Source-rock Potential and Origin of Hydrocarbons in the Cretaceous and Jurassic Sediments of the Punjab Platform (Indus Basin) Pakistan*

Rahmat Ali Gakkhar[1], Achim Bechtel[2], and Reinhard Gratzer[2]

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[1]Oil & Gas Development Company Limited, Head Office, Islamabad, Pakistan (kasurirah@yahoo.com)
[2]Department Applied Geosciences and Geophysics, University of Leoben, Austria

Abstract

A better understanding of the petroleum systems, including source rock characterization, is needed to enhance the success rate of exploration in the Punjab Platform of Pakistan. Bulk geochemical data and biomarker composition are used here to characterize the environment of deposition and the source rock potential of the strata, drilled in the Ali Sahib and Amir Wali wells. Rock-Eval pyrolysis data classify the organic matter in Jurassic to Eocene strata as Type- III kerogen with transition to Type-II. A few samples from the Chichali (Cretaceous) Formation and the Datta Formation (Jurassic) have a fair generative potential for oil and gas.

An algal/microbial origin is proposed for the organic matter present in the samples from the Cretaceous Chichali Formation, whereas a mixed algal/bacterial and land plant origin is proposed for the organic matter of the Cretaceous Lumshiwal, as well as the Samana Suk and Datta Formations (both Jurassic). An anoxic/reducing marine environment during deposition of the Chichali and the Lumshiwal Formations (Cretaceous) is indicated, whereas the Samana Suk and Datta/Kingriali Formations (Jurassic to Triassic) were deposited under oxic to dysoxic conditions. Urs-12-ene, a biomarker for angiosperms, was identified in the Chichali Formation of the Ali Sahib well. All samples are immature to marginally mature. An average vitrinite reflectance (R_r) between 0.5 and 0.6 is estimated from T_{max} and the isomerisation of 17α□□21β (H) C_{31} hopanes.

A condensate sample from the Sarai Sidhu well indicates elevated biodegradation of light hydrocarbons that were derived from the cracking of petroleum. Based on the presence of rearranged drimanes in the condensate, probably originating from pentacyclic triterpenoids originating in angiosperms, and of urs-12-ene in the Chichali Formation, an origin of the condensate in this Formation is proposed. Oil and condensate must have been formed deeper in the Basin, most probably from mature sediments of the Chichali or Datta Formations. The investigated condensate may represent the degraded residue of methanogenic biodegradation responsible for the gas accumulations in the study area.

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Source-rock Potential and Origin of Hydrocarbons in the Cretaceous and Jurassic Sediments of the Punjab Platform (Indus Basin) Pakistan

Dr. Rahmat Ali Gakkhar (presenting author)
OGDCL, Islamabad

Co-authors: Dr. Achim Bechtel and Dr. Reinhard Gratzer Professors at University of Leoben, Austria,

PRESENTATION SCHEME

- Context, Problems
- Objectives
- Study Area, Data Sets
- Workflow, Methodology
- Results / Discussion
- Conclusions and Recommendations
- Acknowledgement

CONTEXT, PROBLEMS

- Despite growing insights from geophysical investigation and drilling activities, the success rate of hydrocarbon exploration in the Punjab Platform is still unsatisfactory.

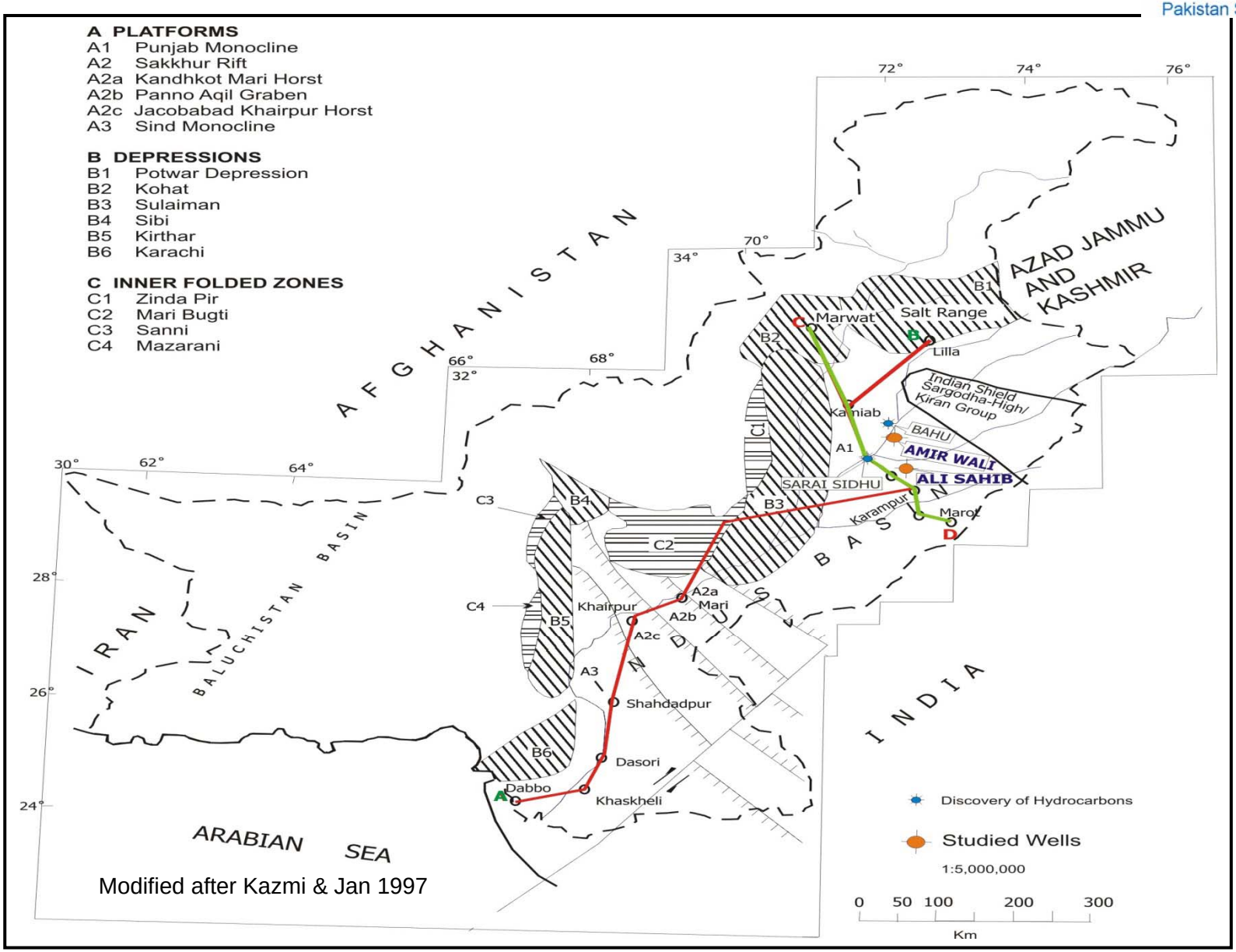
- A better understanding of the source-rock potential in the Punjab Platform is lacking.

- The biomarker studies of solvent extracts from the Cretaceous and Jurassic sediments have never been carried out.

OBJECTIVES

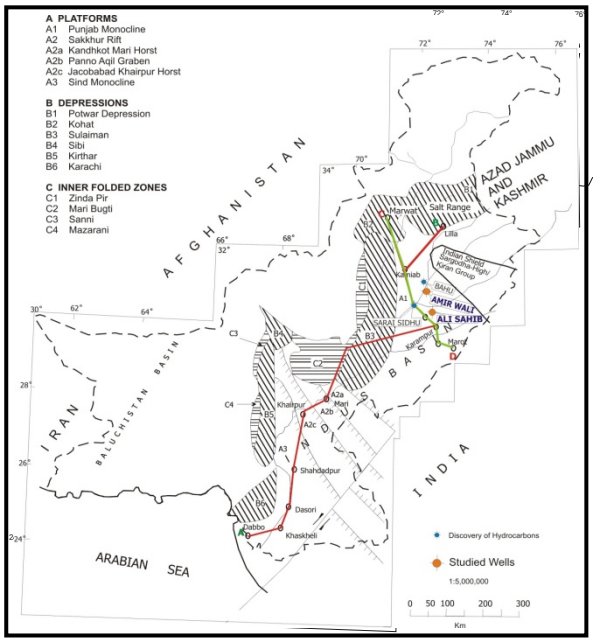
- Cretaceous and Jurassic source-rocks characterization by using bulk geochemical data
- Biomarker study for origin of hydrocarbons and to characterize the environment of deposition
- A better understanding of petroleum systems in the Punjab Platform

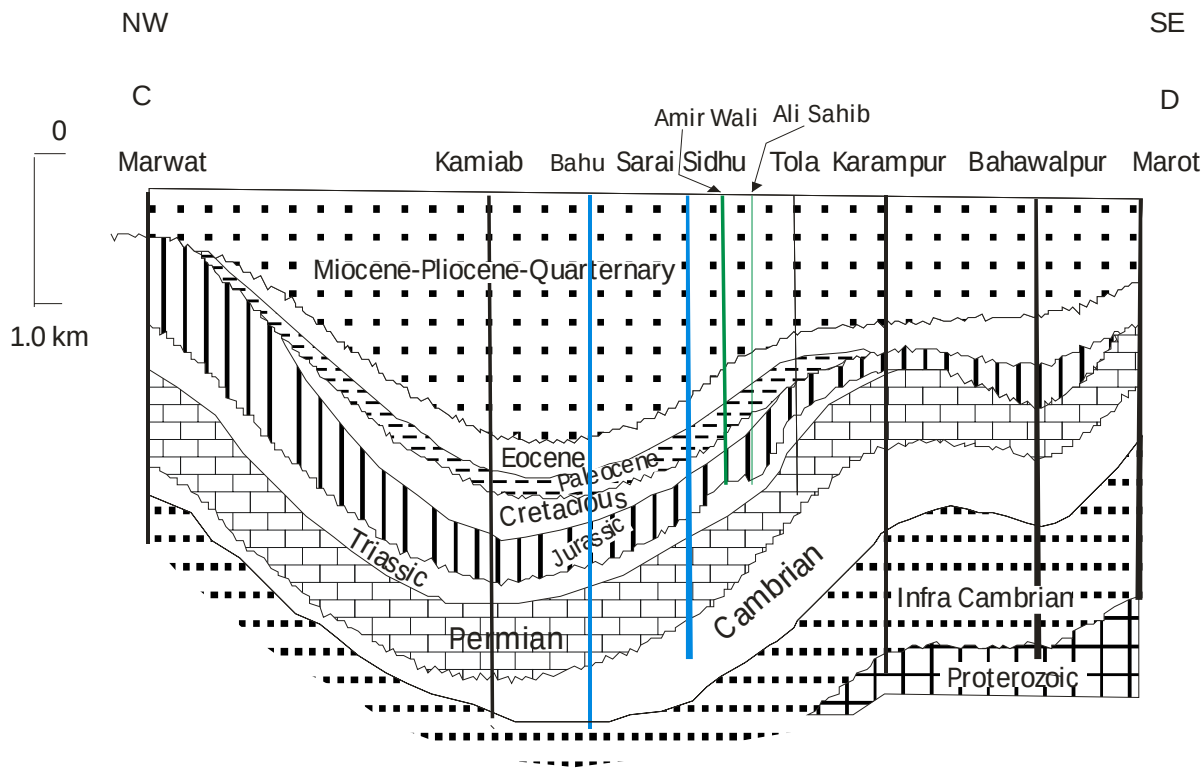
STUDY AREA



Modified after Kazmi & Jan 1997

STUDY AREA





Ali Sahib-1, Amir Wali-1, Bahu-1 and Sarai Sidhu well s have been extrapolated on regional cross-section along A-B; (Modified after Kazmi & Jan 1997).

WORK FLOW, METHODOLOGY

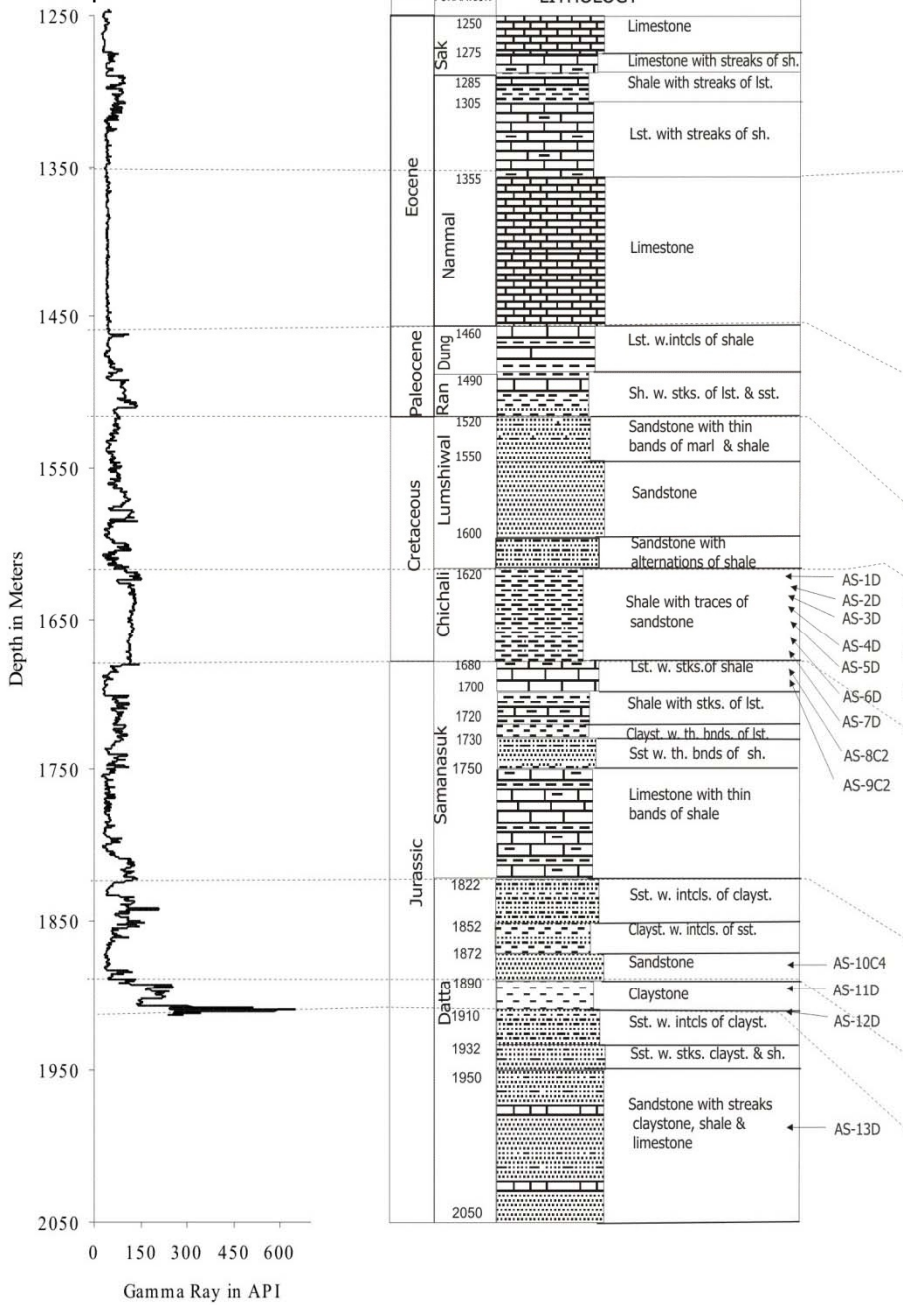
- Lithological, and bulk geochemical studies of cuttings (5-10m interval) and cores (0.3m to 0.5m interval) from Eocene to Jurassic of the Ali Sahib and Amir Wali wells were completed at G&R Labs Islamabad.

- Prepared profile of the wells based upon lithological description and charts/cross-plots of geochemical data.

- Based on good TOC values samples were selected for solvent extract in order to carry out biomarker studies of cores and cuttings at University of Leoben, Austria.

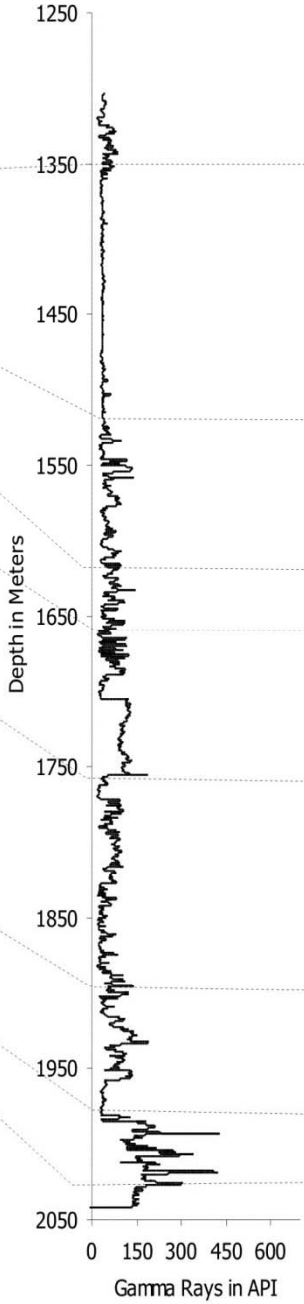
- A condensate sample from Sarai Sidhu well was also included in the study.

Ali Sahib : 23 lithofacies
Samples: 13

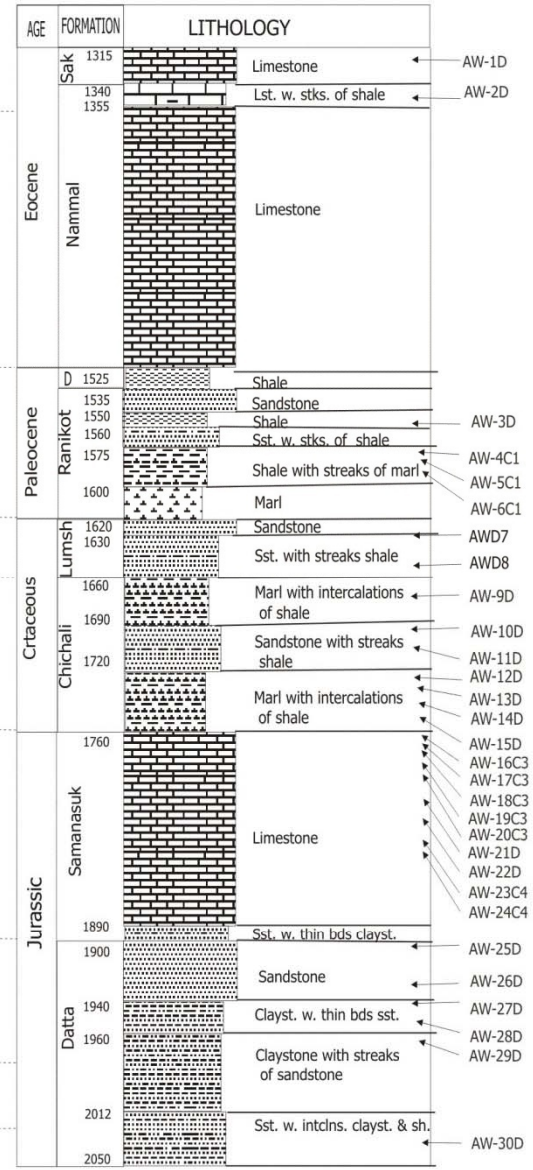


LITHOLOGICAL LOG (PROFILE) OF THE ALI SAHIB WELL

Amir Wali : 20 lithofacies
Samples: 30



LITHOLOGICAL LOG (PROFILE) OF THE AMIR WALI WELL



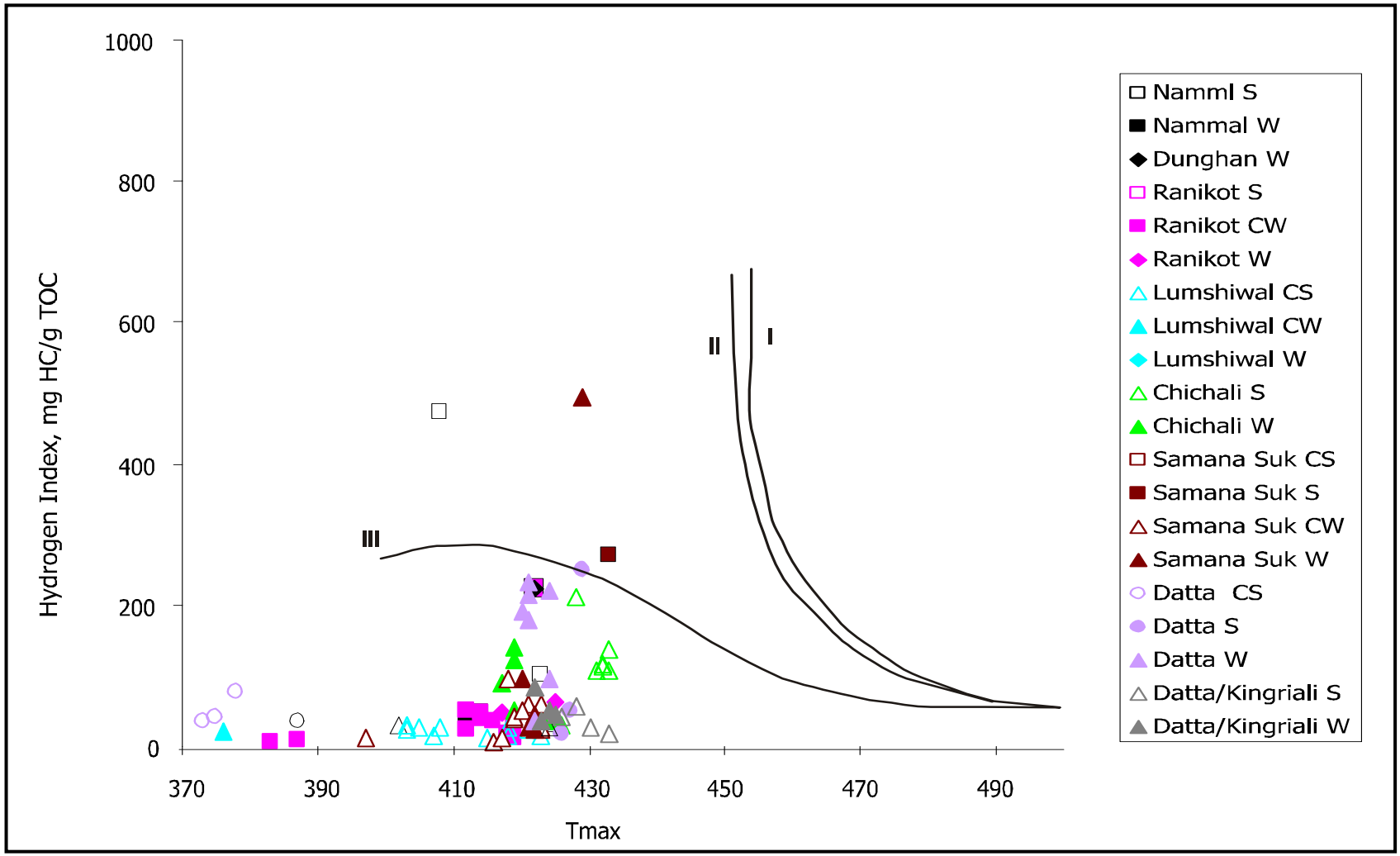
RESULTS/DISCUSSION
A: Rock-Eval analysis

- In Ali Sahib well TOC ranges between 0.79 and 2.26 wt.%, while TOC values in the Amir Wali well is 0.59 to 2.33 wt.% (Table 1).

- The sampled Formations do not show systematic differences in TOC.

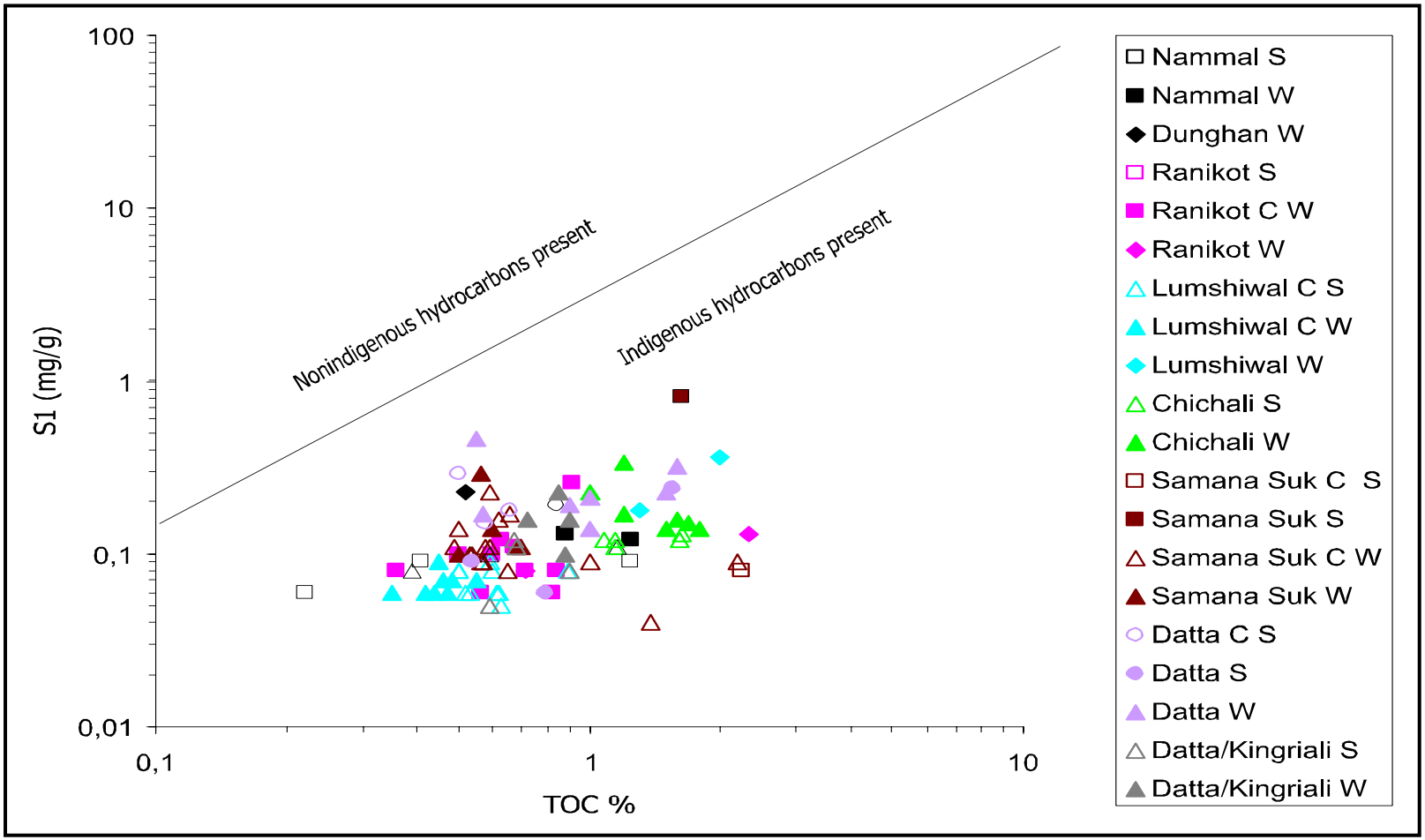
- Enhanced TOC contents are found in shaly and marly horizons of the Chichali Fm and in the limestones of the Samana Suk Fm.

Results/Discussion
A: Rock-Eval analysis



HI versus T_{max} of samples from Ali Sahib and Amir Wali wells. W: Ditch cuttings of the Amir Wali Well, CW: Core of the Amir Wali Well, S: Ditch cuttings of the Ali Sahib Well, CS: Core of the Ali Sahib Well.

RESULTS/DISCUSSION
A: Rock-Eval analysis



Cross-plot of S1 (mg free HC/g rock) versus TOC for the distinguishing of indigenous and nonindigenous hydrocarbons (Hunt, 1996). W: Ditch cuttings of the Amir Wali Well, CW: Core of the Amir Wali Well, S: Ditch cuttings of the Ali Sahib Well, CS: Core of the Ali Sahib Well.

RESULTS/DISCUSSION
B: Bitumen content and composition

- In general, the lithology of the samples with high contents of bitumen extracted is claystone and the lithology of the samples with low contents of extracted bitumen is limestone.

- Samples from the Ali Sahib well show bitumen contents from 0.8 % to 9.0 % (from the Chichali Formation), comparable to the normal bitumen content range (5-15 %, Hunt, 1996).
- In Amir Wali well the extracted bitumen ranges from 0.6% to 16.3% of TOC (from the Datta Formation).

- The saturated hydrocarbon fractions predominate in most samples over the aromatic hydrocarbons.

- The NSO compounds (polar compounds plus asphaltenes) contribute between 6 and 84 % of the EOM (> 40% in most samples).

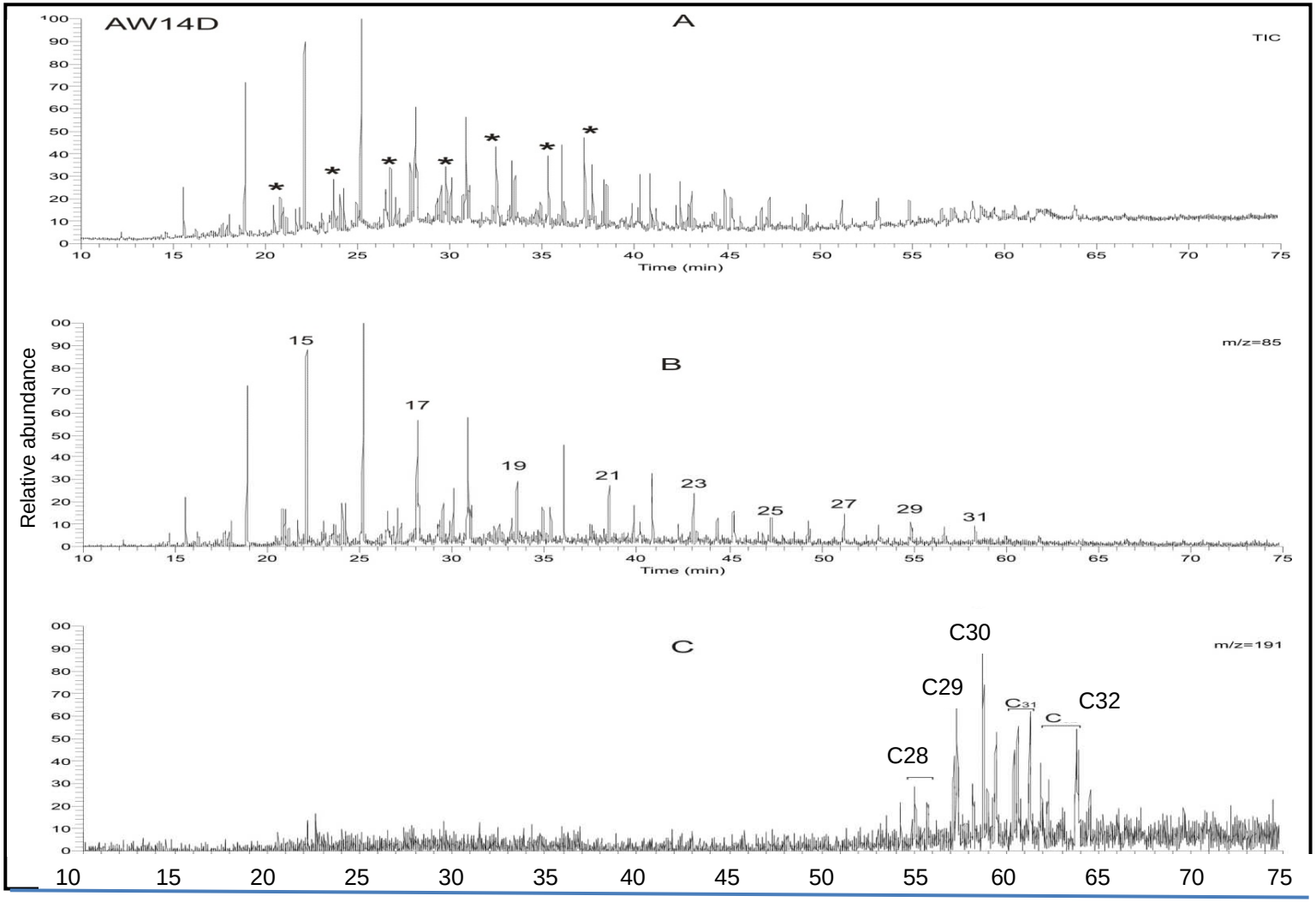
RESULTS/DISCUSSION
C: Molecular composition of hydrocarbons

- Most of the samples are dominated by short to mid-chain n-alkanes (< n-C25). The long-chain n-alkanes (> n-C27) contribute to less than 30 % of the total n-alkanes and do not show a marked odd over even predominance

- High relative contents of short-chain n-alkanes (<C20), are found in the Chichali Formation.

- The relative proportions of long-chain n-alkanes in samples from the Samana Suk and Datta Formations are higher as compared to the samples from the Chichali Fm.

RESULTS/DISCUSSION



(A) Gas chromatogram (total ion current) of the saturated hydrocarbon fraction of sample AW14D (Cretaceous Chichali Fm.). *n*-alkanes are labelled according to their carbon number; branched alkanes are marked by asterisks. (B) Mass chromatogram (m/z = 85) for *n*-alkanes. (C) Mass chromatogram (m/z = 191) for triterpenoids. Characteristic hopanes are labelled.

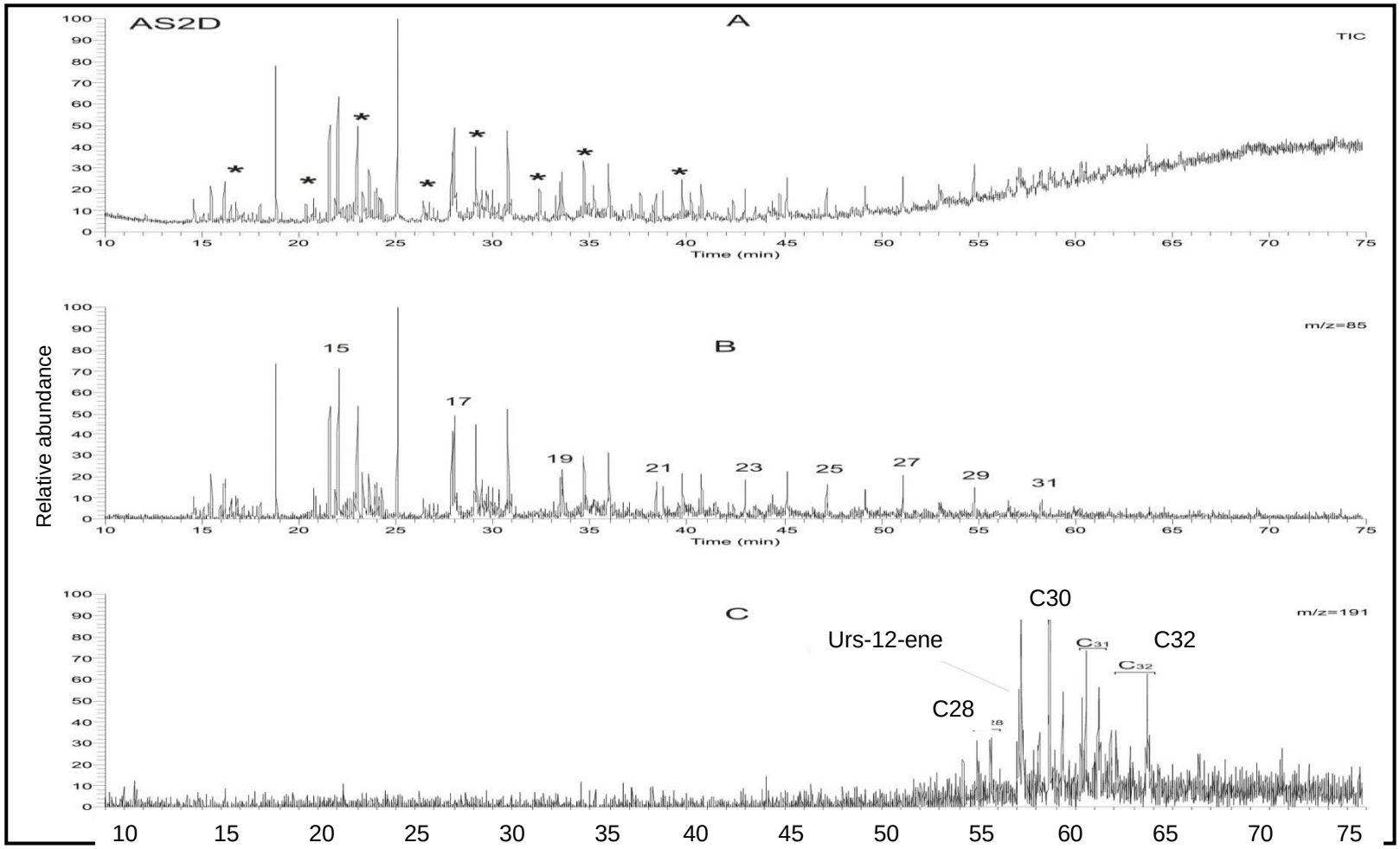
RESULTS/DISCUSSION
C: Molecular composition of hydrocarbons

- The pentacyclic triterpene urs-12.-ene, a biomarker for angiosperms, was identified in the Cretaceous Chichali Fm from the Ali Sahib well.

- Beside a hump in a chromatogram of condensate sample, sesquiterpenoids (drimanes, homodrimanes, and rearranged drimanes, Philp, 1985 and Nytoff et al., 2009) predominate.

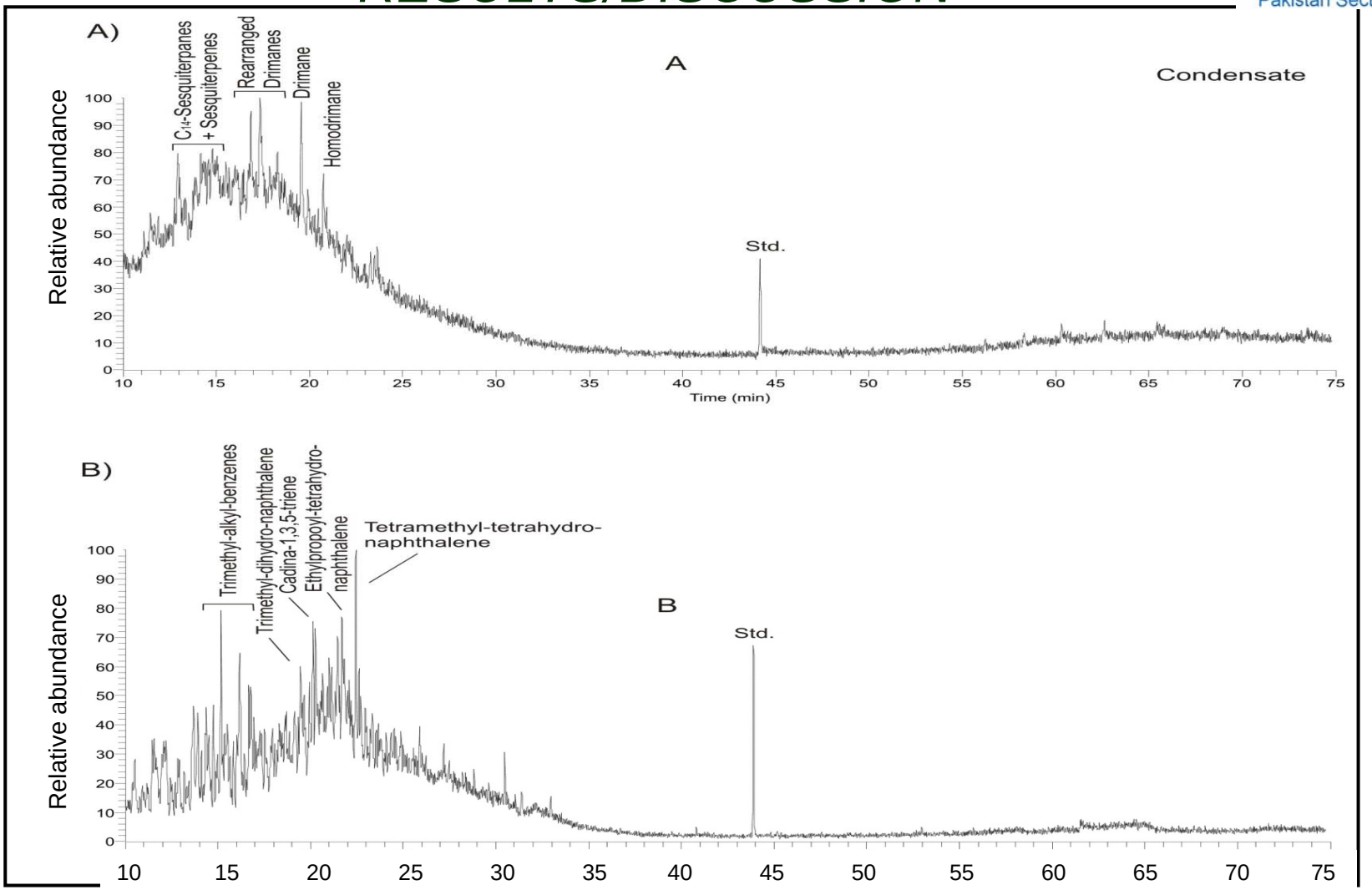
- No *n*-alkanes could be detected in the condensate of Sarai Sidhu well.

RESULTS/DISCUSSION



Gas chromatogram (TIC) of the saturated hydrocarbon fraction of sample AS2D-1 (Cretaceous Chichali Formation). n-alkanes are labelled according to their carbon number; branched alkanes are marked by asterisks. (B) Mass chromatogram (m/z = 85) for n-alkanes. (C) Mass chromatogram (m/z = 191) for triterpenoids. Characteristic hopanes are labelled.

RESULTS/DISCUSSION



Gas chromatograms (TIC) of (A) the saturated hydrocarbon fraction and (B) the aromatics of the condensate sample from the Sarai Sidhu Well. Identified sesquiterpenoids are labelled.

SUMMARY AND CONCLUSIONS

- Rock-Eval pyrolysis data classify the organic matter as Type-III kerogen with transition to Type-II but immature to marginal mature.

- Presence of short - chains n-alkanes (<C20) suggest an algal/microbial origin (Cranwell, 1977) of organic matter in the Chichali Formation.

- Due to the abundance of branched n-alkanes, a mixed algal/bacterial and land plant origin (Cranwell, 1977) proposed for the organic matter of Lumshiwal, Samana Suk and Datta Formations.

- The cross plot of pristane/*n*-C_{17} versus phytane/*n*-C_{18} ratios, suggests an anoxic/reducing marine environment during deposition of the Chichali and the Lumshiwal Fm (Cretaceous), whereas the Samana Suk and Datta/Kingriali Fm (Jurassic to Triassic) were deposited under oxic to dysoxic conditions.

SUMMARY AND CONCLUSIONS

- Based on the DBT/phenanthrene versus pristane/phytane diagram, all samples fall into the fields characteristic for lacustrine sulphate-poor or marine shales.

- The presence of a hump in the saturated and aromatic hydrocarbon fractions of a condensate sample from the Sarai Sidhu well, as well as the absence of *n*-alkanes and the presence of high relative amounts of sesquiterpanes, are interpreted as a result of elevated biodegradation of light hydrocarbons derived from the cracking of petroleum (Nytoff et al., 2009, Philp, 1994, and Alexander et al., 1983).

- Rearranged drimanes are considered to have been derived from the degradation of pentacyclic triterpenoids found in angiosperms. As urs-12-ene has been identified in the Chichali Fm, a possible origin of the condensate from this Fm is proposed.

SUMMARY AND CONCLUSIONS

- Recently, the close association of dry gas with severely degraded oils has been explained by a common methanogenic biodegradation mechanism in subsurface degraded oil reservoirs (Jones et al., 2008).

- Wet gas biodegradation results in gases becoming dryer and oils heavier (Larter and di Primio, 2005).

- In the present case, the condensate may represent the degraded residue of methanogenic biodegradation responsible for the gas accumulations in the study area.

RECOMMENDATIONS

- Biomarker study of solvent extract from the sediments of other wells is recommended.

- Isotopic studies of gas and condensate from Bahu and Sarai Sidhu wells
  would confirm our results.

ACKNOWLEDGEMENTS

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Thank You