# GEOCHEMICAL AND PETROGRAPHIC CHARACTERISATION OF ORGANIC MATTER FROM THE UPPER CRETACEOUS FIKA SHALE SUCCESSION IN THE CHAD (BORNU) BASIN, NORTHEASTERN NIGERIA: ORIGIN AND HYDROCARBON GENERATION POTENTIAL

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# PRESENTATION OUTLINES

- Introduction
  - Geological setting
  - Stratigraphy
- Objectives
- Samples and experimental
- Results and discussion
- Conclusions

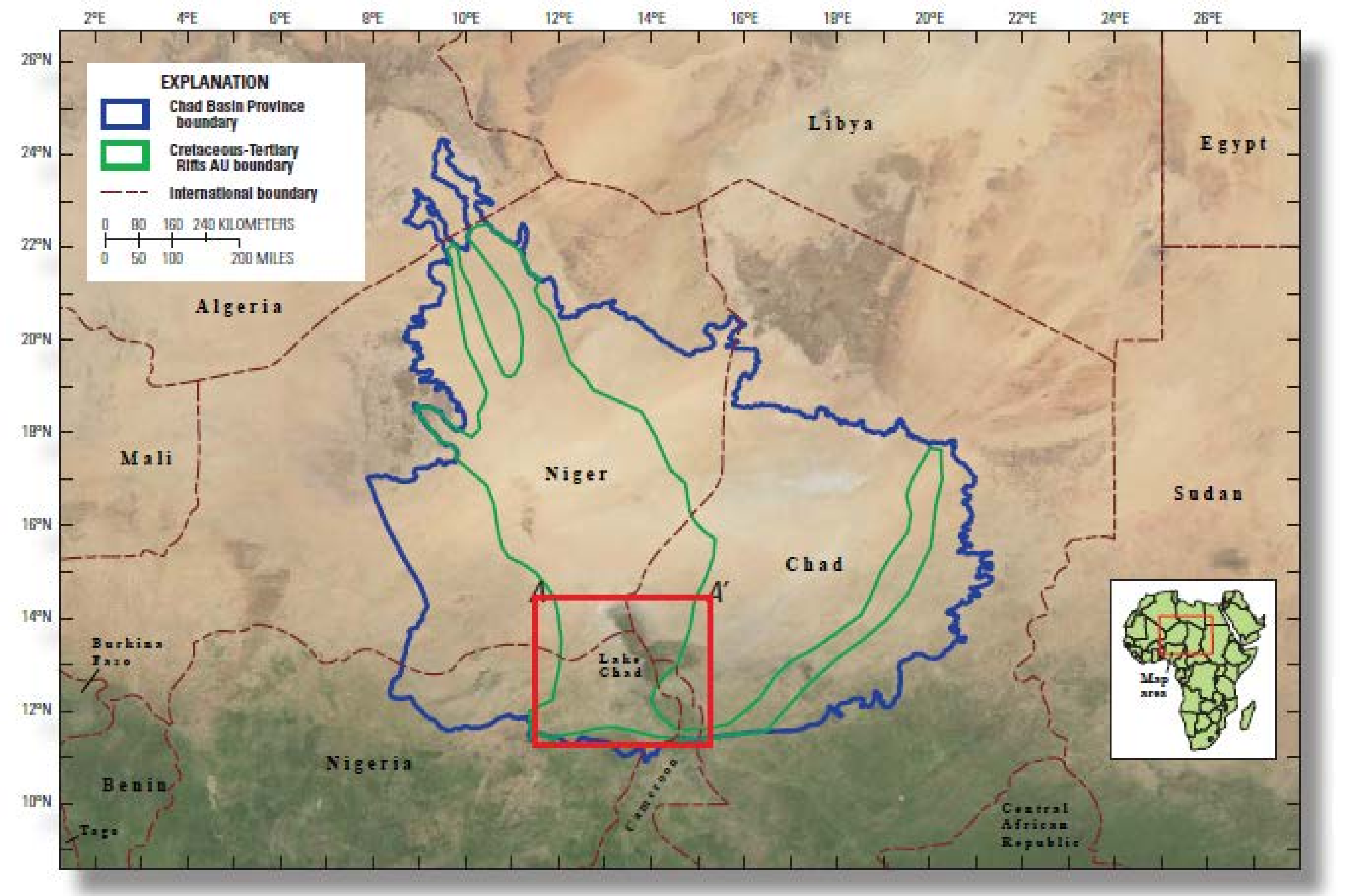
# INTRODUCTION

- Bornu Basin represents the much larger Chad Basin in Nigeria.

- The basin (Chad Basin) extends to parts of Niger Republic, Chad, Cameroon, Central Africa Republic and Nigeria.

- It is the largest intracratonic basin in Africa with an area extent of about 2,300,000 $km^2$.

Fairhead, 1986.

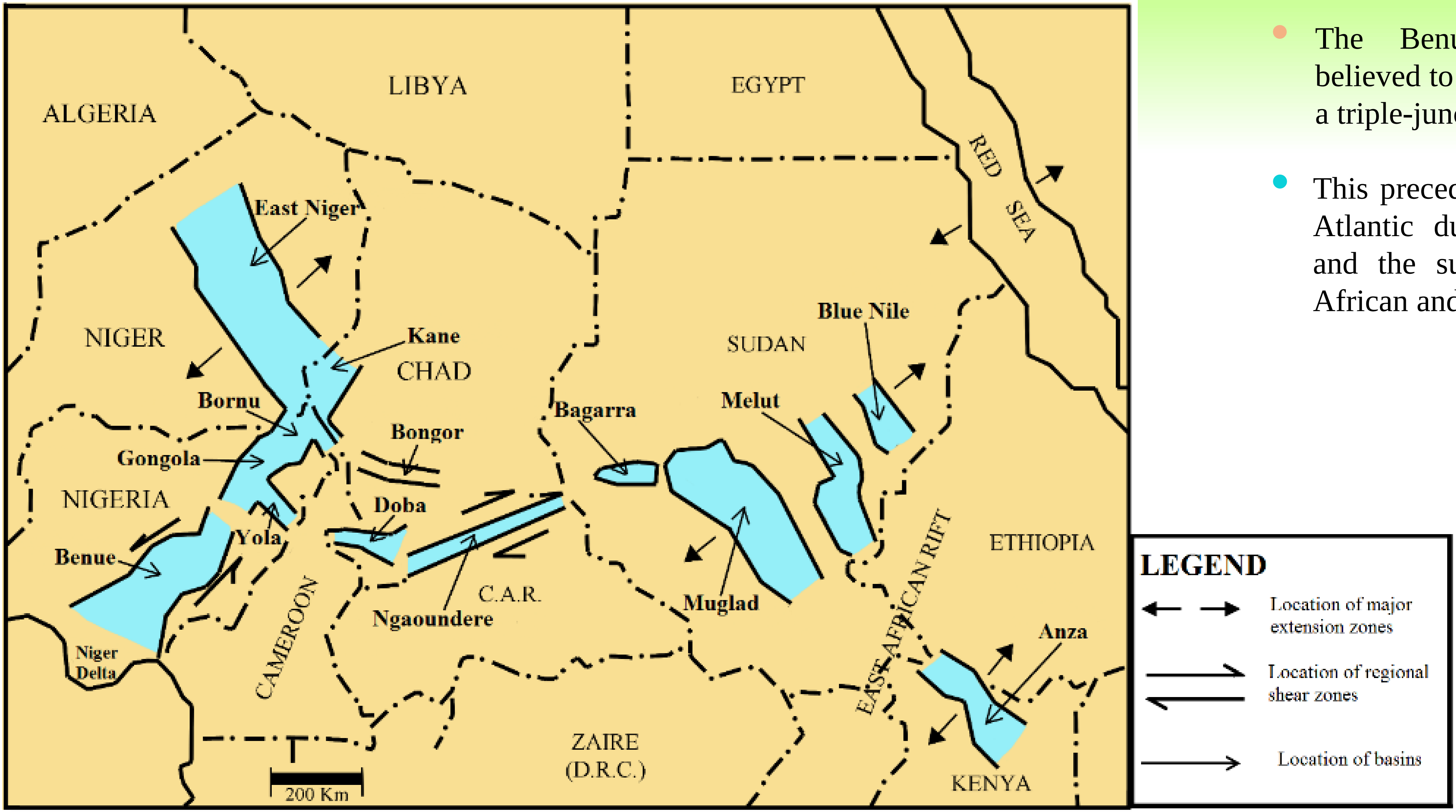



- The Cretaceous Chad Basin belongs to the genetically linked fault and rift system termed the "West and Central Africa Rift System (WCARS)"

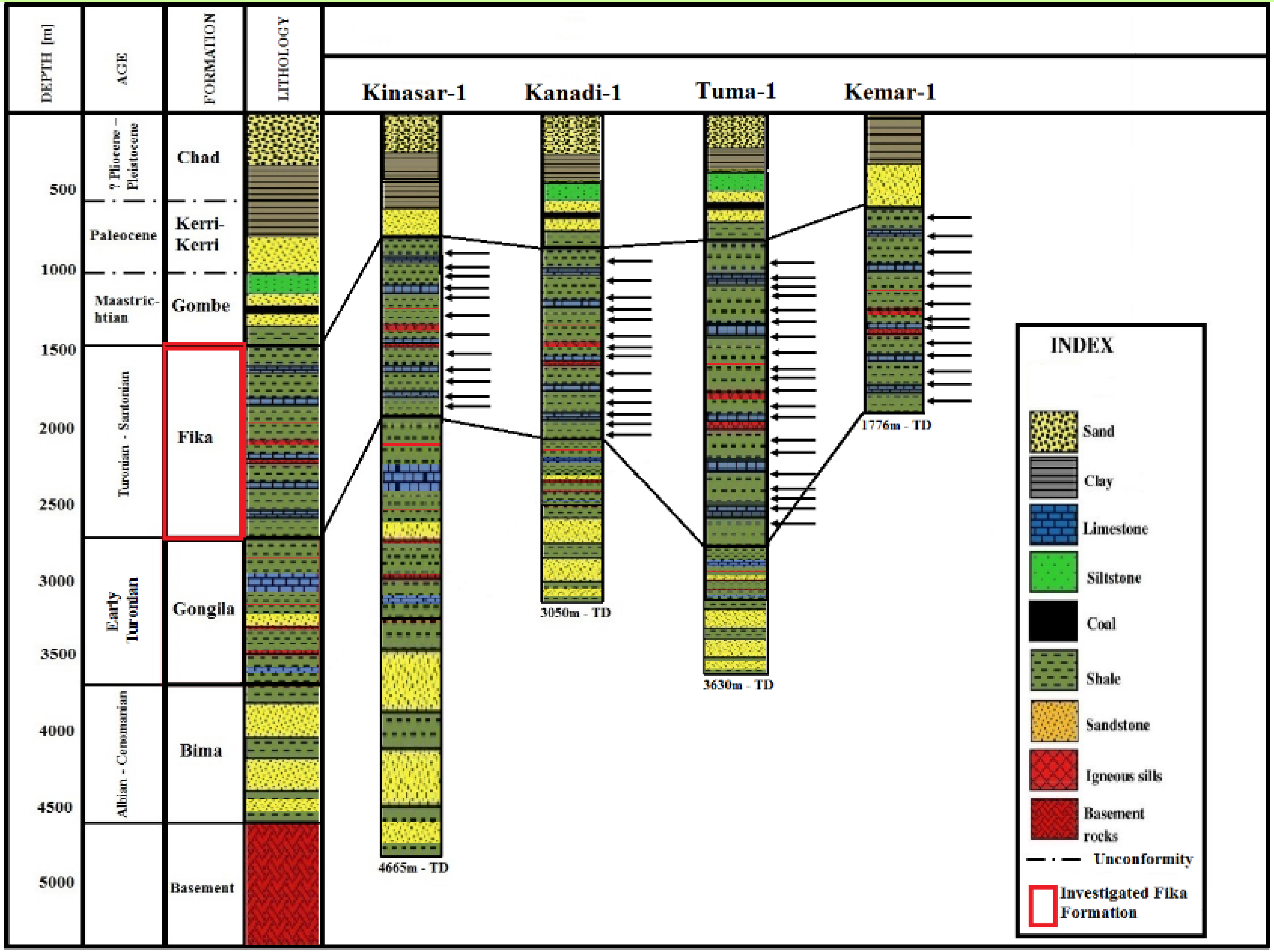
Fairhead (1986); Burke et al. (1972)

**Location of the Chad Basin Province (adapted from USGS Fact Sheet, October, 2010).**

- The Benue-Chad axial trough is believed to be the third and failed arm of a triple-junction rift system.
- This preceded the opening of the South Atlantic during the Early Cretaceous, and the subsequent separation of the African and South American continents




**Regional tectonic map of western and central African rifted basins showing the relationship of the Chad (Bornu) Basin to the Benue, Muglad, Doba and East Niger Basins. (Adapted from Schull, 1988).**




**Stratigraphic succession and sampled intervals in the studied exploratory wells (modified after Avbovbo et al., 1986; Carter et al., 1963 and Okosun, 1995).**

# Problem statements

- Most of the previous geochemical studies on the basin by were primarily based on bulk geochemical parameters (pyrolysis methods).

- However, studies have shown that pyrolysis methods have their constraints against organically lean sediments because of mineral matrix effect.

- At the same time, there have been contradictory results from these studies on the exact kerogen type in the Chad (Bornu) Basin sediments.

- None of these studies have been able to examine the source input and the paleodepositional conditions of organic matter within the sediments.

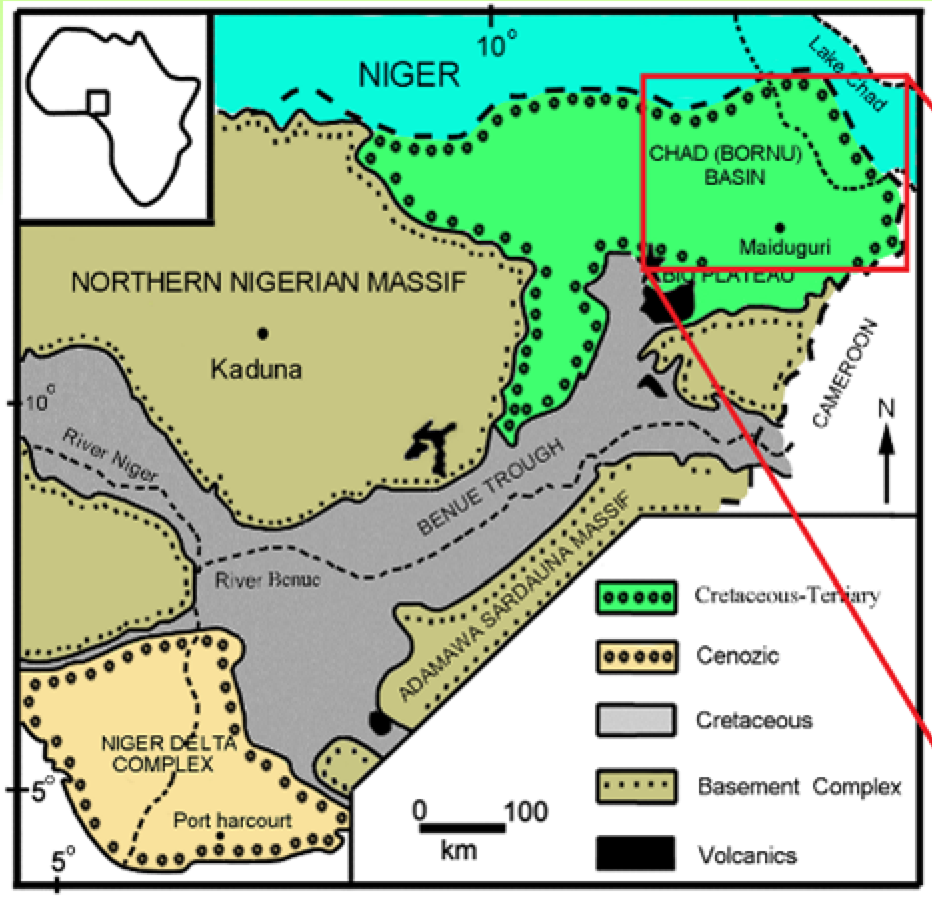
# OBJECTIVES

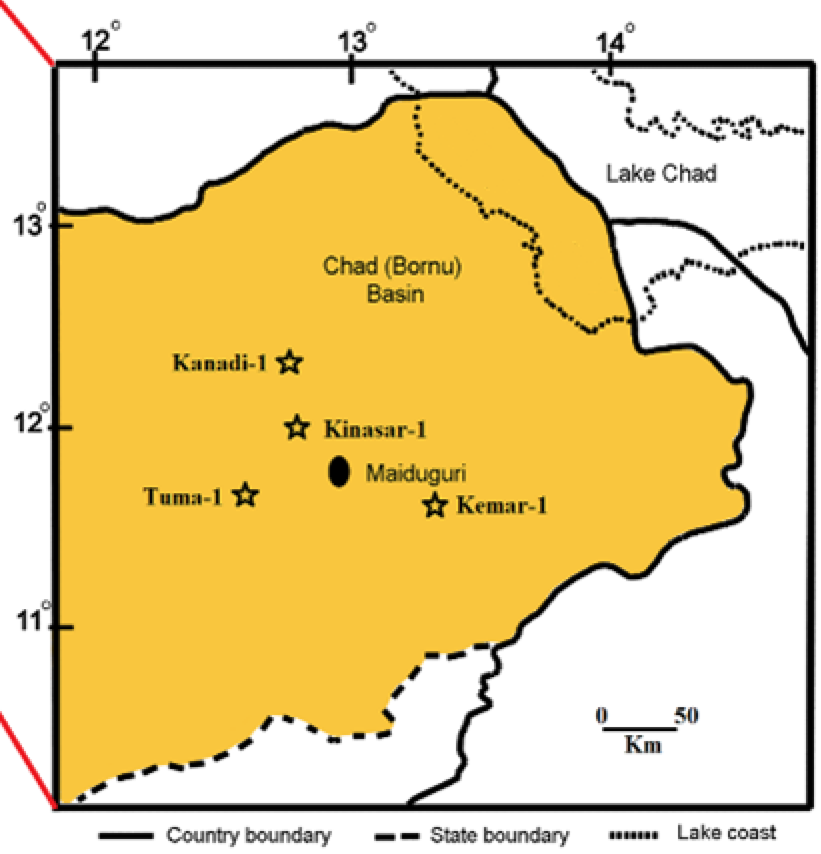
- To provide a detailed overview of the characteristics of the potential source rocks in the Chad (Bornu) Basin (quality, quantity and maturity).

- To assess the depositional conditions, organic matter source input and type in order to give further insight to the depositional environment and improve the overall geochemical information available for the basin.

# SAMPLES AND EXPERIMENTAL

- **Samples**
  - **75 ditch cuttings samples from six exploration wells (Kemar-1, Kanadi-1, Kinasar-1 and Tuma-1).**
- **Experimental**
  - **Organic geochemical analyses**
    - **Bulk geochemical analysis using Weatherford Source Rock Analyzer-TPH/TOC**
    - **Bitumen extraction using Soxhlet Extractor**
    - **Liquid column chromatography (Fractionation)**
    - **GC, GC-MS, GC-MS-MS (Biomarker distributions)**
    - **GC/IRMS (Compound-specific stable carbon isotope analysis)**
    - **Pyrolysis-GC**
    - **Elemental analysis (CHN)**
  - **Organic petrographic analyses**
    - **Kerogen isolation**
    - **Palynofacies**
    - **Vitrinite reflectance measurements**




**Geological Map of Nigeria, showing the Chad (Bornu) Basin and the location map of the studied exploratory wells: Kanadi-1; Kinasar-1; Kemar-1 and Tuma-1 (after Alalade and Tyson, 2010).**

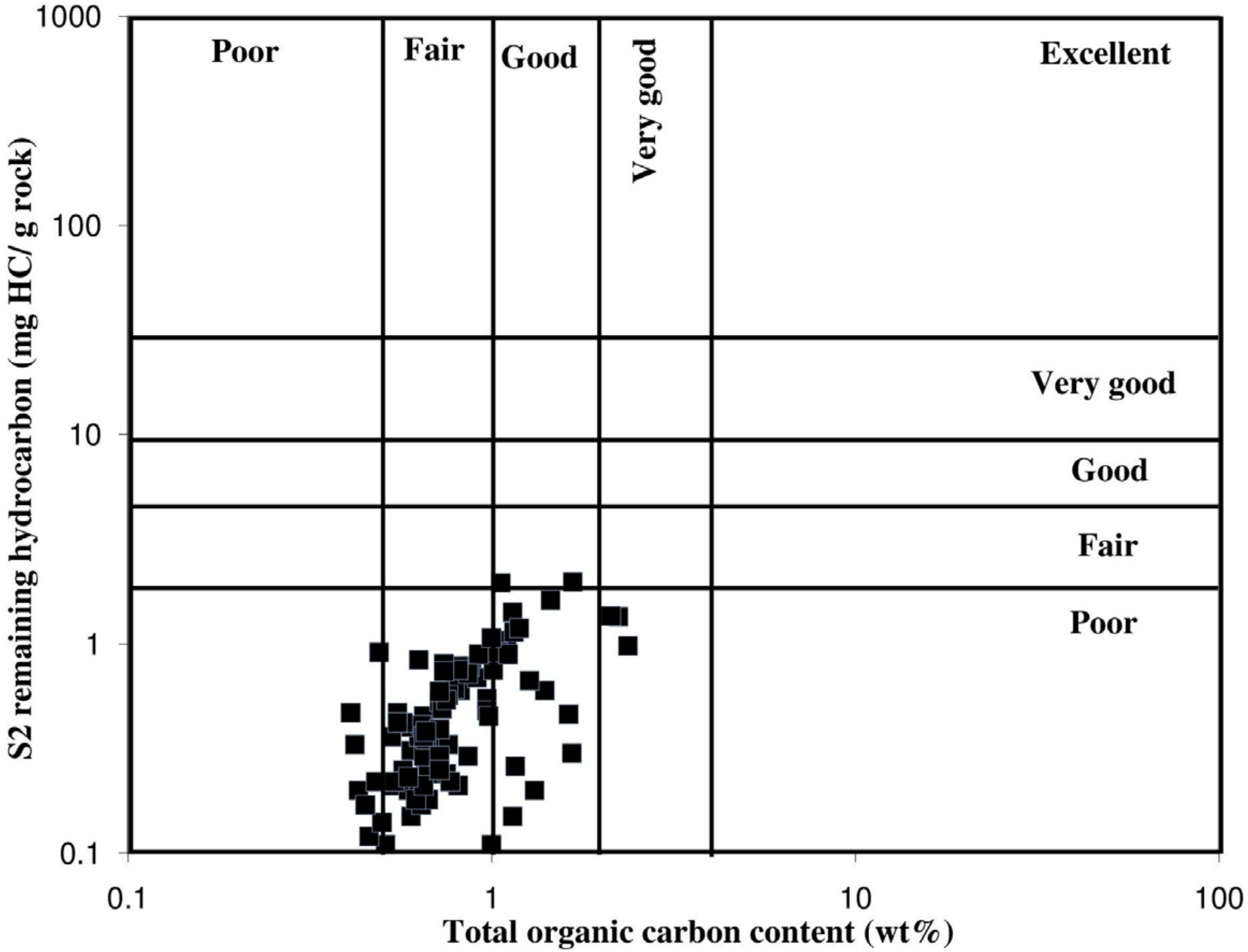
# RESULTS AND DISCUSSION

- **Source rock characteristics**
  - Organic matter richness and source rock quality
  - Organic matter type
  - Maturity of organic matter
  - Hydrocarbon generation potential

- **Organic matter source input and depositional environment**
  - Origin of organic matter
  - Paleodepositional conditions

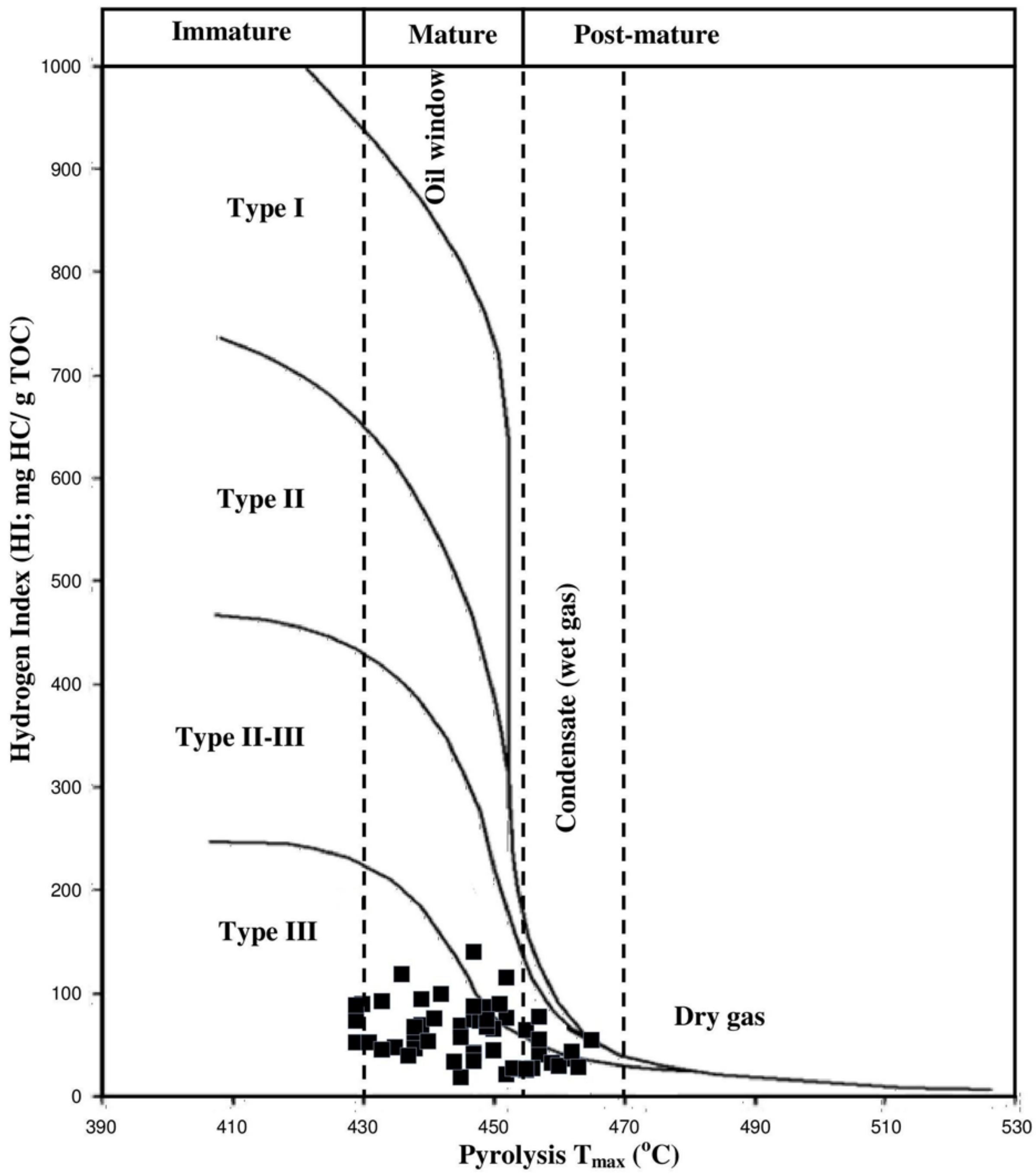
# Source rock characteristics

- Organic matter richness and source rock quality
- Organic matter type
- Maturity of organic matter
- Hydrocarbon generation potential



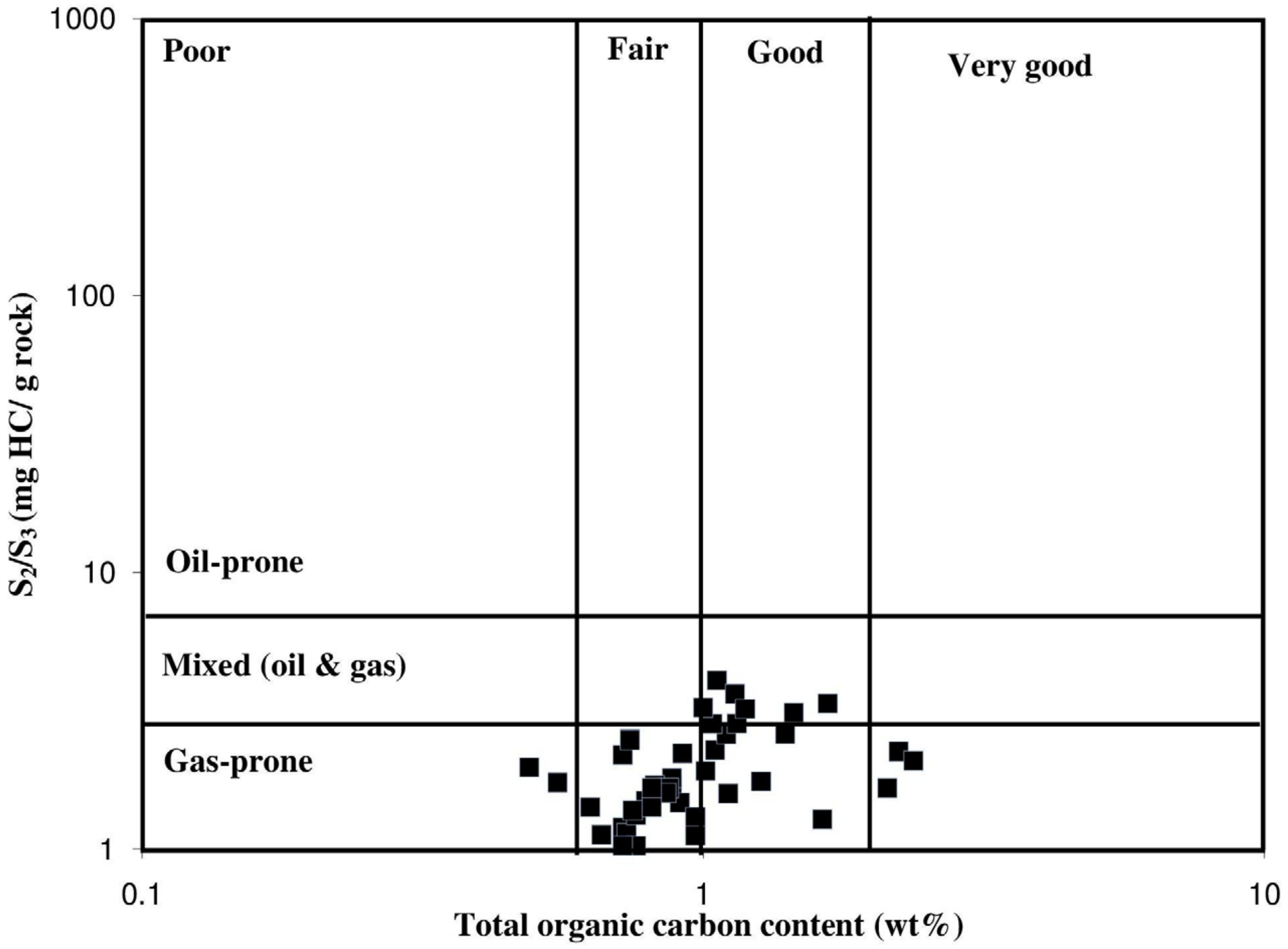

- TOC values range from 0.50 to 2.37 wt.% in the Fika Formation.
- The analysed samples have S2 pyrolysis yield values in the range of 0.06 – 1.98 mg HC/g rock, indicating poor to fair generative potential.

**Relationship between remaining hydrocarbon potential ($S_2$) and total organic carbon (TOC wt. %) for the Fika samples.**



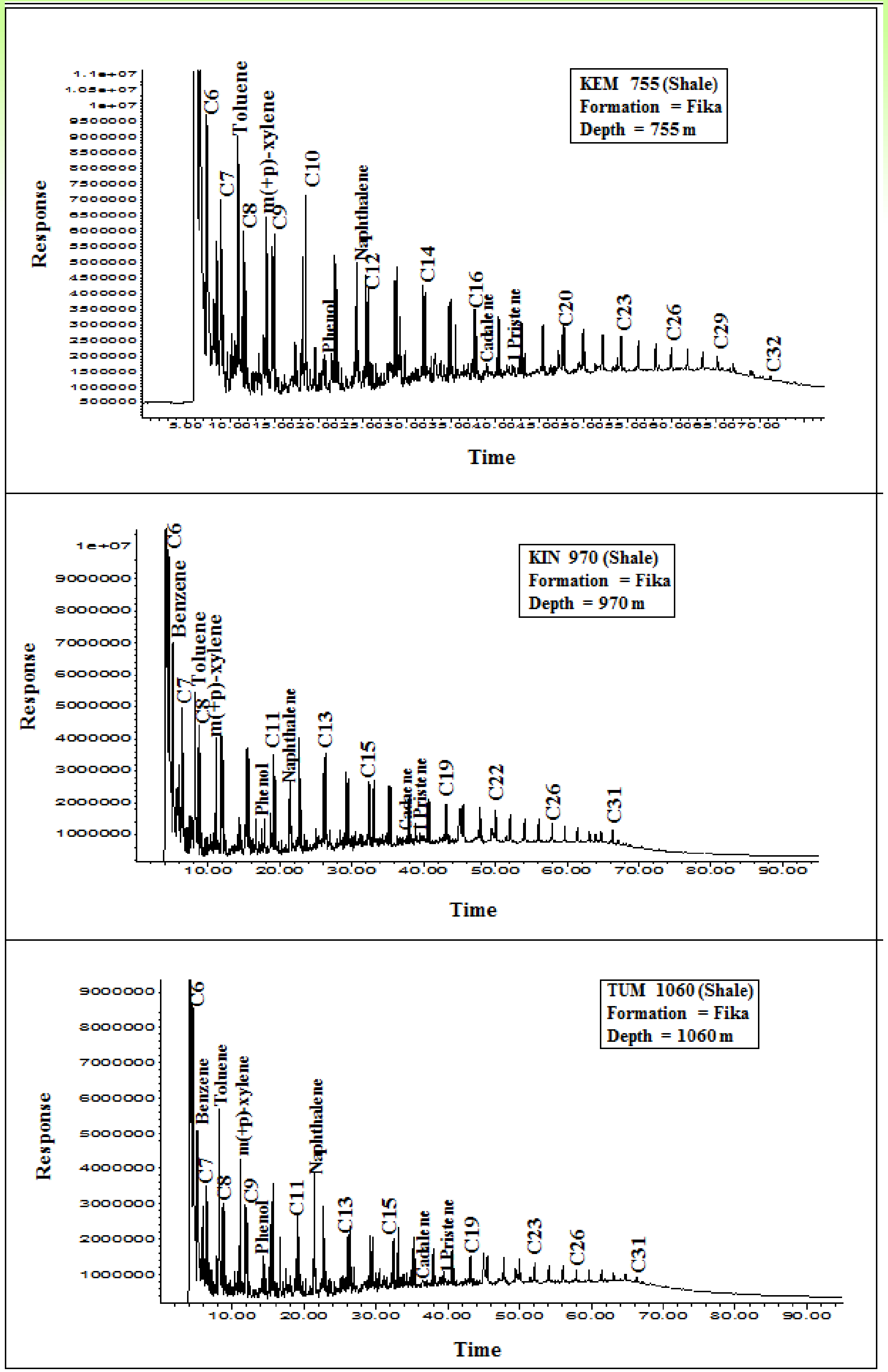

- Plot also shows that the studied samples contain mainly Type III kerogen.

**Plot of hydrogen index (HI) versus pyrolysis $T_{max}$ for the analysed Fika shale samples, showing present-day kerogen quality and thermal maturity stages**



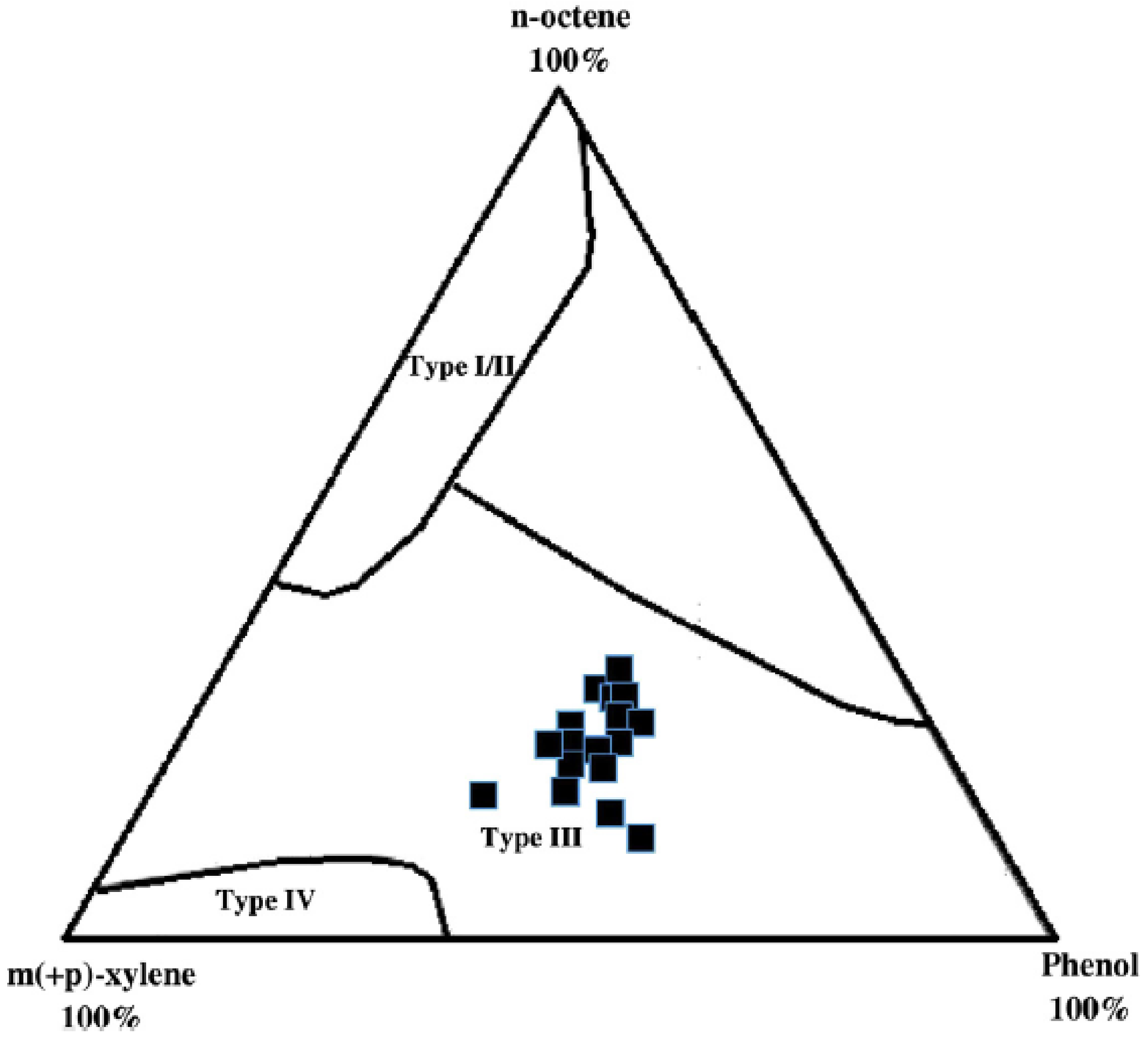

More gas will be generated

**Plot of S2/S3 versus TOC showing hydrocarbon generative potential in Fika sediments.**




- Py-GC pyrograms of Upper Fika samples display more prominent n-alkene/n-alkane doublets in the low molecular weight end (< $n$-$C_{10}$) than in the high molecular weight end (> $n$-$C_{15}$).
- Show that some of the samples contain relatively wax rich Type III/II kerogen
- Indicate organic matter is oil and gas prone, but generates more gas.
- Contain some abundant light aromatic compounds, alicyclic compounds, and sulphur compounds.

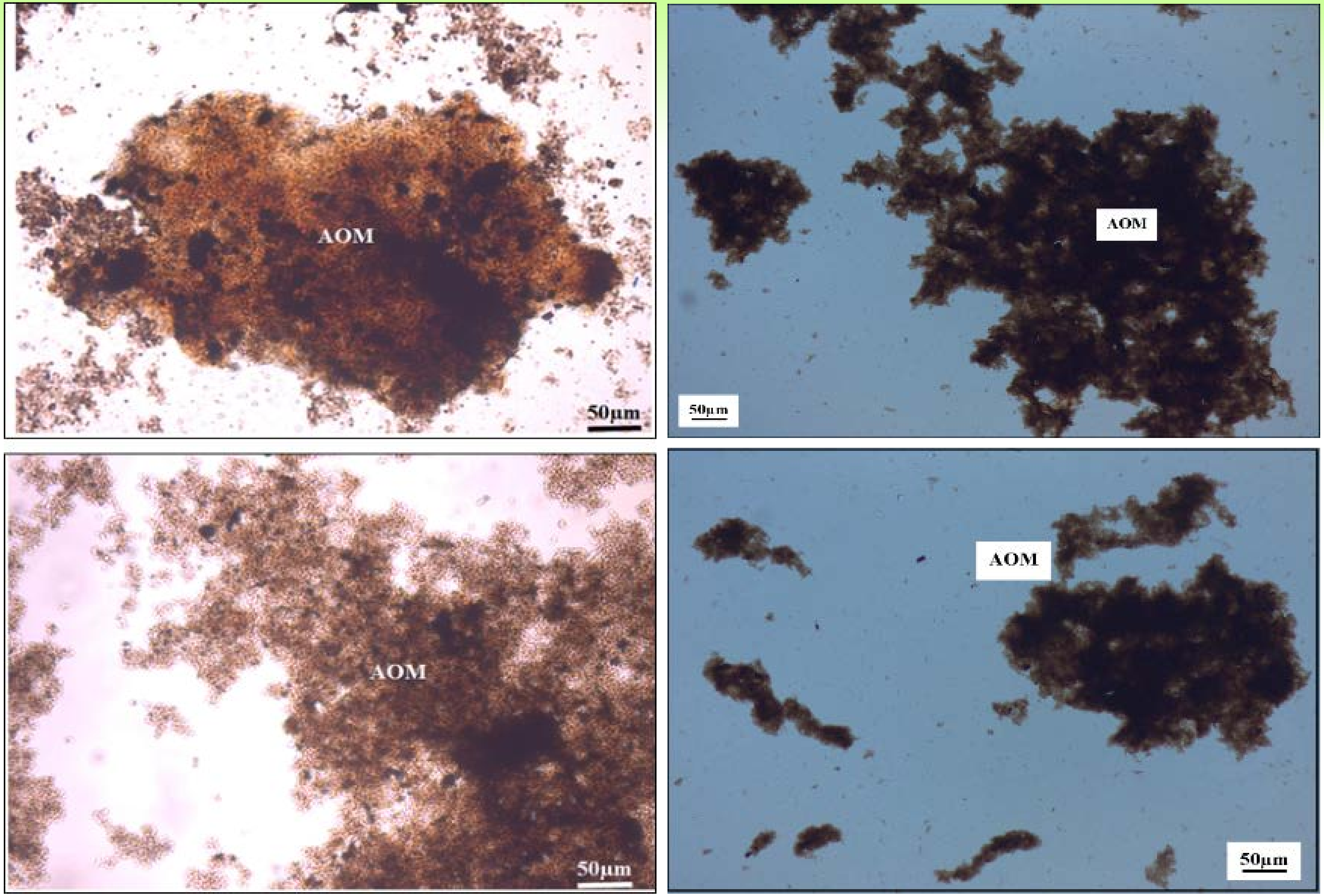
**Representative Py-GC chromatograms of selected Fika Shale samples.**




**Kerogen type classification using Py-GC data according to Larter (1984).**

- Some samples from Fika Formation comprise mixed Type III/II kerogen.

- Py-GC mitigates mineral matrix effect on source rock.

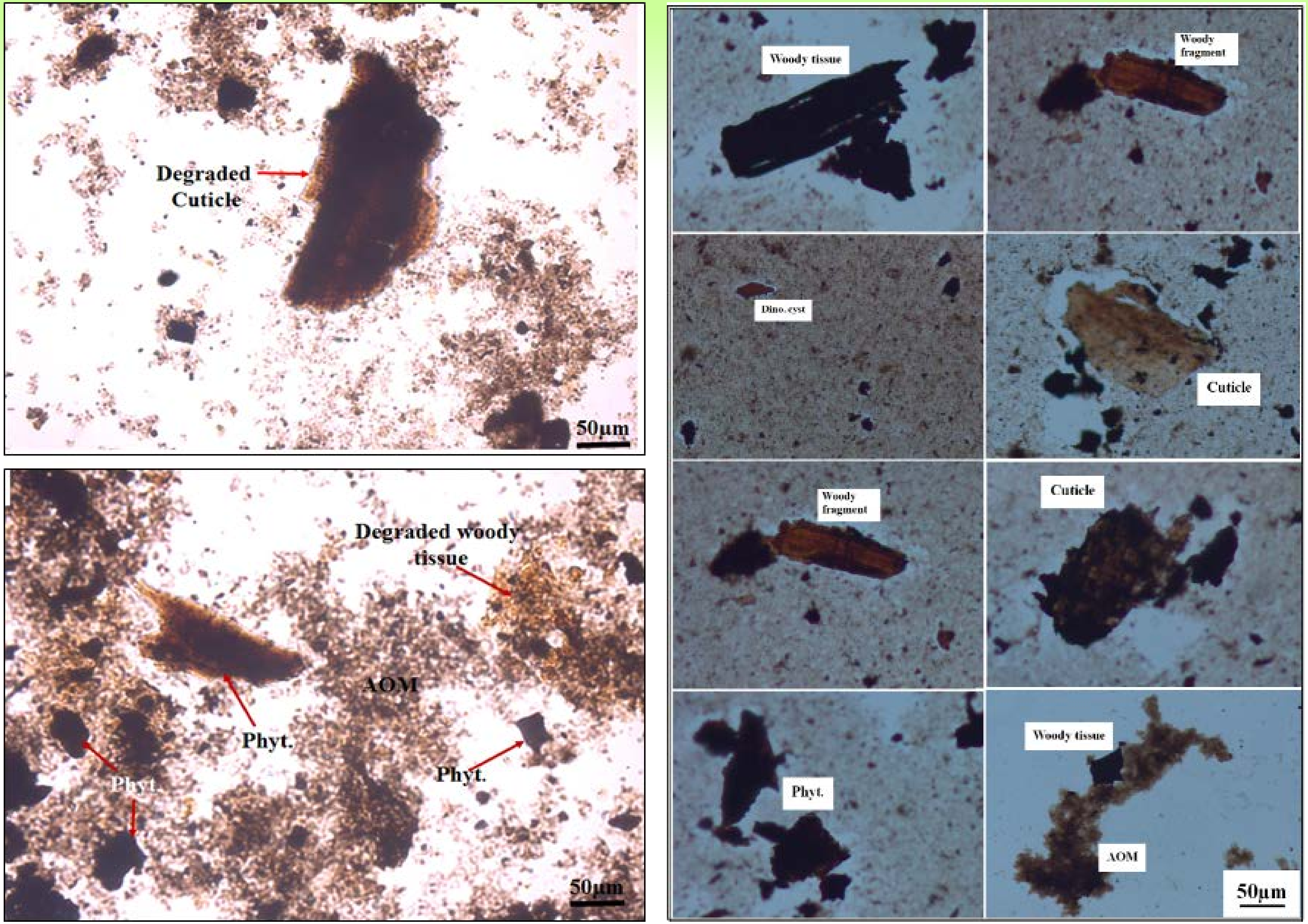



**Photomicrographs of amorphous organic matter (AOM) recognised in the analysed samples.**

- Three main kerogen groups were recognised in the investigated samples, namely amorphous organic matter (AOM), phytoclasts and palynomorphs

Amorphous organic matter

- Over 80% in the kerogen assemblages of all samples.
- Two types - fluorescent and non-fluorescent.
- Percentage of non-fluorescent AOM increases with depth.



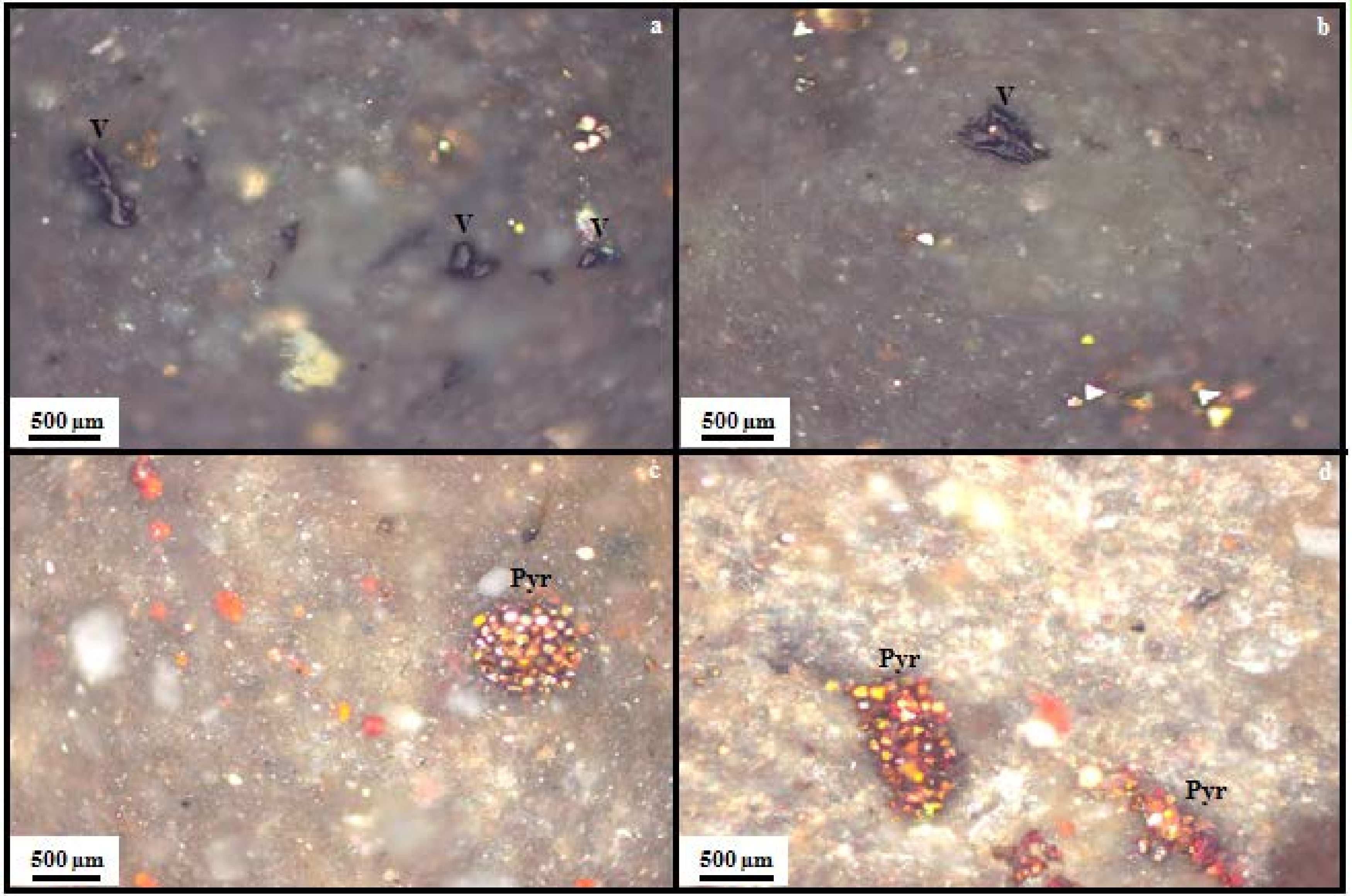

**Photomicrographs of the other kerogen groups recognised in the analysed samples.**

Phytoclasts

- Woody tissue and cuticles – over 15%.
- Woods are structured, opaque black to brown.
- Cuticles are mostly dark brown, slightly degraded.

Palynomorphs

- Sporomorphs and dinoflagellates cysts recognised.
- Dinoflagellate cysts suggest marine deposition.

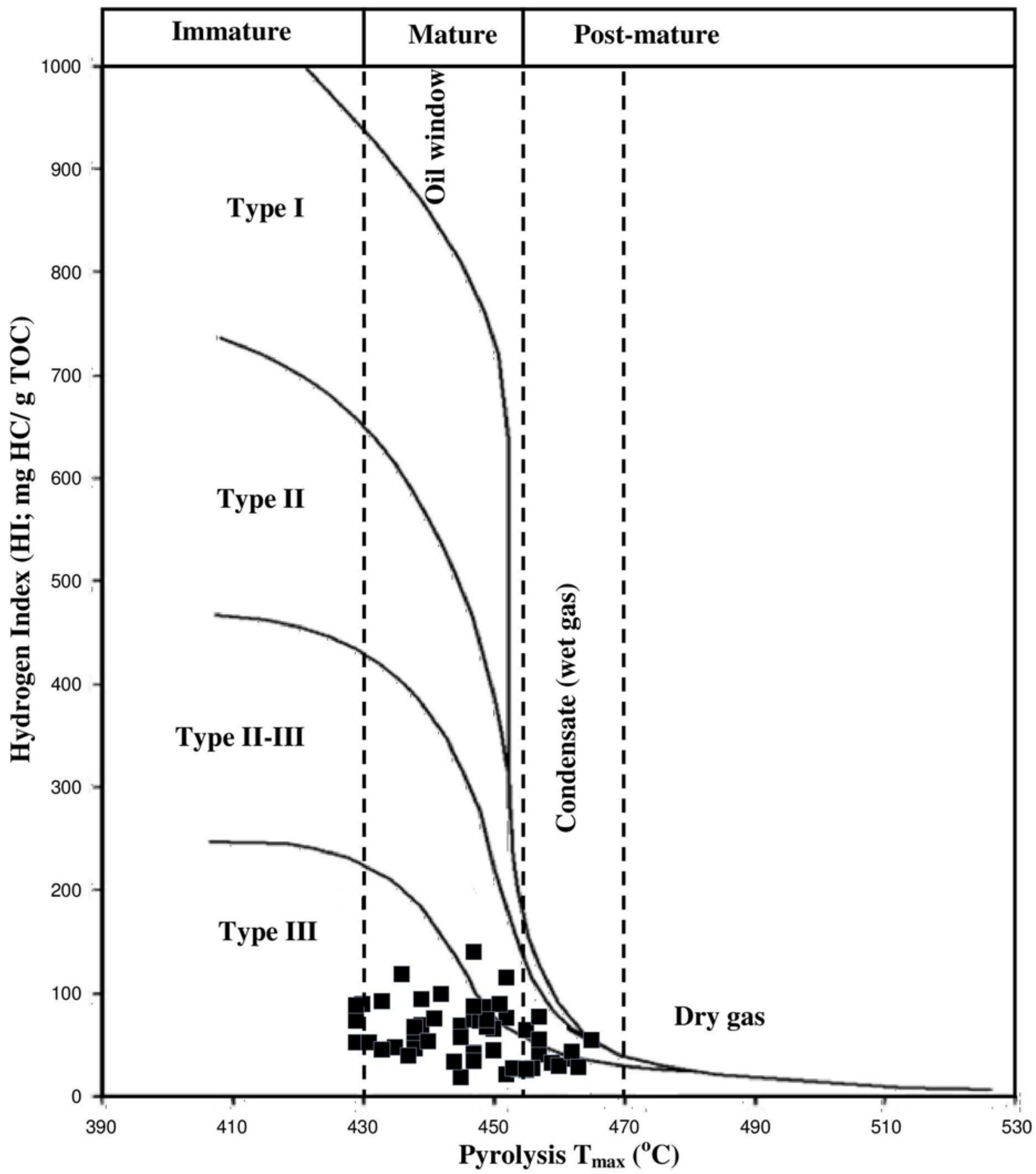



**Photomicrographs of some Fika samples under oil immersion; “a & b” - bitumen staining associated with vitrinite (V) under reflected light and “c & d” - showing presence of framboidal pyrite crystals (Pyr).**

- Bitumen staining associated with vitrinite macerals indicate HC generation.
- Presence of pyrite crystals suggest relatively reducing conditions.

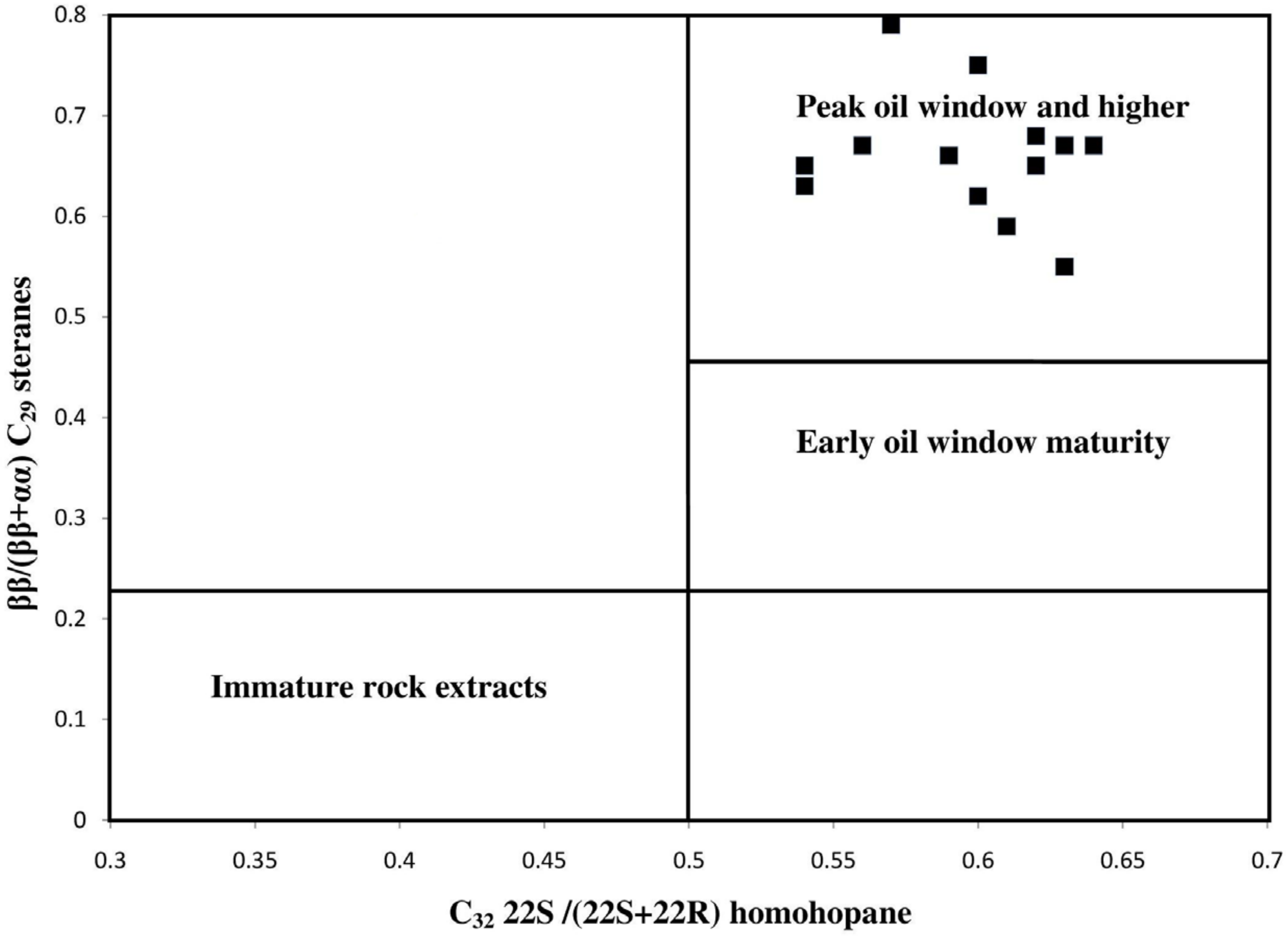
# Elemental (CHN) analysis

- Carbon contents (47.1 to 72.3 %); Hydrogen (1.59 to 5.67 %); Nitrogen (0.77 to 2.99 %).
- H/C atomic ratios range from 0.49 to 1.06
- H/C ratios at the upper part of Fika Formation range from 0.76 to 1.06
- Atomic C/N ratios range from 31.5 to 62.7
- Change in atomic H/C ratio is consistent with the thermal maturity.
- Low N concentration suggest significant input from terrigenous organic source.
- The C/N atomic ratio reflect a significant input from vascular plant.
- H/C ratio also suggest that samples from the upper part of Fika Formation are liquid HC prone.

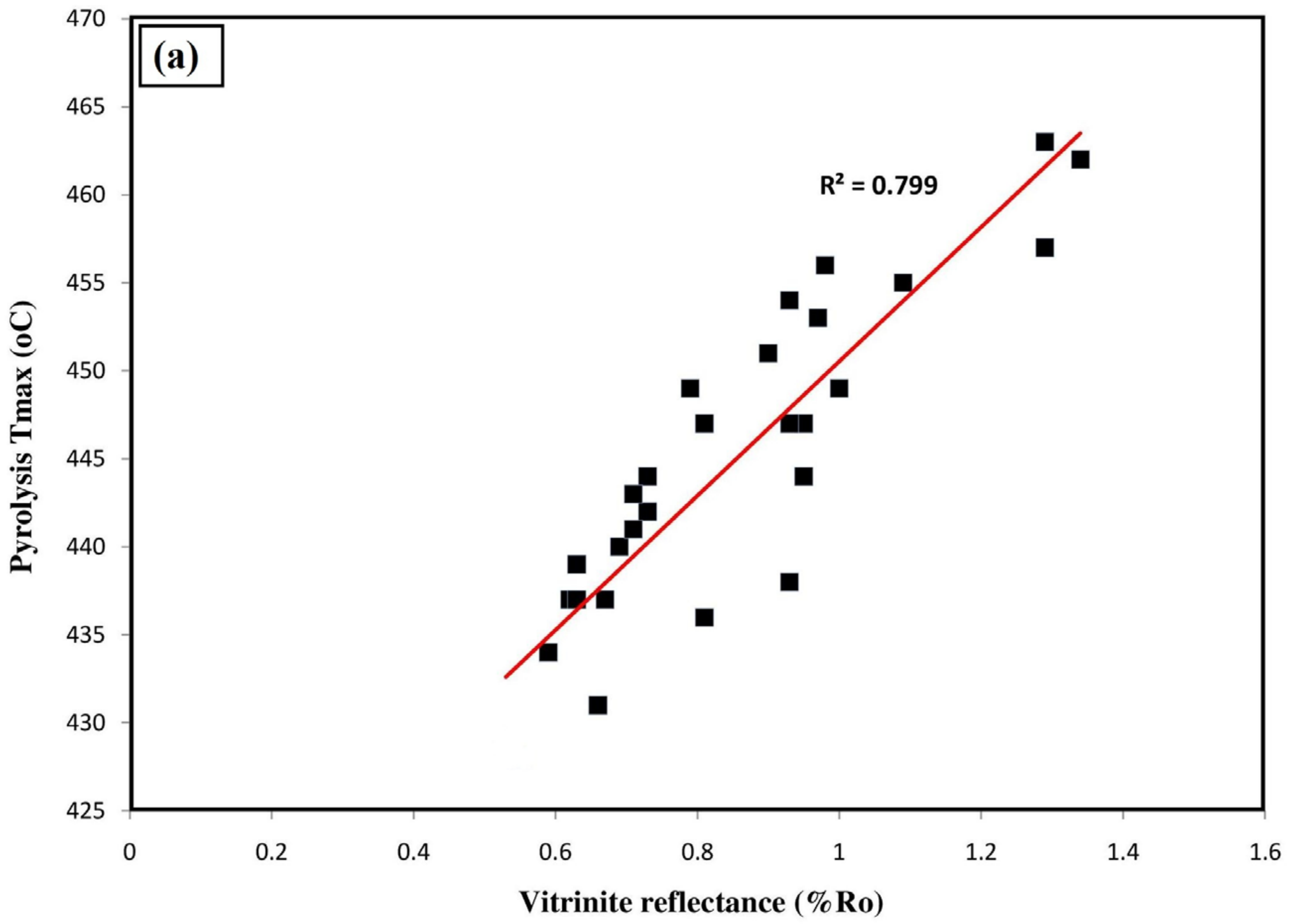



- SRA Tmax show that samples from Fika Fm. are in the early to post mature stage of HC generation.
- Vitrinite reflectance (Ro) range from 0.70 to 1.34%.
- SRA Tmax values range between 430 and 465 ˚C.

**Plot of hydrogen index (HI) versus pyrolysis $T_{max}$ for the analysed Fika shale samples, showing present-day kerogen quality and thermal maturity stages**




**Cross-plot of two biomarker parameters sensitive to thermal maturity of the showing that the samples plot in the area of peak oil window maturity and higher (modified from Peters and Moldowan, 1993).**

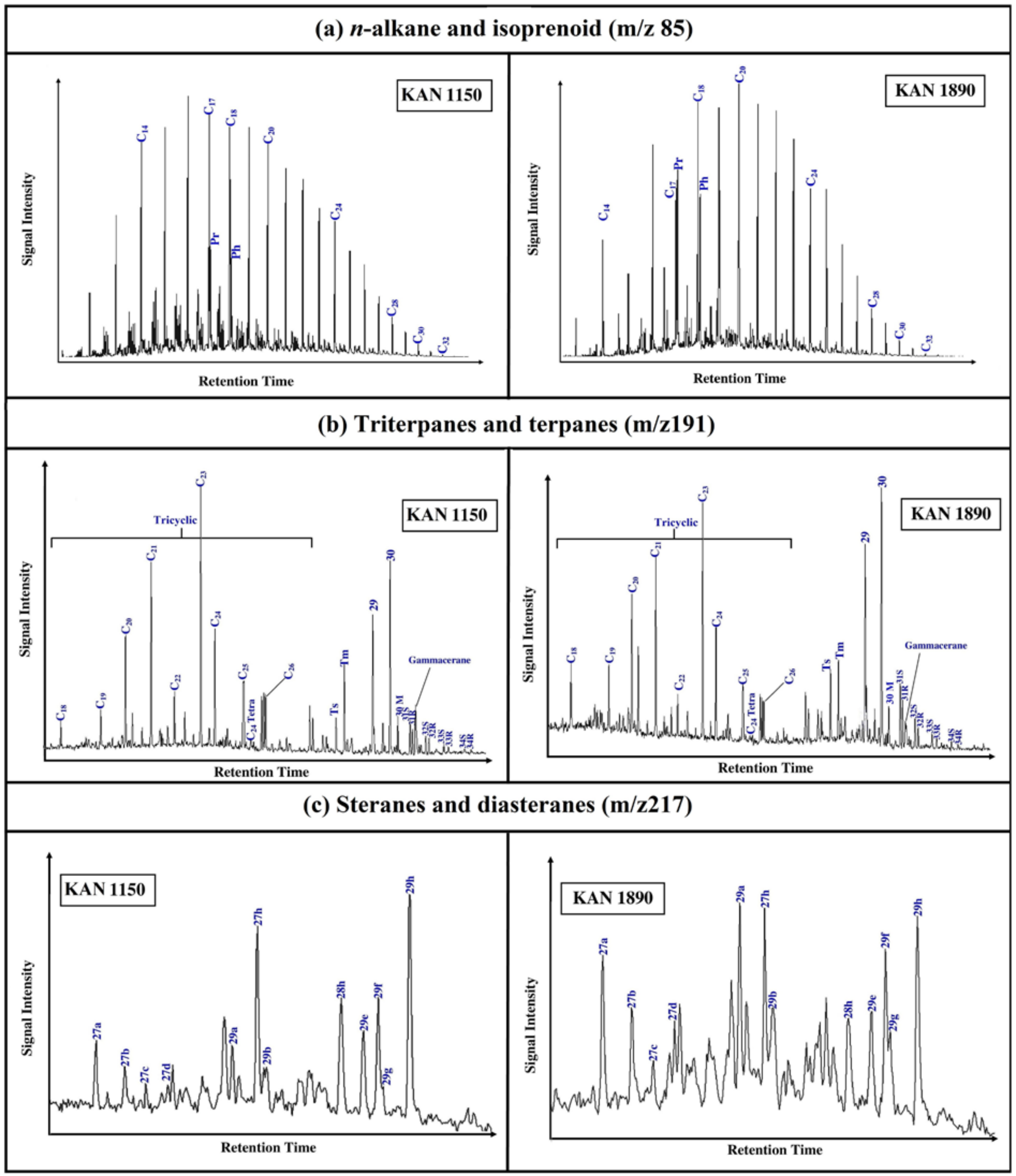



Good correlation

**Cross-plots of pyrolysis Tmax versus vitrinite reflectance (%Ro), showing the maturation of the Fika Shale samples.**

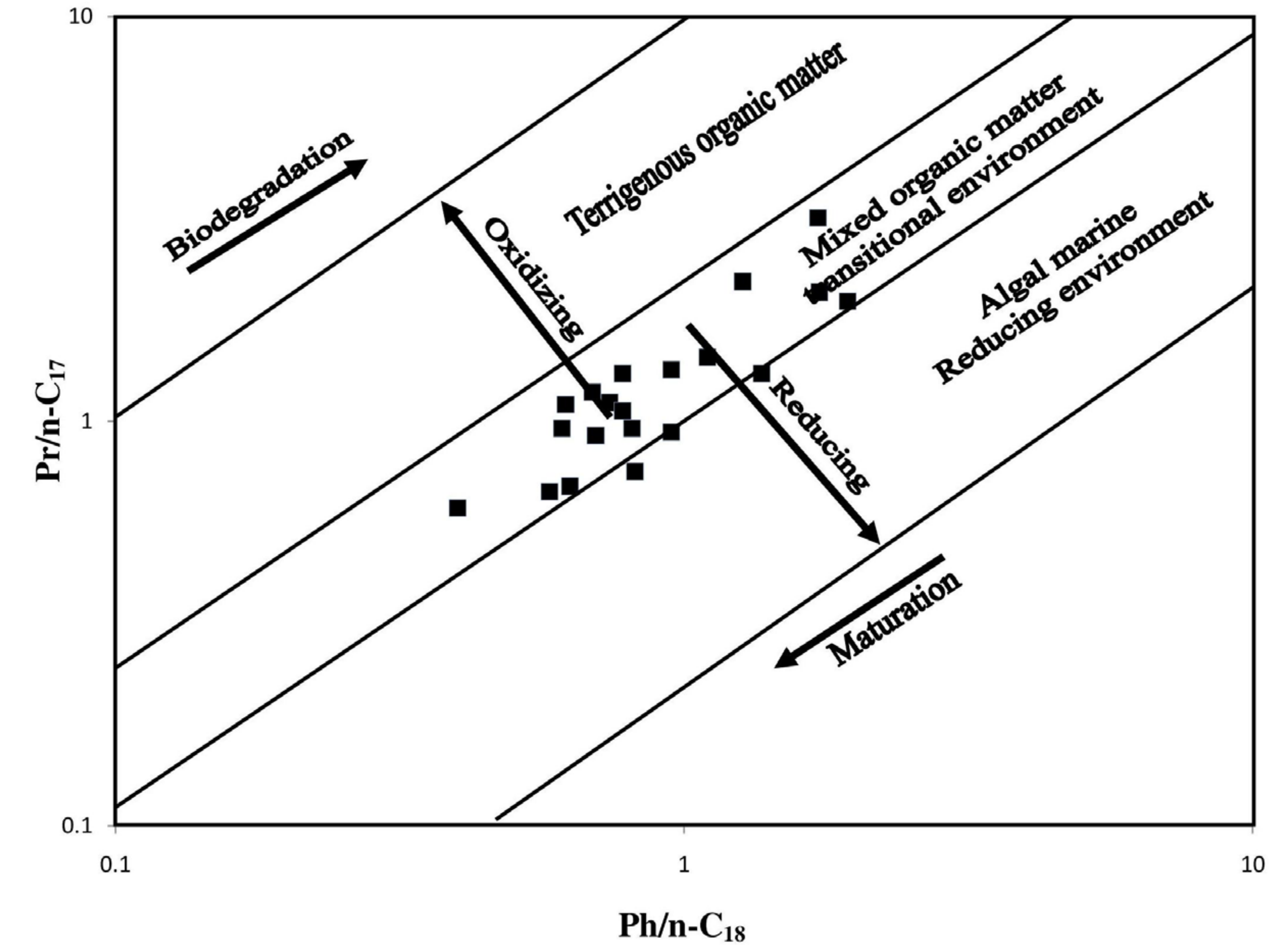
# Organic matter source input and depositional environment

- Origin of organic matter
- Paleodepositional conditions



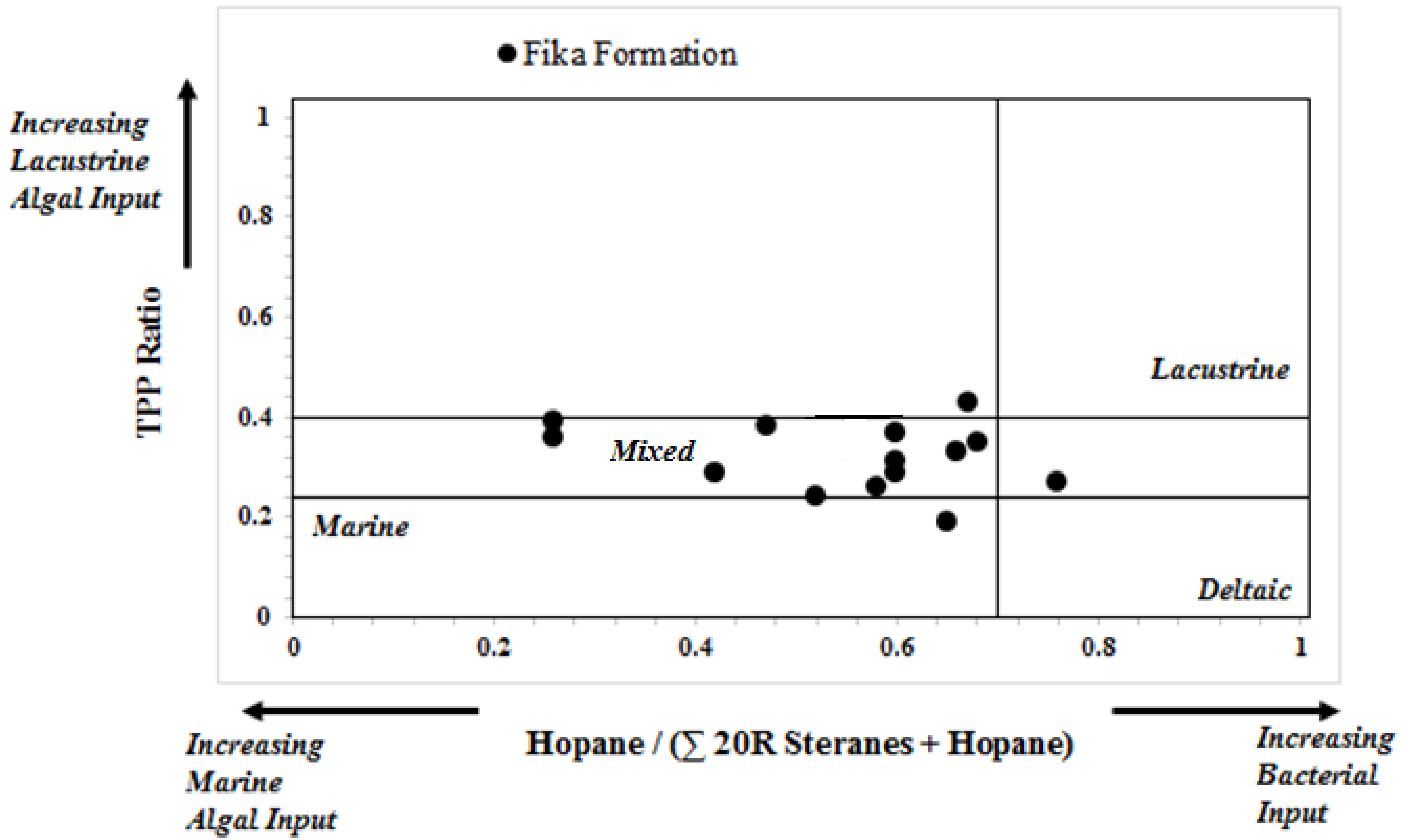

- *n*-alkane patterns show mainly unimodal distribution.
- Clear dominance of low to medium molecular weight n-alkanes.
- This indicates aquatic-derived with significant terrigenous organic matter contribution.
- Pr/Ph ratio range from 0.64 to 1.49.
- Indicate deposition under dysoxic paleodepositional conditions.

**Mass fragmentograms, m/z 85, m/z 191 and m/z 217 of saturated hydrocarbons of some studied Fika shale extracts.**



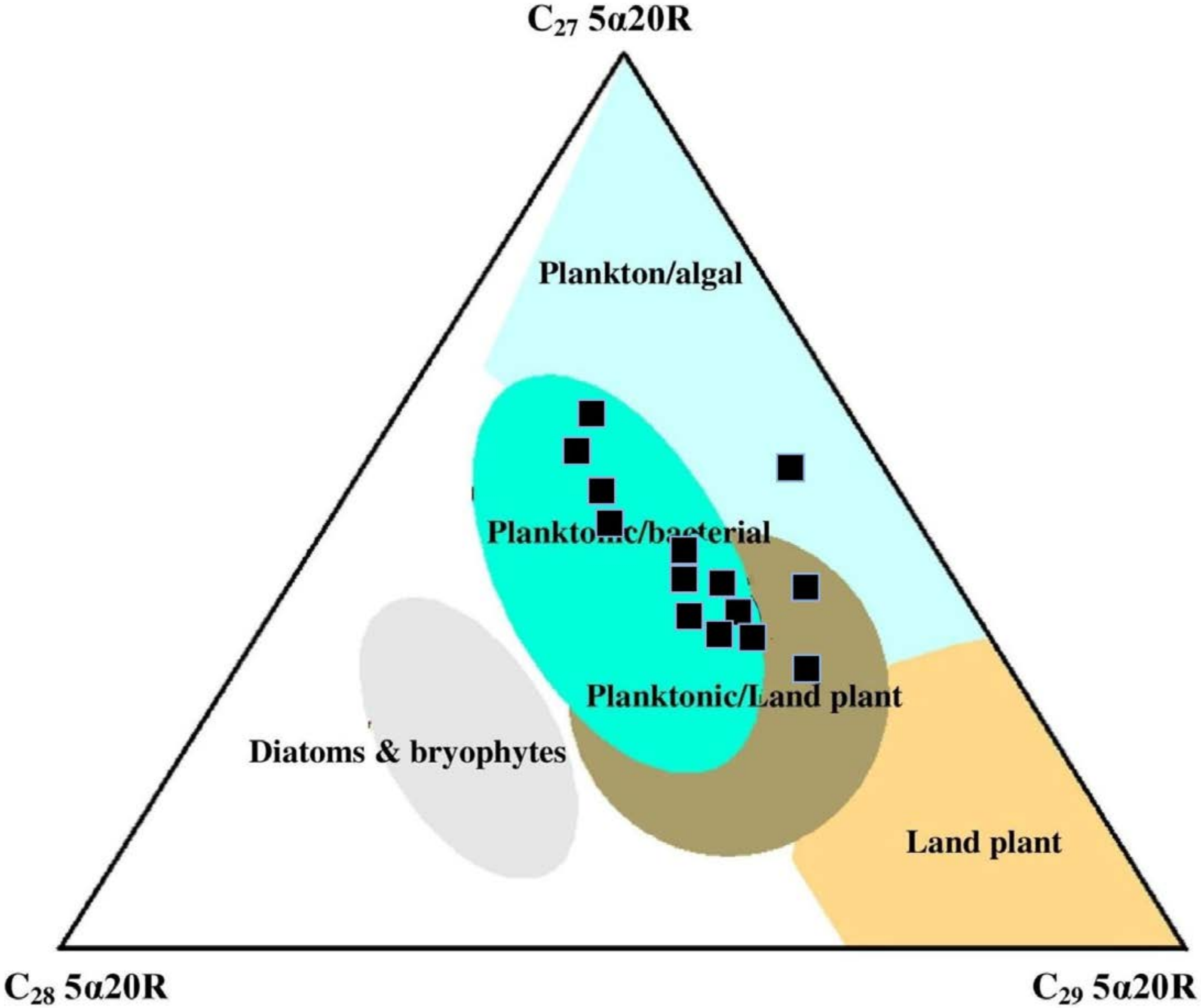

- Cross-plots indicate mixed marine and terrigenous organic materials.

**Phytane to $n$-$C_{18}$ alkane (Ph/$n$-$C_{18}$) versus pristane to $n$-$C_{17}$ alkane (Pr/$n$-$C_{17}$), showing depositional conditions and type of organic matter**



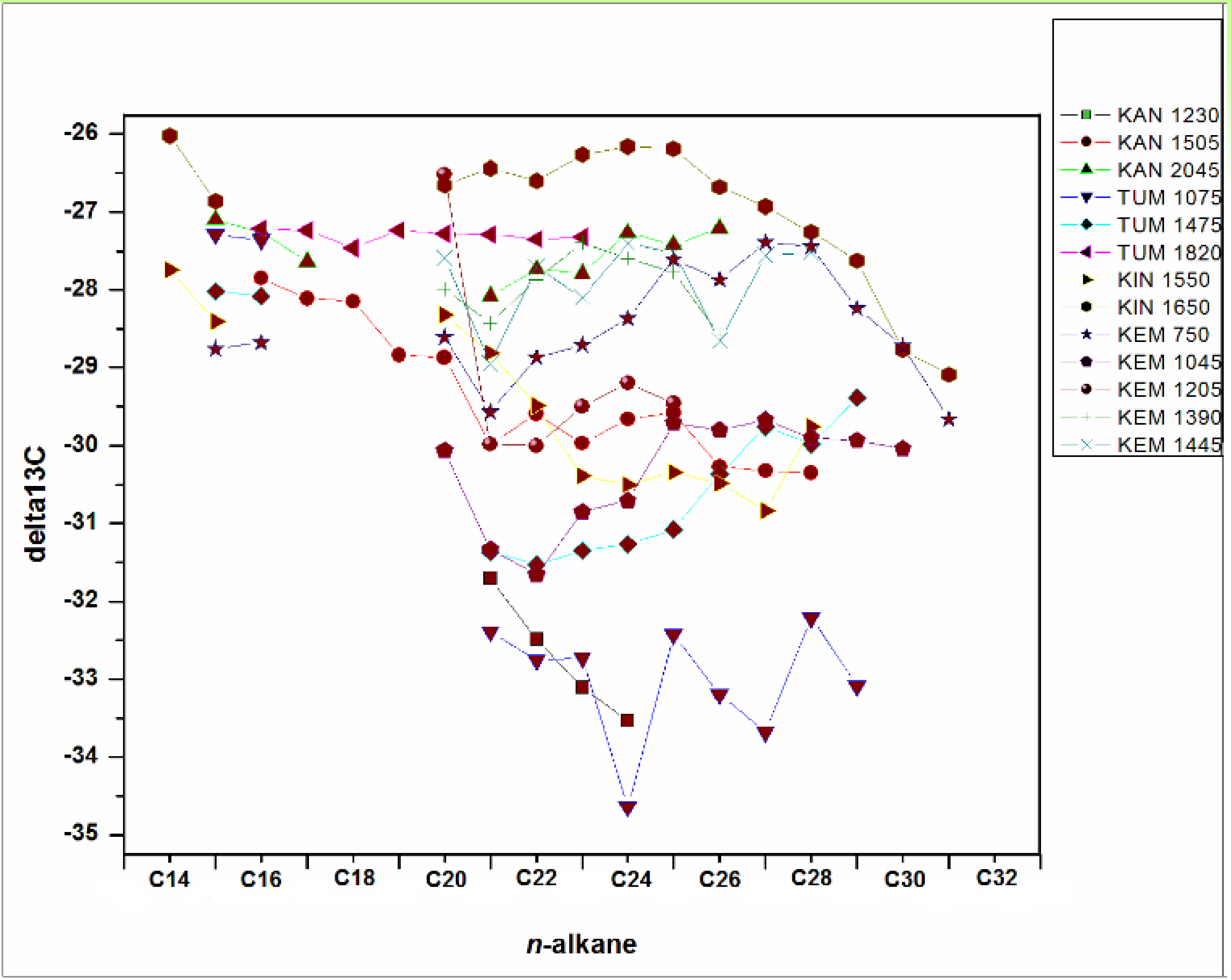

Marine OM have low values for TPP and hopane/(sterane + hopane) ratio while Algal lacustrine OM tend to have high values for both ratios. Terrigenous-rich OM have high values of hopane/sterane, but typically low values of TPP, consistent with a low algal content.

**Cross plot of TPP (tetracyclic polyprenoids) versus hopane/(sterane + hopane) ratio (adapted from Holba et al., 2003).**




Plot shows that the analysed Fika extracts are composed of mixed marine/terrigenous organic matter.

**Ternary diagram of regular steranes ($C_{27}$, $C_{28}$ and $C_{29}$) showing the relationship between sterane compositions and organic matter input, (modified after Huang and Meinschein, 1979).**




***n*-Alkane isotope profile of Fika Formation sediments.**

- The $\delta^{13}$C isotopic values for *n*-alkanes ($nC_{14}$–$nC_{31}$) range from –34.64 to –26.02 δ‰ PDB.
- The most depleted values were observed for the medium chain alkanes ($nC_{21}$–$nC_{26}$), which are characteristics of plant wax derived *n*-alkanes of C3-plants.
- Significant contribution from marine organic matter (i.e. C3 algae or cyanobacteria) is reflected in heavier $\delta^{13}$C isotope values observed in the short chain ($nC_{14}$–$nC_{20}$) alkanes in some of the samples.
- The notably flat portion pattern of the *n*-alkane profile in Fika samples is an indication of marine environment.
- These features show that Fika sediments consist of both terrestrial and marine organic matter.

# Conclusions

- The Upper Cretaceous sediments in the Chad (Bornu) Basin generally have fair generative potential and contain Type III/II, Type III and Type IV kerogens.

- Detailed geochemical analyses and organic petrography provide evidence for a mixed aquatic algae and terrigenous organic matter input deposited under environmental conditions that were mostly dysoxic with fair preservation of organic matter.

- The Fika sediments are in the early-mature oil window to late stage of gas-window.

- The organic matter in Fika Shale is oil and gas prone, but generates more gas.

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# Thank you for listening