[PS]Revised Oil-Source Correlation Models in the Chao-Chang Region and Implications for Lower Cretaceous Petroleum Play Concepts in the Songliao Basin, NE China*

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Abstract

Biomarkers in 60 oil samples from the Chao-Chang region, Songliao Basin, NE China reveal three genetic oil groups and suggest characteristics of their probable source rocks. Group 1 (57 Lower and Upper Cretaceous-reservoired oils over the entire region) was sourced from the Upper Cretaceous Qingshankou Formation (K2Qn1), the main petroleum source rocks in the basin. Group 2 (two Lower Cretaceous-reservoired oils in the Changchunling anticline zone) and group 3 (one Lower Cretaceous-reservoired oil in the Sanzhao sag) derive from two high quality sources with more localized occurrence, corresponding to carbonate-evaporate and freshwater lacustrine facies, respectively. The relative abundance of gammacerane in the group 1 oils suggests the deposition of their type I, algal rich, lacustrine source rocks under conditions of enhanced salinity-stratified water columns, consistent with those in the K2Qn1 member. The large variation in the molecular maturity parameters of the group 1 oils (such as sterane isomerization ratios) was not substantiated by the gross oil compositions and n-alkane concentration. Although we did not intend to address source rock volumes in this molecular study, there is clear evidence against the previously proposed model of downward oil migration from a local source. Instead, lateral migration of the oils derived from the younger K2Qn1 sources in the deeper parts of the Sanzhao and Wangfu sags appears responsible for the occurrence of the group 1 oils in the older Lower Cretaceous reservoirs in the Chaoyanggou terrace and Changchunling anticline zones. The large variation in the biomarker concentrations in source rocks with different maturity levels illustrates how the addition of small amounts of soluble organic matter from a local source (e.g. cap rock and intra-reservoir shale) to a mature oil could potentially compromise its biomarker maturity parameters. Although most oils in the study area derive from the Upper Cretaceous K2Qn1 source, the presence of other oil genetic groups suggests that future exploration in this region should also carefully consider the potential of the not yet penetrated, probably more localized, Lower Cretaceous source rocks in the deeper parts of the basin.

Revised oil-source correlation models in the Chao-Chang region and implications for Lower Cretaceous petroleum play concepts in the Songliao Basin, NE China

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INTRODUCTION

One of the most important tasks in a typical petroleum exploration program is to identify the most effective oil source intervals or kitchens in a basin. Oil-source correlation using molecular geochemistry contributes to exploration successes by providing key constraints for geological models and critical input to exploration scenarios. The validity of correlation results depends largely on how adequately the used correlation parameters reflect the inherited source characteristics and the post-generative processes affecting the studied oils.

This paper presents a case study of petroleum systems in the Chao-Chang region (CC), Songliao Basin, NE China, to demonstrate how molecular geochemical parameters across different oil fractions can provide new insight into petroleum source models in a maturely explored province.

GEOLOGICAL SETTING

The studied CC region, with an area of approximately 5,000 sq. km, is located in the Chaoyanggou terrace-Changchunling anticline zone in the Central Depression of the Songliao Basin (Fig. 1, upper), consisting of the Chaoyanggou and Fangshengtun anticlines, and Bohetai and Dayishu nose-type folds. The likely petroleum source kitchens for the CC region include the Sanzao Sag in the northwest and Wangfu Sag in the southeast. The discovery of over 1.5 billion barrels of proven oil reserves in the Lower Cretaceous strata of the CC region (Fig. 1, lower) resulted from, and promoted, extensive geological and geochemical studies.

Fig. 2 is a generalized stratigraphy of the study area. The likely petroleum source rocks include the first member of the Upper Cretaceous Qingshankou Formation (K_2Qn1) (deposited in a deepwater lacustrine setting) and the sporadically occurring source rocks in the Lower Cretaceous strata that were deposited mostly in shallow water lacustrine setting. Fig. 3 is a map showing the regional maturity variation for the K_2Qn1source rocks in the northern Songliao Basin. Clearly, these rocks in the CC region are currently thermally only marginally mature and thus cannot be the main local source for the discovered oils.

Fig. 4 shows the interpreted sedimentary facies maps in the CC region, illustrating the complex interplays in the Lower Cretaceous source-reservoir systems.

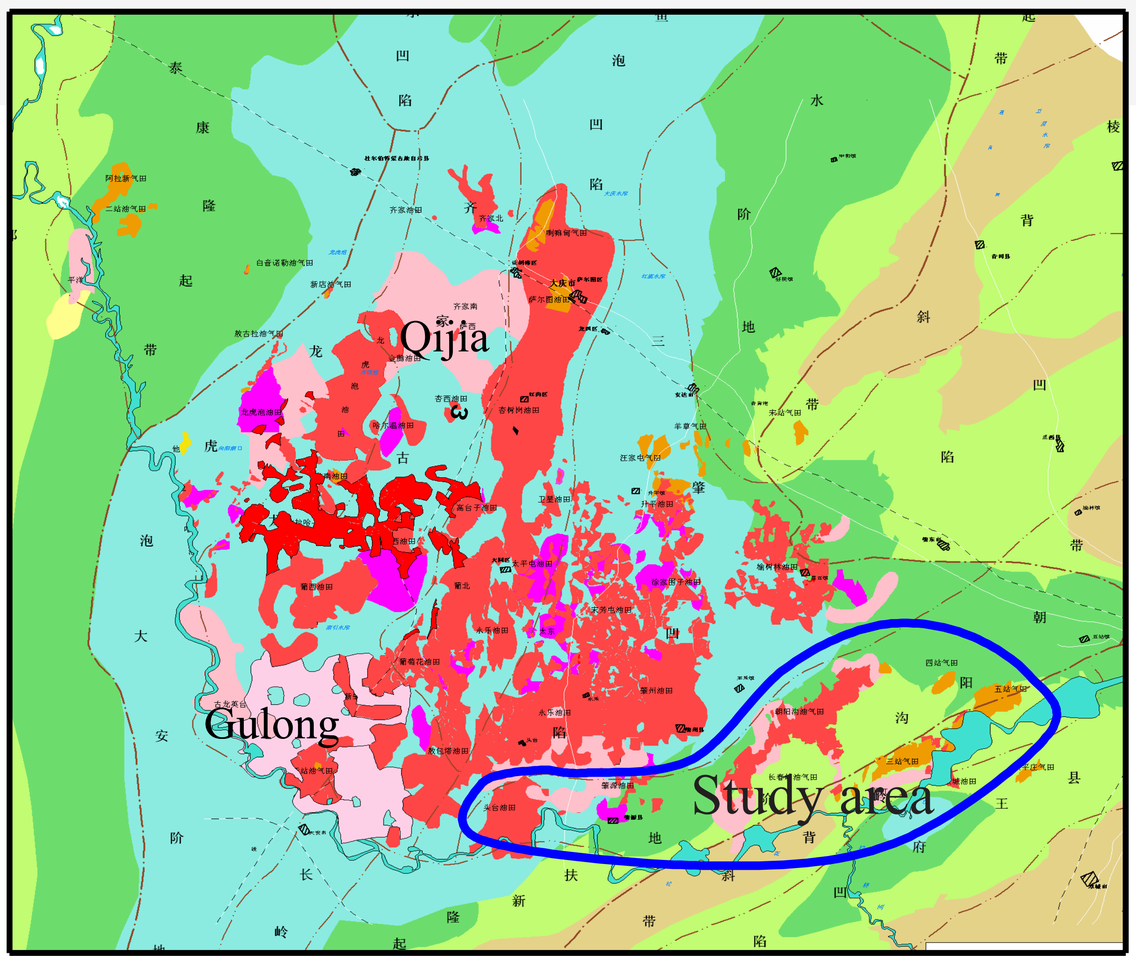
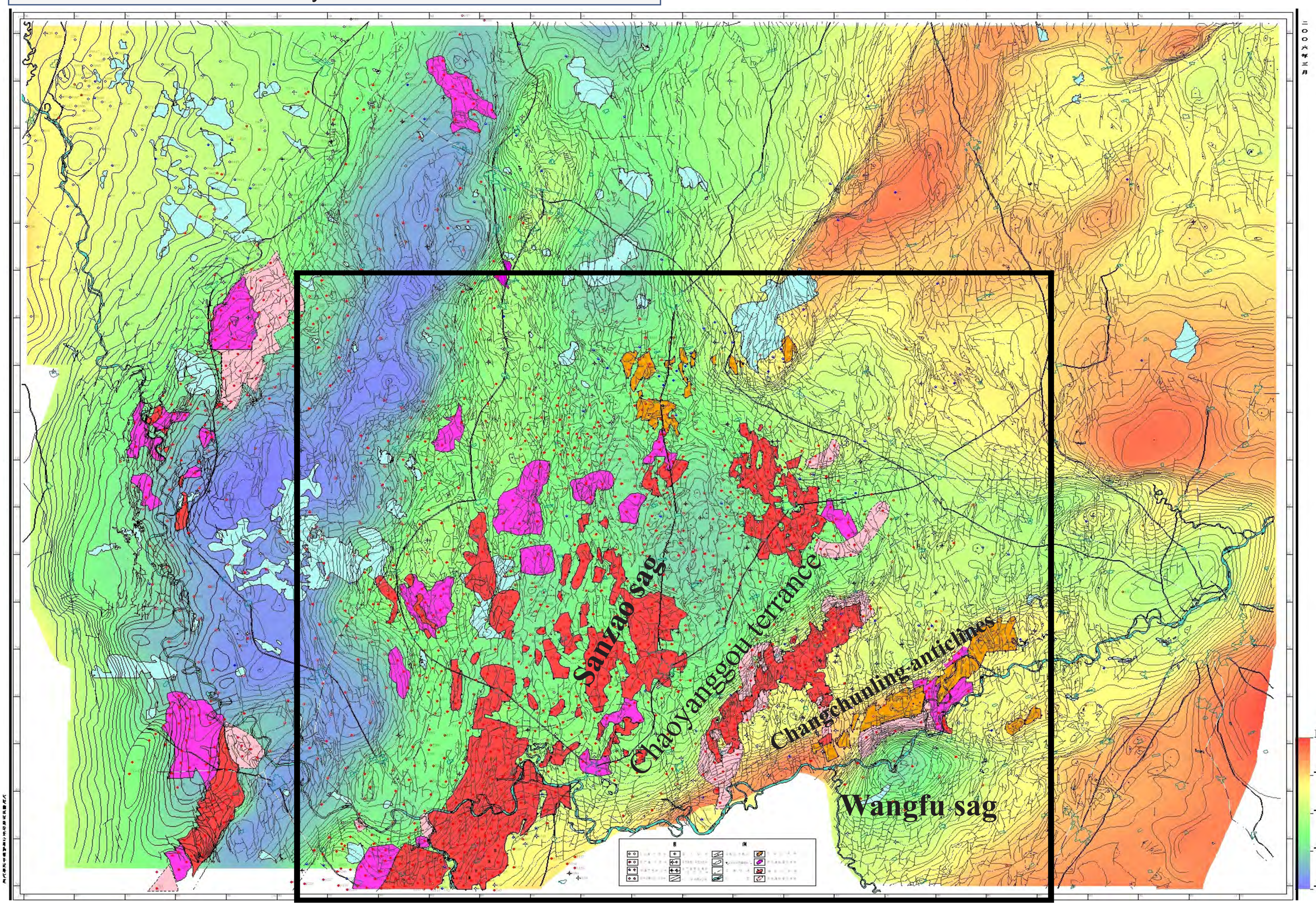


Fig. 1 Map showing major oil discoveries in northern Songliao Basin (above) and enlarged map for Lower Cretaceous oil discoveries in the study area (below)



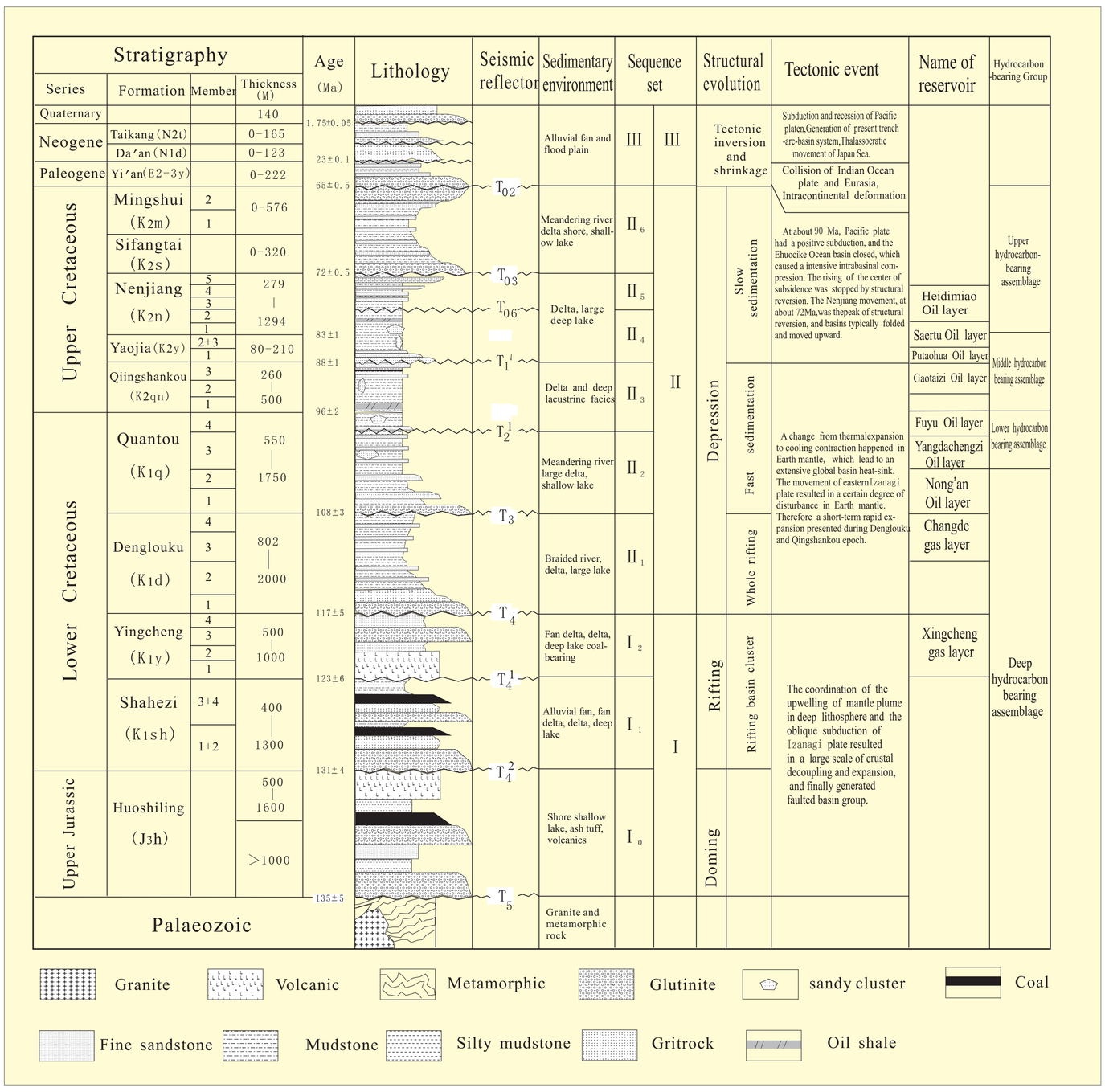


Fig 2. Stratigraphy of the northern Songliao Basin.

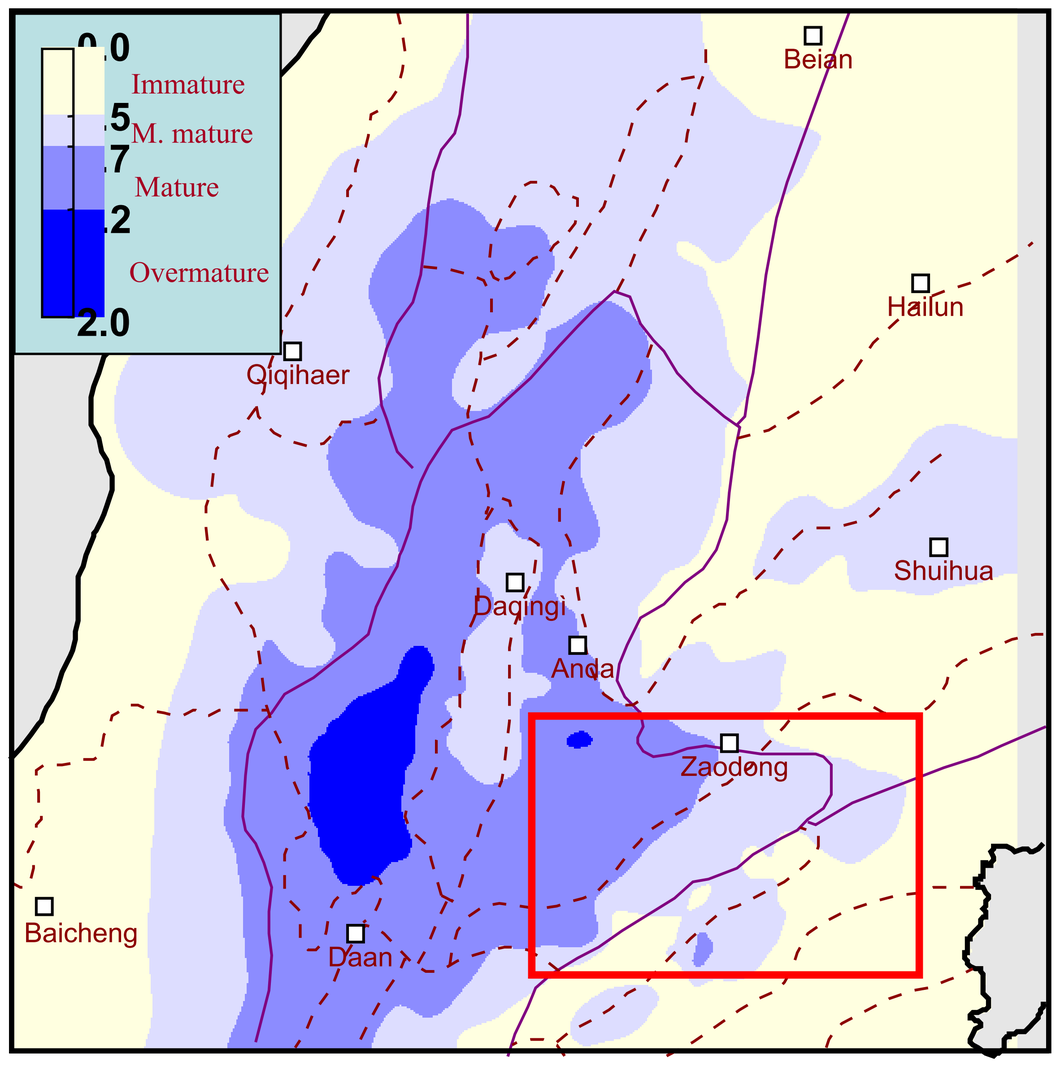
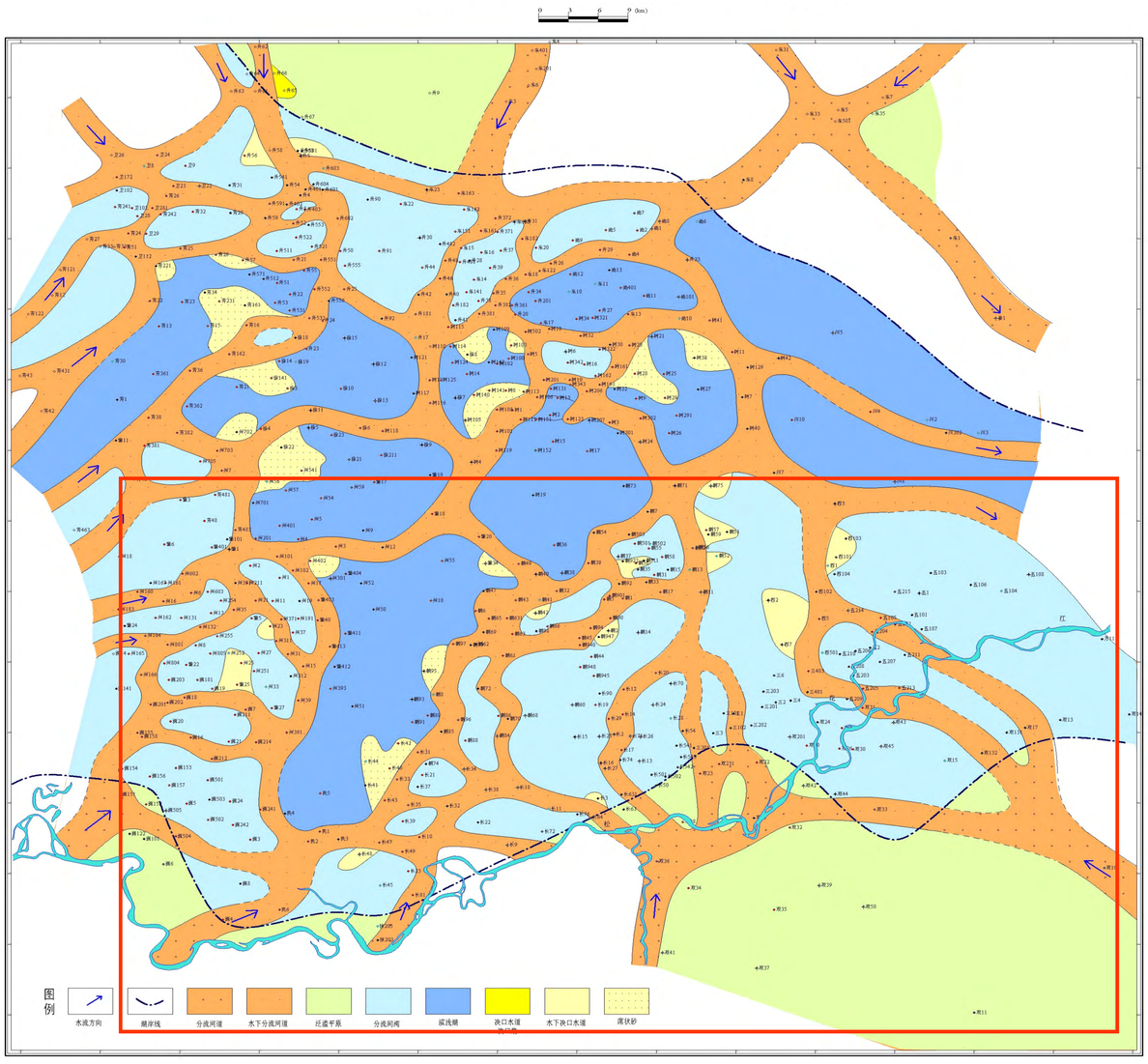


Fig. 3 Map showing the variation in thermal maturity (%Ro equivalent) of the K_2Qn1 source rocks in N. Songliao Basin

Fig. 4. Sedimentary facies map of the first member of the Fuyu Fm. in the study area.



PREVIOUS STUDIES

Earlier oil-source correlation work suggests a significant contribution of marine influenced lacustrine source rocks in the first member of the Upper Cretaceous Qingshankou Formation (K_2Qn1) to the discovered oils in the stratigrapgically older, Lower Cretaceous clastic reservoirs (Fig. 1, lower).

However, many uncertainties remain unresolved. For example, the similarity in the distributions of hopanes and steranes in the discovered oils and the cored K_2Qn1 source rocks provides circumstantial evidence for the contribution of the K_2Qn1 derived oils to most of the oils, but the lack of clear differences in the biomarker distributions of the K_2Qn1 source rocks in different source kitchens makes it difficult to use the qualitative biomarker data to correlate the oils to their effective source intervals or kitchens.

Local petroleum geologists strongly advocate an oil charge model for the Lower Cretaceous fluvial reservoirs that invokes a downward oil migration from the overlying K_2Qn1 source rocks.

APPROACHES

In an attempt to refine more definitive source-specific markers, quantitative analysis was conducted on 55 drill-stem-test oils and 14 representative K2Qn1 source rocks in the CC region, for the concentrations of n-alkanes, isoprenoid alkanes, steranes, hopanes and aromatic hydrocarbons in the isolated C15+ saturated and aromatic hydrocarbon fractions. Acyclic alkanes and aromatic hydrocarbons are present in much higher abundance and wider structural diversity than hopanes and steranes, and thus add new dimensions to biomarker analysis by reducing the uncertainty in oil-source correlation.

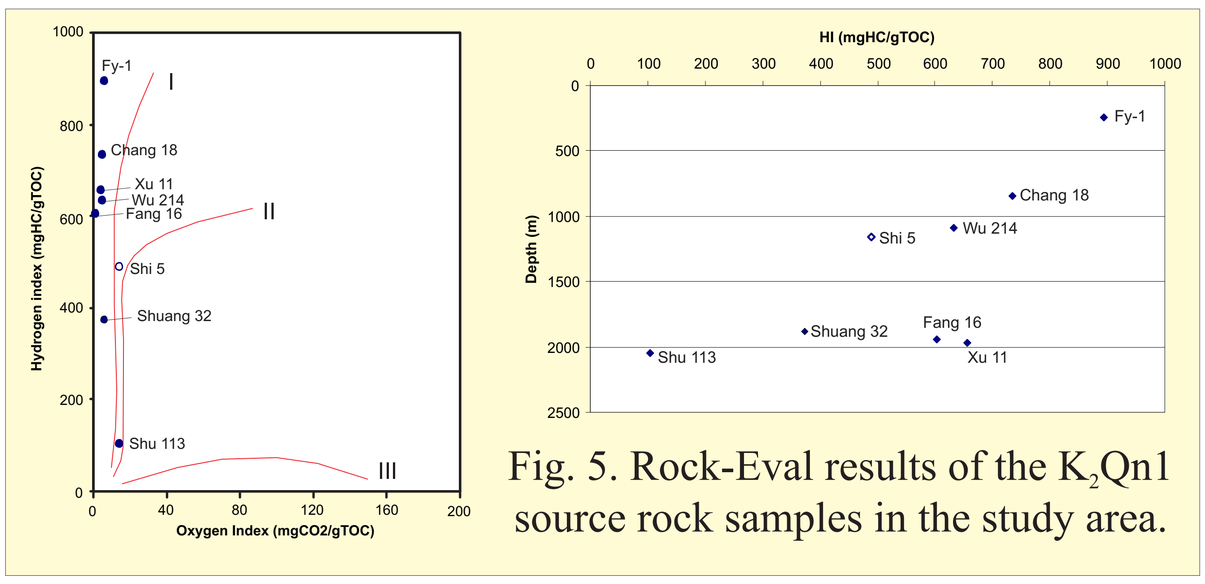


Fig. 5. Rock-Eval results of the K_2Qn1 source rock samples in the study area.

RESULTS & DISCUSSION

SOURCE ROCKS

Consistent with earlier observations, K_2Qn1 source rocks in the vicinity of the oil accumulations of the CC region is thermally immature to marginally mature (Fig. 5).

Organic-rich source rocks do occur in the Lower Cretaceous strata, but no sufficient borehole data to further define their occurrence.

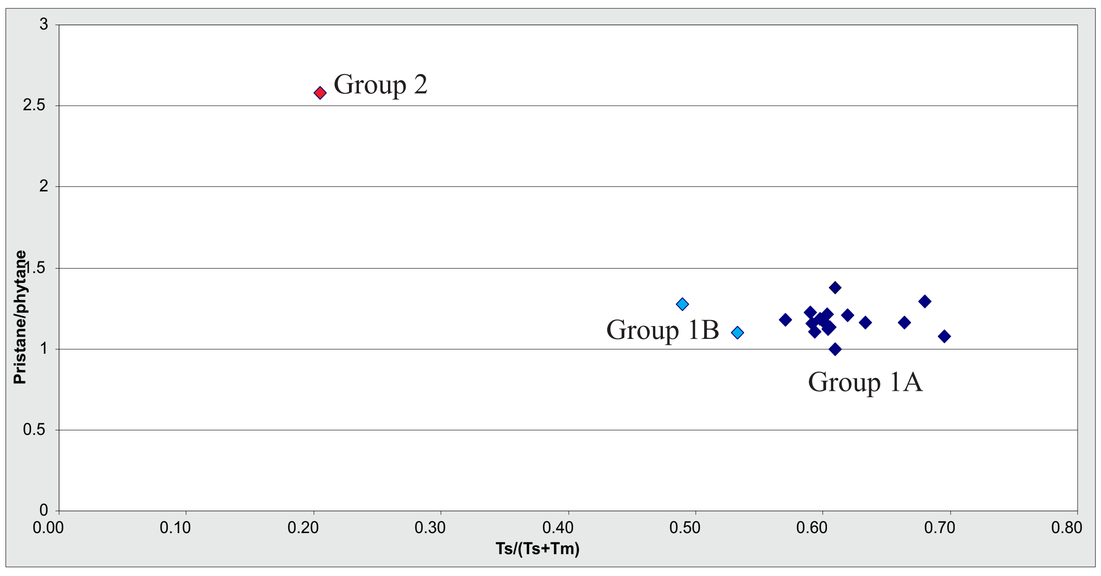
OIL GROUPING

Biomarkers in 60 oil samples from the CC region reveal three genetic oil groups and suggest characteristics of their probable source rocks (Figs. 6 and 7):

Group 1A: 57 Lower and Upper Cretaceous-reservoired oils over the entire region, sourced from the Upper Cretaceous Qingshankou Formation (K_2Qn1), the main petroleum source rocks in the basin;

Group 1B: two Lower Cretaceous-reservoired oils in the Changchunling anticline zone, derived from a localized carbonate-evaporitive source rock ;

Group 2: one Lower Cretaceous-reservoired oil in the Sanzhao sag, derive from a high quality source corresponding to freshwater lacustrine facies.



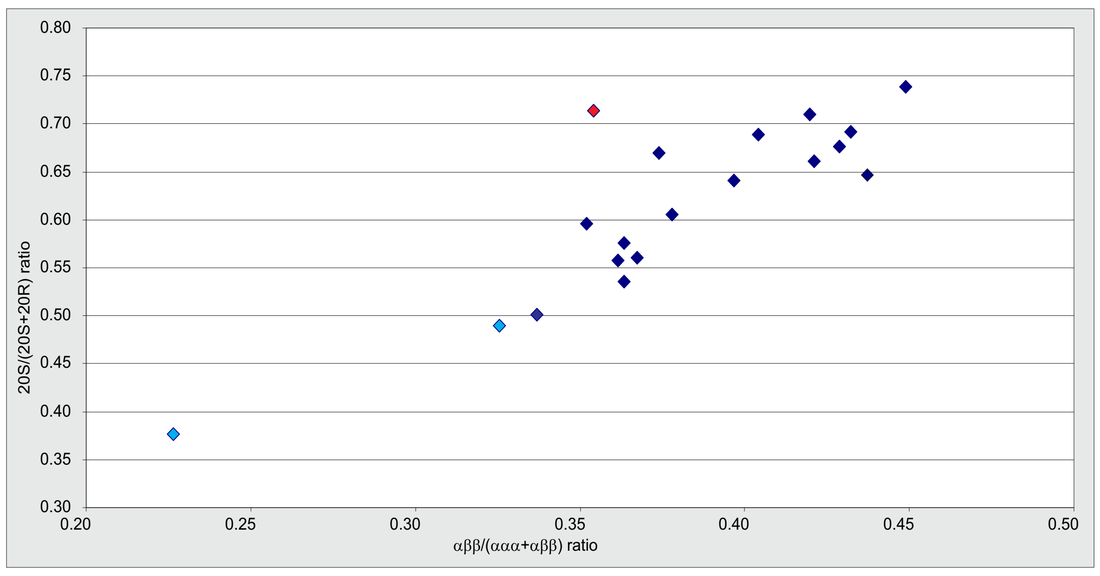


Fig. 6 Biomarker ratios of representative oils.

Oil Grouping

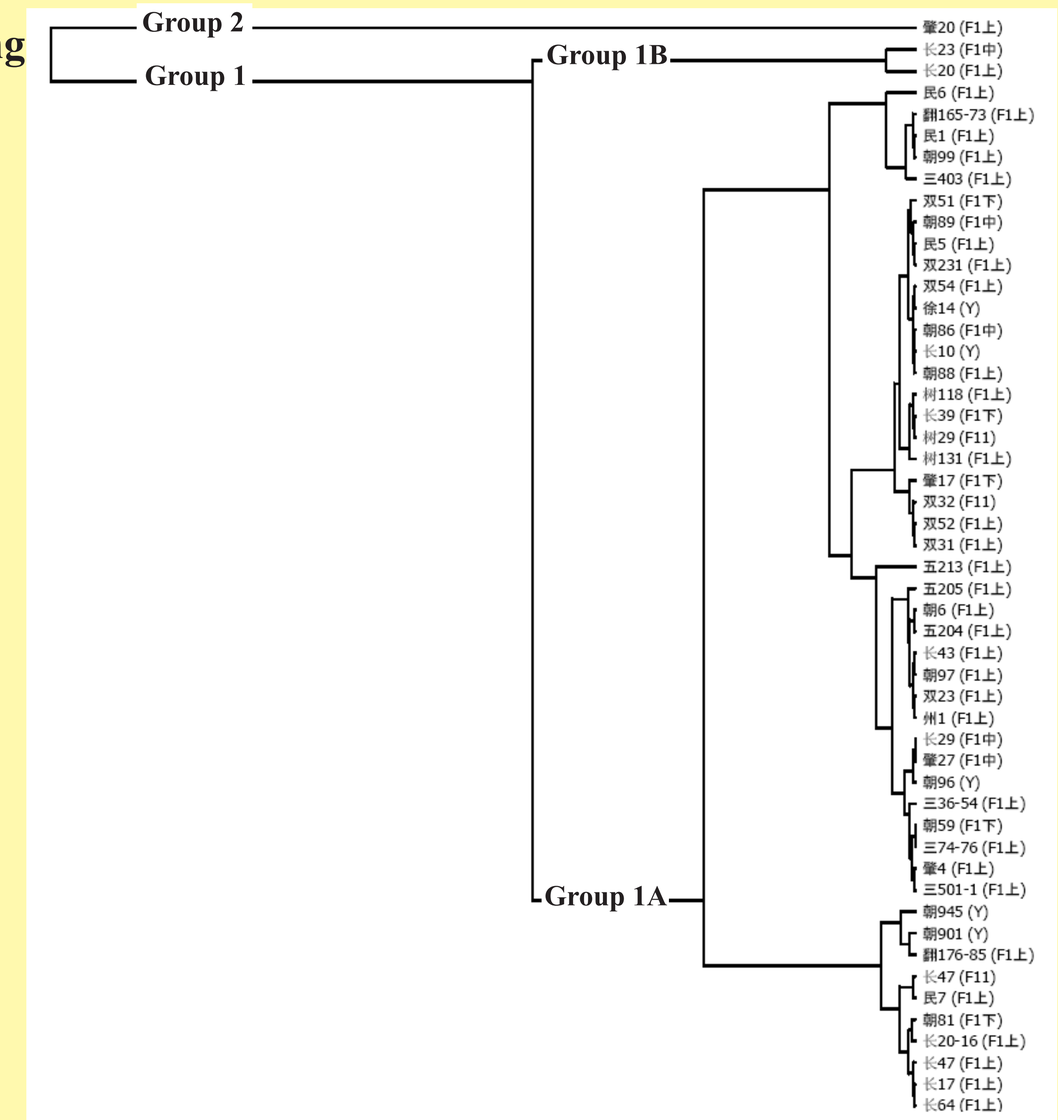


Fig. 7 Classification schemes for oil groupings in the study area, based on cluster analysis of saturate biomarker dada

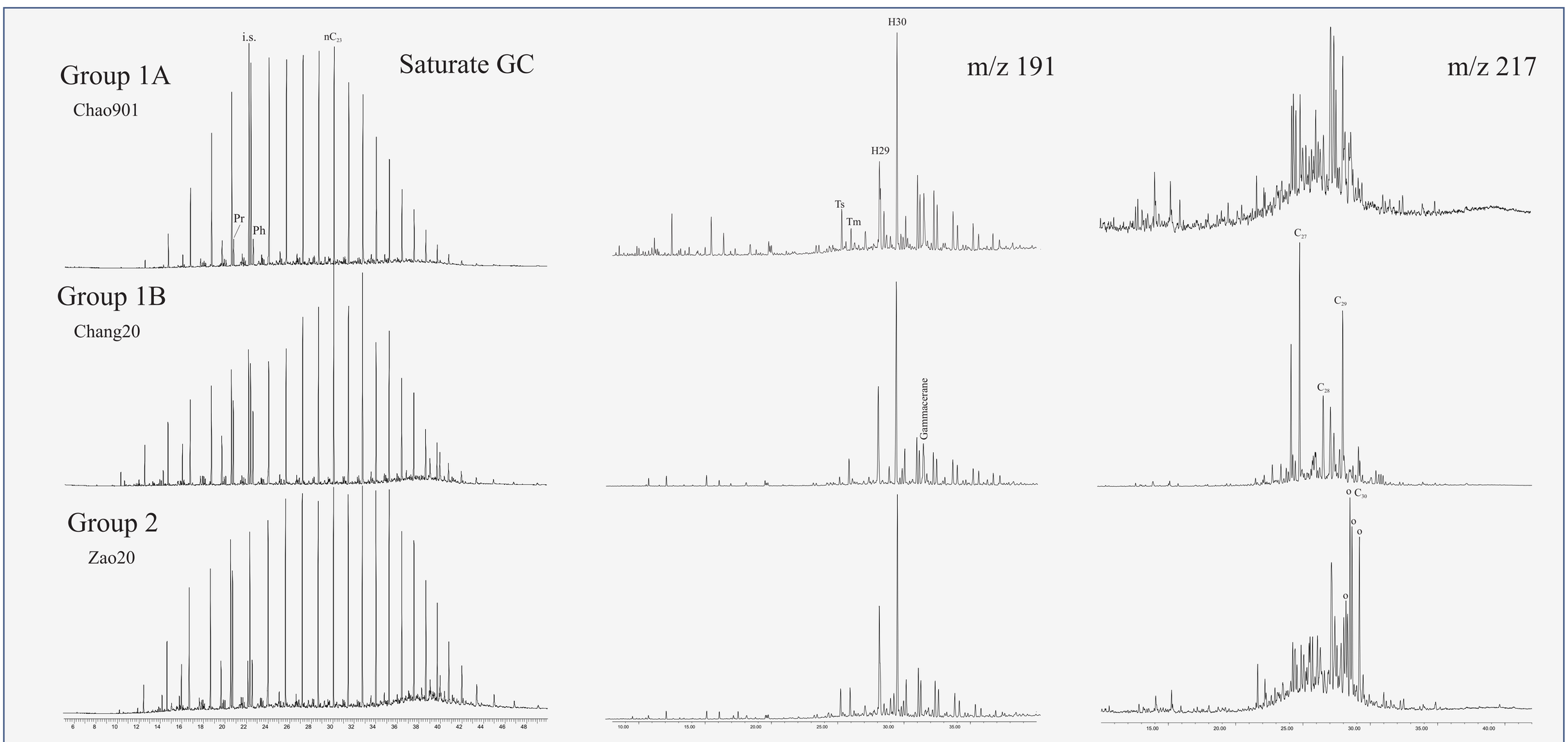


Fig. 8 Representative saturate gas chromatograms, m/z 191 and 217 mass fragmentograms for end member oil samples in the study area.

Oil-source correlation

As shown in Fig. 9, both the concentrations and selected compound ratios of hopanes and steranes in most DST oils generally decrease with increasing reservoir depth. The close tracking of the oils with the studied K_2Qn1 source rocks at similar burial depth would suggest local sources for the oils, with little vertical or lateral migration. In contrast, the concentrations of triaromatic steranes and n-alkanes in the oils do not show any trend with depth.T he concentrations of n-alkanes and most aromatic hydrocarbons in the oils correlate well with the studied source rocks with the largest burial depth.

This suggests that the oils were mostly derived from the deeper parts of the Sanzao and Wangfu sags. Stratigraphic correlation based on seismic and well data indicates that the effective source kitchens for the oils in the CC region are probably located 20-30 km to the north in the Sanzao Sag and 10-20 km to the south in the Wangfu Sag. Downward oil migration model proposed earlier probably would not work here!

The discrepancy in the oil-source correlation using the conventional biomarkers and other quantitatively more abundant molecules in the studied oils suggests caution with the use of conventional biomarker data when concerned source rocks contain biomarkers in drastically different concentrations.

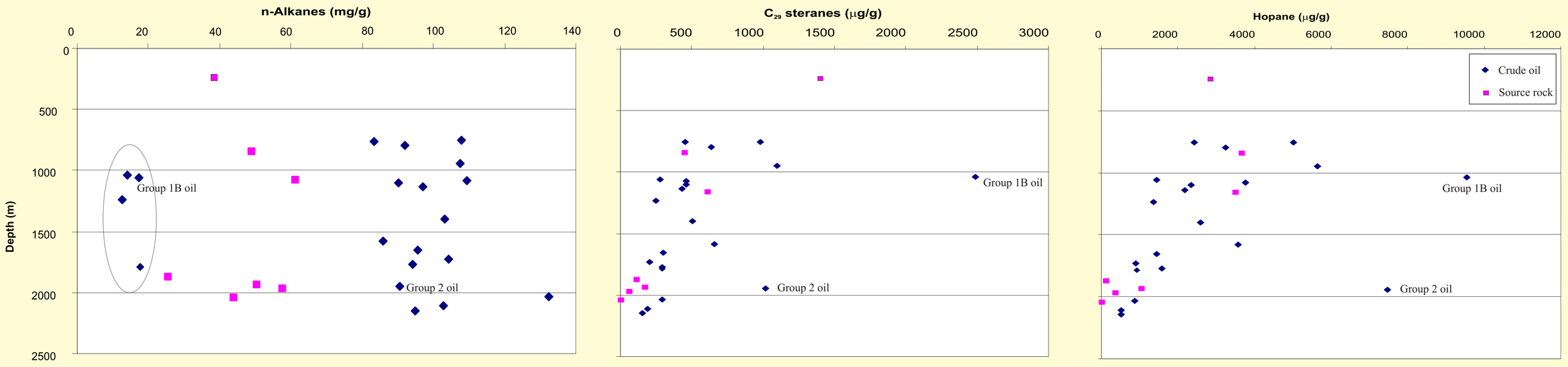


Fig. 9 Variation in the concentrations of selected molecular markers in the oil/source rock extract as a function of sample depth (m).