

# *Natural Gas Geochemistry in Tarim Basin, China and Its Application to Gas Filling History*

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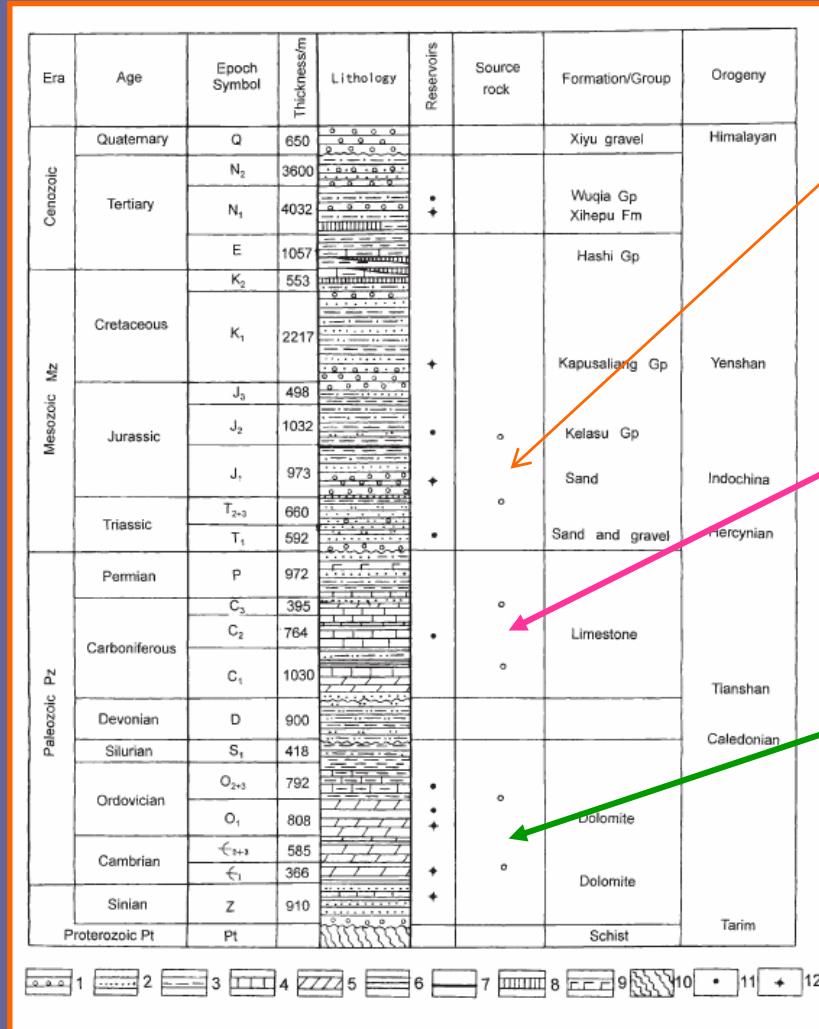
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# **Introduction**

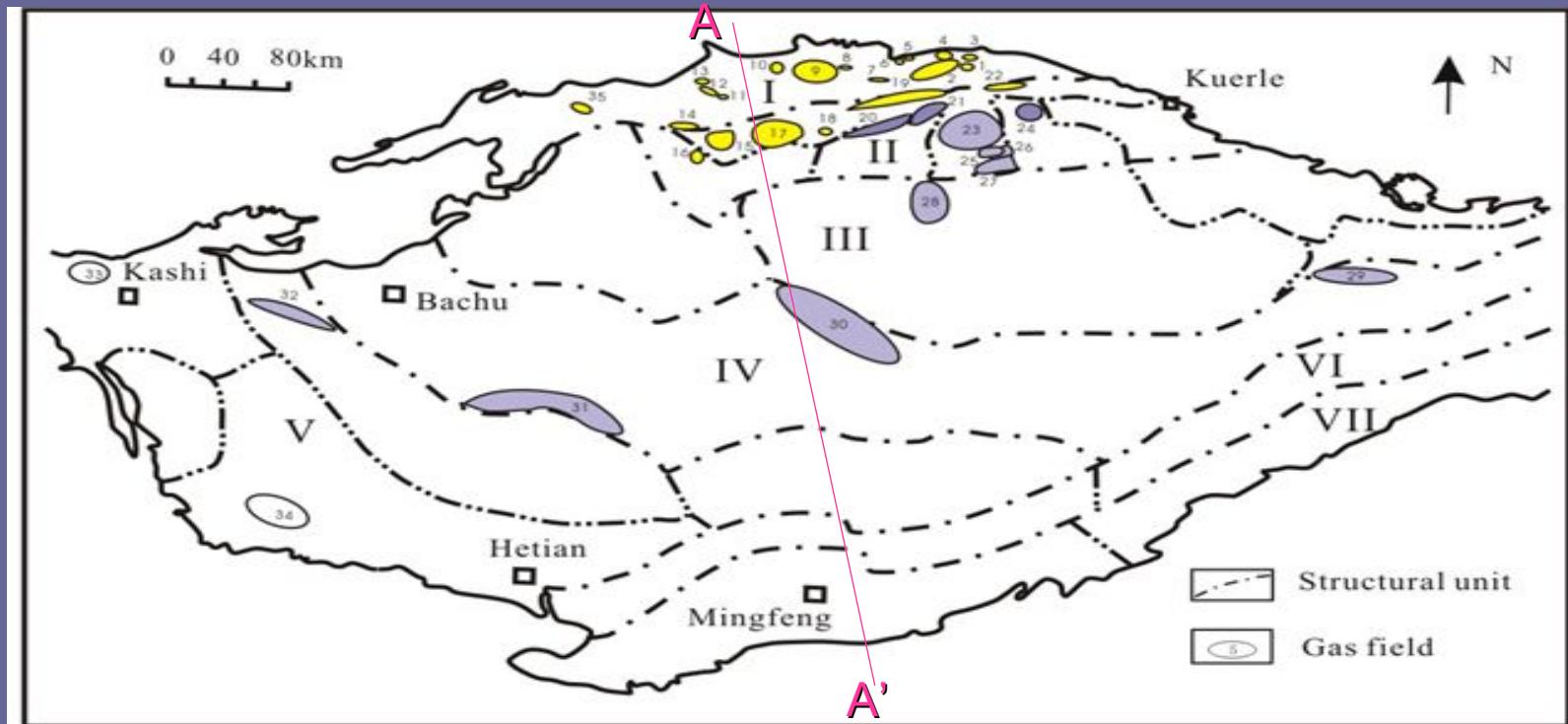
- *For more than 20 years petroleum and natural gas exploration, Chinese geologists have discovered two family groups of natural gas in the Tarim basin, China*
  - *Coal-type gas: derived from Jurassic coal measures of type-III kerogen,  $\delta^{13}\text{C}_2 >-28\text{\textperthousand}$ ;*
  - *Oil-type gas: derived from Ordovician, Cambrian marine sources of type-II and type-I kerogens; or oil secondary cracking.  $\delta^{13}\text{C}_2 <-28\text{\textperthousand}$ .*
- *Gas filling history is an important issue for natural gas exploration, and quantitative gas generation model is an useful tool to address the following issues:*
  - *Gas generation and expulsion from sources*
  - *Gas thermal maturity*
  - *Gas filling history and gas charging time*
  - *Gas reserves evaluation*

# Three Sets of Potential Source Rocks in the Tarim Basin, China



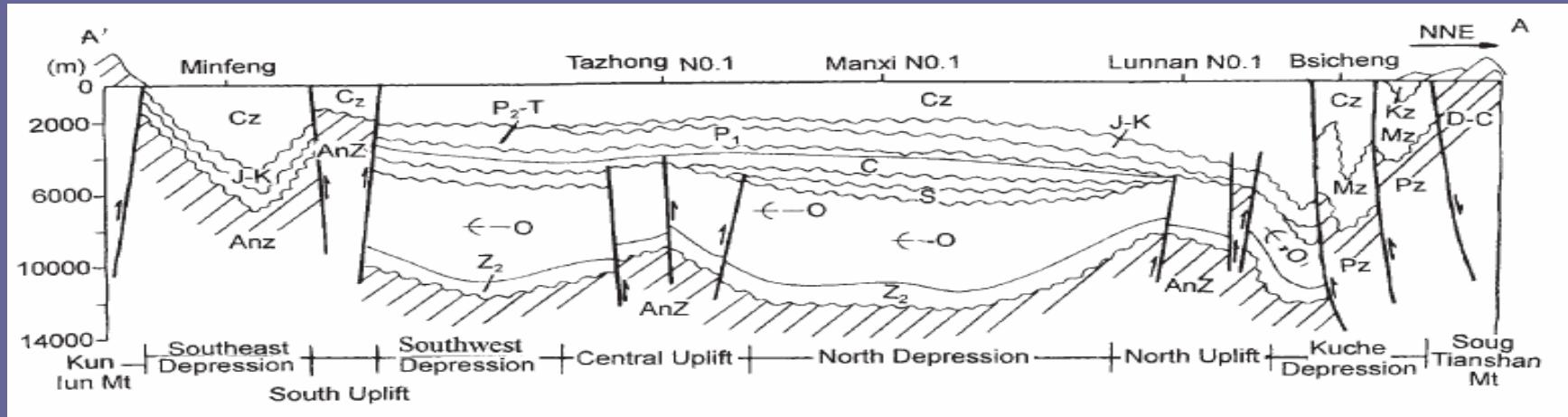
- Triassic- Jurassic continental source rocks Type III kerogen (humic) with an average TOC of 1.8% to 67%.
- Carboniferous –Permian source rocks Type II and III kerogen with TOC = 0.47% - 5%.
- Sinian-Ordovician marine source rocks Type I kerogen (sapropelite) with TOC = 0.2-3.4%.

# *Tectonic Elements and Gas Fields in the Tarim Basin, China*



1-DN1,2-DN2,3-Tuizi,4-Yinan,5-Yixi,6-Kezi,7-DQ5,8-Kela3,9-Kela2,  
10-Kela1,11-DWQ,12-DB,13-Tubei,14-Quele,15-YTK,16-YD,17-YM7,  
18-HQ,19-YH,20-YKL,21-DH,22-TRG,23-LN,24-Caohu,25-STM,26-JF,  
27-JLK,28-HD,29-Yingnan2,30-TZ,31-HTH,32-Qu3,33-AK1,34-KKY,35-WC1  
I-Kuqa Depression,II-Taibei Uplift,III-North Depression, IV-Tazhong Uplift,  
V-Southwest Depression,VI-Tanan Uplift, VII-Southeast Depression

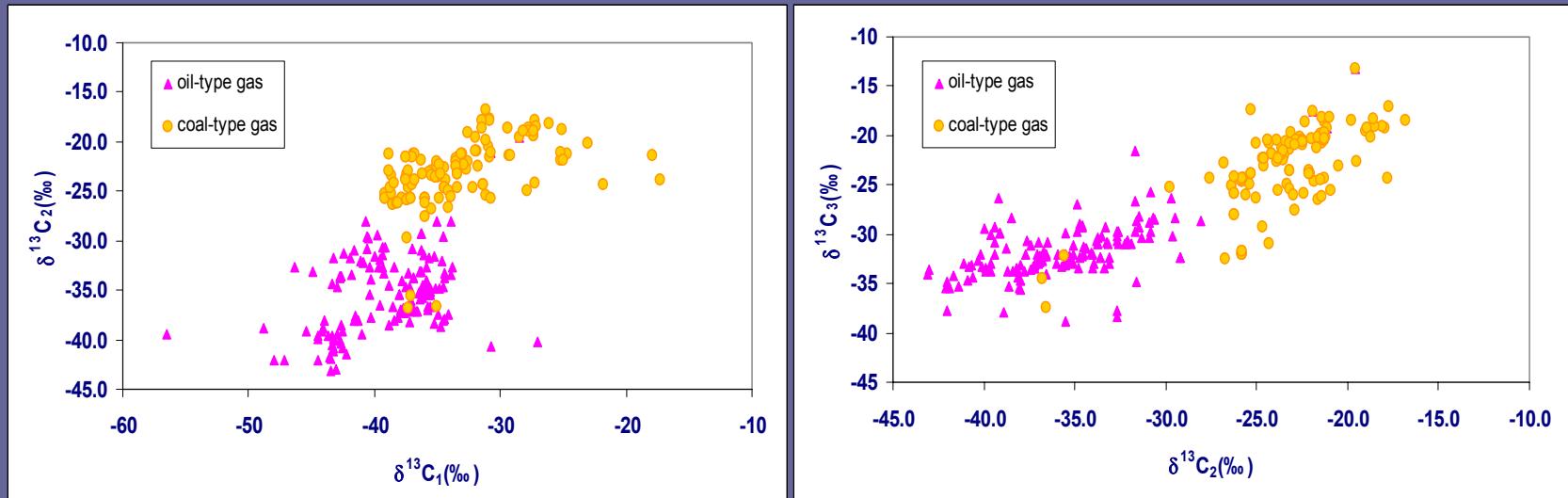
# Structure Cross Section of the Tarim Basin



- *Sinian-Lower Paleozoic Unit*  
highly-mature to post-mature marine carbonate sediments with thickness >9500m
- *Upper Paleozoic Unit*  
mature to highly mature clastic deposits with a maximum thickness of 4500m.
- *Mesozoic-Cenozoic Unit*  
terrestrial clastic deposits up to thickness of 11,000m in thickness in the sedimentary center.

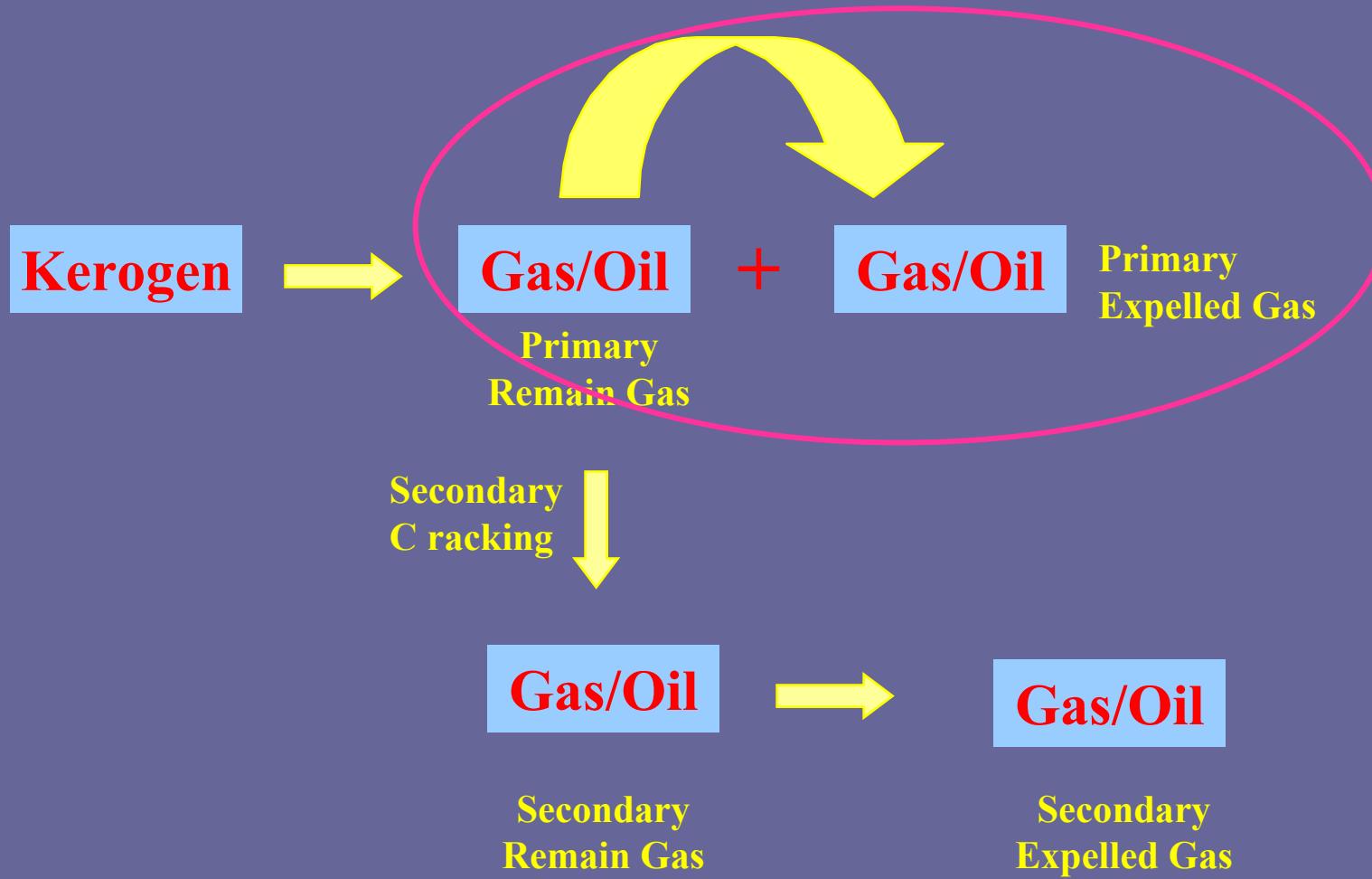
According to Chen et al., 2000

# *Carbon Isotopic Compositions are Effective Indicators for Gas Origin Identification*

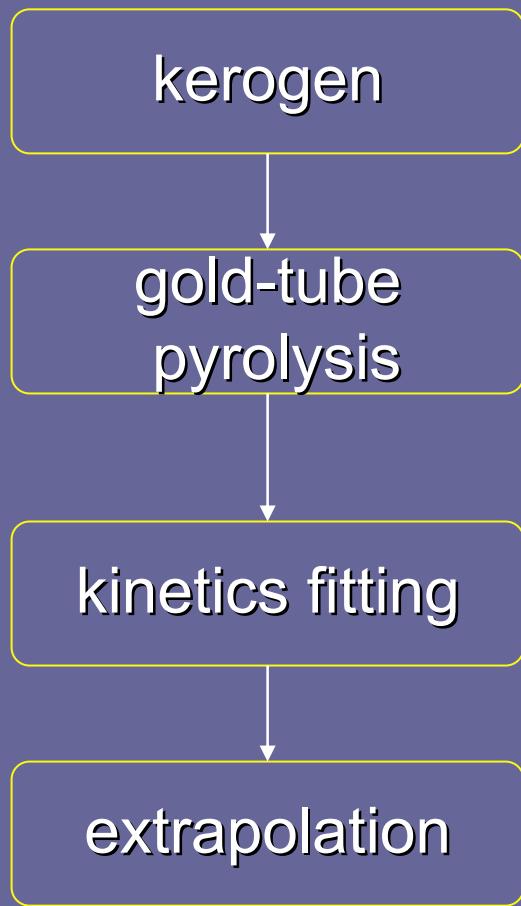


- Coal-type gas possesses heavier carbon isotopes of ethane and propane compared with oil-type gas.
- A positive relationship of  $\delta^{13}\text{C}_2$  and  $\delta^{13}\text{C}_1$ , and  $\delta^{13}\text{C}_3$  suggests that the thermal genetic gases from organic matter cracking under high temperature and pressure are a dominant source in the Tarim basin.
- GOR-isotope quantitative model can apply to the understanding of natural gas formation and gas filling history.

# *Possible Scenario of Gas Generation and Modeling*



# *Flow Chart for Gas Generation Kinetics Investigation*



Immature source

Gas Yields and Carbon Isotopes Measurement

Ea: activation energy  
Af: frequency factor

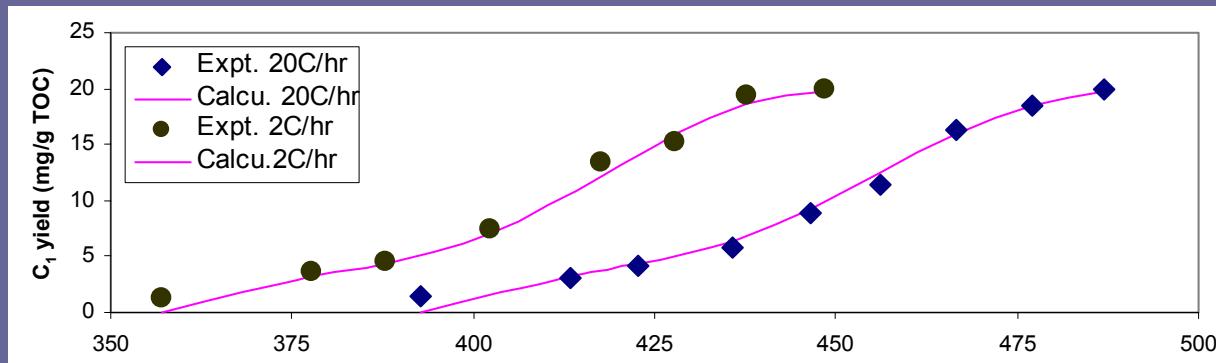
Timing of gas generation,  
migration and accumulation

# *Geochemical Properties of Jurassic Coal Selected for Simulation*

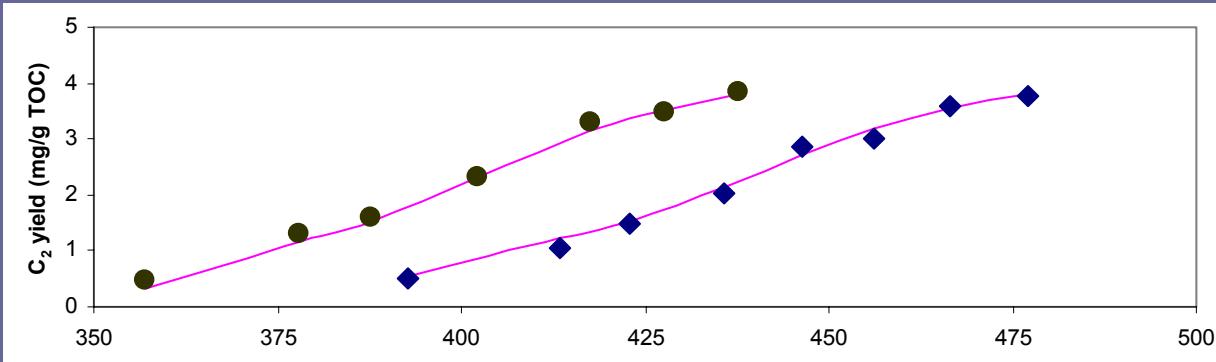
sample	percentage	TOC	$\delta^{13}\text{C}$	HI
	(%)	(%)	(‰)	(mgHC/gTOC)
Coal ( $\text{Ro} = 0.4\%$ )		67.4	-24.3	238
vitrinite	42.3	66.1	-24.8	157.8
fusinite		68.3	-24.6	32.6
semi-fusinite	42.3	70.4	-24.6	33.7
Exinite	<10	74.5	-24.8	464.2

# *Gas Generation From Coal Anhydrous Pyrolysis at Two Different Heating Rates*

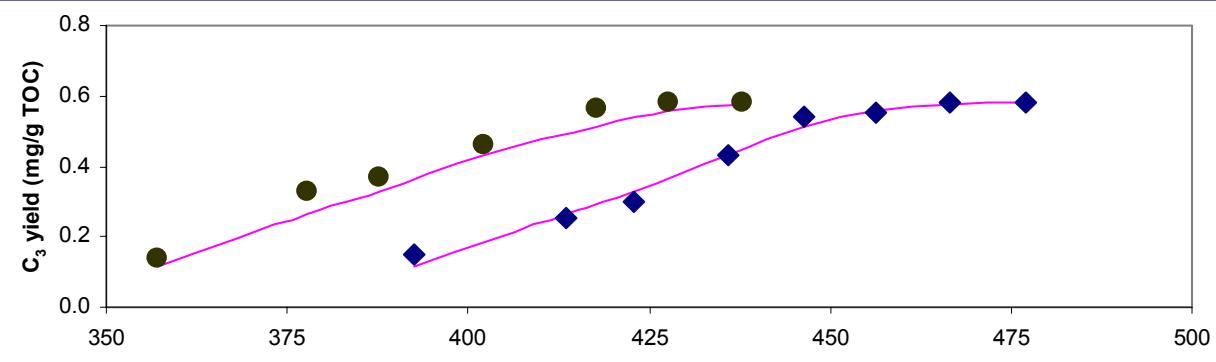
*Gas Yield (mg/g TOC)*



$C_1$



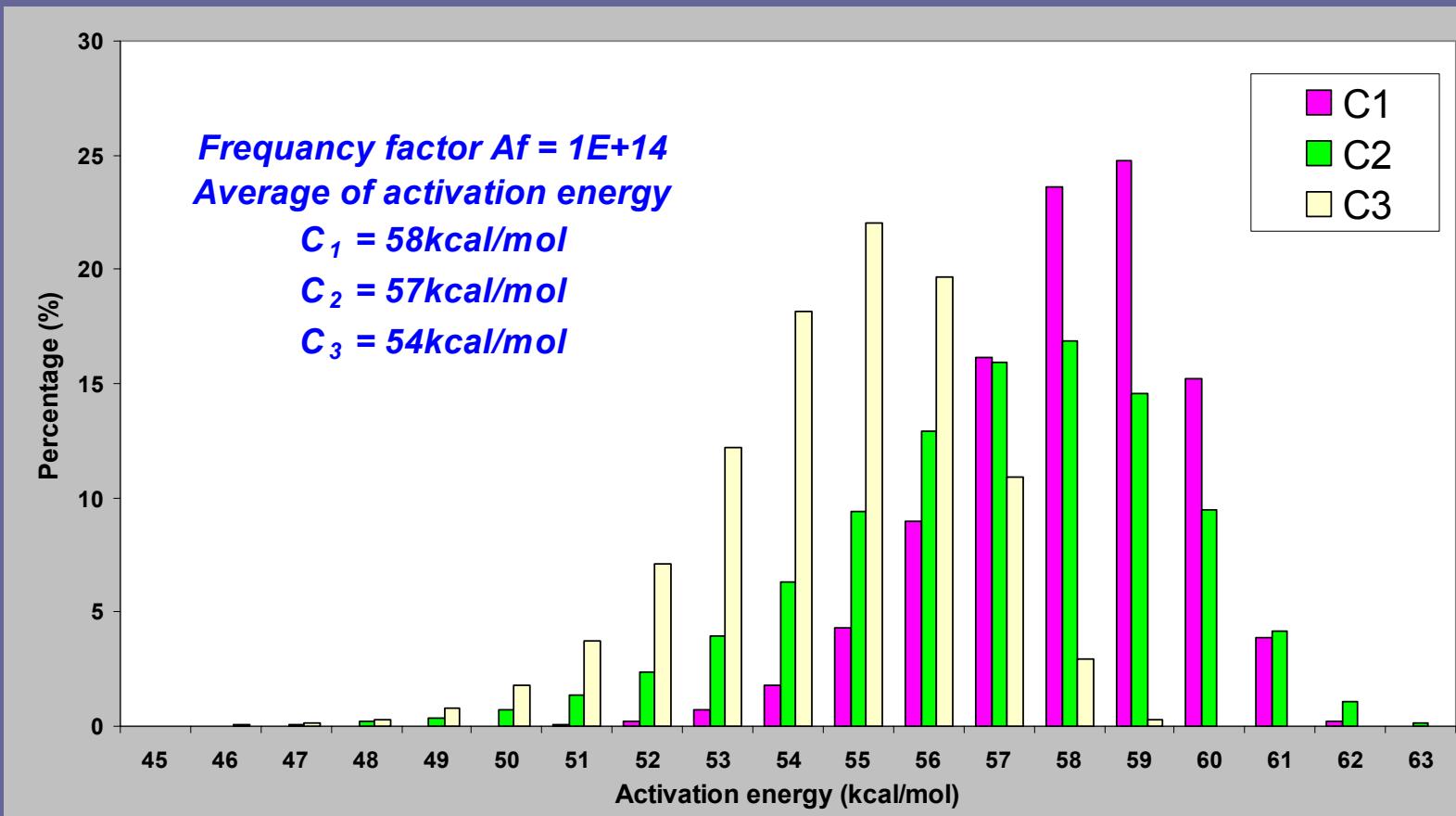
$C_2$



$C_3$

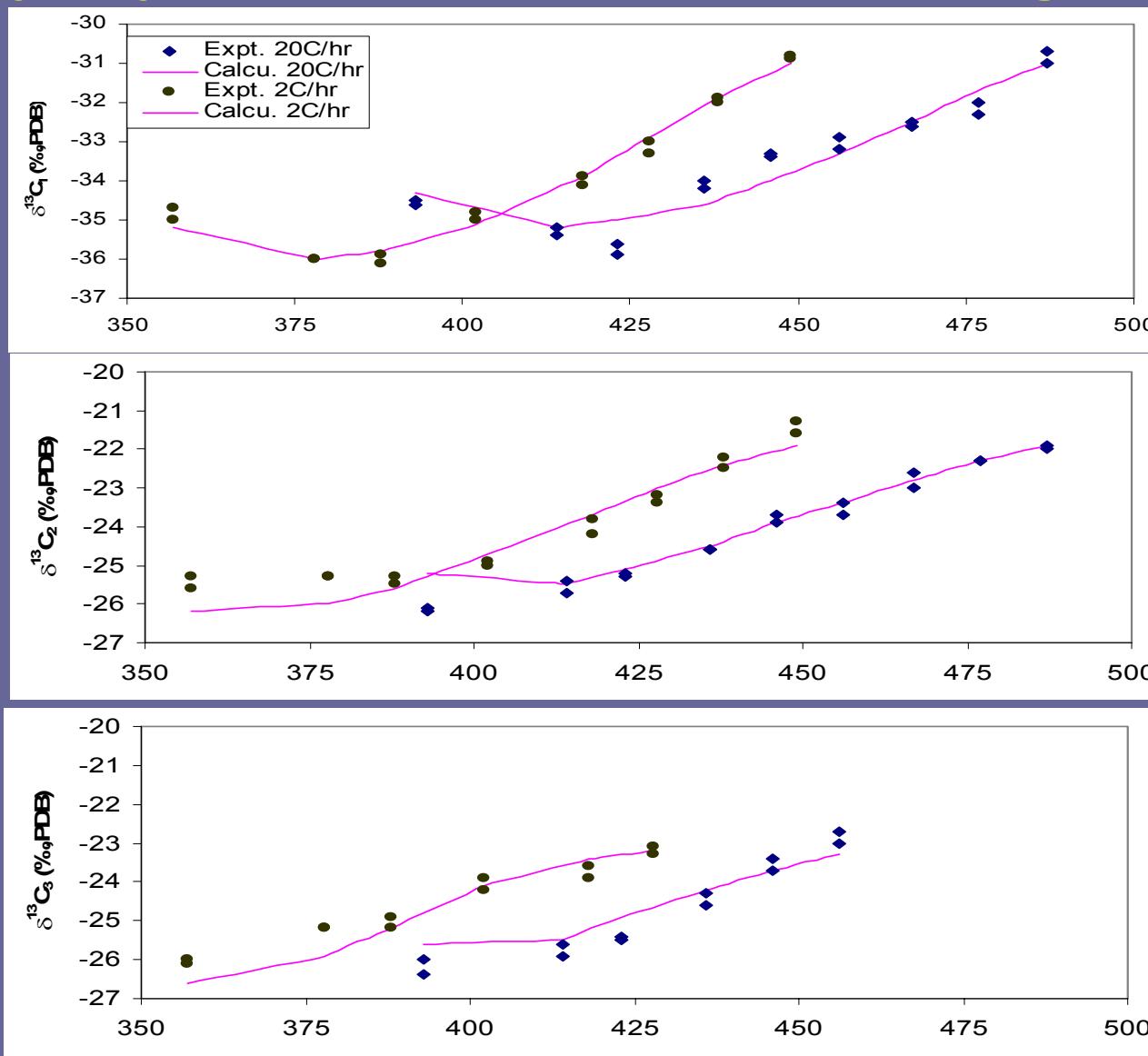
*Temperature ( $^{\circ}$ C)*

# *Activation Energy Distribution of Gas Generation From Jurassic Coal*



# *Carbon Isotopes of Gases From Coal Anhydrous Pyrolysis at Two Different Heating Rates*

$\delta^{13}\text{C}$  (‰, PDB)



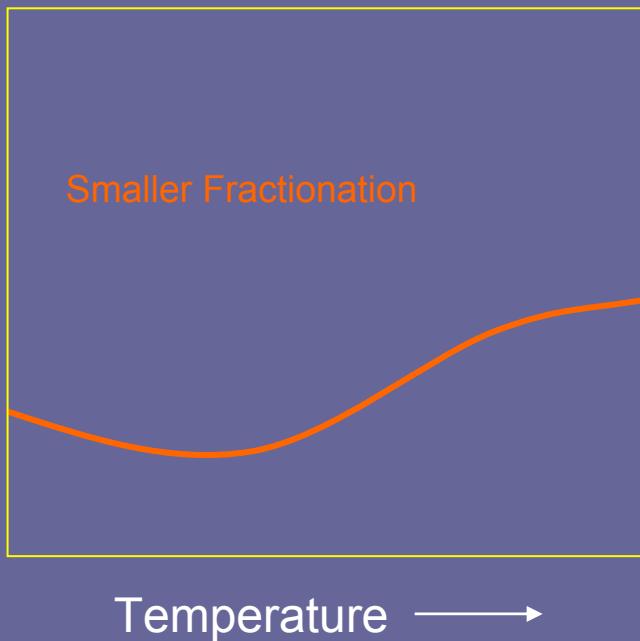
$C_1$

$C_2$

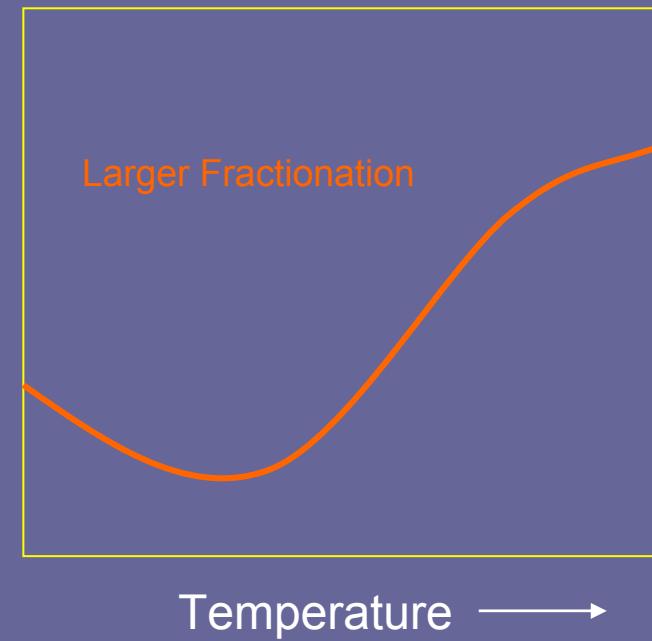
$C_3$

# *Observed Gas Isotope Fractionations in the Laboratory and Nature*

Laboratory Temperatures



Geological Temperatures



*Laboratory pyrolysis data cannot be directly compared with geological data. Only through extrapolation of kinetic gas isotope fractionation can one use pyrolysis data to predict gas isotope changes with time and temperature.*

# *Kinetics Parameters of Isotope Fractionations For Basin Modeling*

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
Alpha(1)	1.02	1.02	1.02
BetaLow (cal/mol)	1	10	10
BetaHigh (cal/mol)	85	80	80
Eo (kcal/mol)	59.4	61.4	61.6
Sigma (% Eo)	22.3	37.9	30.9
Gamma (‰)	-30.1	-21.2	-23.0

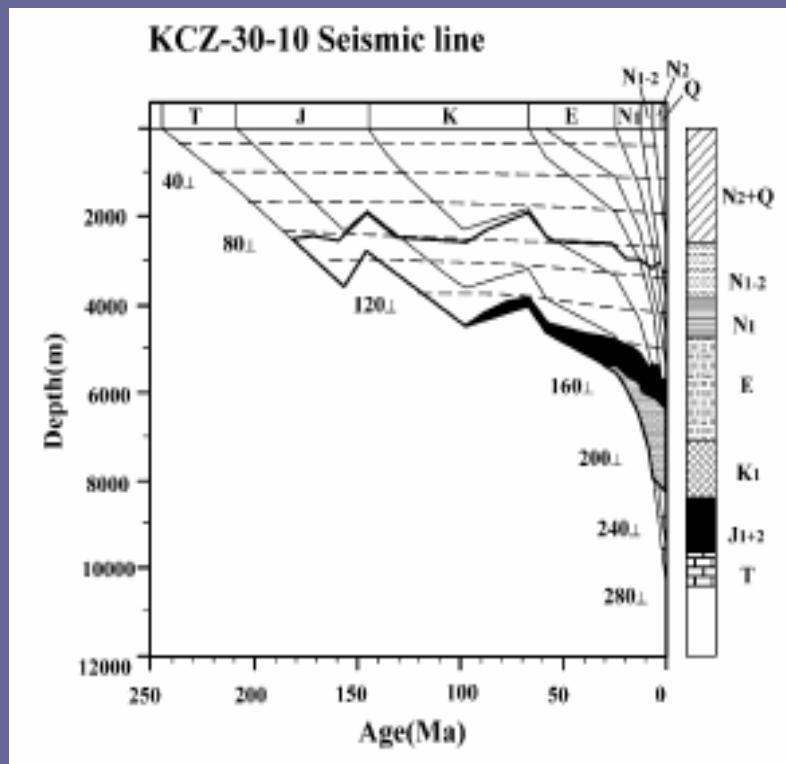
*Extrapolation of kinetic gas isotope fractionation obtained from pyrolysis data is able to predict gas isotope changes with time and temperature under geological condition.*

# *Geological Application of GOR-Isotope Model in Tarim Basin*

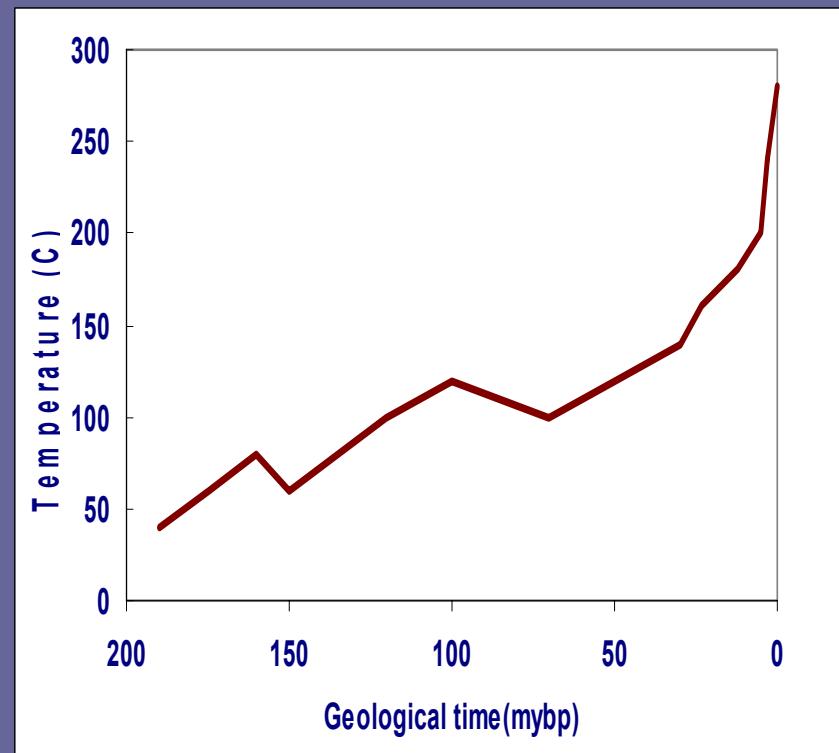
- *Timing of Gas formation and Expulsion*
- *Gas filling history*
- *Gas thermal maturity*
- *Gas reserves estimation*
- *Gas recharging time*

# *Burial Thermal History of Jurassic Source Rock in the Tarim Basin*

*Burial history curve*

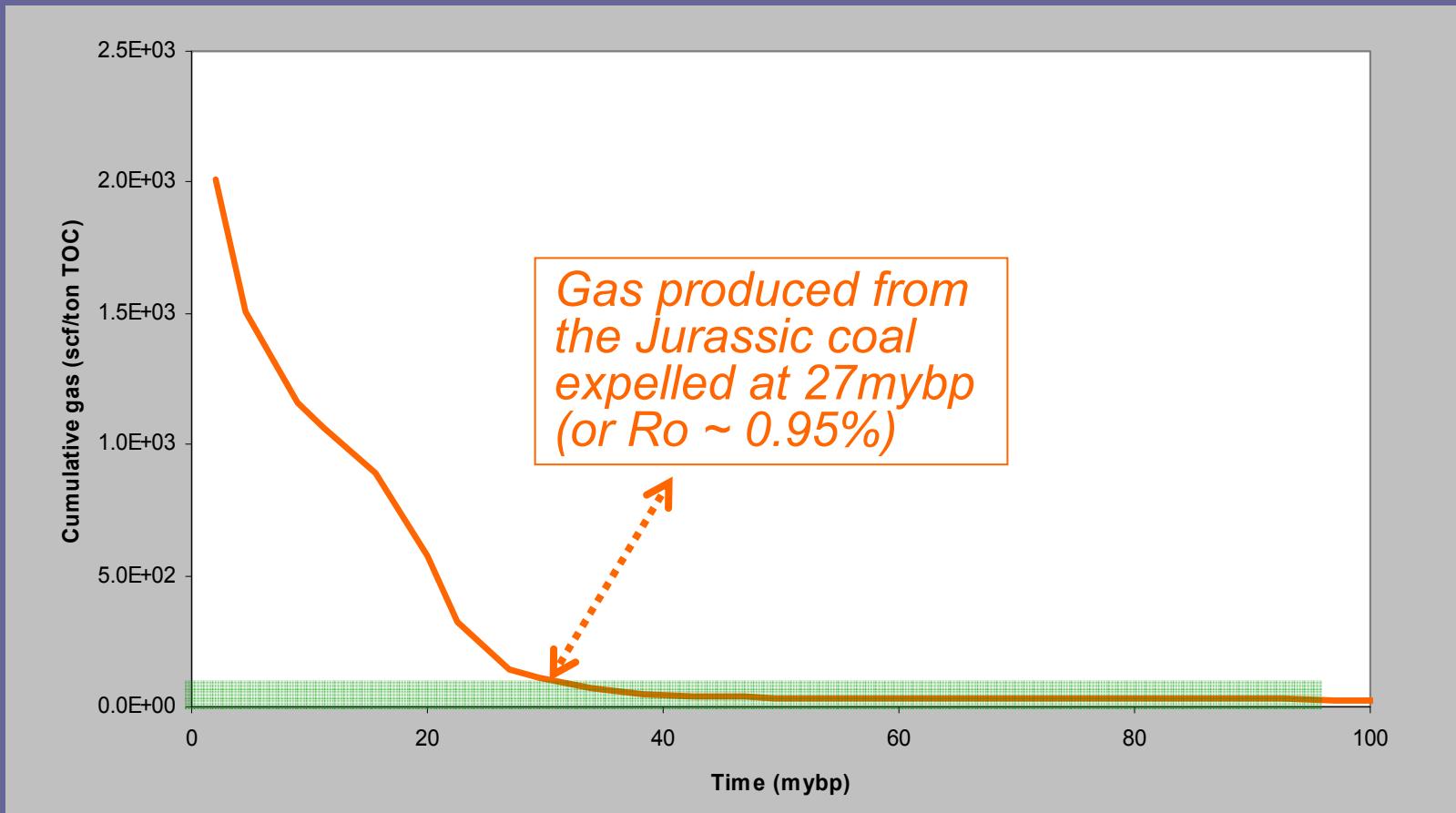


*Time-Temperature curve of the bottom of Jurassic source*

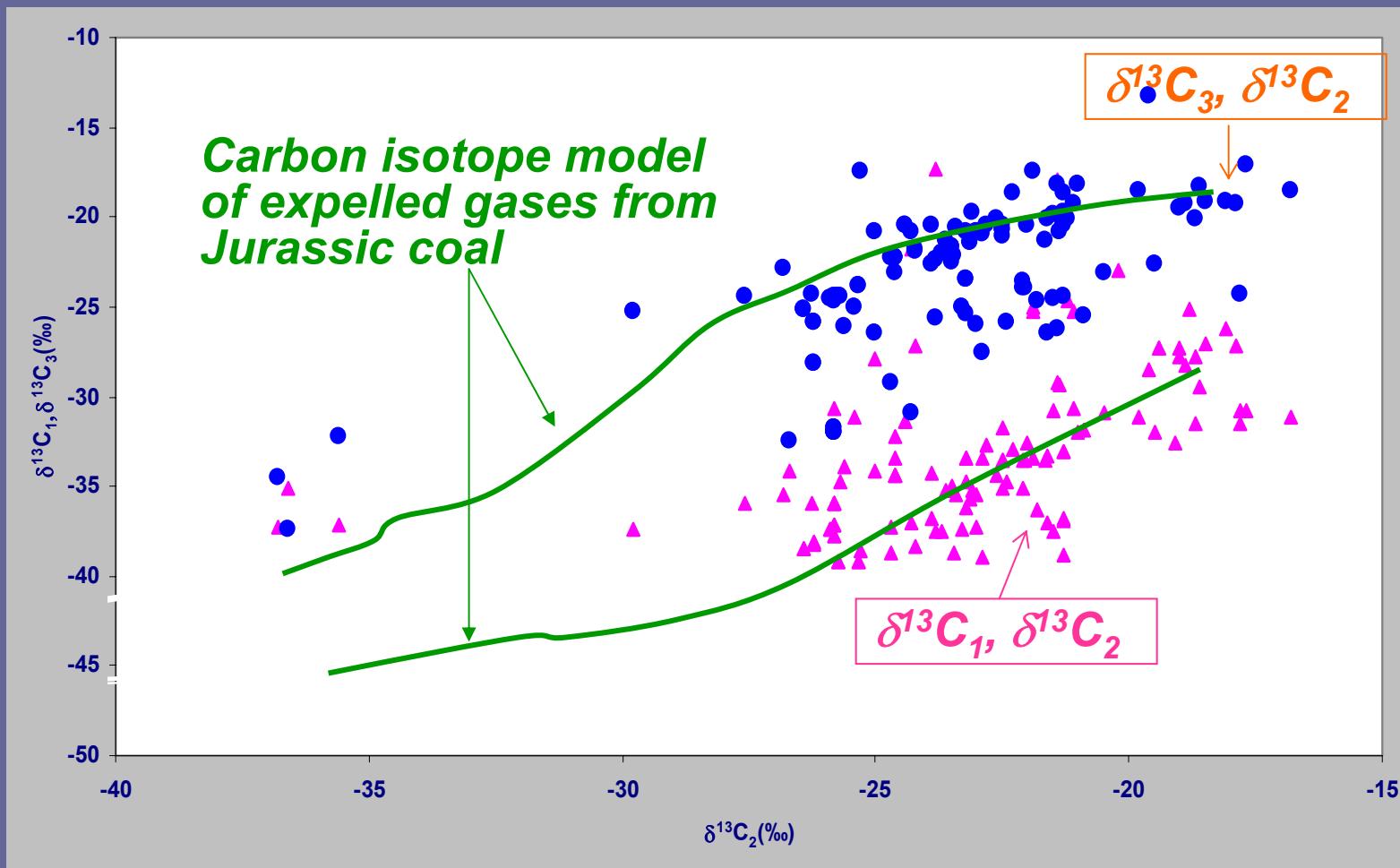


According to Liang et al. 2003

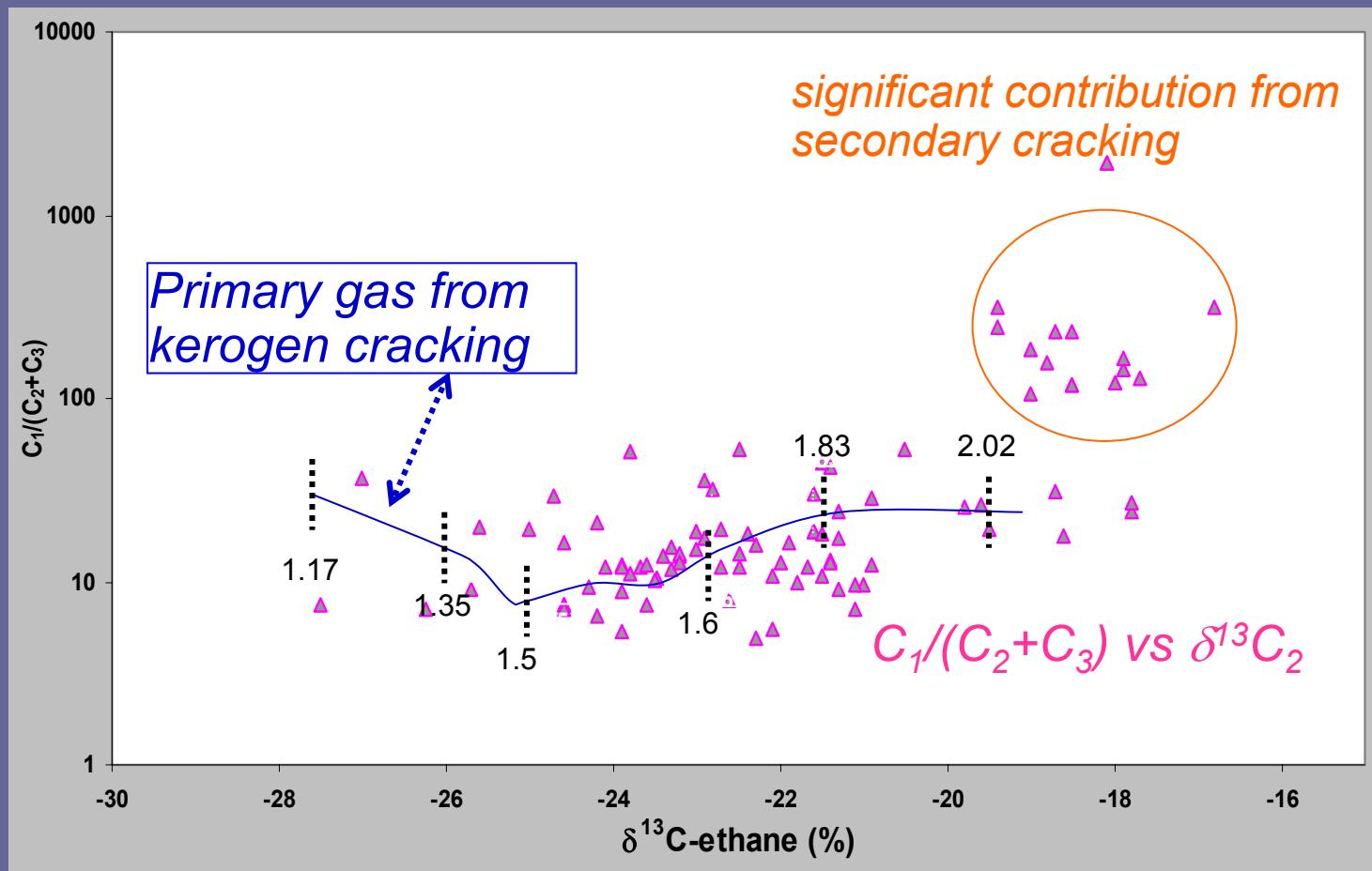
# *Gas Generation from Jurassic Coal Source In the Tarim basin*



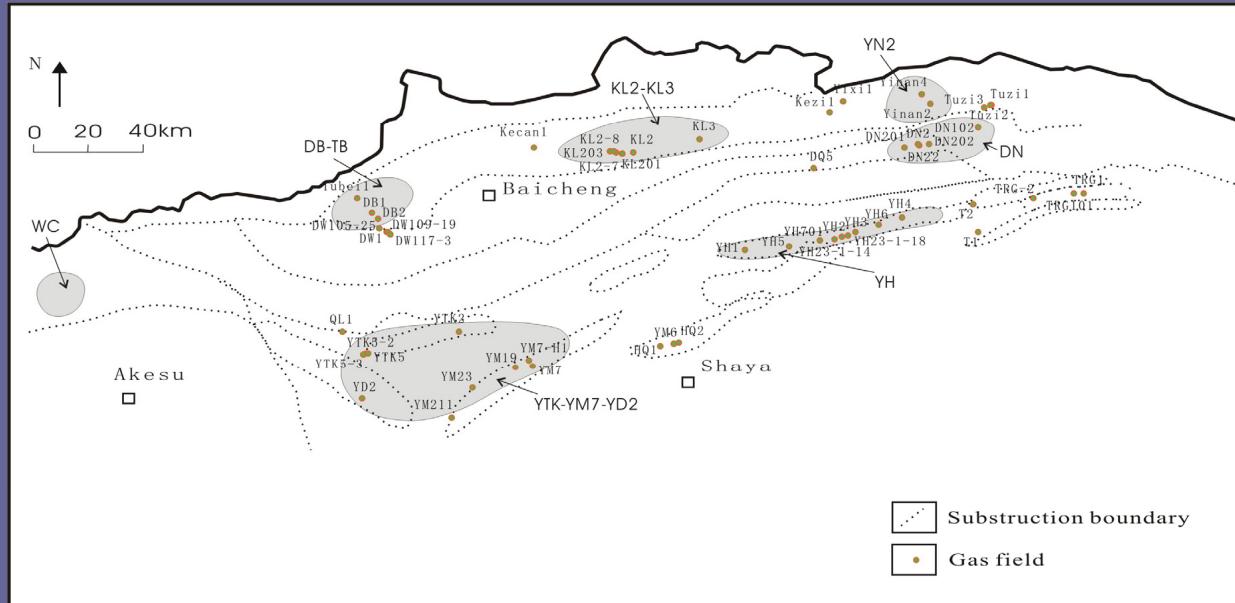
# *Modeling Carbon Isotopes of Expelled Gases from Jurassic Coal Match with Geological Observation of Natural Gases in Reservoirs*



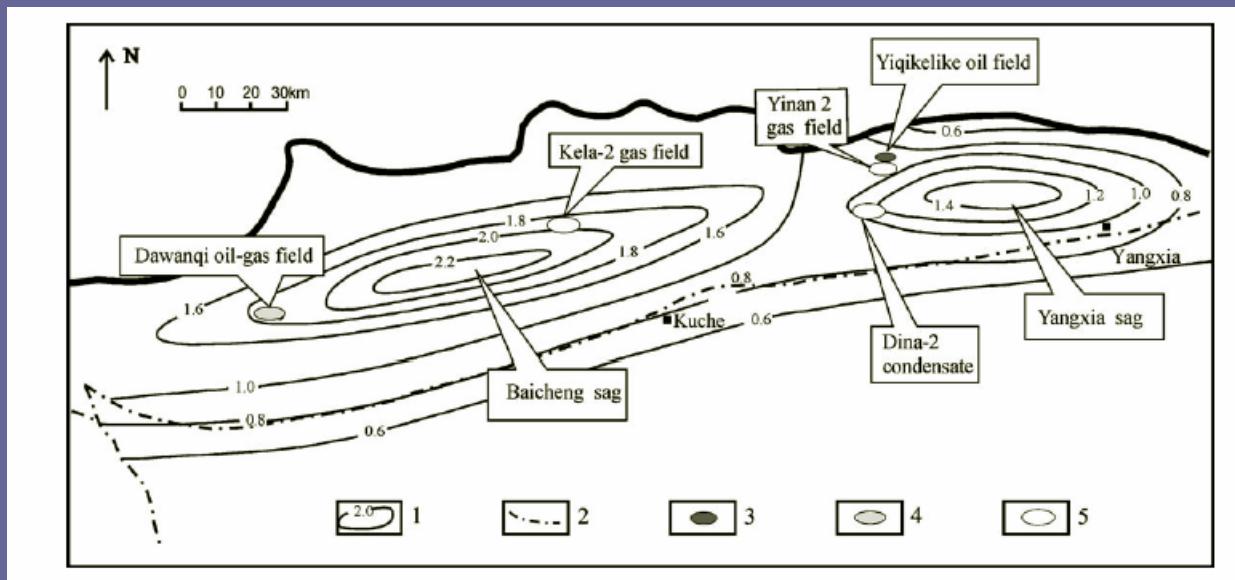
# *Thermal Maturity of Coal-type Gas in Tarim Basin*



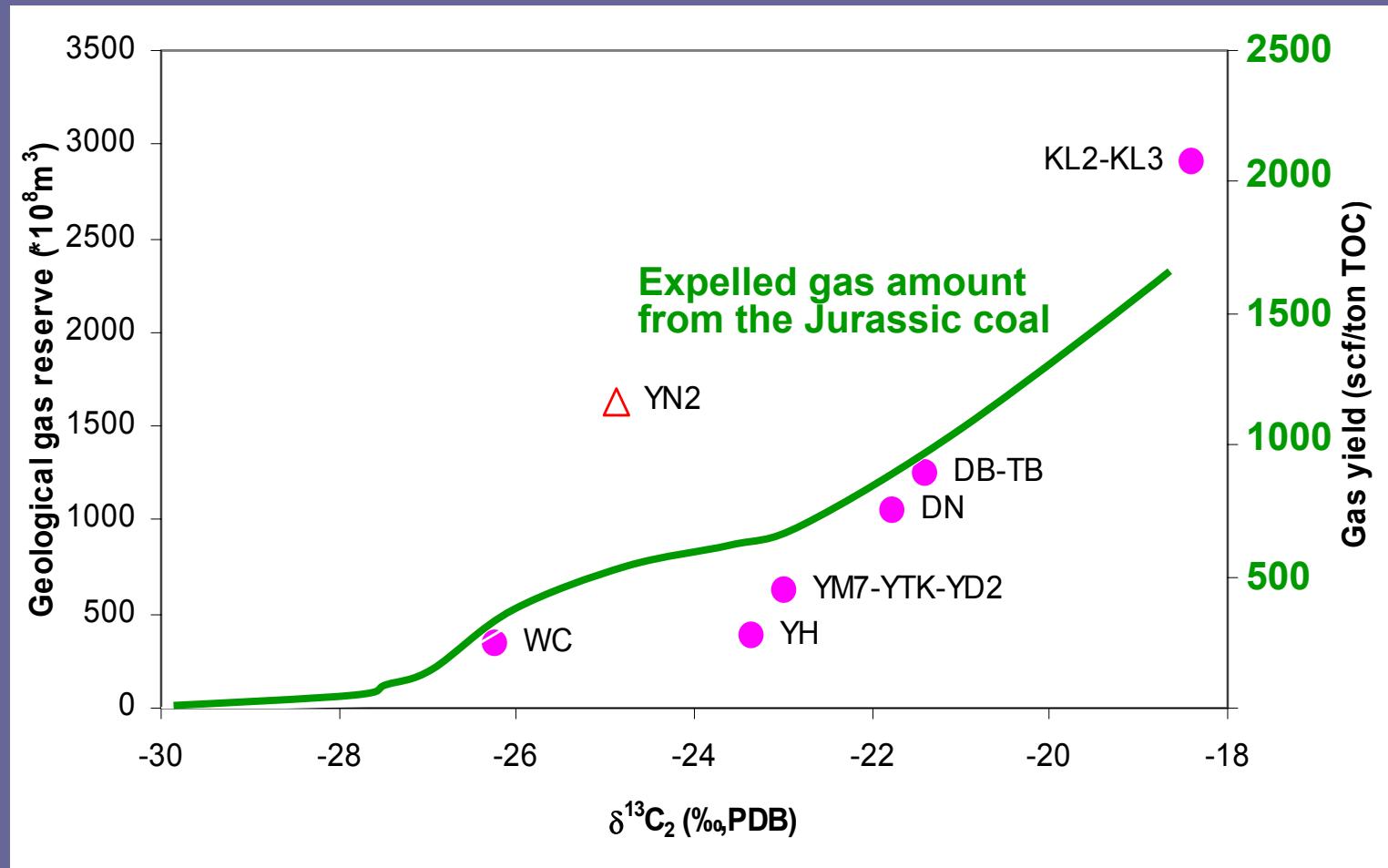
## Distribution of Gas Fields in Kuqa Depression



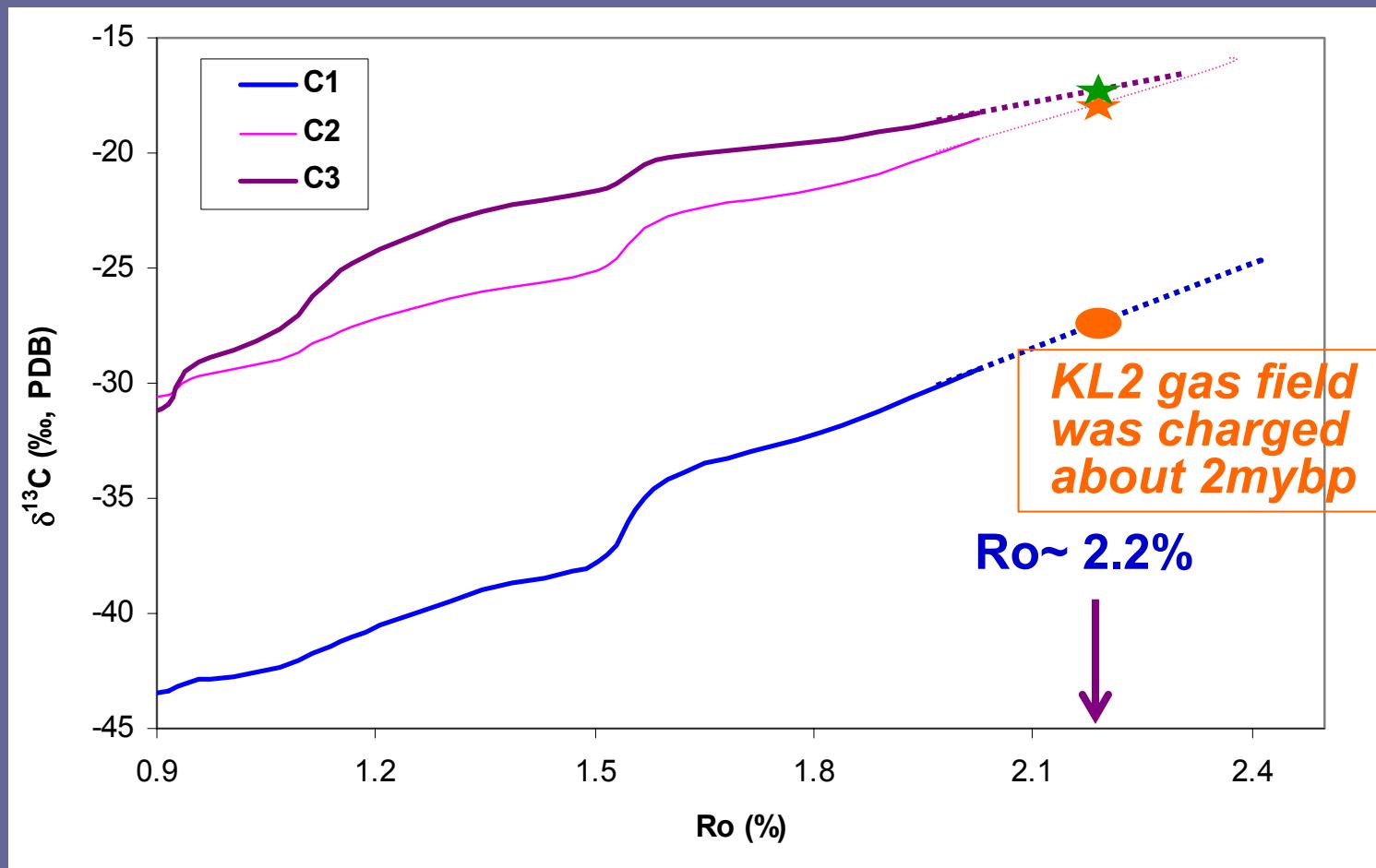
*Ro (%) contour of Jurassic coal gas source in Kuqa Depression (according to Qin et al., 2006)*



# Gas Reserves Prediction By Gas Geochemistry Isotope Model



# *Kela 2 Large-size Gas Field Was Probably Charged About 2 mybp*



# **Conclusions**

- Oil-type gas and coal-type gas can be clearly differentiated by the carbon isotopic compositions of C<sub>1</sub>, C<sub>2</sub> and C<sub>3</sub> in natural gases from the Tarim basin. Coal-type gas possesses heavier carbon isotope of ethane and propane compared with that of oil-type gas.
- Thermal genetic gases from organic matter cracking under high temperature and pressure are a dominant source in the Tarim basin.
- Quantitative kinetics model provides a useful tool for dynamically understanding gas recharging history, determining gas maturity, predicting gas reserves and recharging time in an effective trap.
- Expelled gas from Jurassic coal occurred about 27mybp once the produced gas is abundant enough to meet coal absorption.
- The recharging of Kela 2 large-sized gas field probably occurred about 2my before present time.
- Expelled gas retained in the Jurassic coal until faults as gas migration pathway became available at about 2mybp.