

# **Study on Oil-Source Correlation Methods of Severely Biodegraded Oils in Bozhong Subbasin, Bohai Bay Basin, China\***

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## **Abstract**

There are three organic-rich, oil-prone source rock intervals in Bozhong Subbasin, Bohai Bay Basin: the third and the first members of Shahejie Formation, and the Dongying Formation. Most oils with burial depths less than 2,000m (6,562ft) are severely biodegraded as evidenced by the occurrence of 25-norhopanes. To recognize the source of the biodegraded oils, biomarker characteristics of the three source rock intervals are identified and several oil-source correlation methods are applied.

The upper Eocene third member of Shahejie Formation (E2s3) is dominated by semi-deep and deep lacustrine facies mudstone with highest TOC contents and hydrocarbon indices, and it has low gammacerane, C<sub>19</sub> tricyclic terpane and C<sub>24</sub> tetracyclic terpane contents, and high 4,23,24-trimethyl triaromatic dinosterane and 4-methyl-24-ethyl triaromatic sterane contents, indicating light saline water and blooming dinoflagellates paleoenvironment. The lower Oligocene first member of Shahejie Formation (E3s1) is saline lacustrine facies mudstone, lime mudstone and limestone with relatively high TOC contents and hydrocarbon indices. It has high gammacerane and 4,23,24-trimethyl triaromatic dinosterane contents, low C<sub>19</sub> tricyclic terpane, C<sub>24</sub> tetracyclic terpane and 4-methyl-24-ethyl triaromatic sterane contents. The upper Oligocene Dongying Formation (E3d) is semi-deep and deep lacustrine facies mudstone in its lower part, with relatively high contents of vitrinite and nonfluorescent amorphous organic matter and classified as mixed type I and III kerogens. It has low gammacerane and 4-methyl triaromatic sterane homologues contents, high C<sub>19</sub> tricyclic terpane and C<sub>24</sub> tetracyclic terpane contents, indicating fresh water, freshwater algae dominated and partially terrigenous organisms input paleoenvironment.

Carbon isotope of whole oil, 4-methyl triaromatic sterane homologues, gammacerane, C<sub>19</sub> tricyclic terpane, C<sub>24</sub> tetracyclic terpane, carbazole, and crude oil density and viscosity are used to determine the source of severely biodegraded oils. The biodegradation has little effect to carbon isotope of whole oil. The whole oil carbon isotopes from E2s3 and E3d source rock intervals are heavier than -27‰ and lighter than -28‰ respectively in east Bozhong Subbasin, and that from E3s1 source rock interval are intervening. 4-methyl triaromatic sterane homologues discussed above can distinguish oils from the three source rock intervals, and they are seldom influenced by biodegradation.

## **Selected References**

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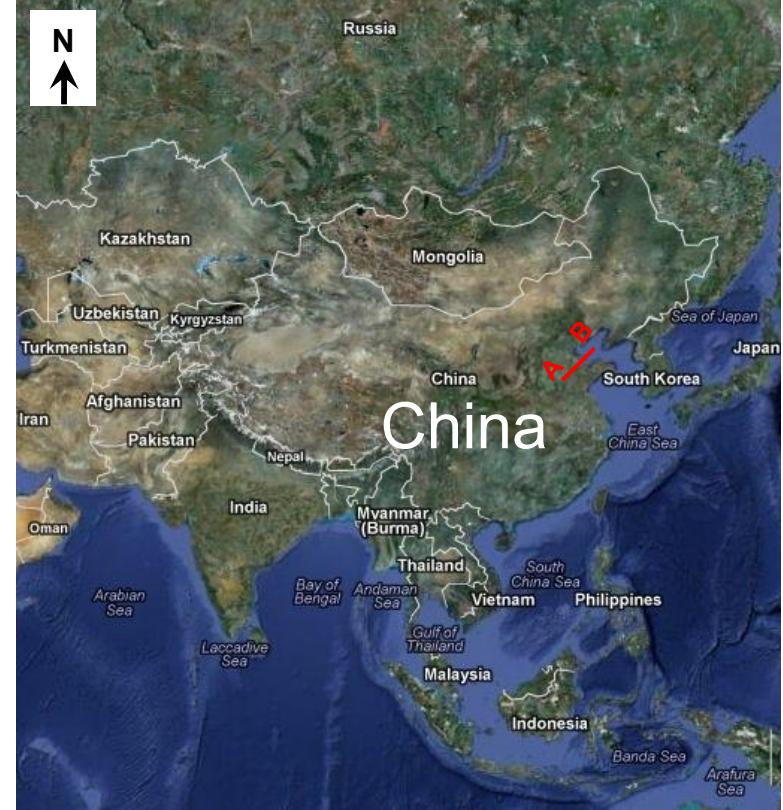
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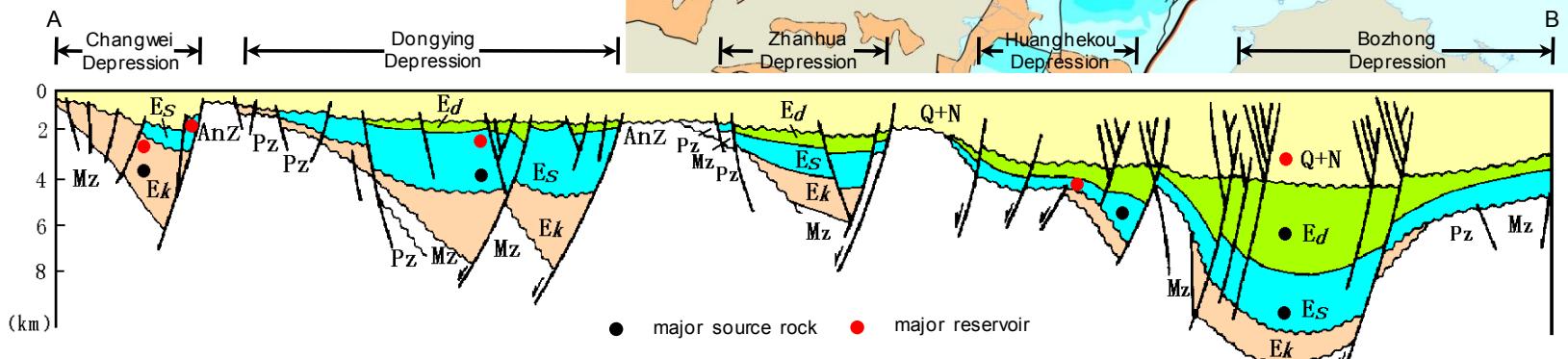
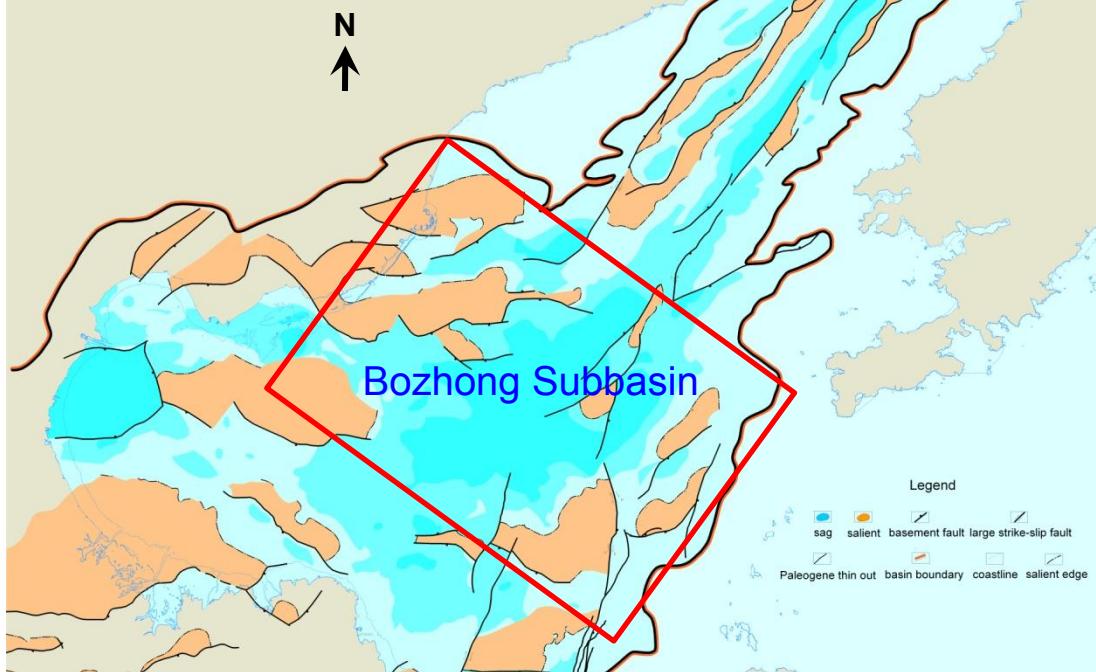
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- 1. Geological background**
- 2. Biomarker characteristics of three kinds of oils**
- 3. Oil-source correlation of severely biodegraded oils**



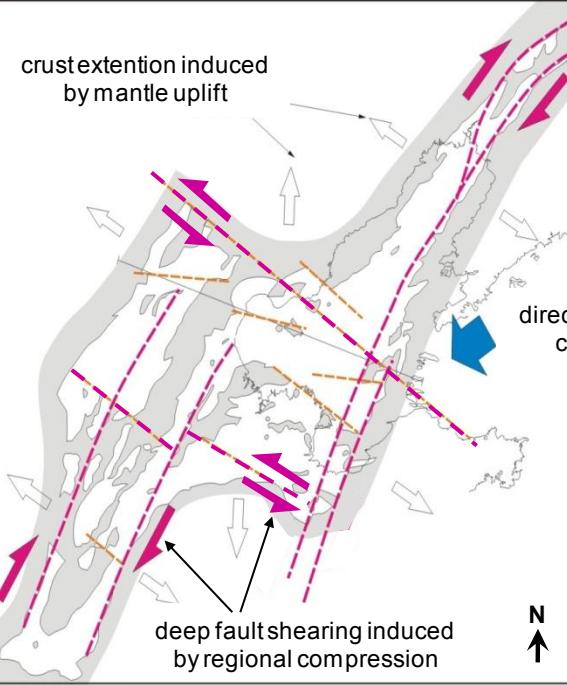
## Bozhong Subbasin, center of Bohai Sea



Northeast Cross Section of Bohai Bay Basin

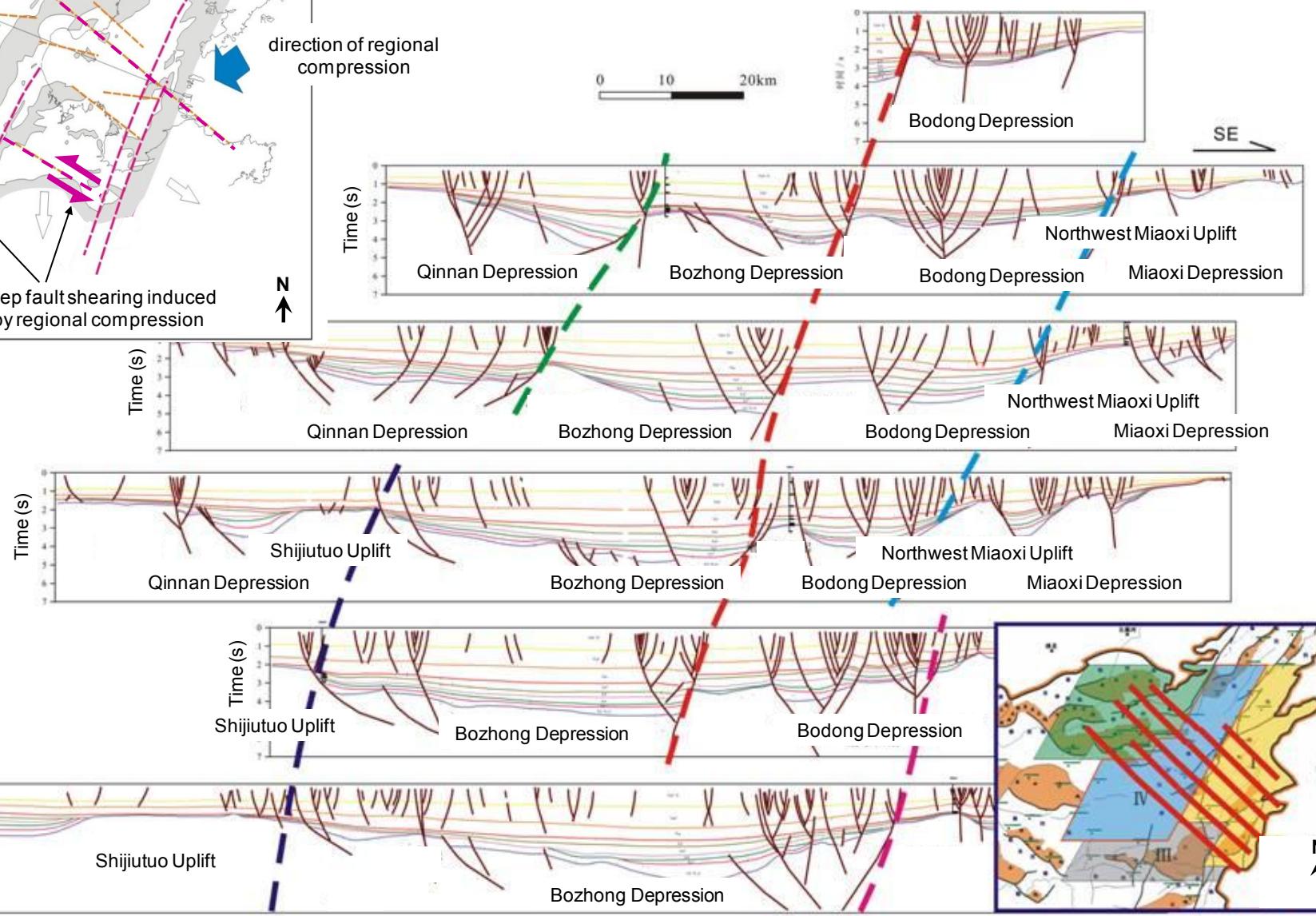
Zhu Weilin, Mi Lijun et al, 2009

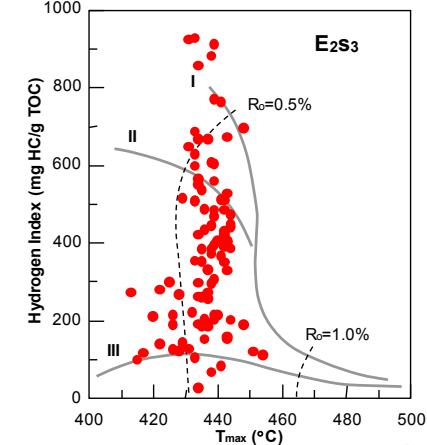
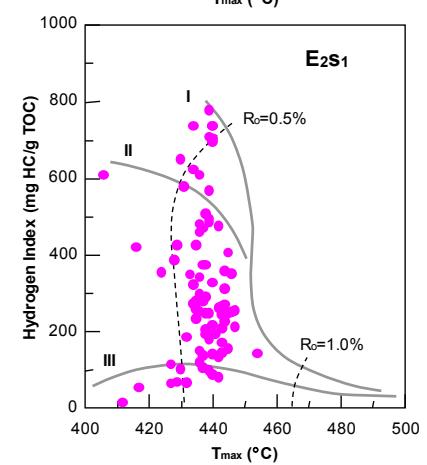
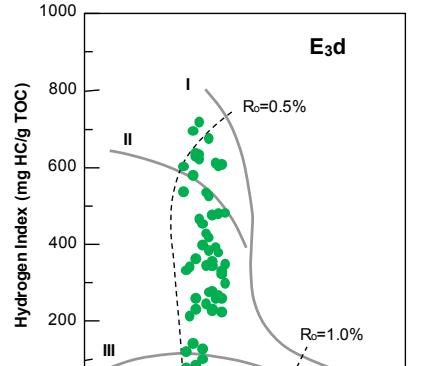
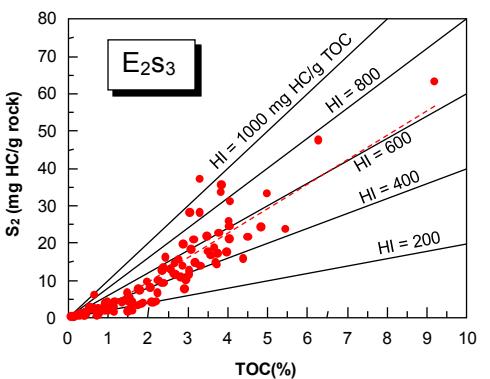
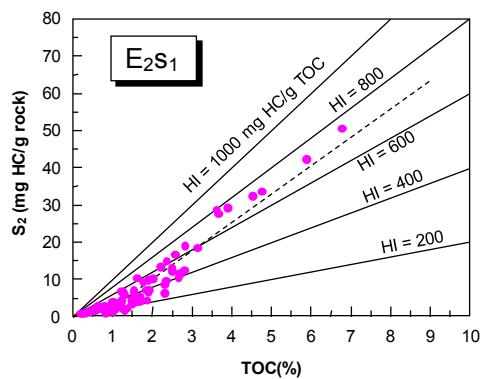
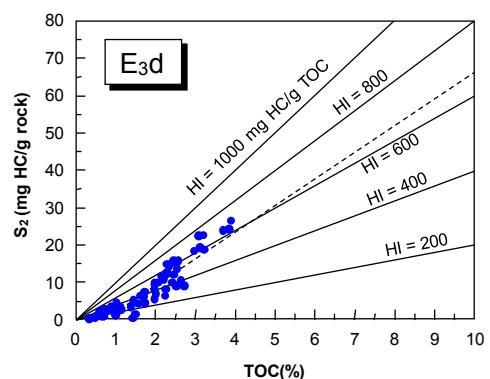
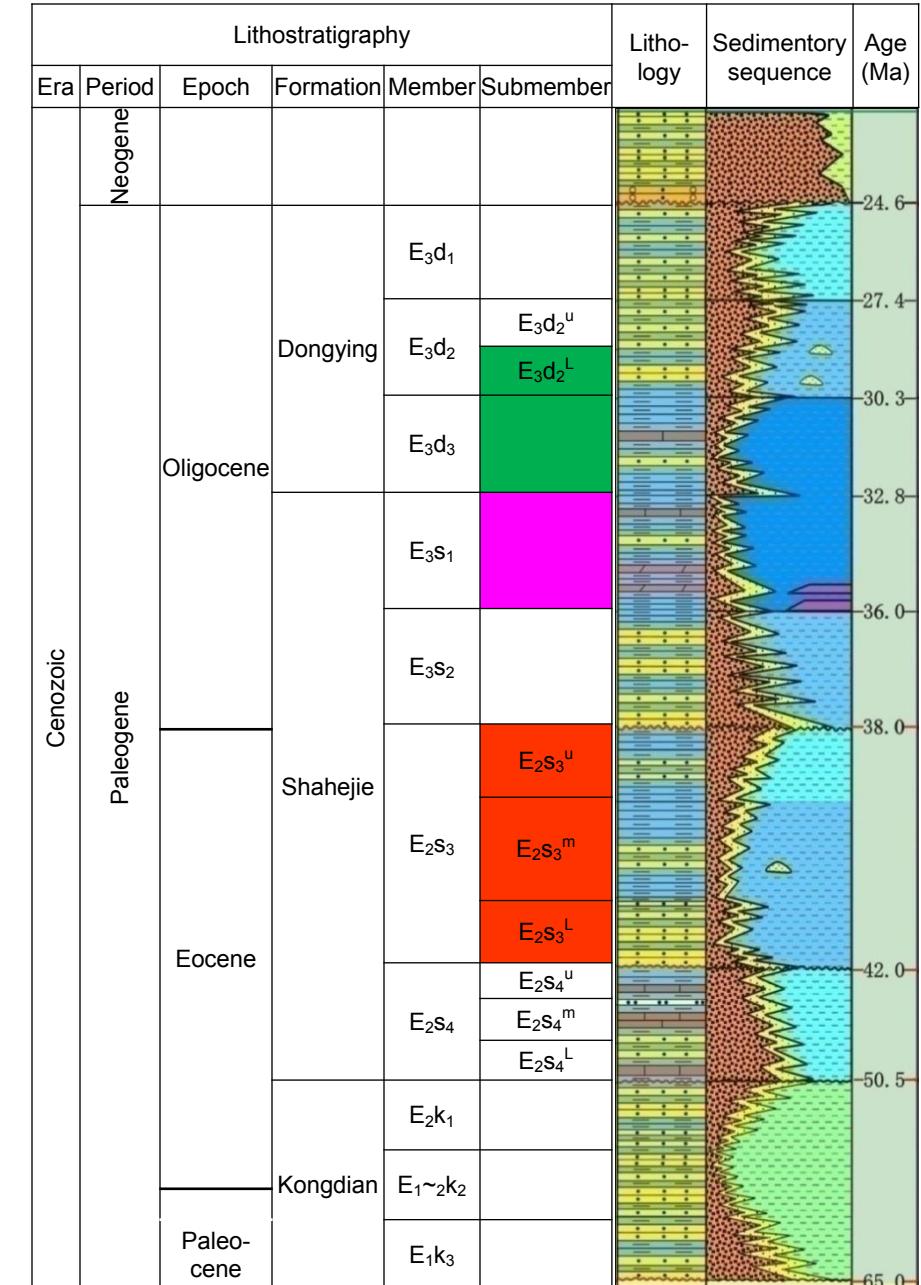
crust extension induced  
by mantle uplift



- ◆ Double dynamics: regional compression and mantle uplift
- ◆ Bozhong Subbasin: incised by multi-base ment faults

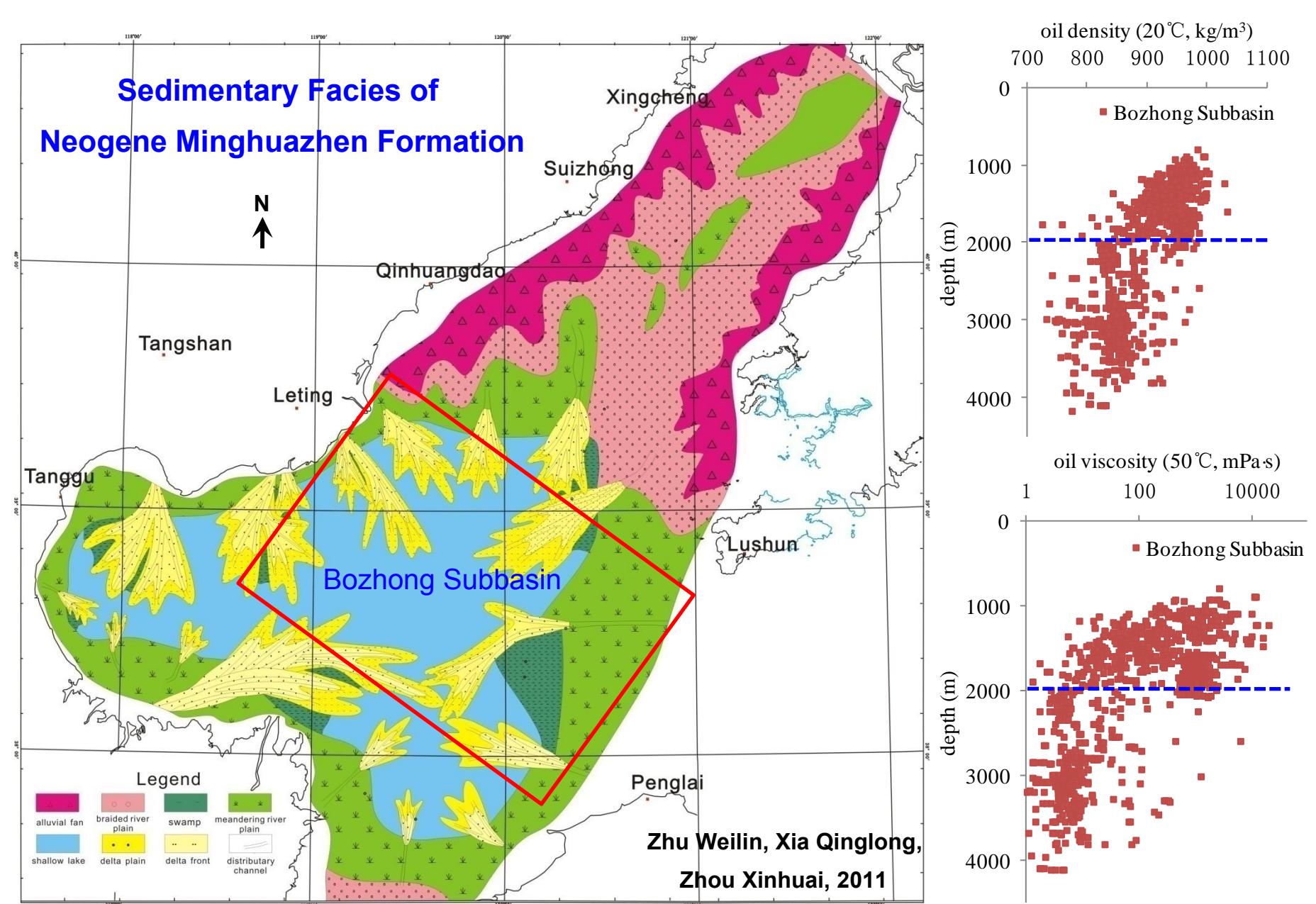
Tang Liangjie, 2009





Hao Fang, 2009

◆ Three major source rocks: E<sub>2s</sub><sub>3</sub>, E<sub>3s</sub><sub>1</sub> and E<sub>3d</sub>. The upper, the less important.

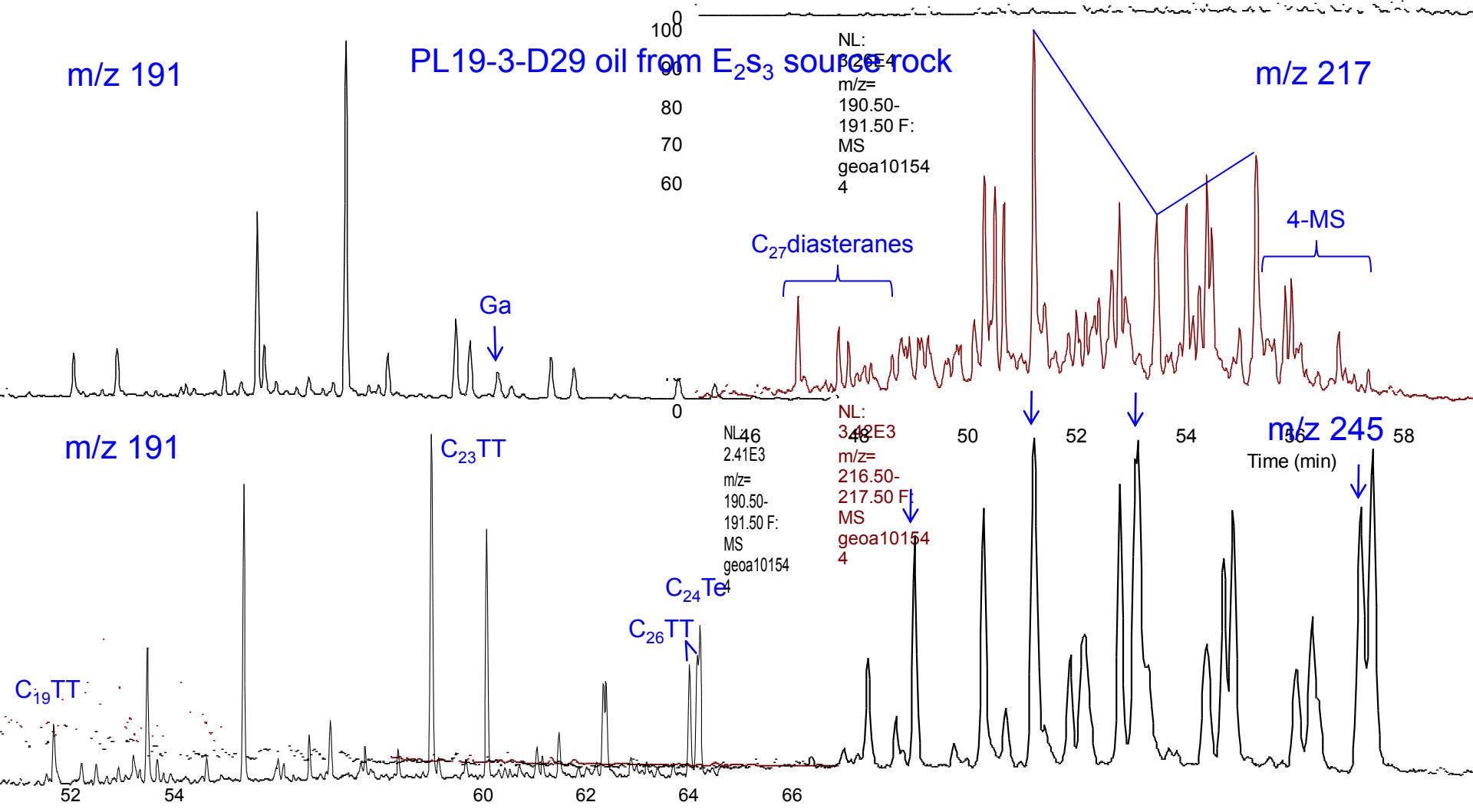


- ◆ Neogene Guantao and Minghuazhen Formation develops shallow water delta facies
- ◆ Neogene is the major reservoir in Bozhong Subbasin, bearing huge heavy oil reserves. 6

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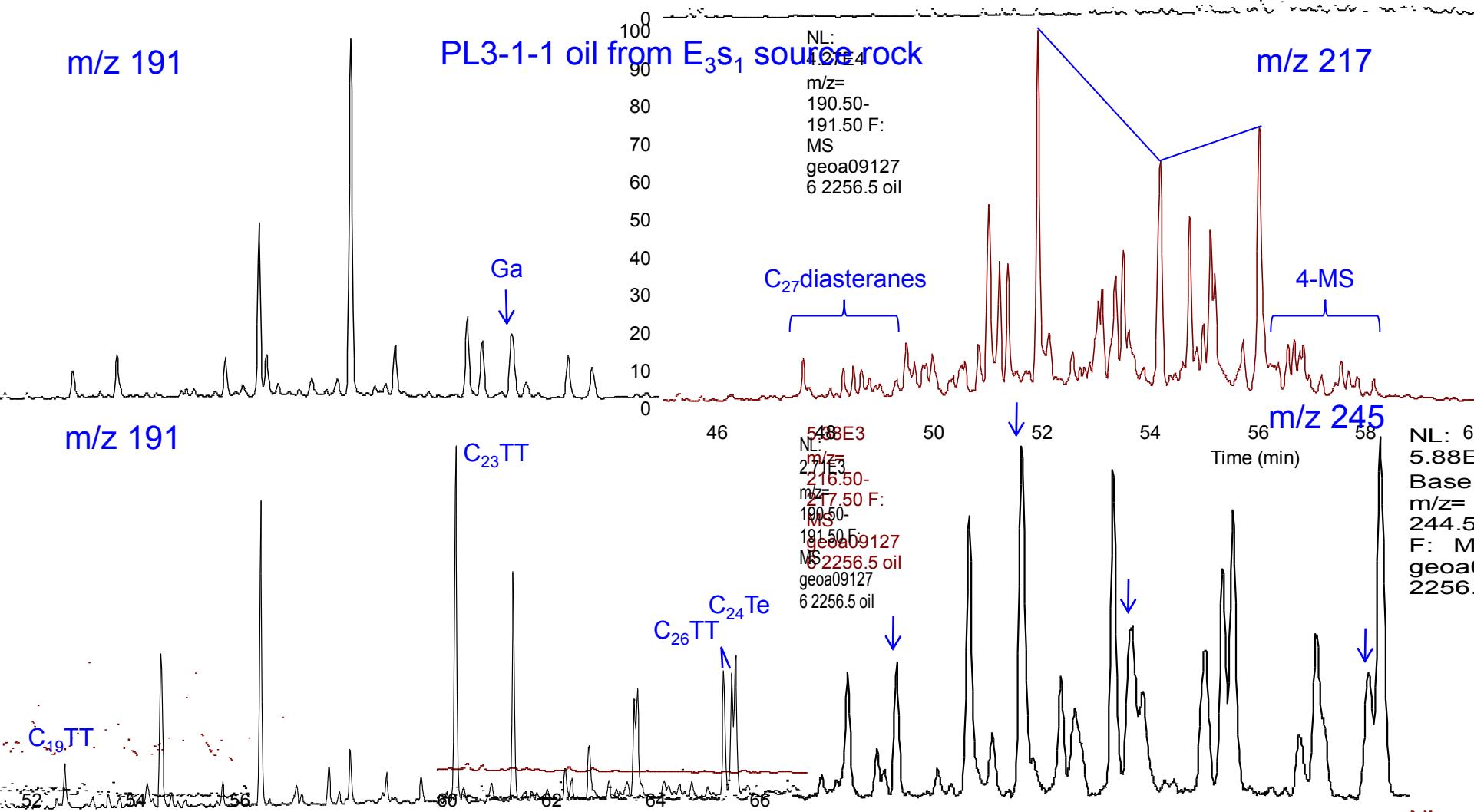


◆ Light saline

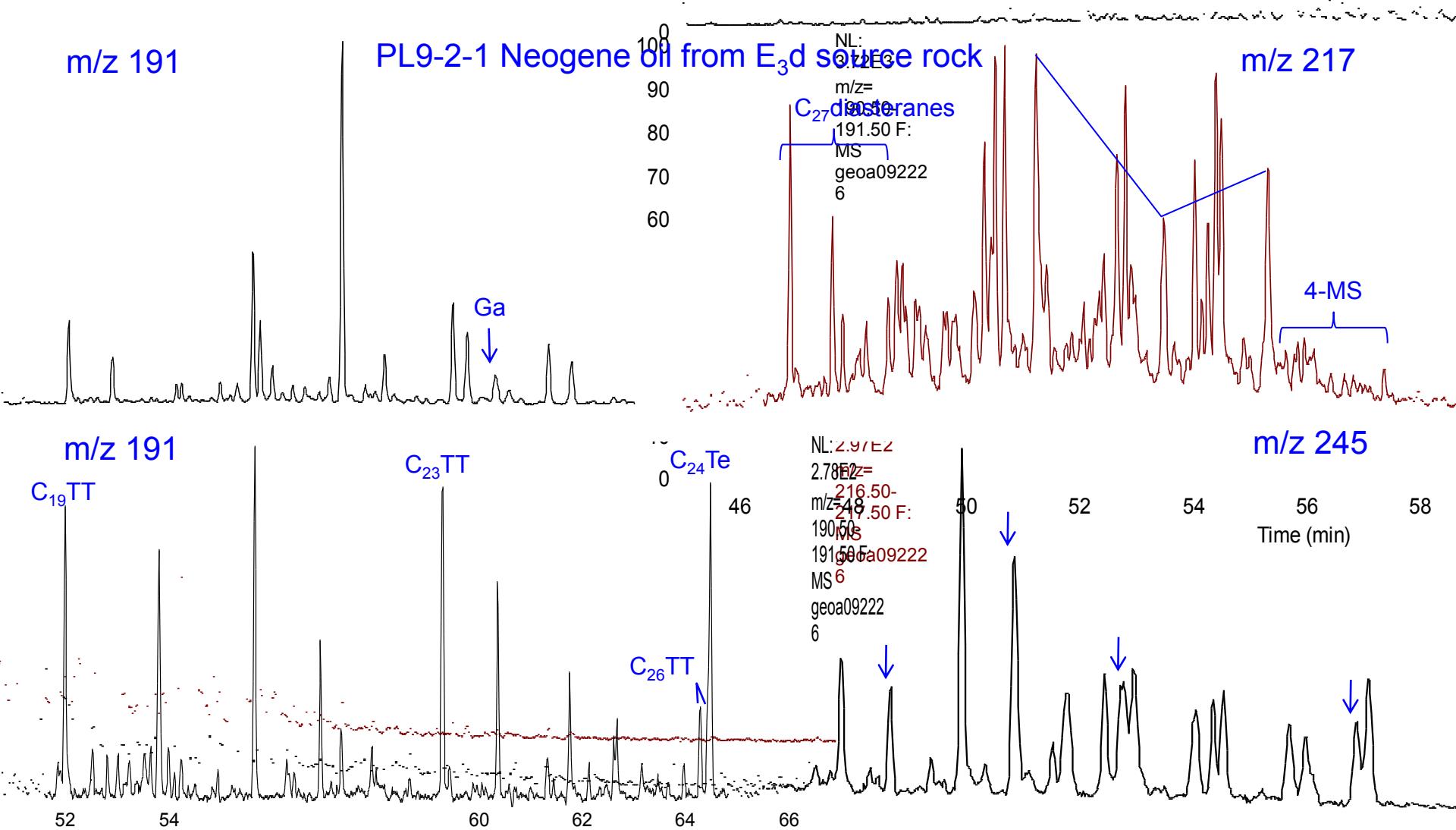
◆ Estuarine facies

◆ Excellent source rock thickness: up to 400m, TOC: up to 4%

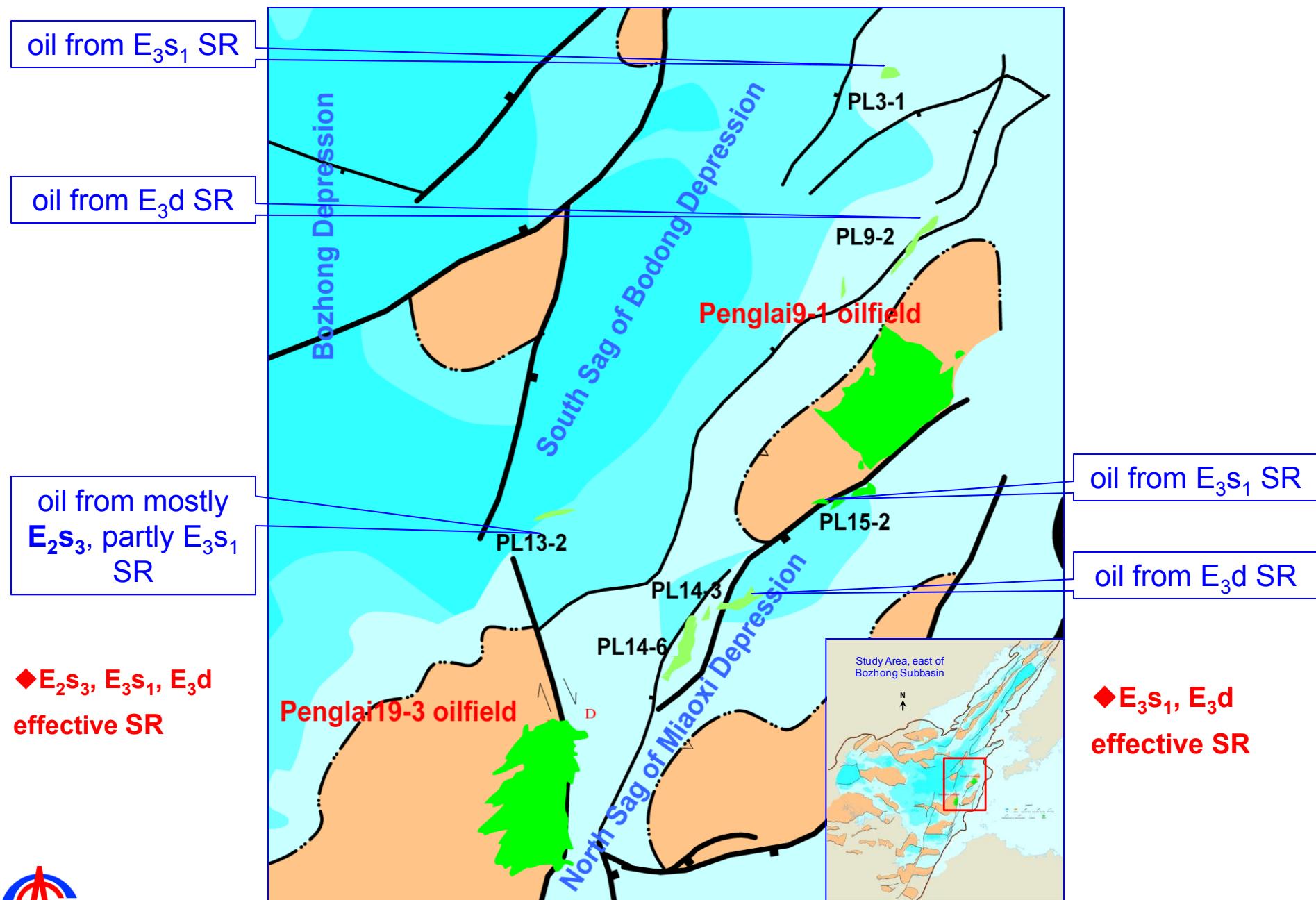
◆ Low Gammacerane; low diasteranes, low C<sub>19</sub> tricyclic terpane and C<sub>24</sub> tetracyclic terpane;  
high 4-methyl steranes, high C<sub>27</sub>-C<sub>29</sub> triaromatic steranes



- ◆ Saline water lacustrine facies
  - ◆ Excellent source rock thickness: up to 250m; TOC: up to 3.5%
  - ◆ High Gammacerane; low diasteranes, low C<sub>19</sub> tricyclic terpane and C<sub>24</sub> tetracyclic terpane, low 4-methyl steranes, low 4-methyl triaromatic steranes and 4-methyl-24-ethyl triaromatic steranes; high 4,23,24-trimethyl triaromatic dinosteranes



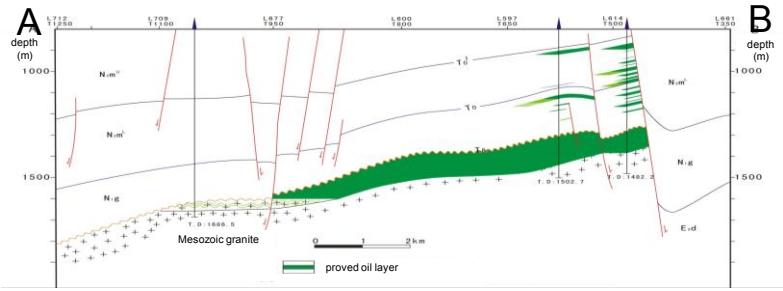
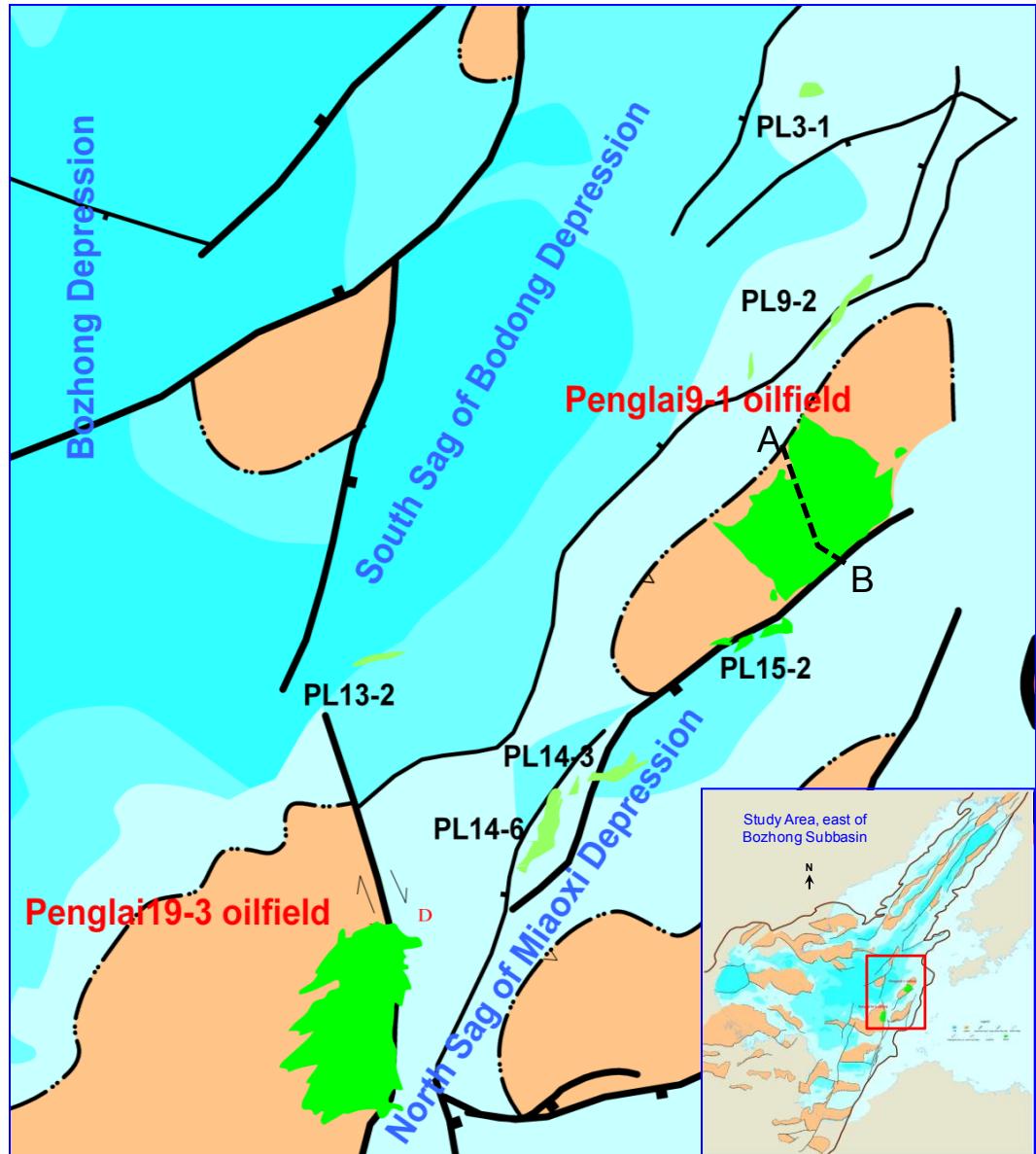
- ◆ Fresh water lacustrine facies
- ◆ Excellent source rock thickness: up to 450m; TOC: up to 3%
- ◆ Low Gammacerane; high diasteranes, high  $C_{19}$  tricyclic terpane and  $C_{24}$  tetracyclic terpane; low 4-methyl steranes, low  $C_{27}$ - $C_{29}$  triaromatic steranes



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Wang Xin, 2012

◆ **Penglai9-1 oilfield: Mesozoic granite buried hill and Neogene sandstone reservoirs, 7-8 level of oil biodegradation**

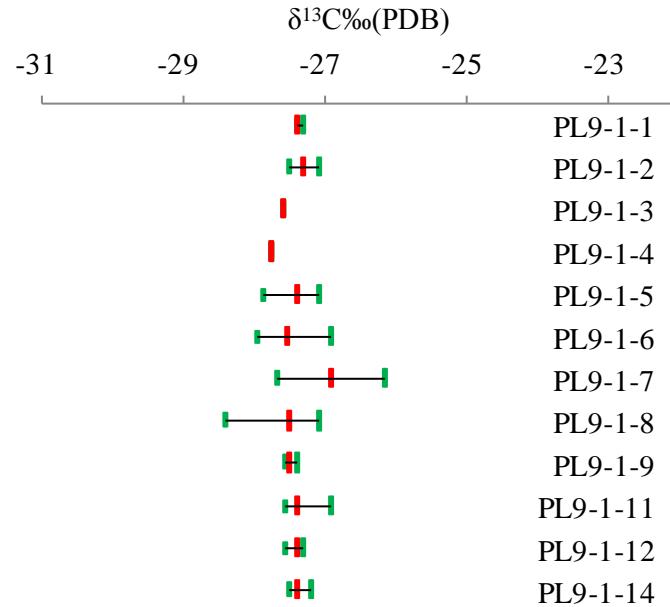
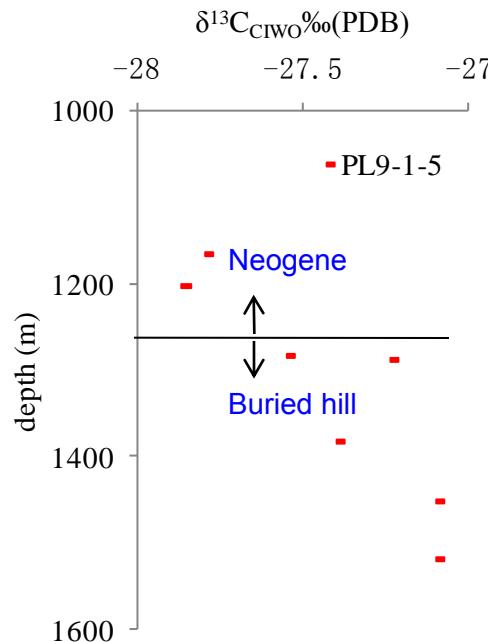
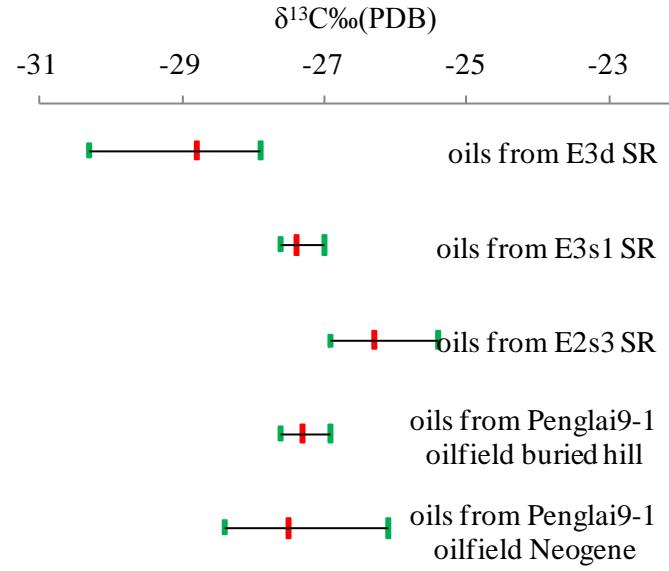
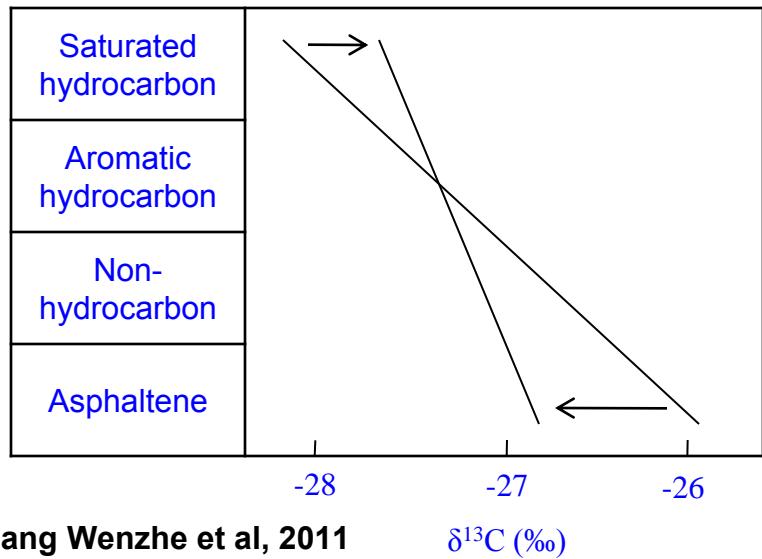
- ◆ **Direction: Bodong or Miaoxi?**
- ◆ **Source rock: E<sub>2</sub>s<sub>3</sub>, E<sub>3</sub>s<sub>1</sub>, E<sub>3</sub>d?**
- ◆ **Difference: Mz hill and Neogene?**

# **Oil-source Correlation Methods of Severely Biodegraded Oils**

- ◆ Carbon isotope of whole oil: affected little by biodegradation
- ◆ Aromatic hydrocarbon: C<sub>27</sub>-C<sub>29</sub> triaromatic steranes
- ◆ Saturated hydrocarbon: Gammacerane
- ◆ Non-hydrocarbon: carbazole absolute concentration and kinds
- ◆ Crude oil properties: density and viscosity



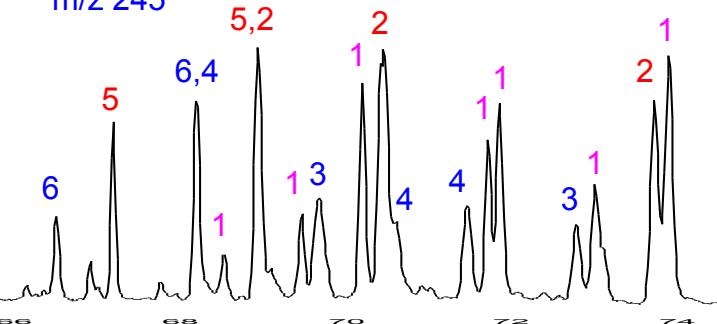
# Carbon Isotope of Whole Oil (CIWO)



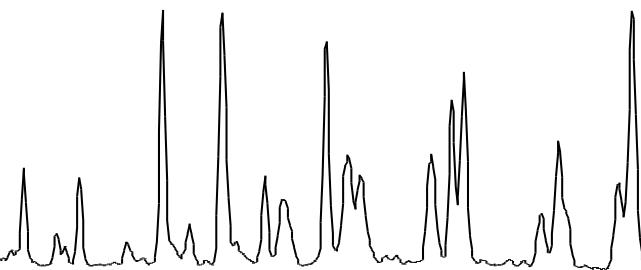
# $C_{27}$ - $C_{29}$ 4-methyl Triaromatic Sterane Homologues

PL19-3-D29 N<sub>1</sub>g oil from E<sub>2</sub>s<sub>3</sub> source rock

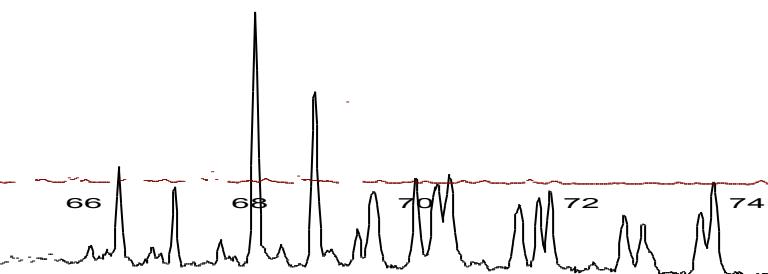
m/z 245



PL15-2-1 N<sub>1</sub>g oil from E<sub>3</sub>s<sub>1</sub> source rock



PL9-2-2 N<sub>1</sub>g oil from E<sub>3</sub>d source rock



1. 4,23,24-trimethyl triaromatic dinosteranes ( $C_{29}$ ), TADS;
2. 4-methyl-24-ethyl triaromatic steranes ( $C_{29}$ ), 4-M-24-EAS;
3. 3-methyl-24-ethyl triaromatic steranes ( $C_{29}$ );
4. 3-methyl-24-methyl triaromatic steranes ( $C_{28}$ );
5. 4-methyl triaromatic steranes( $C_{27}$ ), 4-MTAS;
6. 3-methyl triaromatic steranes ( $C_{27}$ ), 3-MTAS;

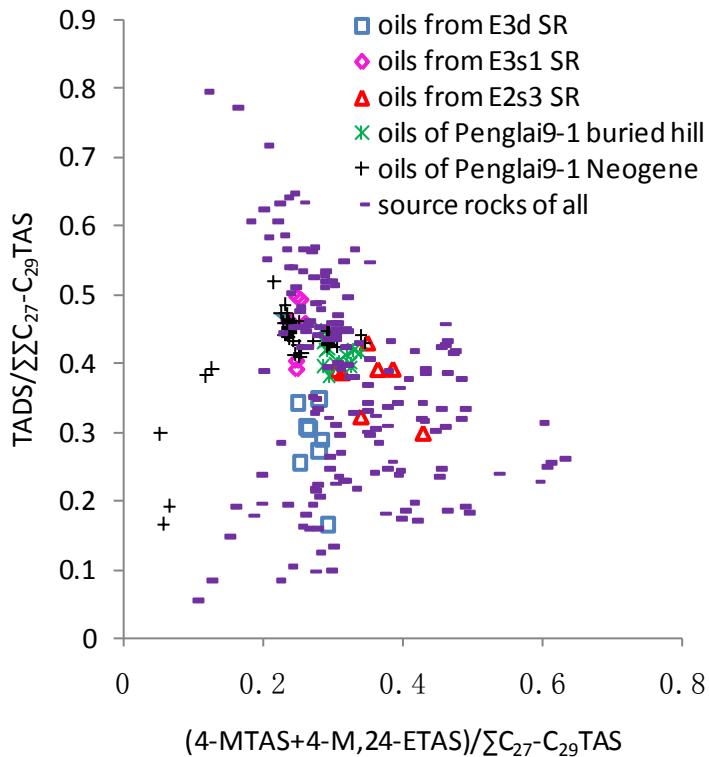
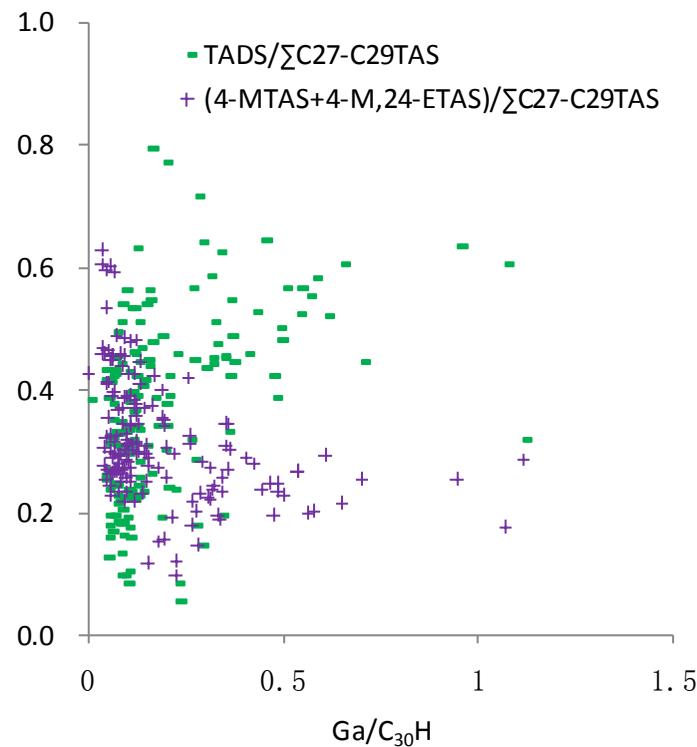
◆ Aromatization possible products of 4-methyl sterane homologues

◆ Identification 1: Bian Lizeng, et al. Chinese Science Bulletin, 2000, 45(23): 2554-2558.

◆ Identification 2: Zhang Shuichang, et al. ACTA PETROLOGICA SINICA, 2000, 21(6): 23-28.

◆ Significance: Moldowan J M, et al. Geology, v. 24, no.2, p. 159-162.

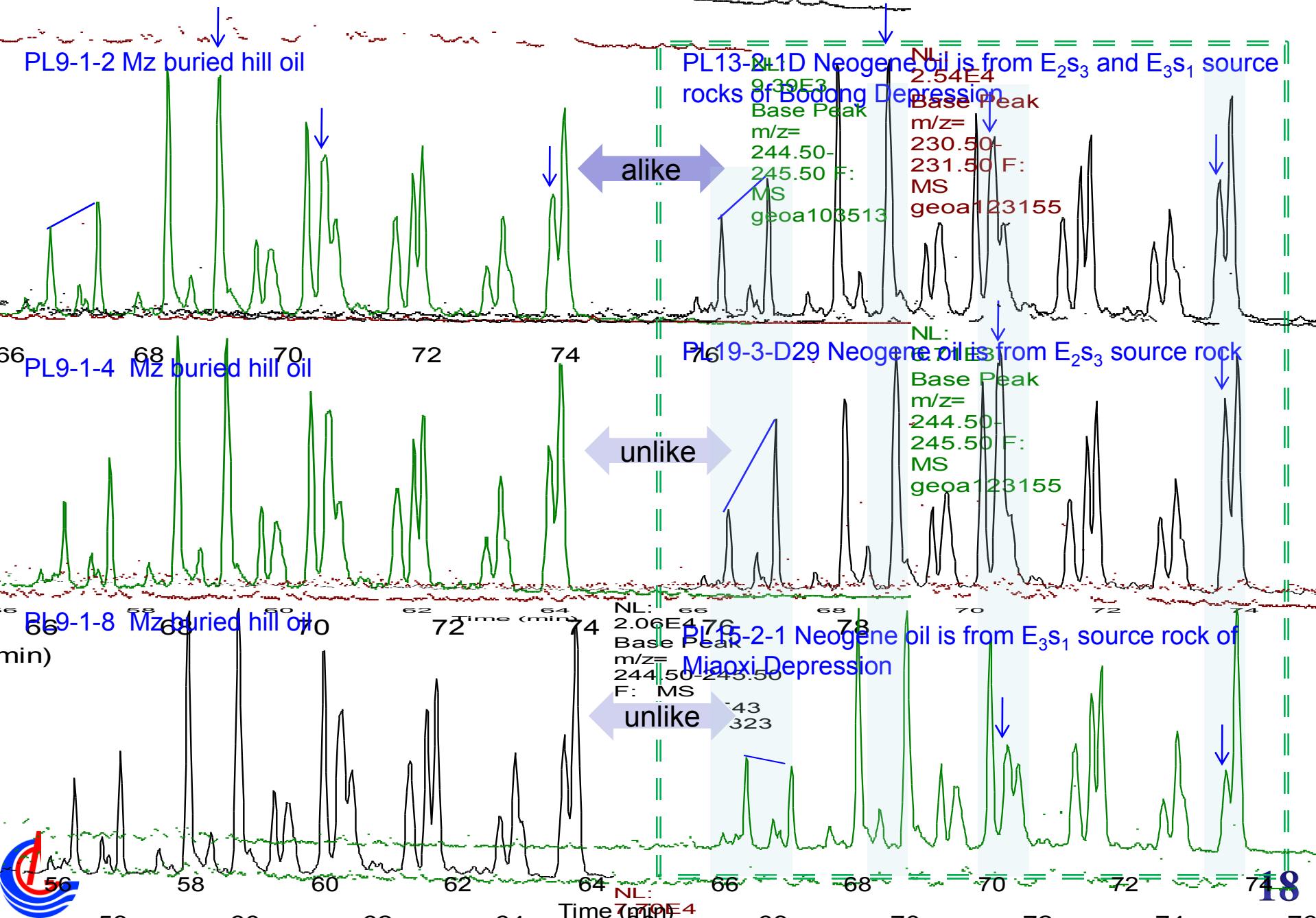
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1.82E4  
Base Peak  
m/z=  
230.50-  
231.50 F:  
MS  
geoa09366  
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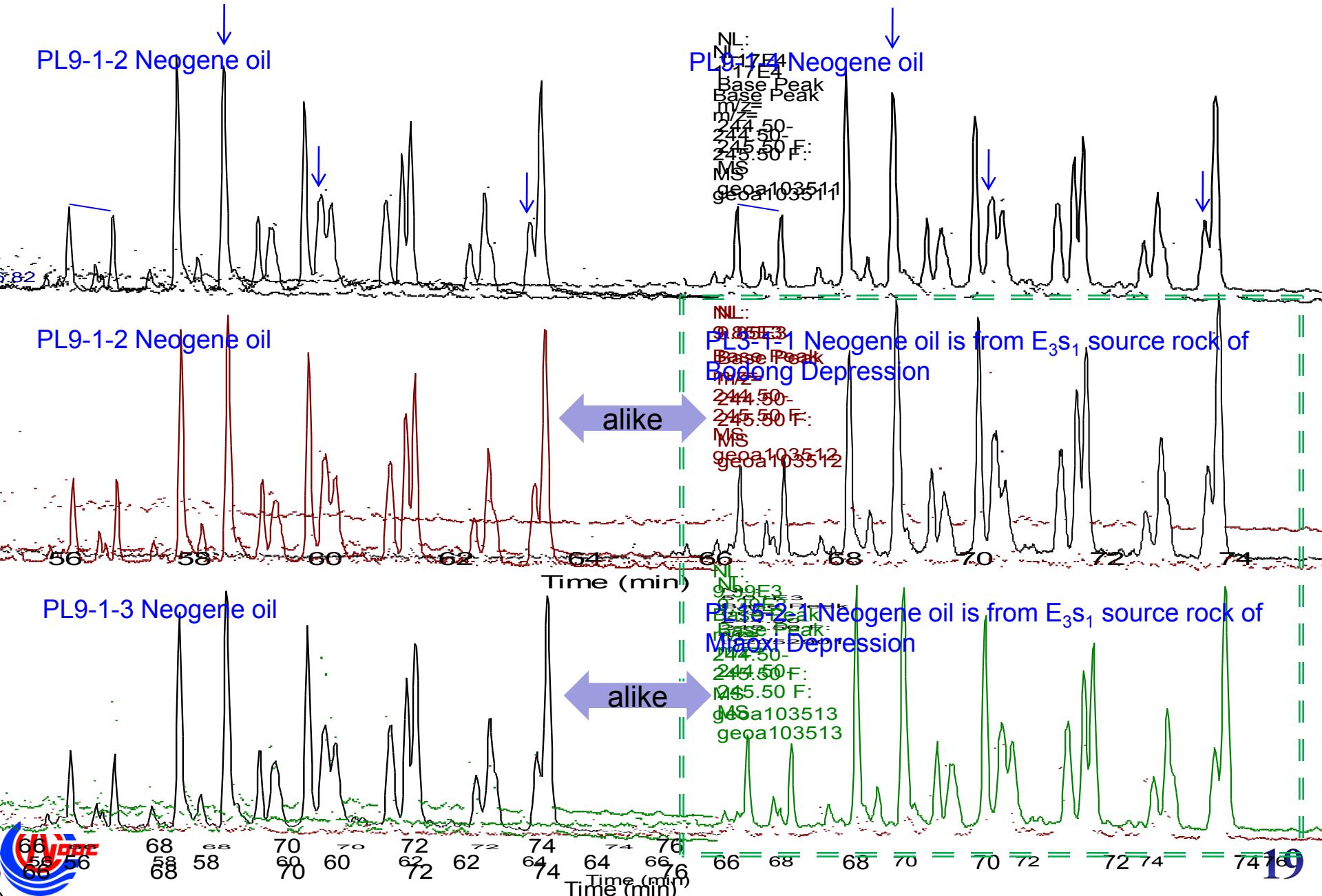
◆ 4,23,24-trimethyl triaromatic dinosteranes originating dinoflagellates adapt to saline water, while 4-methyl triaromatic steranes and 4-methyl-24-ethyl triaromatic steranes originating dinoflagellates adapt to slight saline water

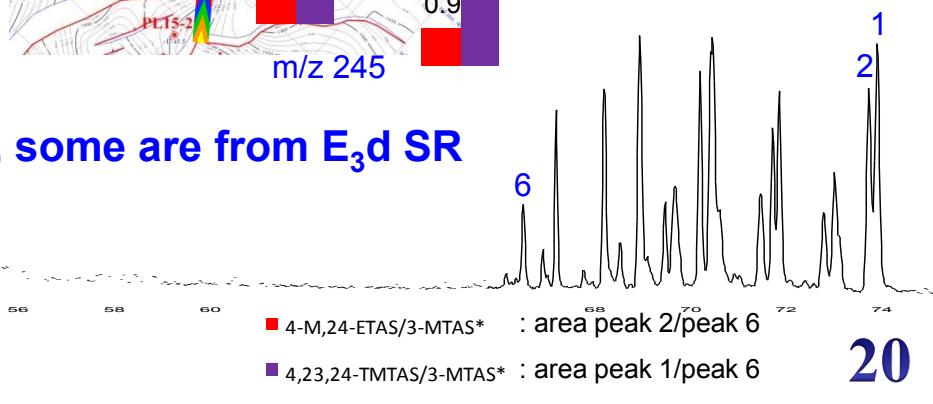
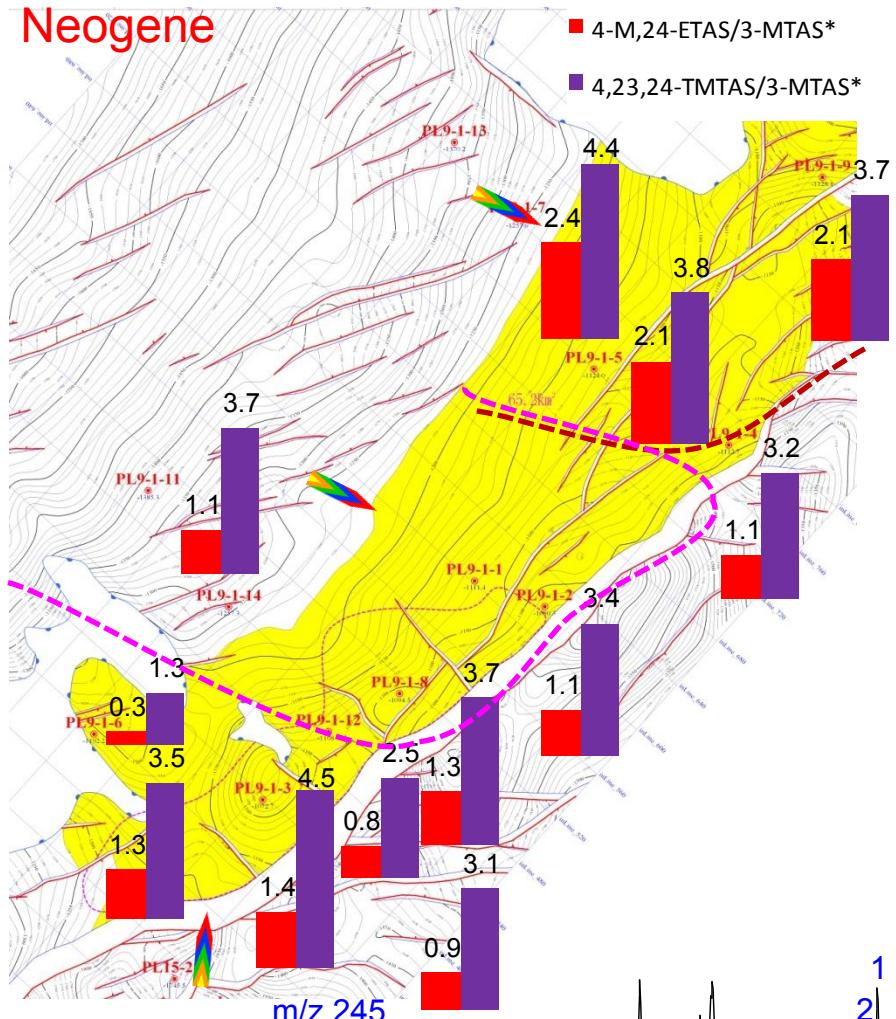
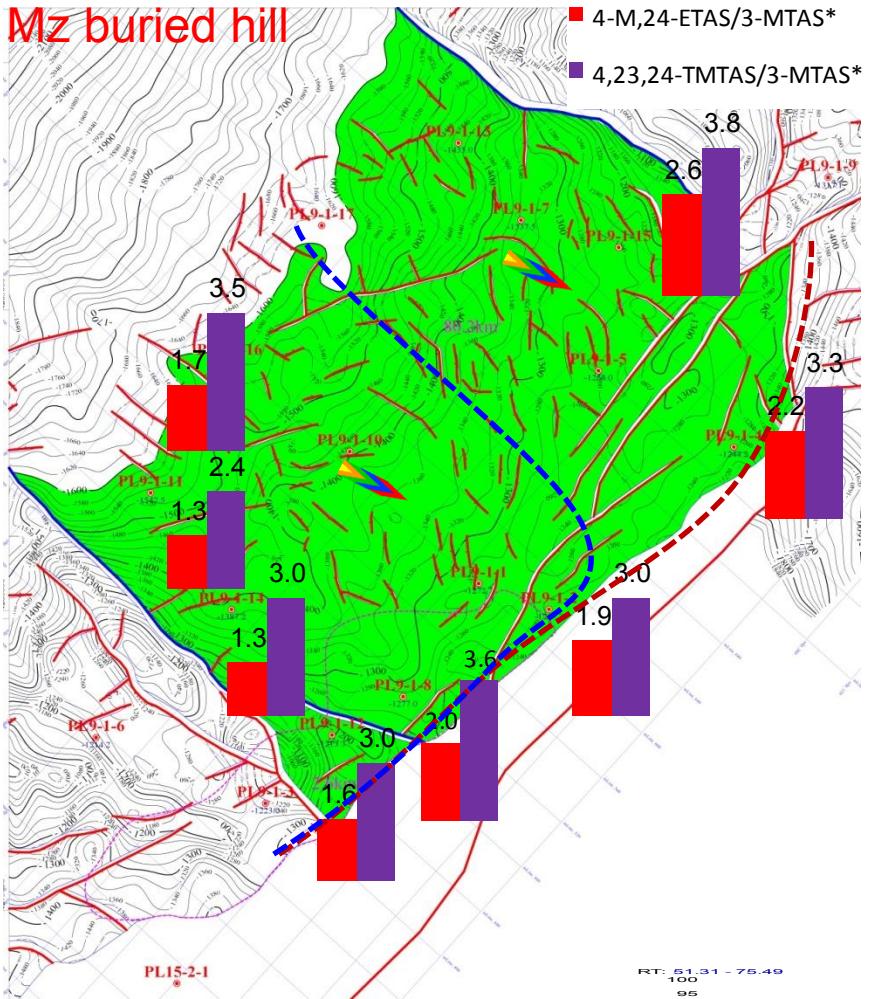
◆ C<sub>27</sub>-C<sub>29</sub> 4-methyl triaromatic sterane homologues can distinguish oils from E<sub>2</sub>s<sub>3</sub>, E<sub>3</sub>s<sub>1</sub>, E<sub>3</sub>d source rocks. Oils of Penglai9-1 buried hill are mainly from E<sub>2</sub>s<sub>3</sub> and E<sub>3</sub>s<sub>1</sub> source rocks; Oils of Penglai9-1 Neogene are mainly from E<sub>3</sub>s<sub>1</sub> source rock, and some are from E<sub>3</sub>d source rock.

# Oils of Penglai9-1 Buried Hill are from E<sub>2</sub>s<sub>3</sub> and E<sub>3</sub>s<sub>1</sub> Source Rocks



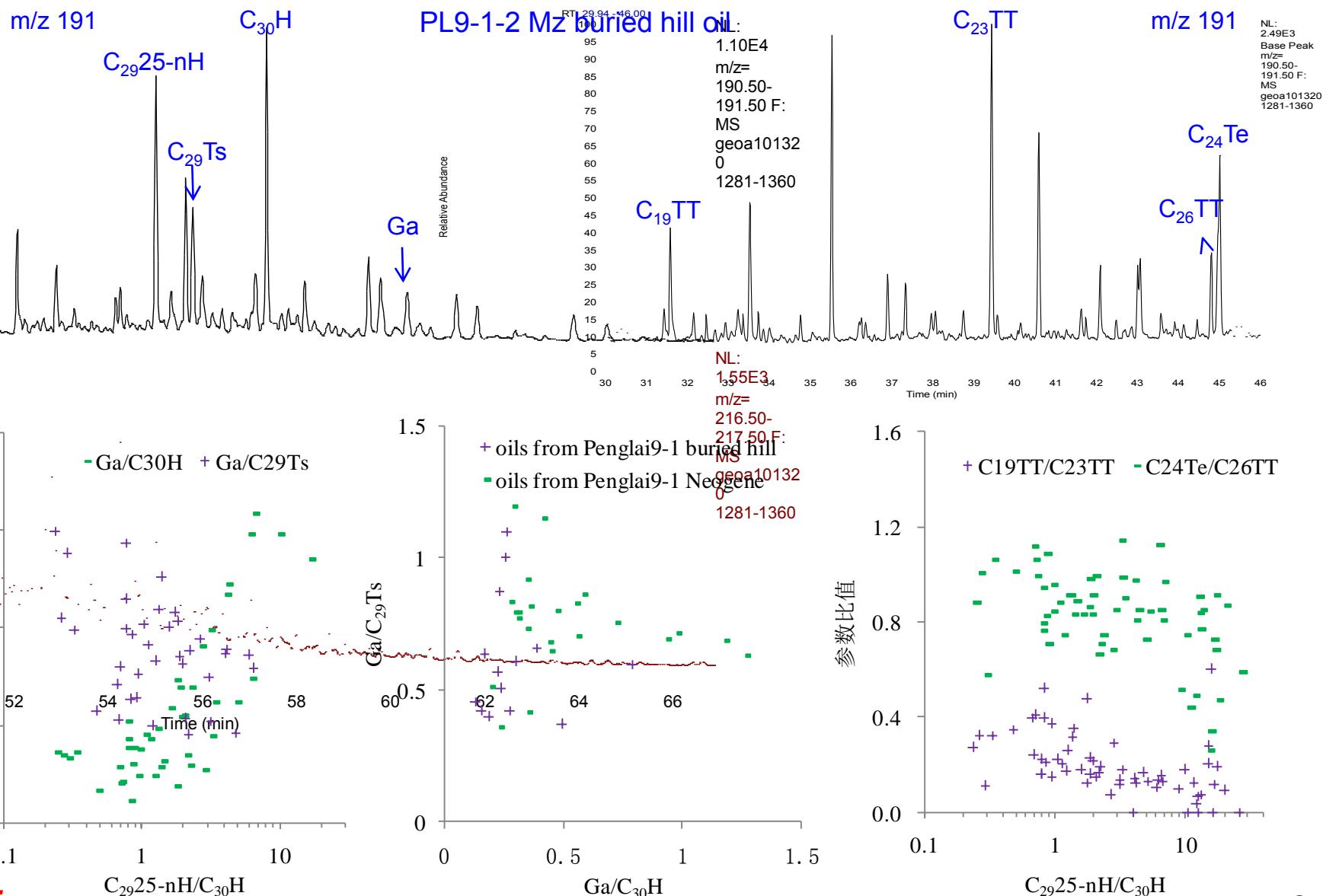
# Oils of Penglai9-1 Neogene are Mainly from E<sub>3</sub>s<sub>1</sub> Source Rock

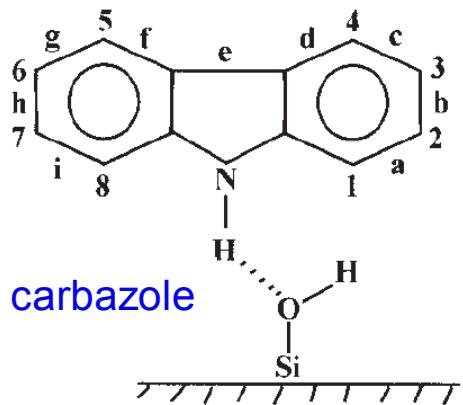




- ◆ Buried hill oils: mainly from  $E_2s_3$  and  $E_3s_1$  SR, some are from  $E_3d$  SR
  - ◆ North Neogene oils: from  $E_2s_3$  and  $E_3s_1$  SR
  - ◆ Middle Neogene oils: mainly from  $E_3s_1$  SR
  - ◆ South Neogene oils: from  $E_3s_1$  and/or  $E_3d$  SR

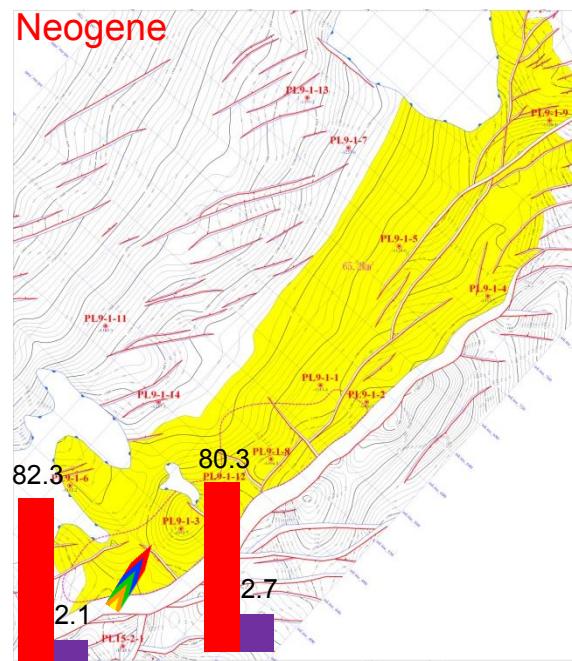
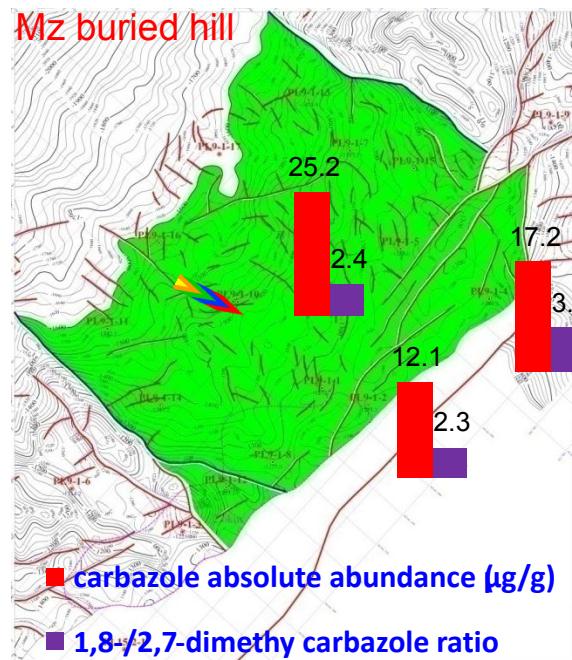
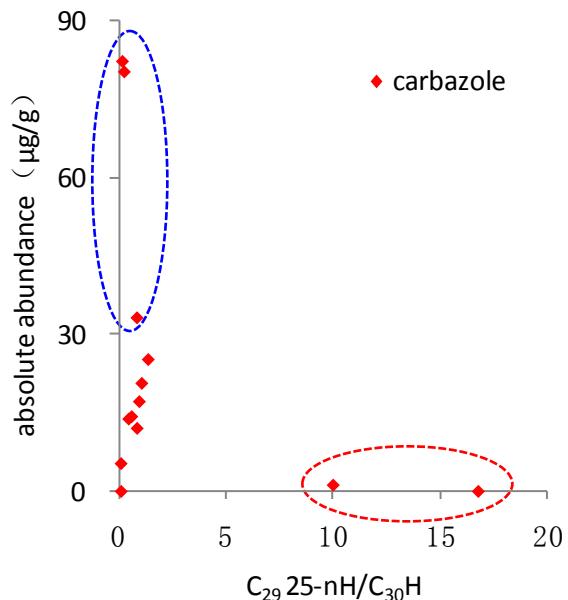
## Gammacerane Abundance: Buried Hill Oils Lower than Neogene Oils

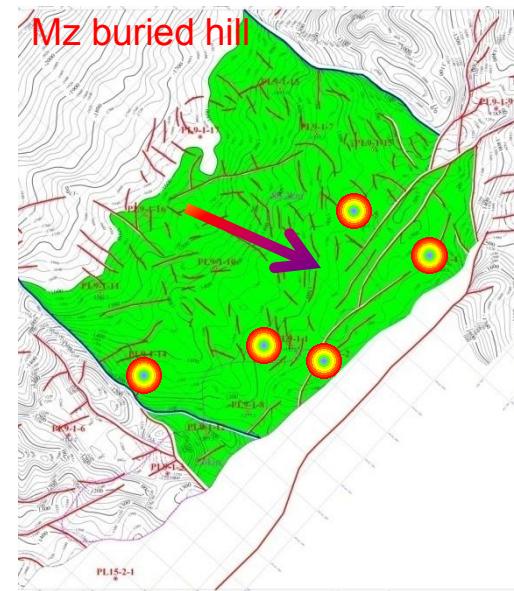
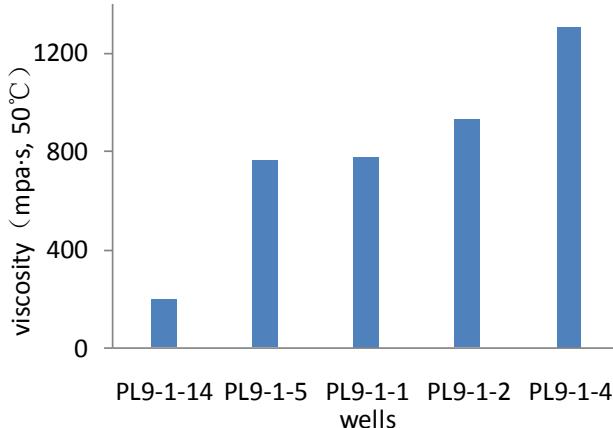
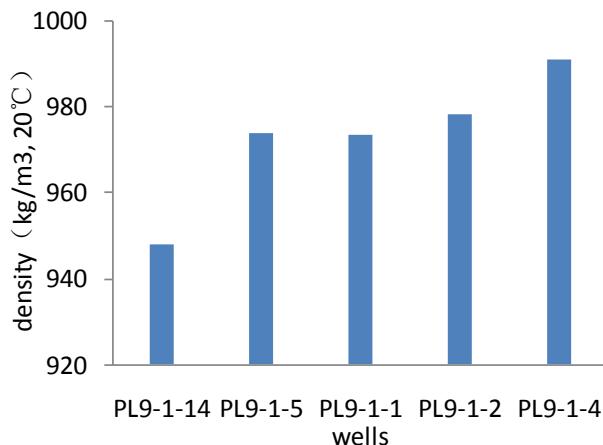




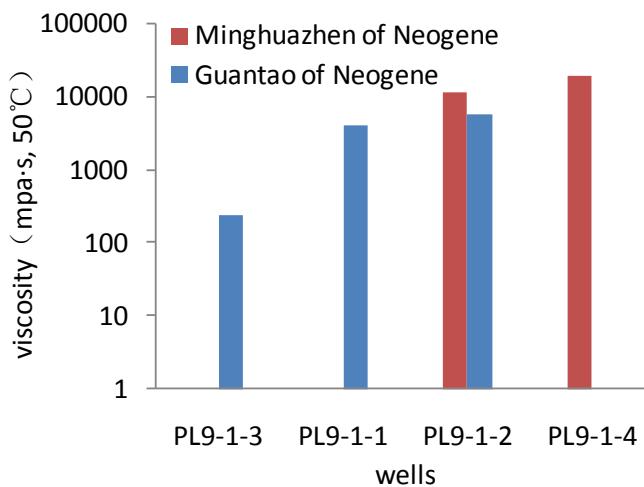
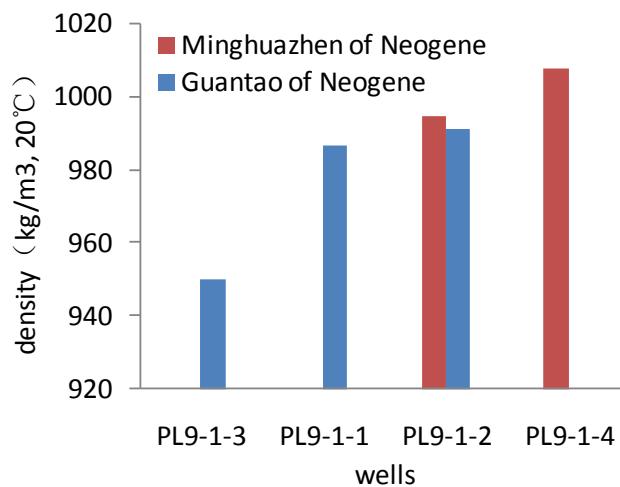
- ◆ Absolute abundance of carbazole decreasing
- ◆ N shielded type(1,8-dimethyl carbazole) relative abundance increasing

Wang Tieguan, 2011

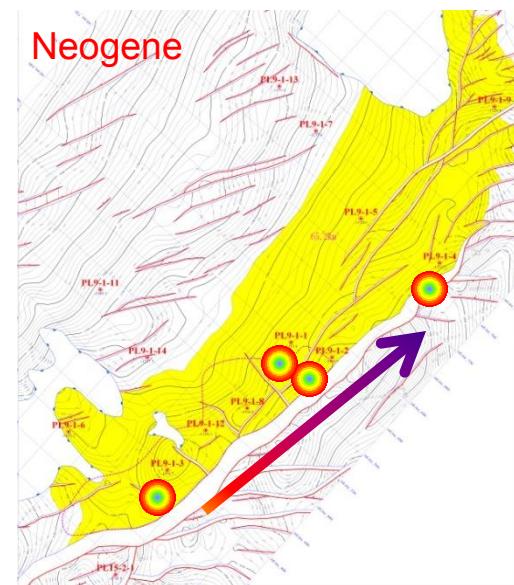


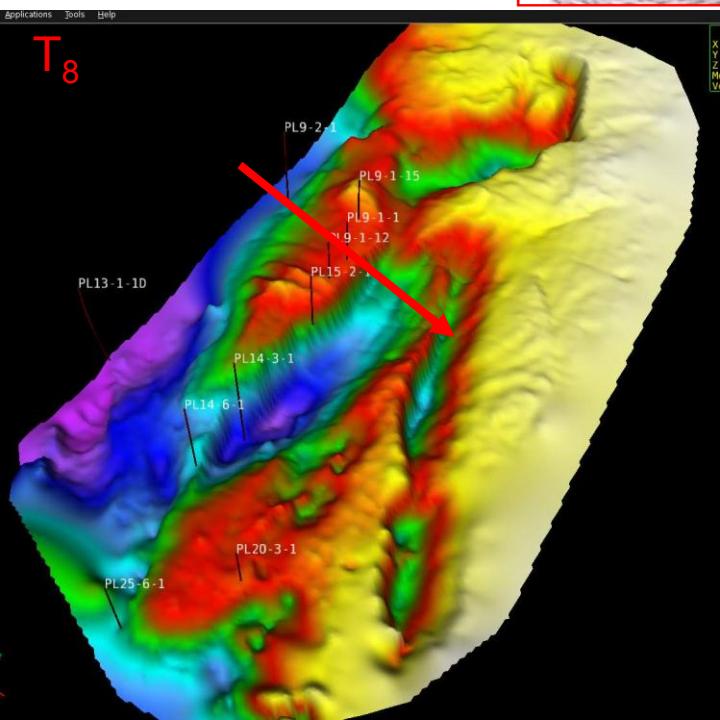
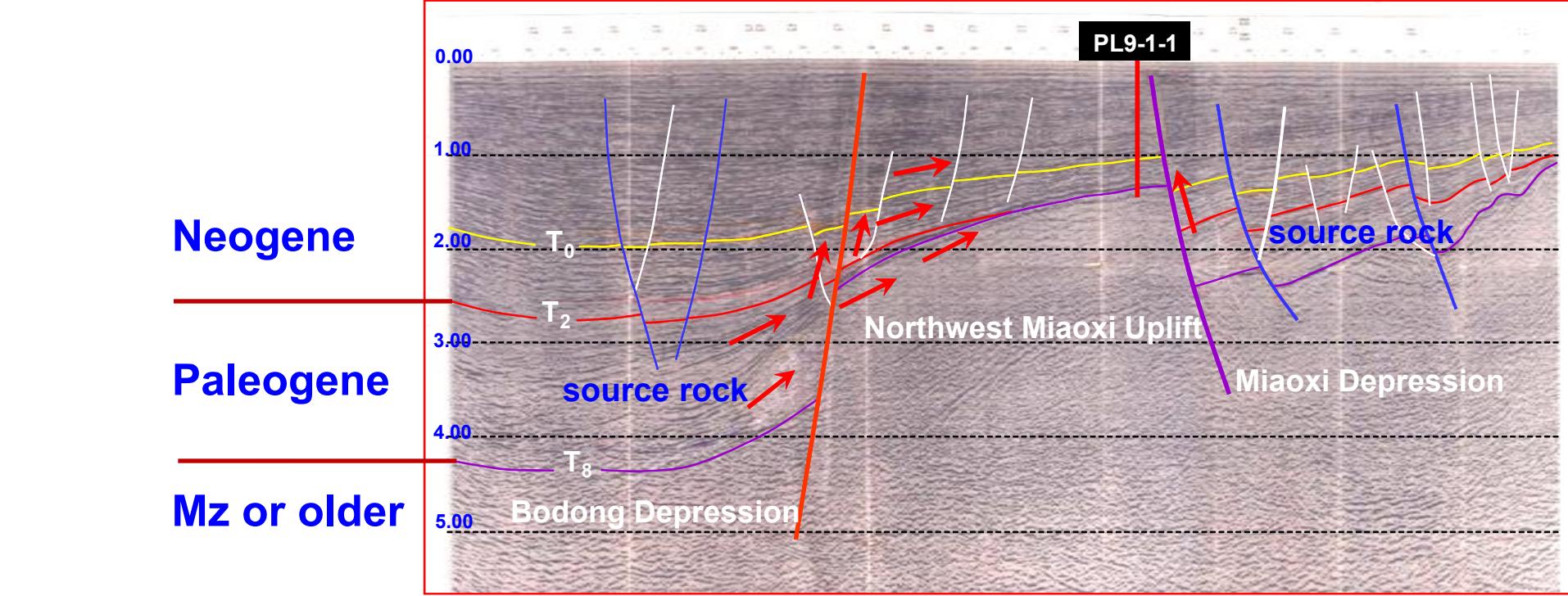


### Crude Oil Density and Viscosity Variation of Penglai9-1 Buried Hill



### Crude Oil Density and Viscosity Variation of Penglai9-1 Neogene





## Petroleum System:

- ◆ Effective source rock?
- ◆ Source rock distribution?
- ◆ Migration pathway?
- ◆ Reservoir model?

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