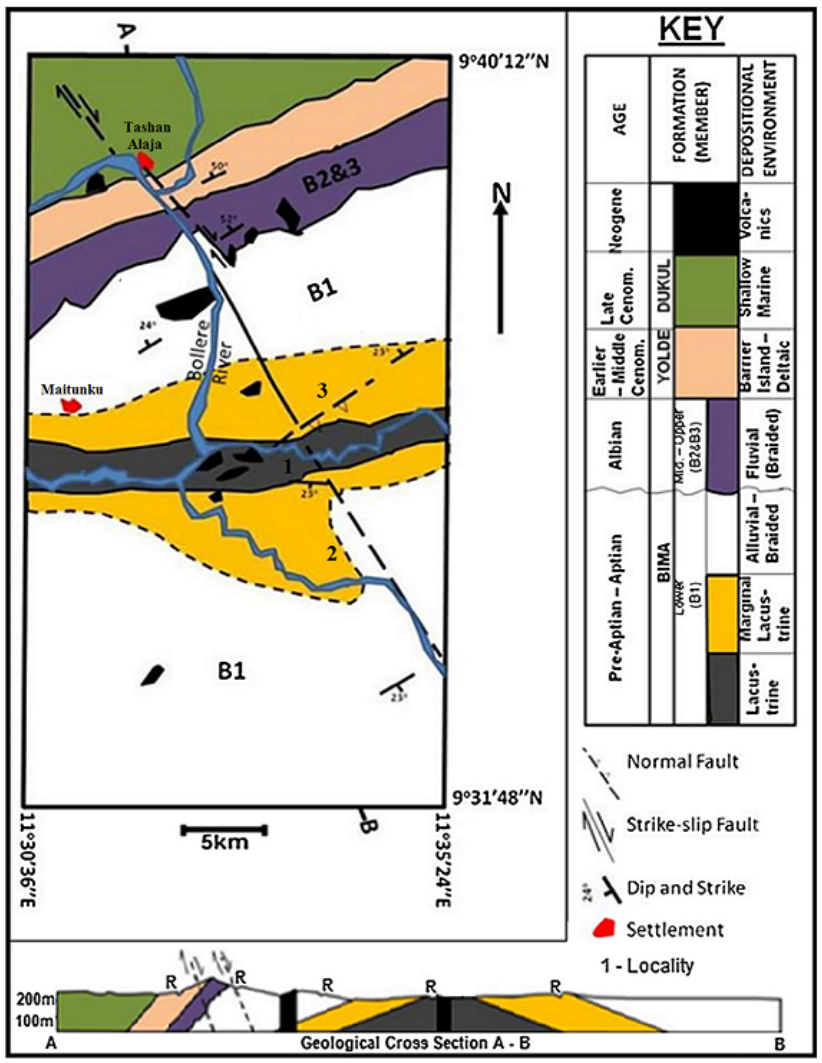


Figure 2: Stratigraphic succession of Northern Benue Trough and other basins in WCARS (After Abubakar, 2014)

Papers mainly utilized and reviewed from this study are the works of;

- Carter et al. (1963),
- Allix et al. (1971),
- Guiraud and Maurin, (1992),
- Akande et al. (1998),
- Jauro et al. (2007),
- Obaje et al. (2004)
- Abubakar et al. (2008) and among many others



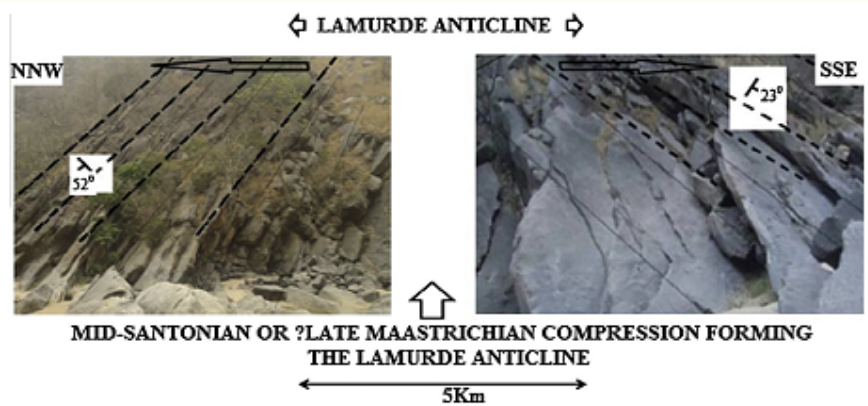


Figure 3: (a) Geological map of the study area showing the locations of sedimentology logs and (b) schematic outcrops photo of the asymmetric Lamurde Anticline with older beds exposed to the surface (After Sarki Yandoka et al., 2014)

PROBLEM STATEMENTS

The research is to provide a comprehensive assessment and will also answer uncertainties such:

- Are there lacustrine sediments in Bima Formation as present in similar formations within the West and Central African Rift System?

- Are the sediments preserved and matured enough to have generated or expelled liquid components of hydrocarbons?

- Is the Tertiary volcanics have effect on the thermal maturity of the sediments and is this critical to the oil and gas accumulation?

OBJECTIVES

- To identify, describe and log the lithostratigraphic units and carry out detail facies analysis,

- To collect shale samples and determine the organic matter quality (type), quantity (richness), thermal maturity and hydrocarbon generation potential,

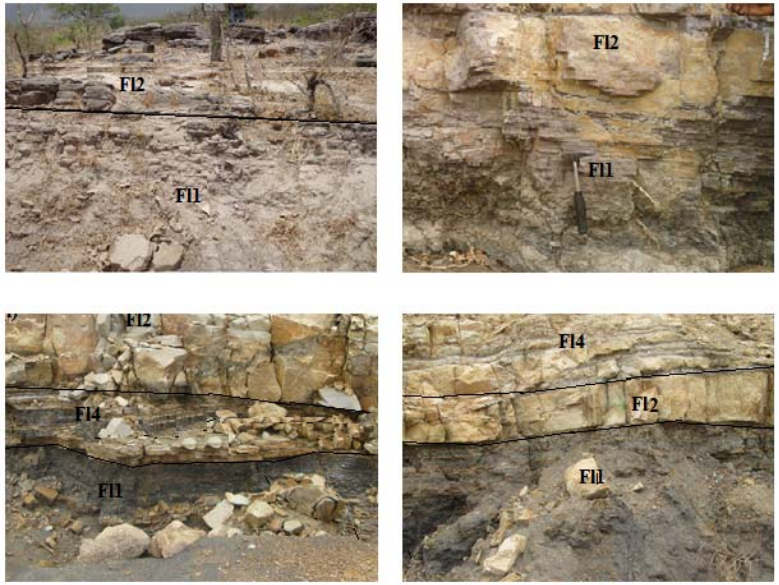
- To determine the source inputs or origin and paleodepositional conditions/preservation of the organic matter,

- To assess the influence of volcanics on the potential source rocks maturity and its relation to hydrocarbon generation potential

MATERIALS AND METHODS

1. FIELD METHODS

- Sedimentary Logging
- Sample Collection



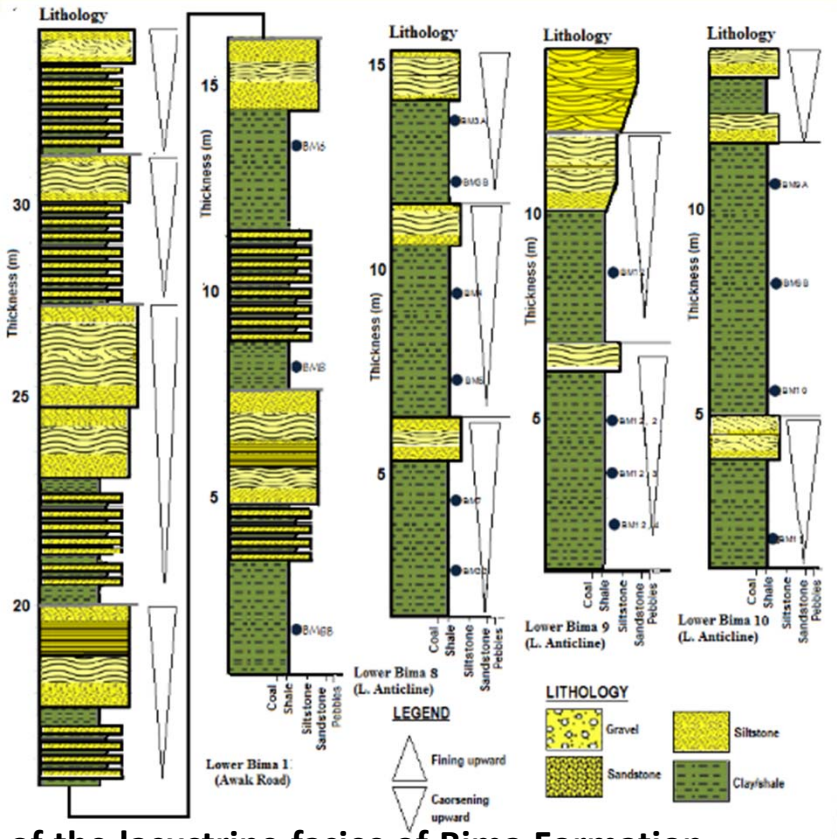


Figure 4: Sedimentary logs and field photographs of the lacustrine facies of Bima Formation from the Yola Sub-basin, Northern Benue Trough (After Sarki Yandoka, 2015)

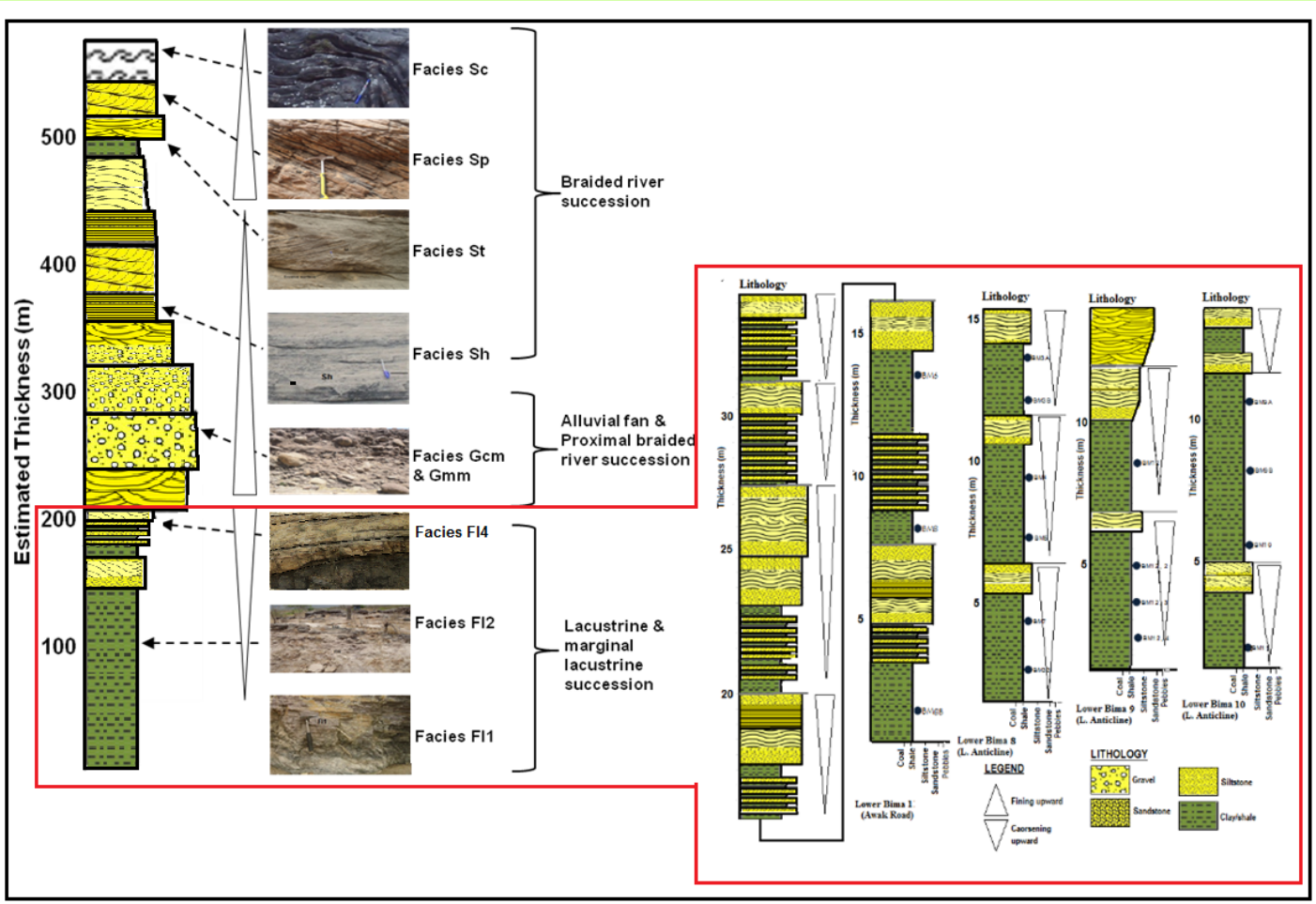


Figure 5: Composite litholog of Lower Bima Member and sedimentary logs of lacustrine sediments (After Sarki Yandoka et al., 2015)

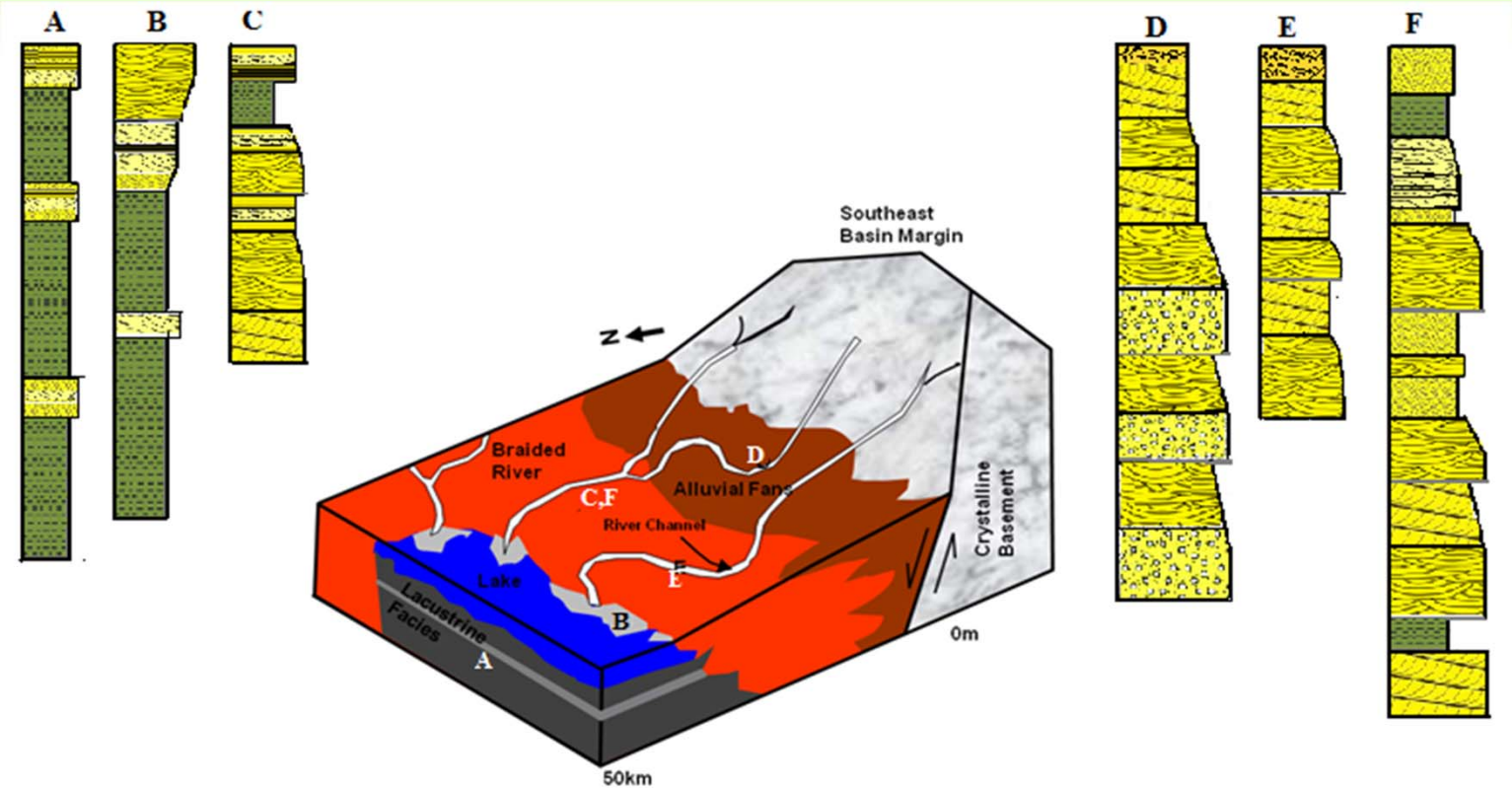


Figure 6: Depositional Model of the Bima Formation showing the alluvial fan, braided river and lacustrine facies (After Sarki Yandoka et al., 2014)

2. ORGANIC GEOCHEMICAL METHODS

- SRA/Rock Eval Pyrolysis
- Pyrolysis GC
- GC-MS & GC-MS/MS

3. ORGANIC PETROLOGICAL METHODS

- Vitrinite reflectance
- Kerogen isolation
- Palynofacies analysis

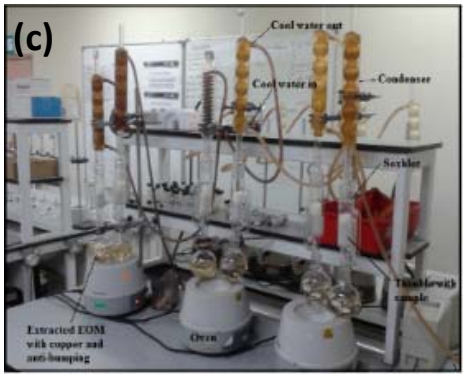


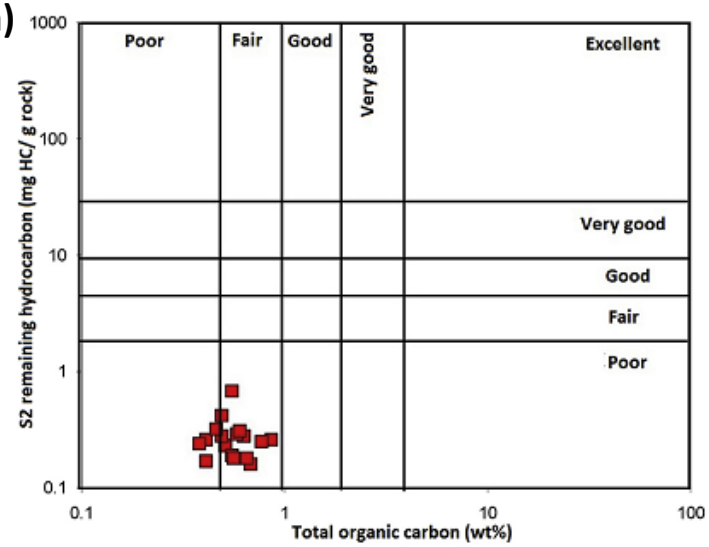
Figure 7: (a) source rock analyzer, (b) soxhlet extraction, (c) organic petrographic microscope and (d) GC-MS & PyGC (Geochemistry Section, University of Malaya)

RESULTS AND DISCUSSIONS

1. KEROGEN CHARACTERISATION

HI: 24 - 127 mg HC/g TOC, **Kerogen Types**: III/IV

(a)



TOC (wt.%): 0.38-0.86, **EOM (ppm):** 580-855, **HC (ppm):** 232-478

(b)

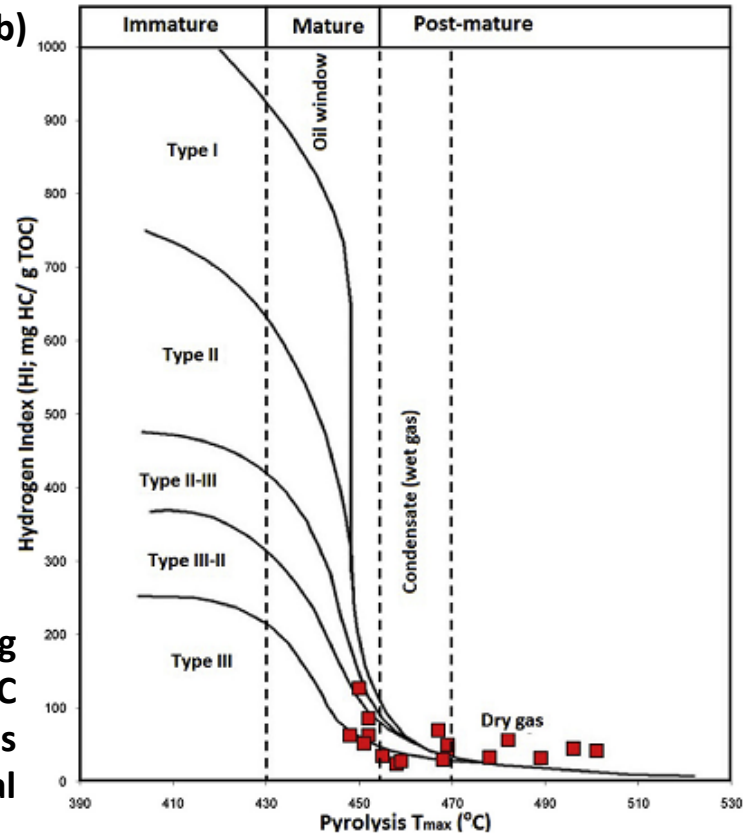
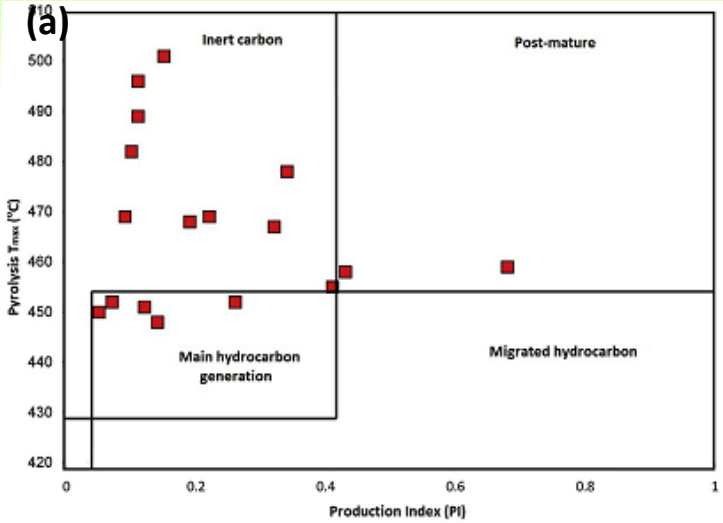
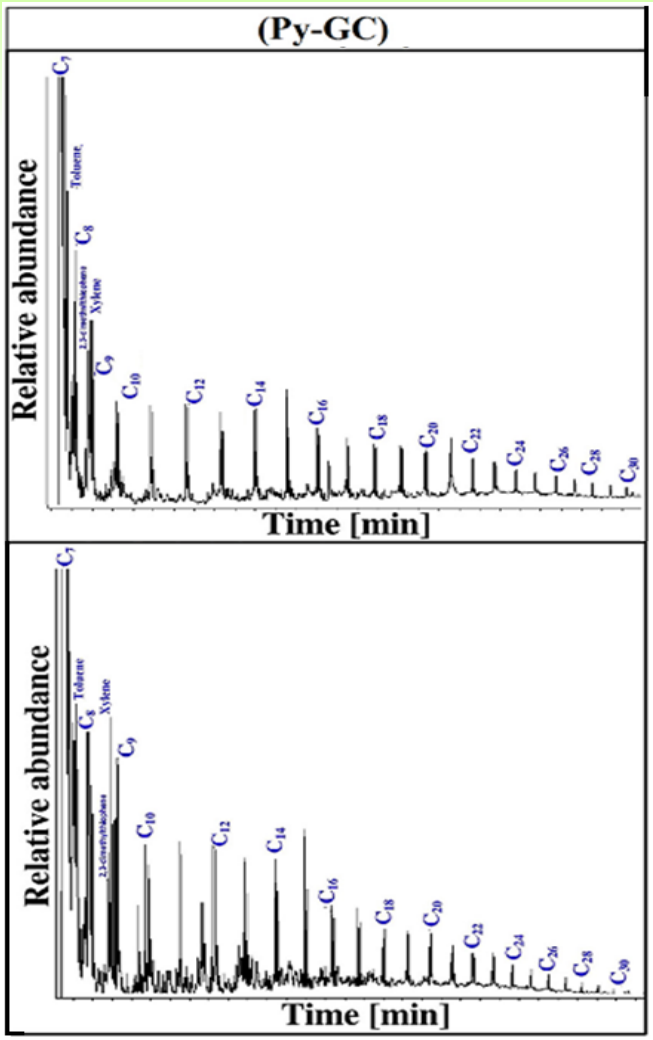


Figure 8: (a) Relationship between remaining hydrocarbon potential (S2) and total organic carbon (TOC wt. %) content (b) Plot of hydrogen index (HI) versus pyrolysis Tmax showing kerogen typing and thermal maturity stages (After Sarki Yandoka et al., 2017)

(a)



(b)



n-C15 – Higher

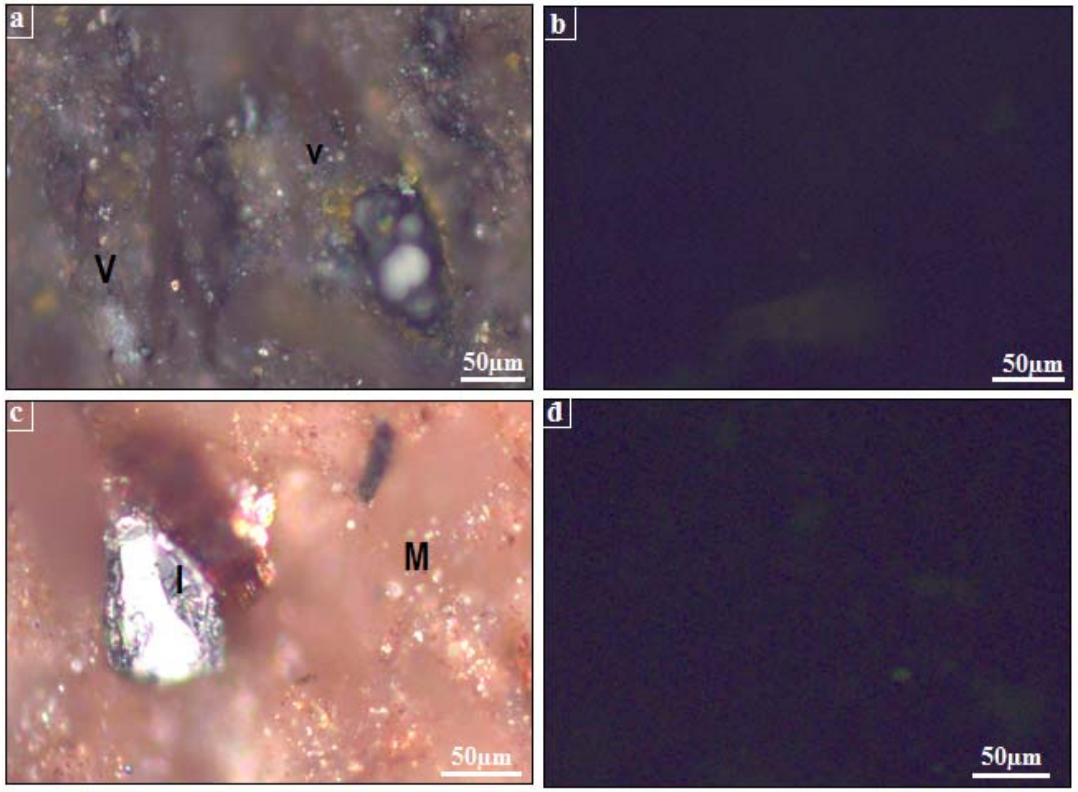
n-C10 - Lower

Type I Kerogen (lacustrine algae)

Type III Kerogen (higher plants)

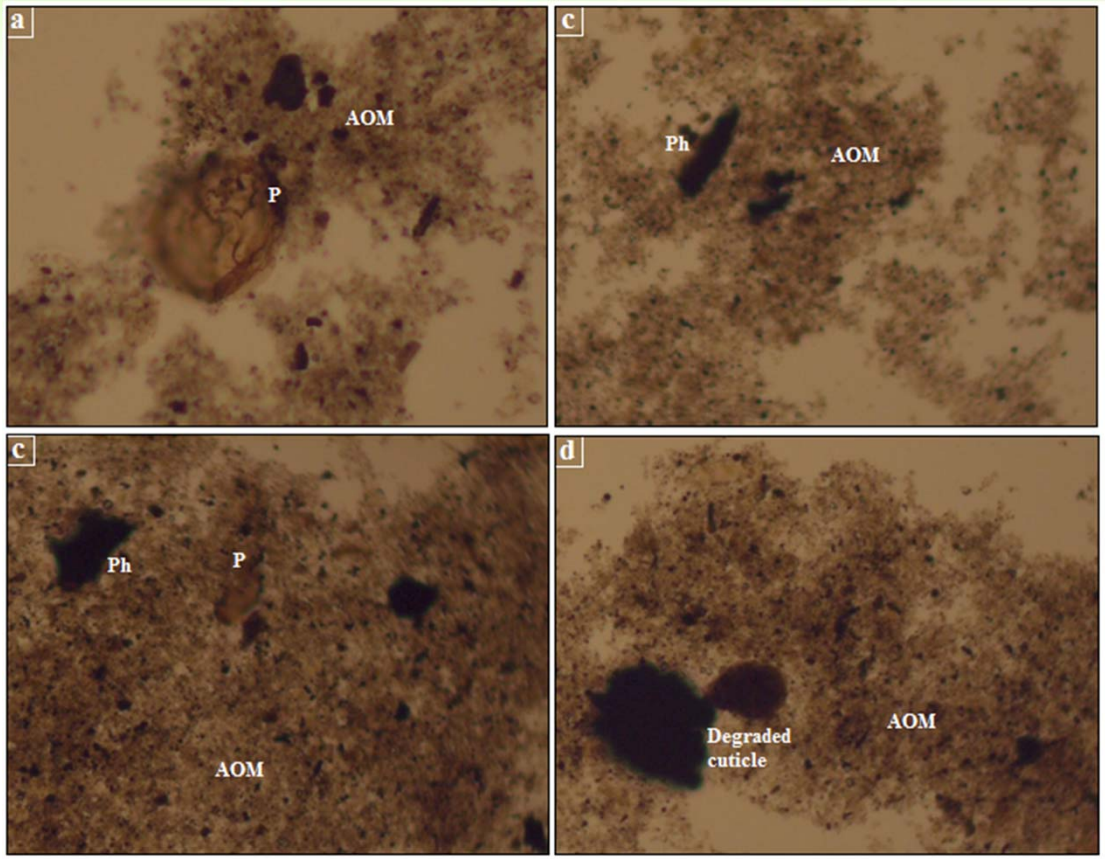
Figure 9: (a) Cross-plots of pyrolysis Tmax versus production index (PI), showing the maturation and nature of the hydrocarbon products and (b) Pyrolysis GC pyrograms showing n-alkene/alkane doublets and labelled peaks used as kerogen type proxies

2. ORGANIC PETROGRAPHY



Lacustrine shales have high vitrinite reflectance values in the range 0.82 - 2.02 VRo%; peak-late-oil window to post-maturity stage

Figure 10: Photomicrographs of phytoclasts showing; vitrinites, inertinites, pyrites and mineral matter. a & c: under reflected light. b & d: under fluorescence light; completely dark due to high thermal maturity experienced by the shales.



AOM light to dark brown – more 80%

Phytoclasts (woody tissue, cuticles) - less 20%

Palynomorph (spores, pollens, algae) - low 5%

Palynofacies supports Type III kerogens

Algal materials (Type I kerogen, oil-prone) might have been converted to hydrocarbons

Figure 11: Photomicrographs of amorphous organic matter (AOM), phytoclasts (Ph) and palynomorph (P) under transmitted light

2. BIOMARKER DISTRIBUTIONS

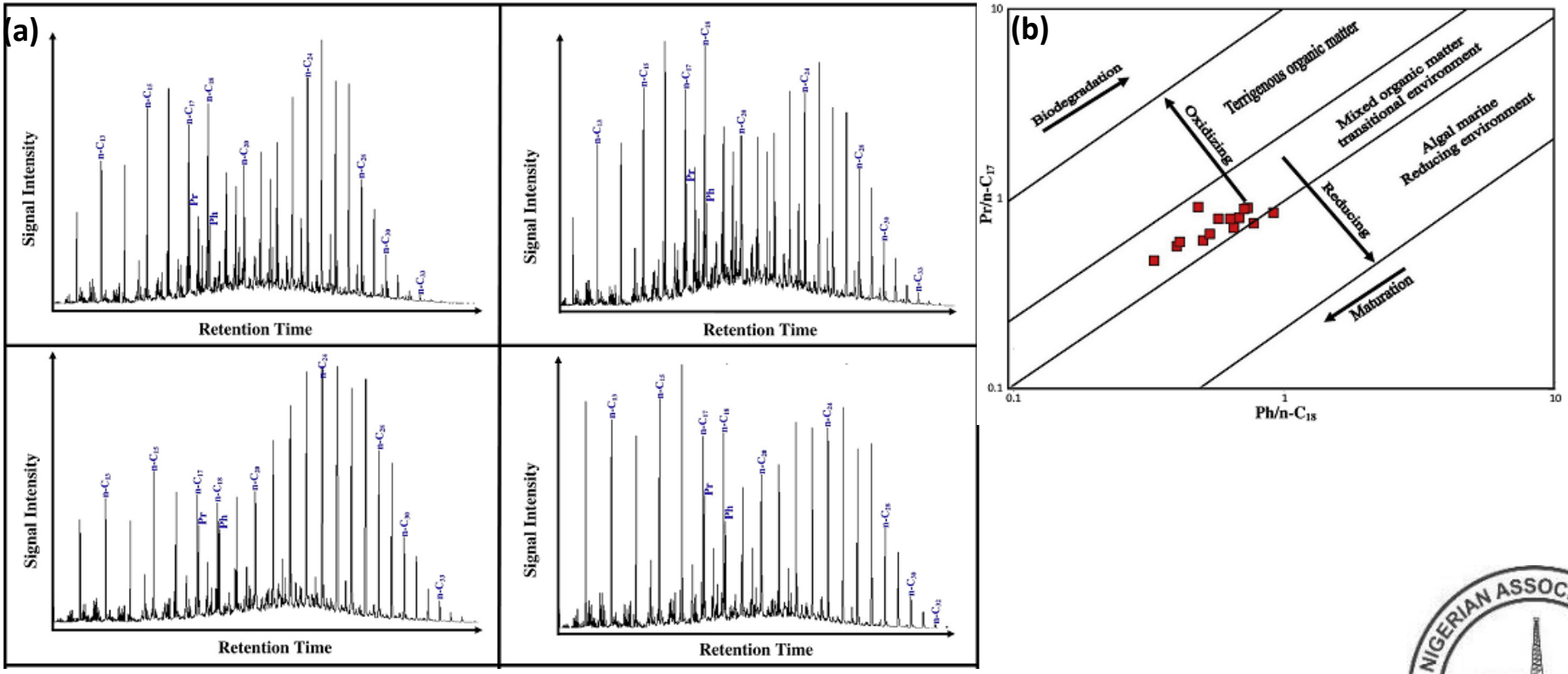
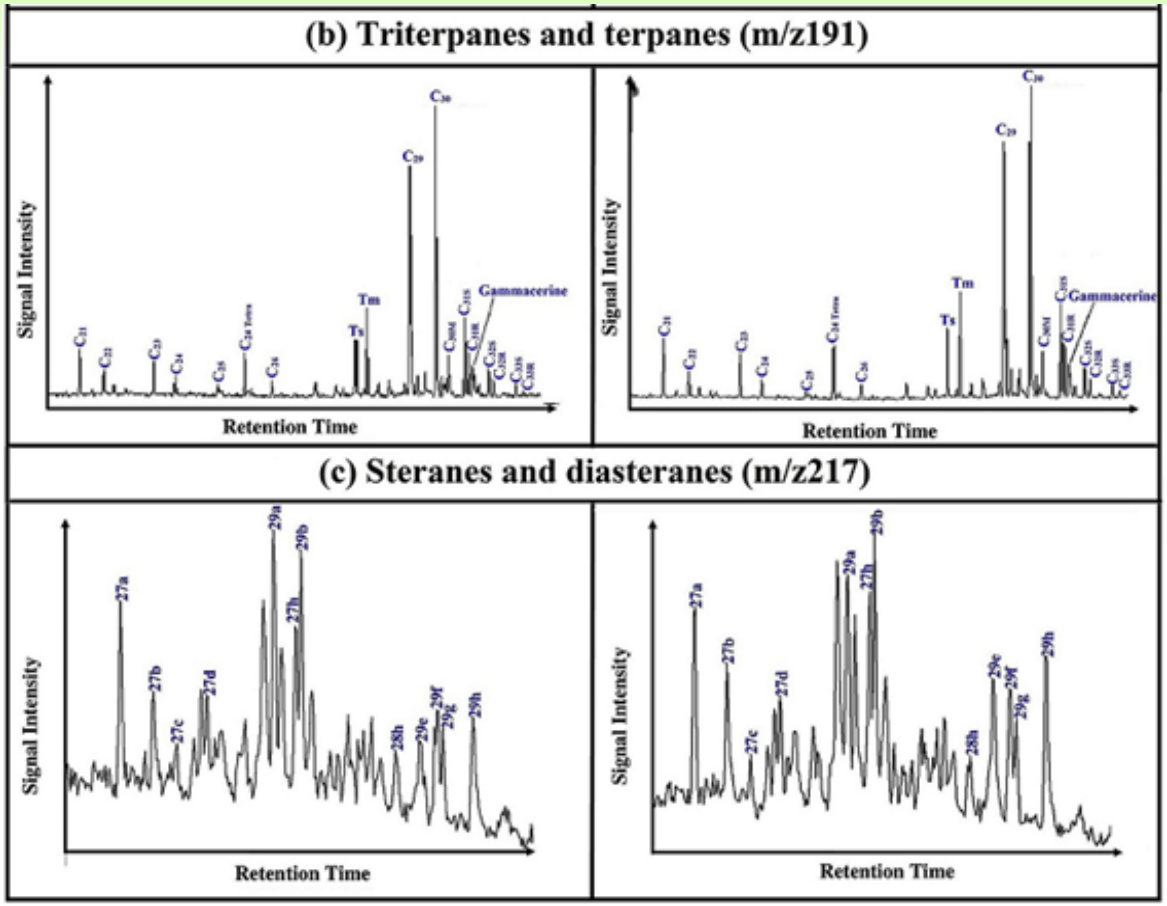


Figure 12: (a) Mass fragmentograms of m/z 85 of saturated hydrocarbons and (b) cross plots of Pr/nC17 vs Pr/nC18 (After Sarki Yandoka, 2015)



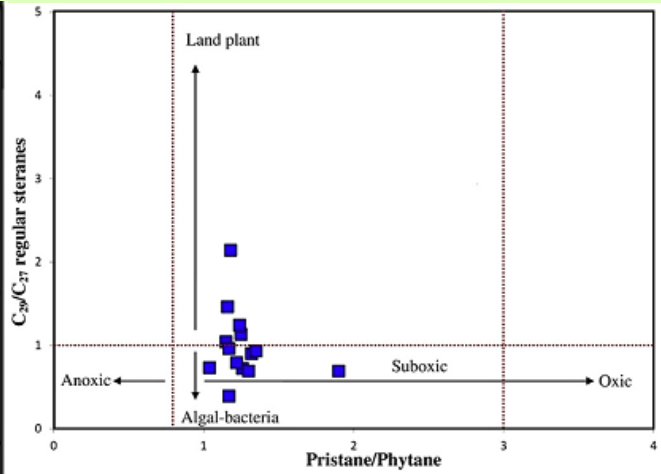


Figure 13: The m/z 191 mass fragmentograms with m/z 217 mass fragmentograms of saturated hydrocarbon fractions and cross-plots of pristane/phytane ratios versus C29/C27 regular steranes

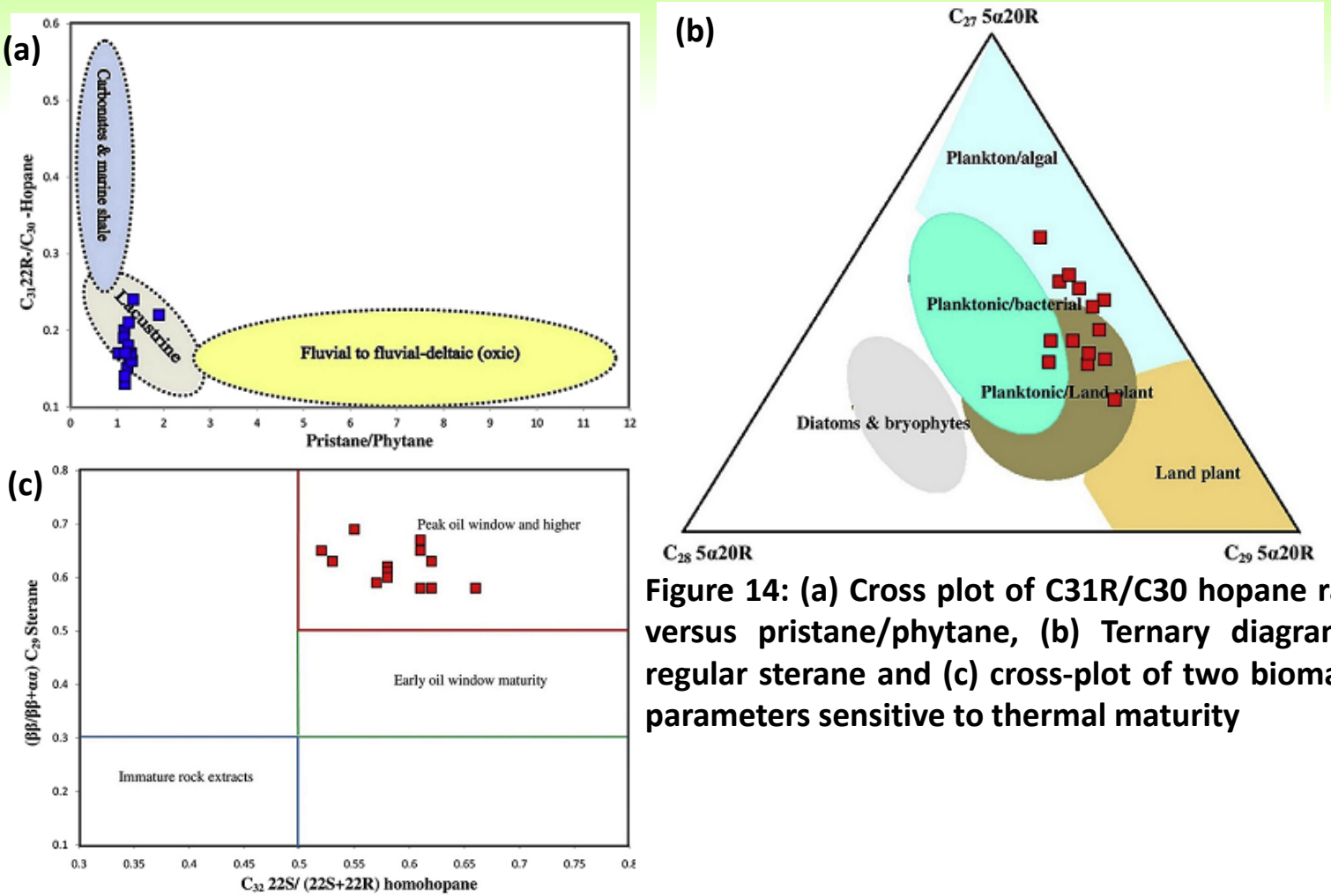
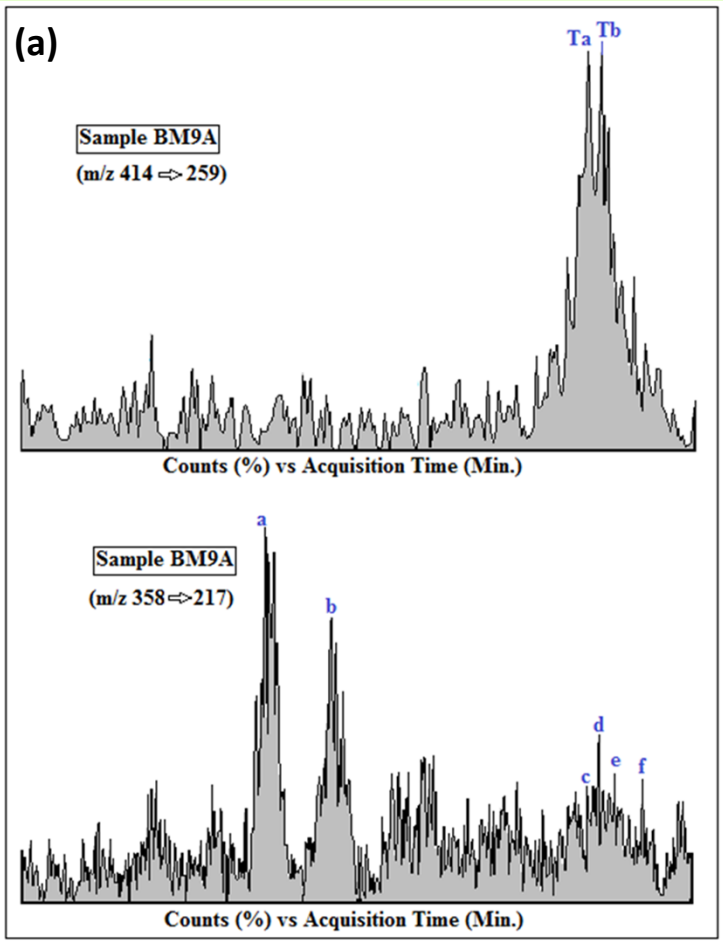


Figure 14: (a) Cross plot of C31R/C30 hopane ratios versus pristane/phytane, (b) Ternary diagram of regular sterane and (c) cross-plot of two biomarker parameters sensitive to thermal maturity



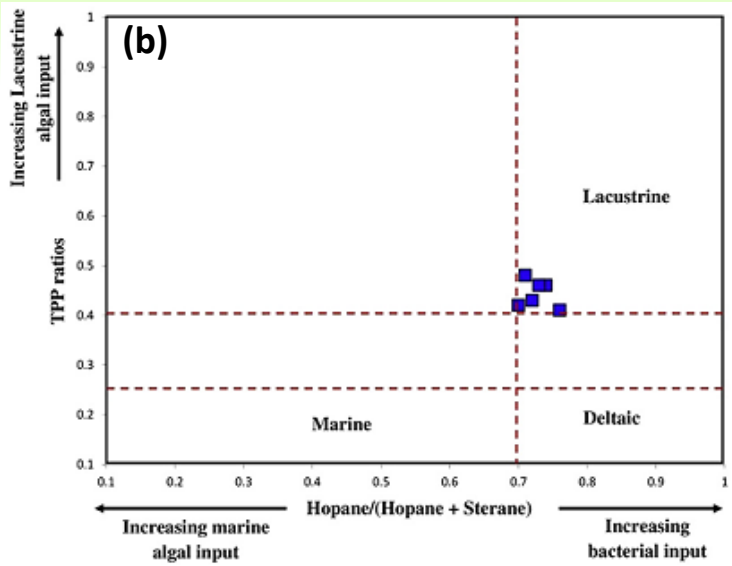
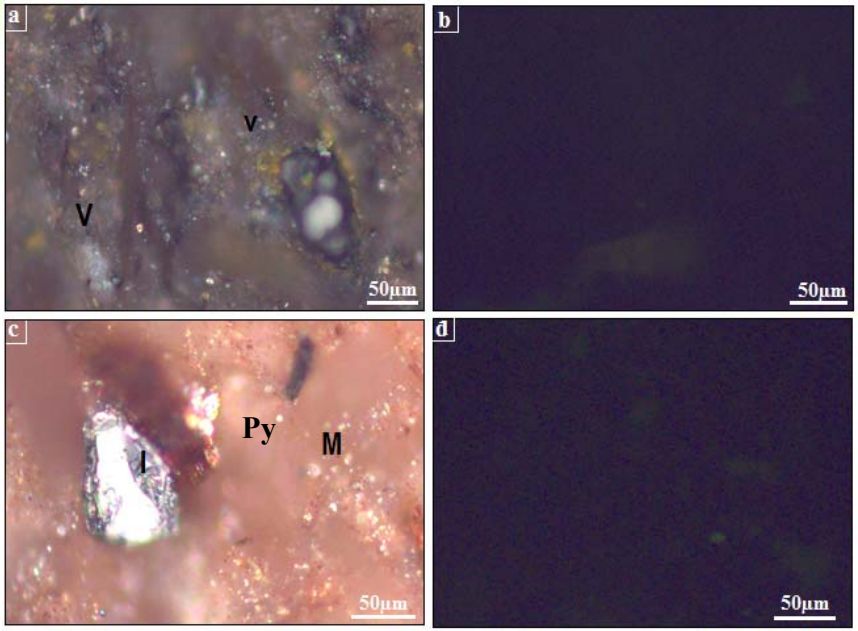
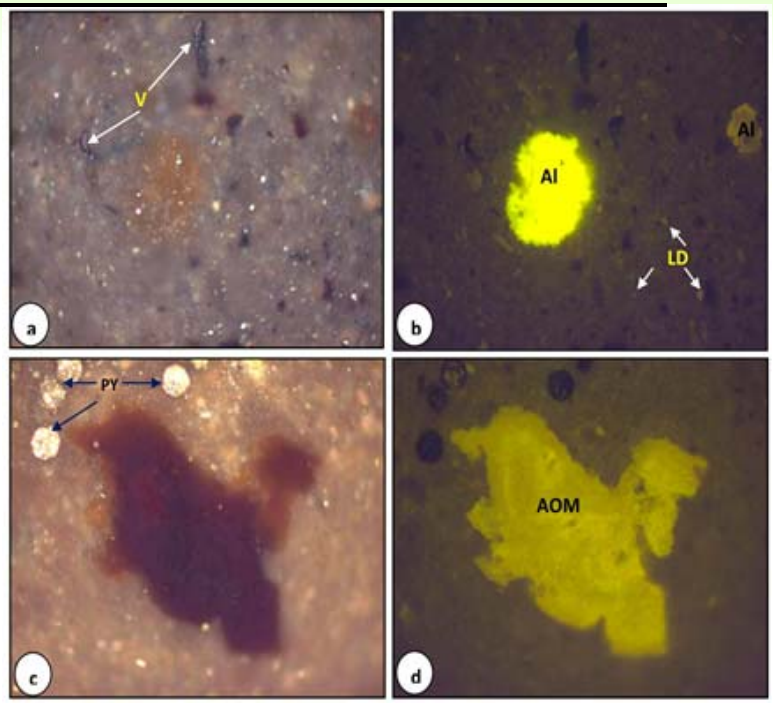


Figure 15: (a) C30 Tetracyclic Polyprenoids (TPP) and (b) cross plot of TPP ratios versus hopane/hopane+steranes (modified after Holba et al., 2003)

REGIONAL COMPARISON *with "MUGLAD BASIN"*

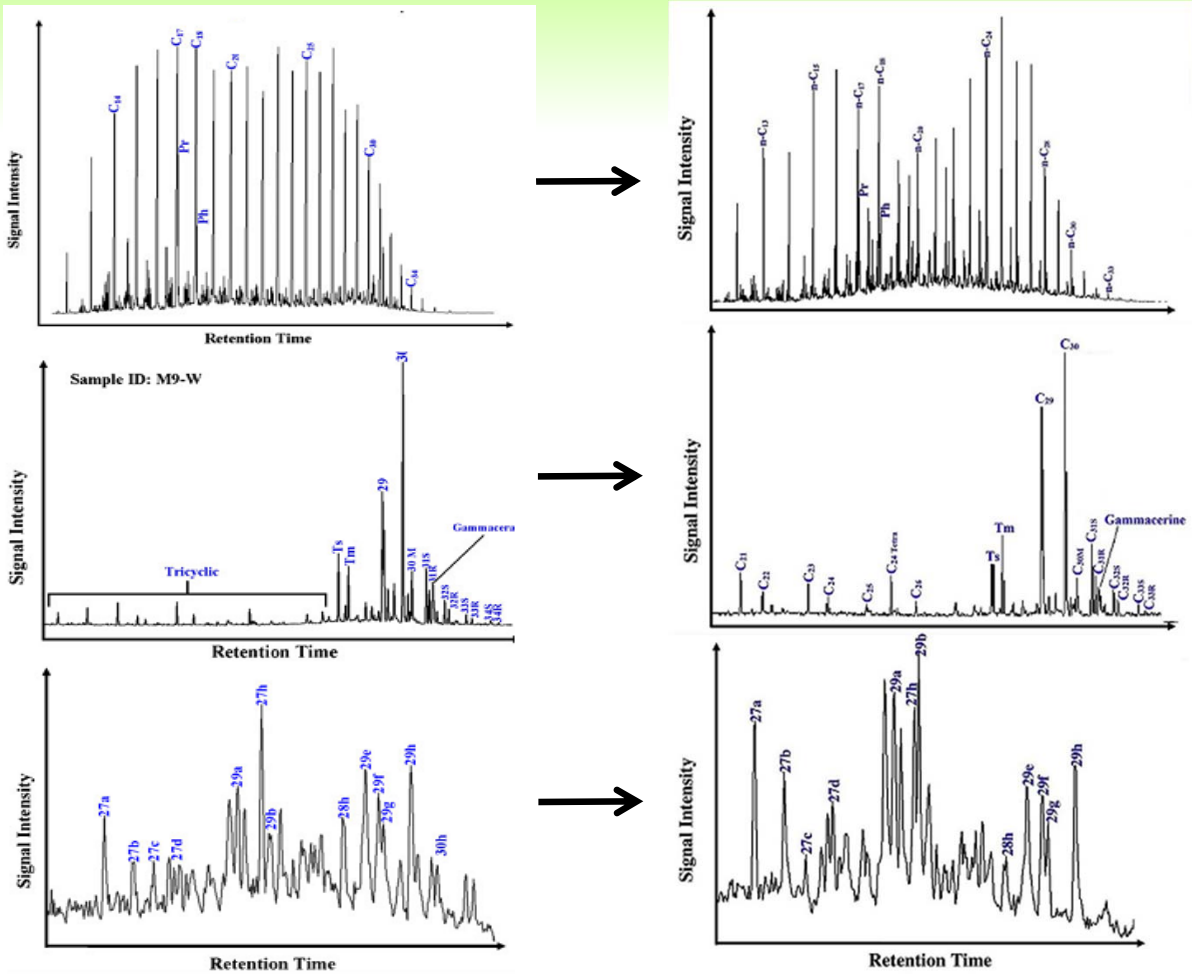


Bima Shales *(From Sarki Yandoka et al., 2017)*
%VR - 0.82 and 2.02; peak-late-oil window and post-maturity stage



Abu Gabra Shales *(From Makeen et al., 2015)*
%VR - 0.58 and 0.72 %; thermally mature and have reached oil generation window

Figure 16: Photomicrographs of Vitrinites, inertinites and mineral matter for Bima Shales and Vitrinites, Alginite and AOM (under reflected and fluorescence lights)



Abu Gabra Shales

Bima Shales

Figure 17: Mass fragmentograms of m/z 85, 191 and 217 of Abu Gabra and Bima Shale samples showing the similarities of the peaks and organic matter source inputs and depositional conditions (After Makeen et al., 2014 and Sarki Yandoka, 2015)

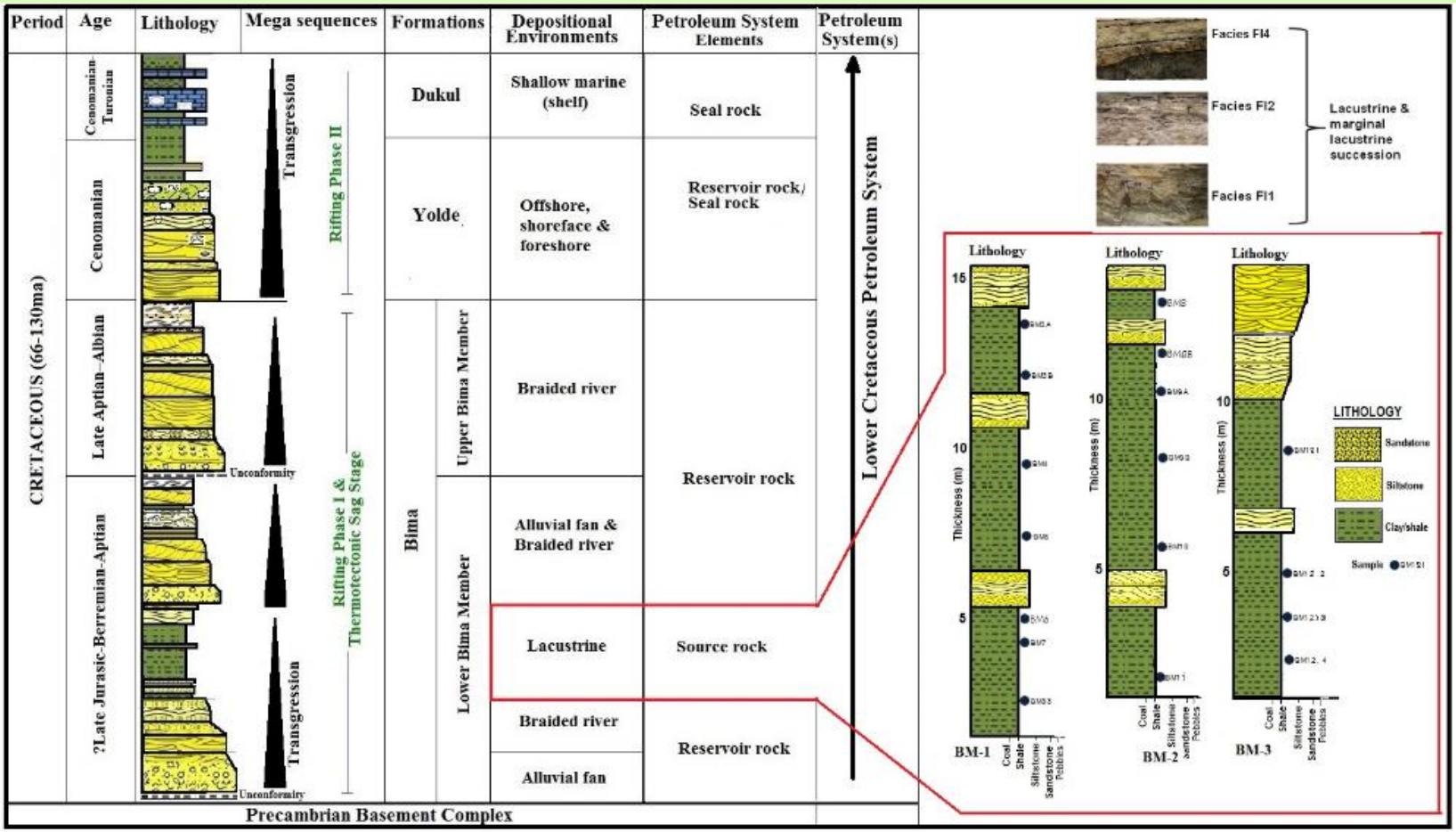


Figure 18: Predicted Lower Cretaceous Petroleum System in NBT showing the prospective source rock (Lacustrine Shales) for the system, Bima Formation (After Sarki Yandoka et al., 2017)

CONCLUSIONS

- The analysed shale samples were deposited in lacustrine environment and received contributions of aquatic algae and microorganisms with a significant amount of terrigenous inputs, deposited under suboxic to relatively anoxic conditions,

- The organic matters contain some evidences of Type I (lacustrine algae) but predominantly Type III (terrestrial land-plants) and Type IV (inert carbon) kerogens and are likely to have generated oil and major gas at deeper part of the basin,

- The sediments experienced high thermal maturity and this enhanced the organic matters therefore, most of the hydrocarbons that formed in the course of thermal maturation were further cracked into gas probably due to the thermal effects of Tertiary volcanics known to be present in the basin,

- The presence of lacustrine sediments may therefore, suggest potential occurrence of the Lower Cretaceous petroleum source rocks in NBT; an insight which is expected to guide the current hydrocarbon exploration campaign in the basin

SELECTED REFERENCES

- Abubakar, M.B., Dike, E.F.C., Obaje, N.G., Wehner, H., Jauro, A., (2008). Petroleum prospectivity of Cretaceous Formations of Gongola Basin, Upper Benue Trough, Nigeria; An organic geochemical perspective on a migrated oil controversy. Journal of Petroleum Geology 31(4), 387 – 408.
- Akande S.O., Ojo O.J., Erdtmann, B.D., Hetenyi M, (1998). Paleoenvironments, source rock potential and thermal maturity of the Upper Benue rift basins, Nigeria: implications for hydrocarbon exploration. Organic geochemistry 29, 531-542.
- Holba, A.G., Dzoub, L.I., Wood, G.D., Ellisd, L., Adame, P., Schaeffere, P., Albrechte, P., Greenef, T., Hughes, W.B., 2003. Application of tetracyclic polyprenoids as indicators of input from fresh-brackish water environments. Organic Geochemistry 34, 441–469.
- Horsfield, B., (1989). Practical criteria for classifying kerogens: some observations from pyrolysis-gas chromatography. Geochim. Cosmochim. Acta 53, 891–901.
- Makeen, Y.M., Abdullah, W.H., Hakimi, M.H., 2014. Biological markers and organic petrology study of organic matter in the Lower Cretaceous Abu Gabra sediments (Muglad Basin, Sudan): origin, type and palaeoenvironmental conditions. Arab J Geosciences DOI 10.1007/s12517-013-1203-z.
- Obaje N.G., Wehner H, Abubakar M.B., Isah M.T., (2004). Nasara 1 well Gongola Basin (Upper Benue Trough, Nigeria): Source rock evaluation. Journal of Petroleum Geology 27 (2), 191–206.
- Peters K.E., Cassa M.R., (1994). Applied source rock geochemistry. In: Magoon, L.B., Dow, W.G. (Eds.), the Petroleum System — From Source to Trap. American Association of Petroleum Geologists, Memoir, 60, pp. 93–120.
- Peters K.E., Walters C.C., Moldowan J.M., (2005). The Biomarker Guide: Biomarkers and Isotopes in Petroleum Exploration and Earth History, second ed., vol. 2. Cambridge University Press, Cambridge.
- Sarki Yandoka, B.M., Abubakar, M.B., Abdullah, W.H., Amir Hassan, M.H., Adamu, B.U., Jitong, J.S., Aliyu, A.H., Adegoke, K.A., (2014). Facies analysis, palaeoenvironmental reconstruction and stratigraphic development of the Early Cretaceous sediments (Lower Bima Member) in the Yola Sub-basin, Northern Benue Trough, NE Nigeria. Journal of African Earth Sciences 96, 168–179.
- Sarki Yandoka, B.M., Abdullah, W.H., Abubakar, M.B., Hakimi, M.H., Adegoke, A.K., (2015b). Geochemical characterisation of Early Cretaceous lacustrine sediments of Bima Formation, Yola Sub-basin, Northern Benue Trough, NE Nigeria: Organic matter input, preservation, paleoenvironment and palaeoclimatic conditions. Marine and Petroleum Geology 61, 82 – 94.
- Sarki Yandoka, B.M., Abdullah, W. H., Abubakar, M.B., Hakimi, M.H., Adegoke, A.K., Haruna, A.I., Yaro, U.Y., (2017). Hydrocarbon potential of Early Cretaceous lacustrine sediments from Bima Formation, Yola Sub-basin, Northern Benue Trough, NE Nigeria: Insight from organic geochemistry and petrology. Journal of African Earth Sciences 129, 153-164

ACKNOWLEDGEMENT(s)

NATIONAL CENTRE FOR PETROLEUM RESEARCH AND DEVELOPMENT
NCPRD

UNIVERSITY OF MALAYA
ILMU PUNCAK KEMAJUAN
The Leader in Research & Innovation

BAYERO UNIVERSITY, KANO

NIGERIAN ASSOCIATION OF PETROLEUM EXPLORATIONISTS
SINCE 1975

Thank You For Listening