

PSGeochemical Study of the Sinemurian *Arietites Bucklandi* Zone in the Blue Lias of Lyme Regis (Dorset, UK)*

Armando Nava Cedillo¹ and Geoffrey D. Abbott²

Search and Discovery Article #51363 (2017)**

Posted March 6, 2017

*Adapted from poster presentation given at AAPG International Conference & Exhibition, with SEG, Cancun, Mexico, September 6-9, 2016

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¹Pemex Exploration and Production, Veracruz, Mexico (armando.nava@pemex.com)

²Newcastle University, UK

Abstract

This is a study of the origin on the cyclicity of the different horizons in the Blue Lias of Dorset, UK. The origin of these rhythmic deposits has been attributed to climatic changes promoted by orbital cyclicity. In this study, the aliphatic and aromatic fractions from the organic-extracted rock samples of different layers in the *Arietites bucklandi* zone were analyzed with GC and GC-MS to identify changes in the thermal maturity, depositional environment, input of organic matter, and redox conditions. There is no significant change in thermal maturity as a function of burial depth as recorded by C31 17α(H), 21β(H) 22S/(22S + 22R) and C27 Ts/(Ts+Tm). Differences in the average chain length (ACL), carbon preference index (CPI), biomarkers ratios (Pr/Ph, DBT/P, and C27, C28, C29 steranes), as well as the presence and abundance of isorenieratane in ten samples reveal significant variations in depositional conditions and type of organic carbon in the sequence. A high TOC content and HI values in the undisturbed laminated shale is related to water stratification and sulphidic conditions in the photic zone with estuarine circulation during humid climatic stages with high runoff of terrestrial organic matter from the continent. Moreover, low TOC and HI in the highly bioturbated light marls correspond to periods of dry climate conditions that promoted anti-estuarine circulation with bottom water oxygenated and preferential deposition of marine organic matter. Climatic conditions seem to influence the preservation and primary productivity of organic matter in the Blue Lias.

Geochemical study of the Sinemurian *Arietites bucklandi* zone in the Blue Lias of Lyme Regis (Dorset, UK)

^a Pemex Exploración y Producción, Activo Aguas Profundas, Poza Rica Veracruz, Mexico; ^b Civil Engineering and Geosciences, Newcastle University UK.
e-mail: armando.nava@pemex.com

Introduction

The deposits of the Blue Lias at Lyme Regis, Dorset, England exhibit a marked rhythmic stratification. This distinctive characteristic has captured the attention of several researchers who have worked in order to explain the origin of this cyclicity as well as the depositional environment. Most of these studies (House, 1985; Weedon, 1985; Waterhouse, 1999) have reported dominant frequencies in periods similar to those defined by the Milankovitch theory (23, 46 and 100 Ma.) and they have suggested that these deposits were influenced by orbital forcing.



Fig. 1 Area of study.

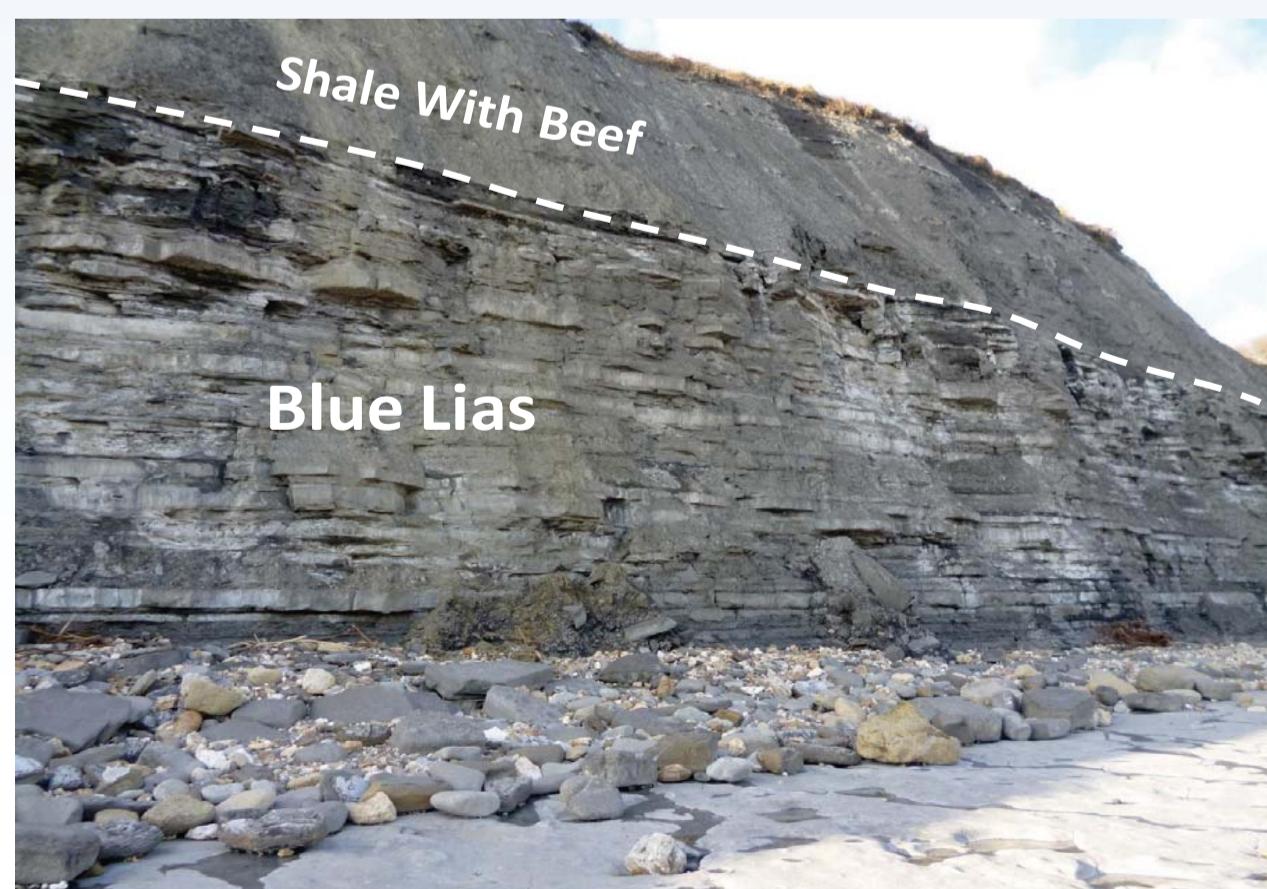


Fig. 2 Blue Lias outcrop at Lyme Regis UK.

Objectives

The aim of this project was to establish whether there was cyclicity in the depositional conditions of the Blue Lias Formation at Lyme Regis and to explore possible changes in the maturity, redox conditions, organic input as well as depositional environment.

The specific objectives of the project included:

- To identify changes of organic content (TOC) and Hydrogen Index (HI) as a function of burial depth.
- To define and evaluate the redox conditions in the different layers.
- To identify isorenieratane or its derivatives and investigate changes in its abundance as a function of depth.



Fig. 3 Section analysed in this study.

Methods

For this study, sixteen samples were available from an outcrop of the Blue Lias formation at Lime Regis, Dorset, UK. These samples were collected and described by Najm Salem (Newcastle University) from the *Arietites bucklandi* zone from the layer 22 to 36 (Lang, 1924).

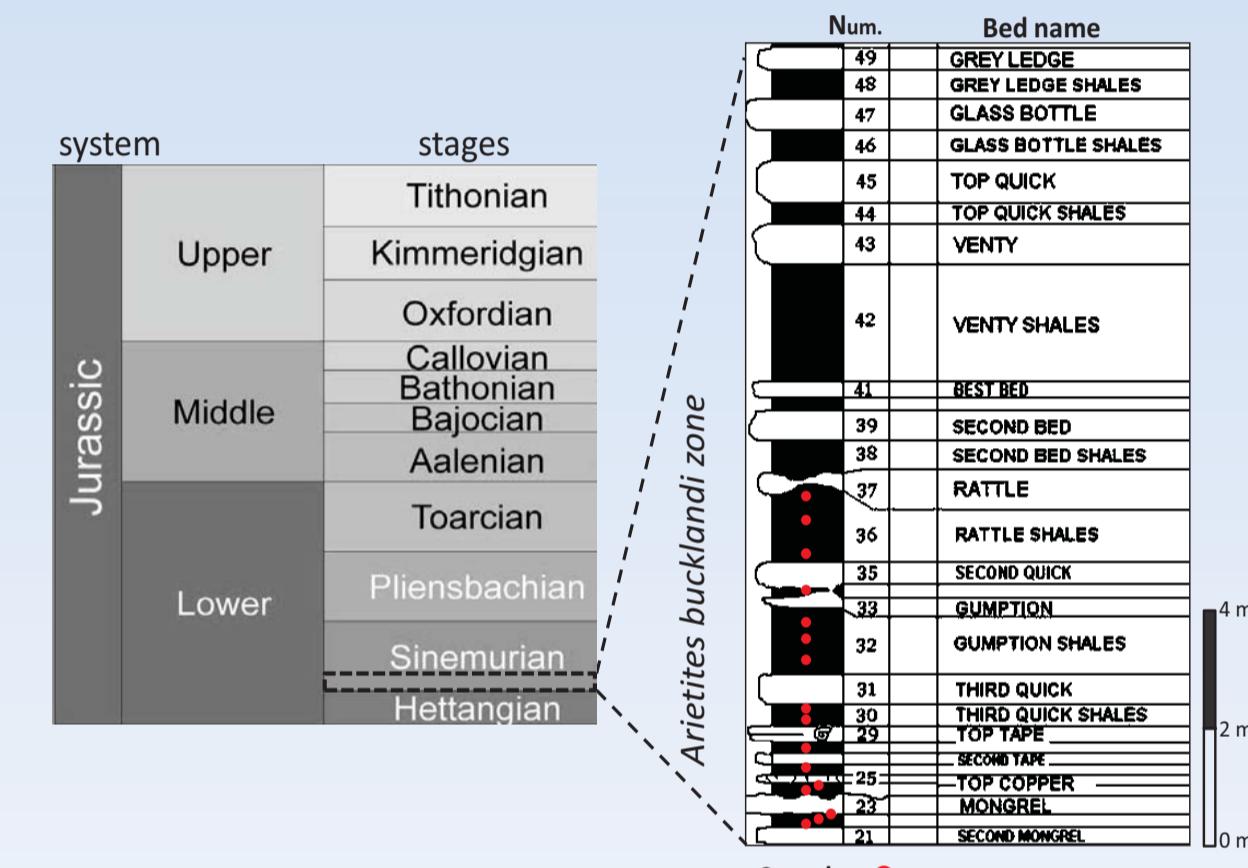


Fig. 4 Blue Lias outcrop at Lyme Regis UK, adapted from West 2001, based on Lang 1914, 1924.

Ten to fifteen grams of powdered sample were extracted with the Soxtec method. The extracted organic matter was separated by Thin Layer Chromatography, after that the Aliphatic and Aromatic fraction were analysed with GC and GC-MS

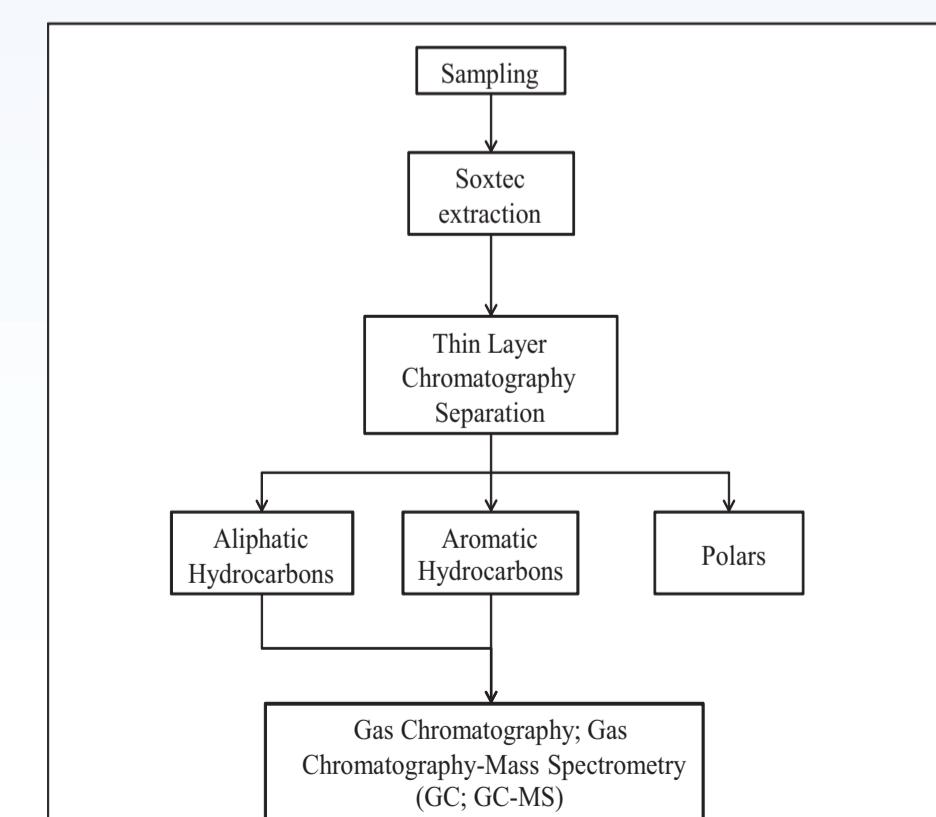


Fig. 5 Simplified workflow of the different methods used.

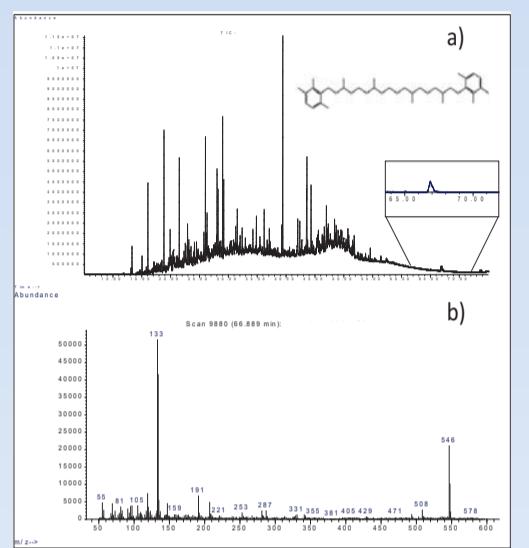
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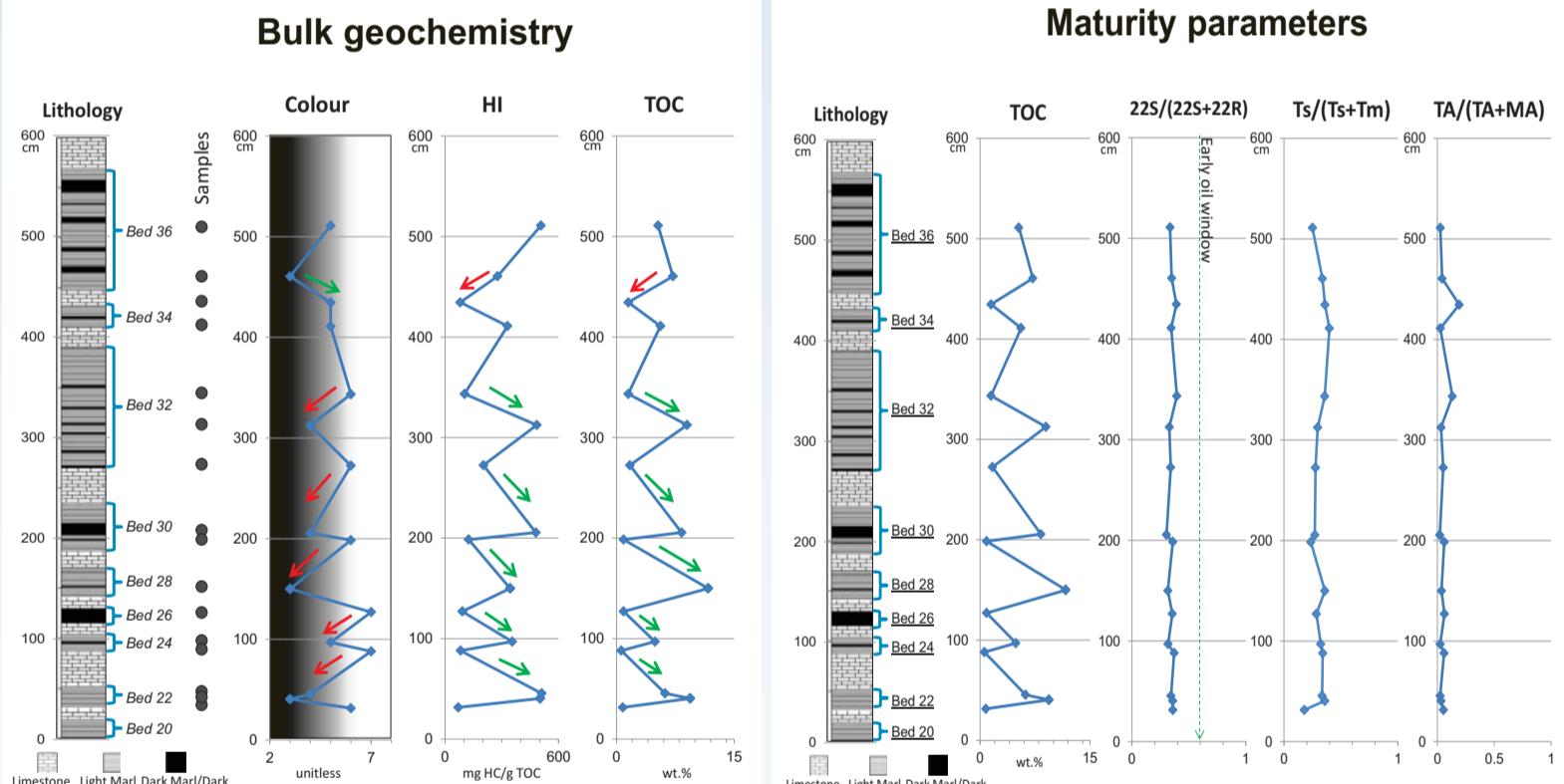
Results & Discussion

Geochemical Parameters

Num	Hopanes	Carbon Num.	Num	Monocyclic sterols	Carbon Num.
H1	22,29,30-Trisnorhopane (Ts)	27	M1	Colestane-20R	27
H2	22,29,30-Trisnorhopane (Tm)	27	M2	Colestane-20R	27
H3	B8-Hopane2	27	M3	Ergostane-20S	28
H4	Hop-13(18)ene	29	M4	B8-Ergostane	29
H5	oB-Hopane	29	M5	B8-Stigmastane 20S	29
H6	Hop-17(21)ene	30	M6	B8-Stigmastane 20R	29
H7	B8-Hopane	29	M7	Se-Colestane 20R	27
H8	oB-Hopane	30	M8	Se-Ergostane 20S	28
H9	Hop-22(29)ene	30		Se-Stigmastane 20R	29
H10	oB-Hopane(22S)	31		Se-Stigmastane 20S	29
H11	oB-Hopane(22R)	31		Stigmastane 20S	28
H12	B8-Hopane	30	T1	Colestane 20S	26
H13	B8-Hopane	31	T2	Ergostane 20S	27
H14	B8-Hopane	32	T3	Colestane 20R	26
H15	B8-Hopane	33	T4	Ergostane 20R	27
H16	B8-Hopane	34	T5	Stigmastane 20R	28
H17	B8-Hopane	35			
	Stearanes				
S1	5B(H),14a(H),17a(H)-Cholestan-20R	27			
S2	5a(H),14a(H),17a(H)-Cholestan-20R	27			
S3	5B(H),14a(H),17a(H)-Ergostane 20R	28			
S4	5a(H),14a(H),17a(H)-Ergostane 20R	28			
S5	5B(H),14a(H),17a(H)-Stigmastane 20R	29			
S6	5a(H),14a(H),17a(H)-Stigmastane 20R	29			

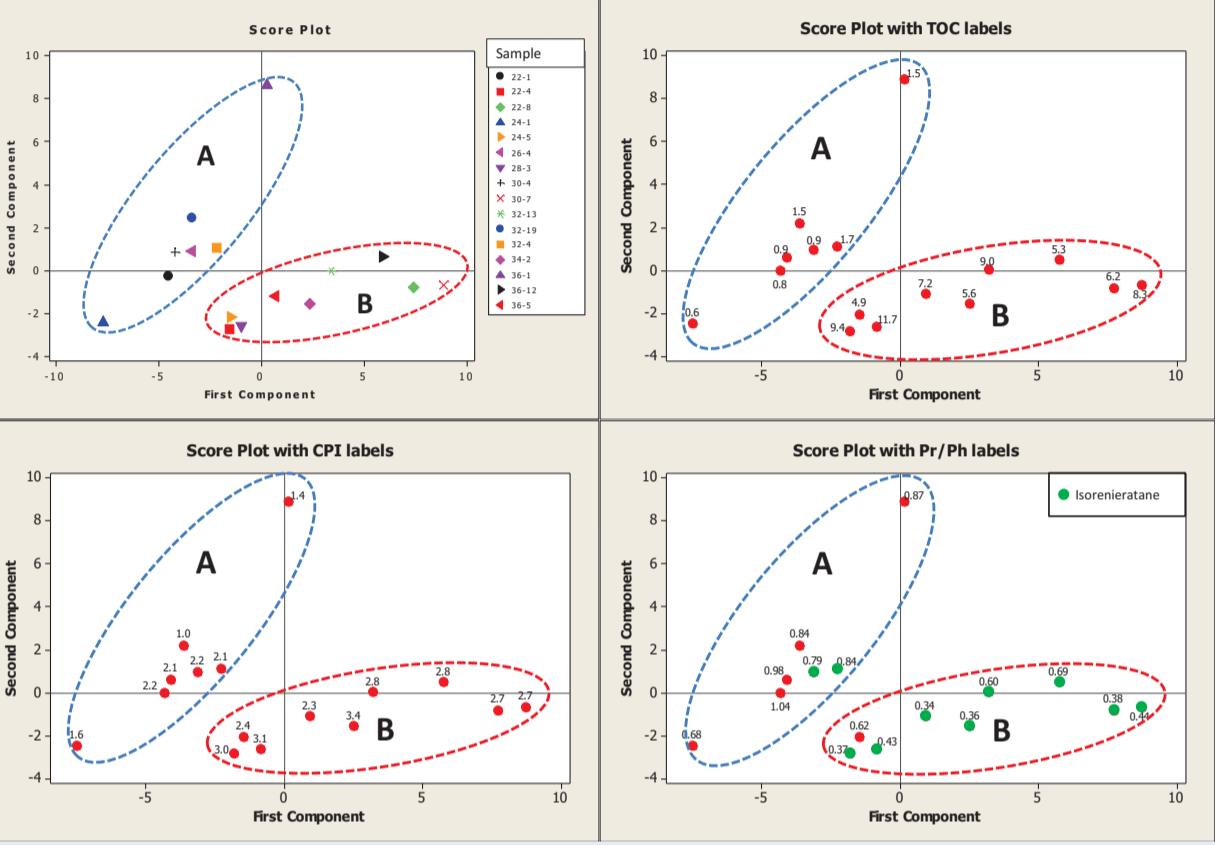


Bulk geochemistry

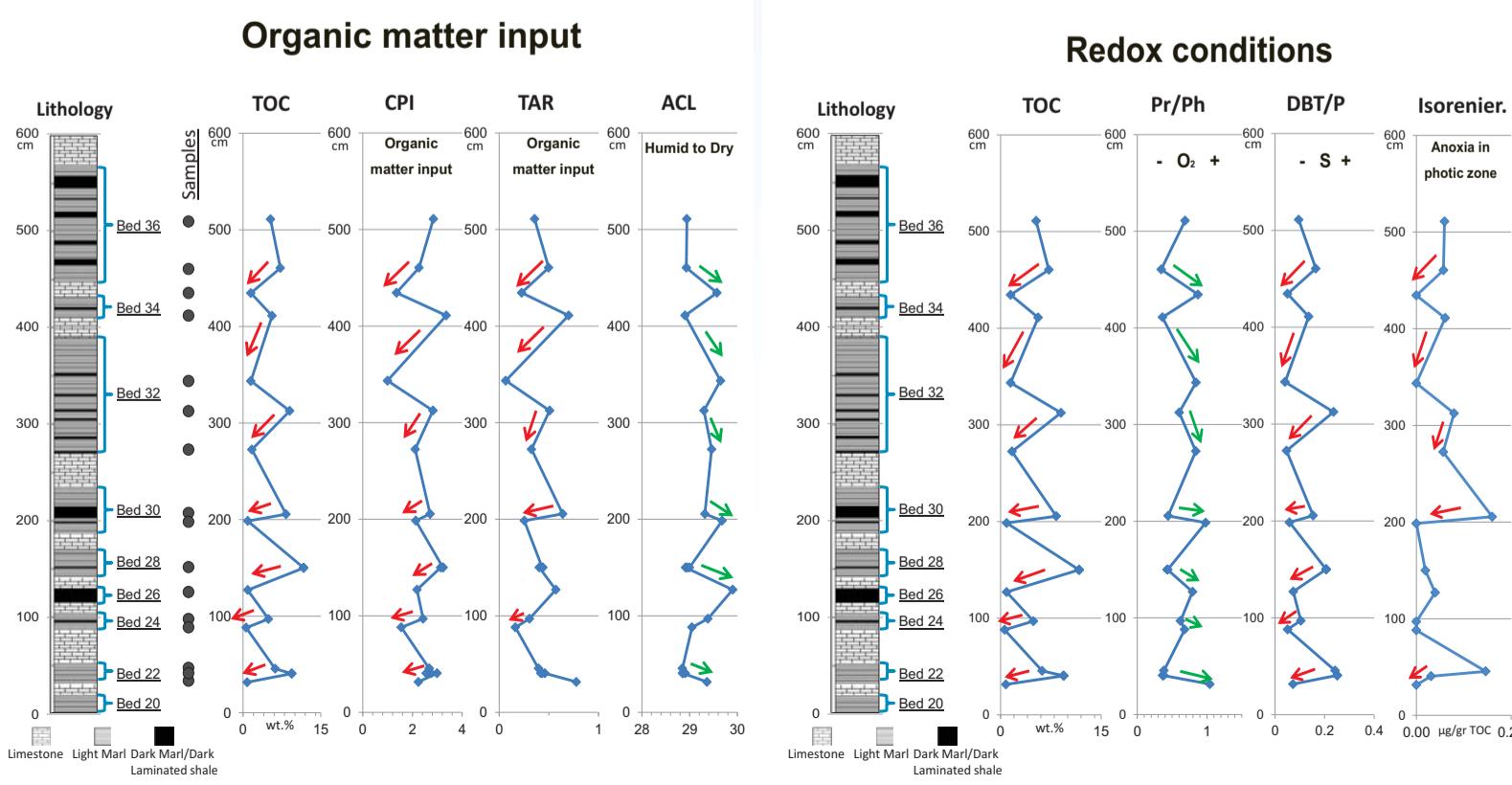


Maturity parameters

Statistical Analysis (PCA)

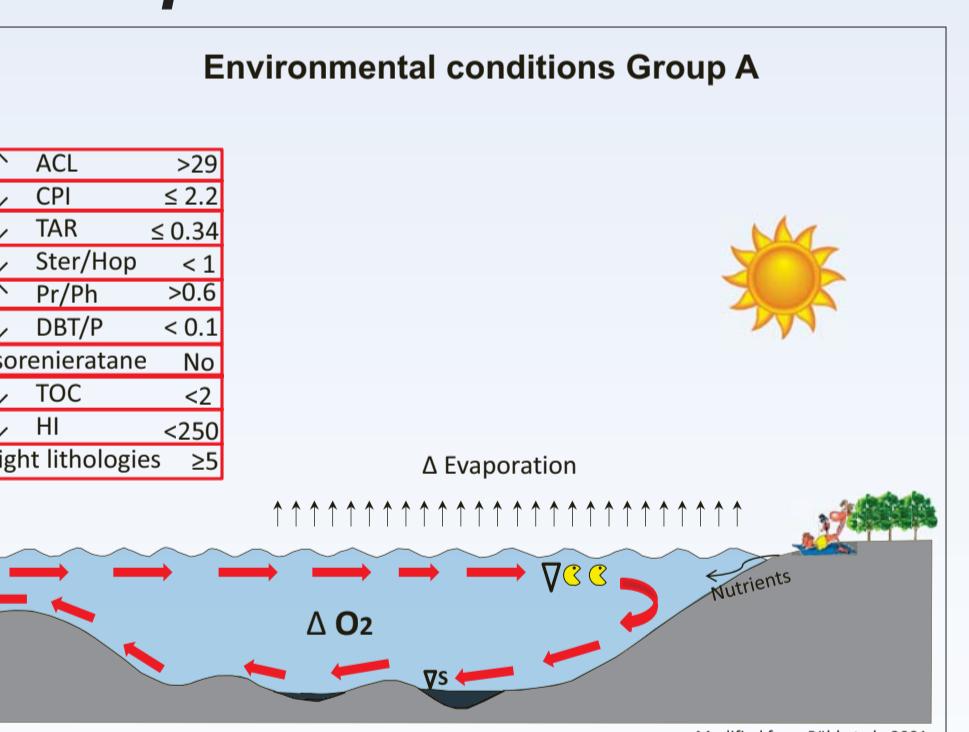


Organic matter input

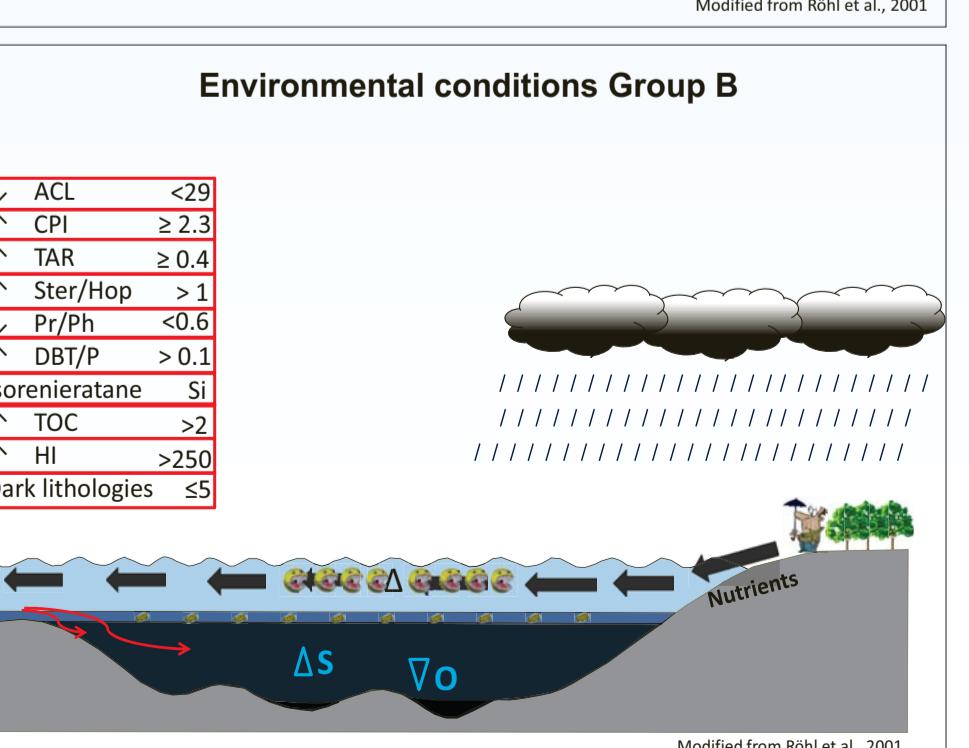


Redox conditions

Depositional Conditions



Environmental conditions Group B



Conclusions

- There is no significant change in the level of thermal maturity of the sixteen samples as a function of burial depth (Fig. 3.10). Periods of anoxia in the photic zone were confirmed by the presence of isorenieratane in ten samples. Most of the lithologies above 2% of TOC exhibited the presence of isorenieratane, which indicates depletion in the level of oxygen and sulphidic conditions in the photic zone.
- Preservation of organic matter was enhanced by depletion in the oxygen level during deposition. Black laminated shale represents periods of depleted oxygen in the section.
- The organic matter exhibits two components. The first is marine organic matter deposited in a shallow marine environment. The second is terrestrial organic matter. The proportion of every component is subject to environment conditions; marine organic matter is fostered in dry periods. Moreover, the deposition of terrestrial organic matter is promoted during humid atmospheric conditions from land run-off.
- Regular changes in the depositional conditions were identified in the Blue Lias at the *Arietites bucklandi* zone. Dark layers rich in organic carbon correspond to periods of humid atmospheric conditions, water stratification and low biogenic activity, while light lithologies are associated with episodes of low precipitation, dry atmospheric conditions and high biogenic activity.

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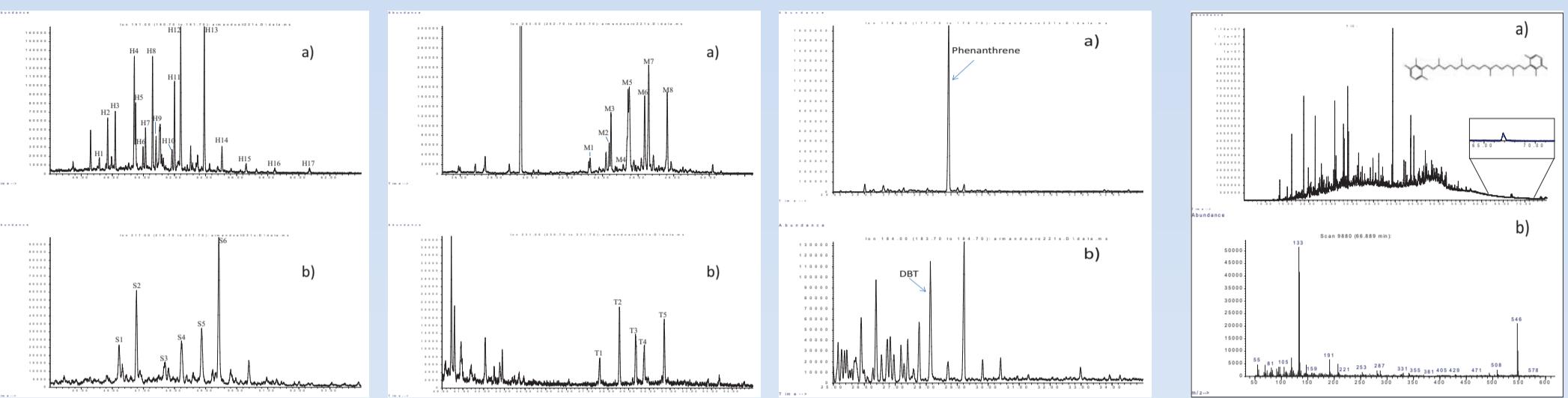
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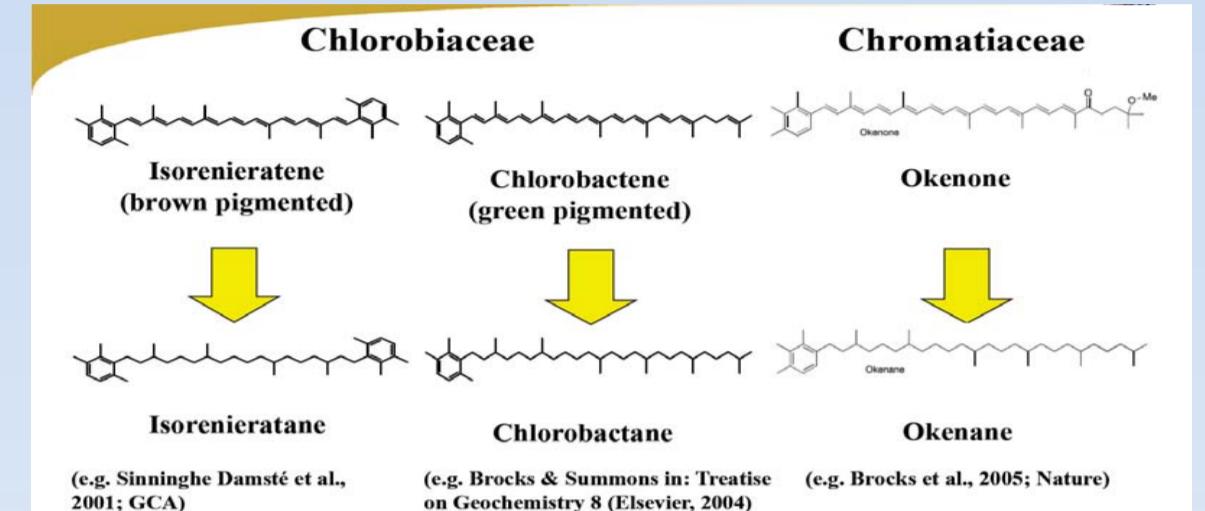
Appendix I

Biomarkers Identification

Num	Hopanes	Carbon Num.
H1	22,29,30-Trihomoehopane (Ts)	27
H2	22,29-Hopane?	27
H3	22,29-Trihomoehopane (Tm)	27
H4	Hop13(18)ene	29
H5	22,29-Hopane	29
H6	Hop-17(21)ene	30
H7	22,29-Hopane	29
H8	22,29-Hopane	30
H9	Hop-22(29)ene	30
H10	22,29-Hopane(22S)	31
H11	22,29-Hopane(22R)	31
H12	22,29-Hopane	30
H13	22,29-Hopane	31
H14	22,29-Hopane	32
H15	22,29-Hopane	33
H16	22,29-Hopane	34
H17	22,29-Hopane	35
Num	Monocyclic sterols	Carbon Num.
M1	Ster-Colestanate 20S	27
M2	Ster-Colestanate 20R	27
M3	Ster-Ergostane 20S	28
M4	Ster-Colestanate 20R	27
M5	Ster-Stigmastane 20S	29
M6	Ster-Stigmastane 20R	28
M7	Ster-Ergostane 20R	29
M8	Ster-Stigmastane 20R	29
Num	Triaromatic sterols	Carbon Num.
T1	Colestanate 20S	26
T2	Ergostane 20S	27
T3	Colestanate 20R	26
T4	Stigmastane 20S	28
T5	Ergostane 20R	27
Num	Aromatics	Carbon Num.
S1	5β(H),14α(H),17α(H)-Cholestanate 20R	27
S2	5α(H),14α(H),17α(H)-Cholestanate 20R	27
S3	5β(H),14α(H),17α(H)-Ergostane 20R	28
S4	5α(H),14α(H),17α(H)-Ergostane 20R	28
S5	5β(H),14α(H),17α(H)-Stigmastane 20R	29
S6	5α(H),14α(H),17α(H)-Stigmastane 20R	29
Num	Steranes	Carbon Num.
S1	5β(H),14α(H),17α(H)-Cholestanate 20R	27
S2	5α(H),14α(H),17α(H)-Cholestanate 20R	27
S3	5β(H),14α(H),17α(H)-Ergostane 20R	28
S4	5α(H),14α(H),17α(H)-Ergostane 20R	28
S5	5β(H),14α(H),17α(H)-Stigmastane 20R	29
S6	5α(H),14α(H),17α(H)-Stigmastane 20R	29

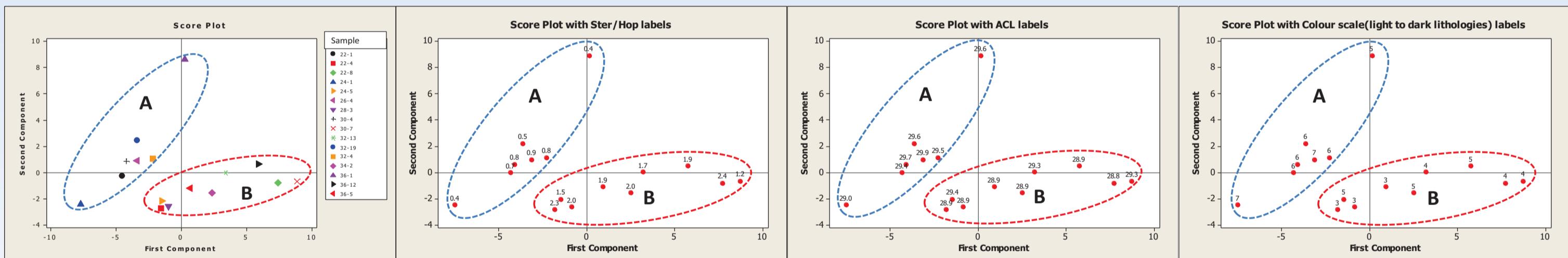


Isorenieratane



Taken from MSc Petroleum Geochemistry notes, Newcastle University 2012

Principal Component Analysis



Anoxia extends into photic zone

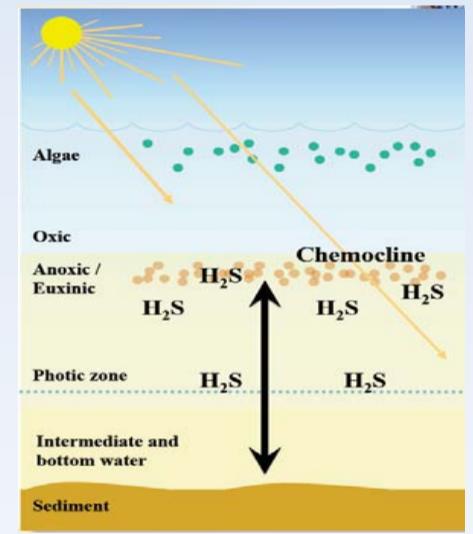
- Rare today (Black Sea)
- More extensive in past (for review see Meyer and Kump, Annu. Rev. Earth Planet. Sci., 2008)

Photic Zone Euxinia

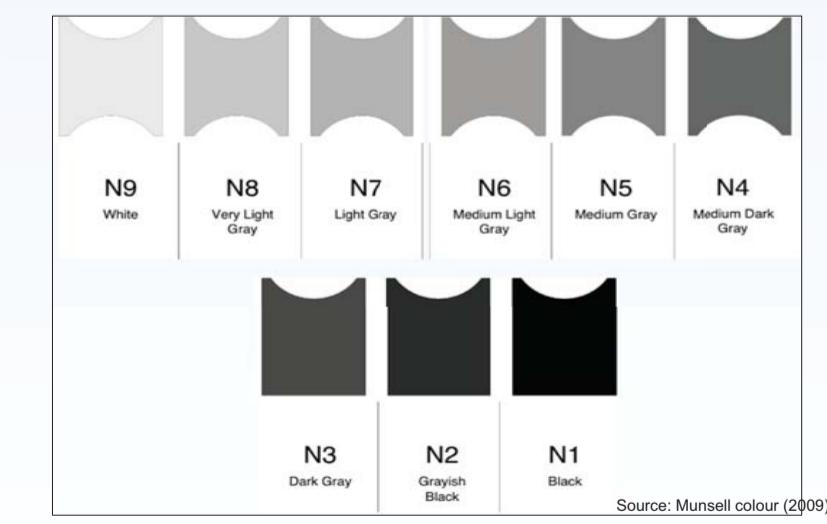
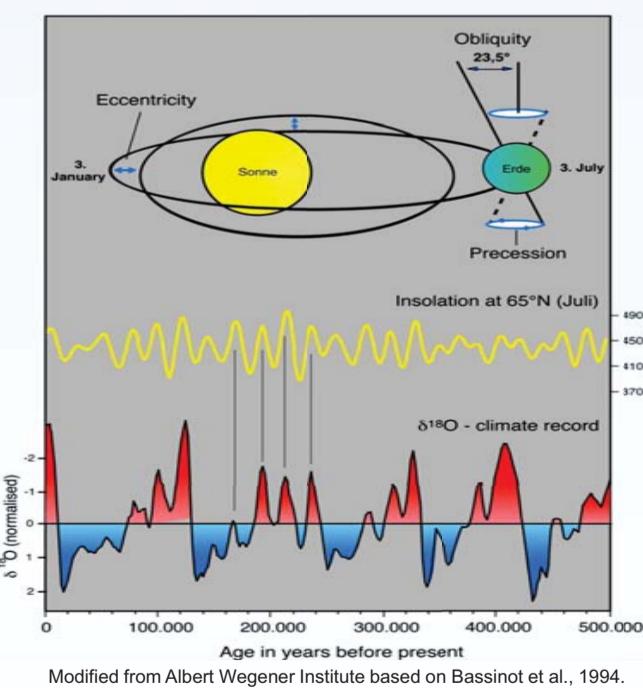
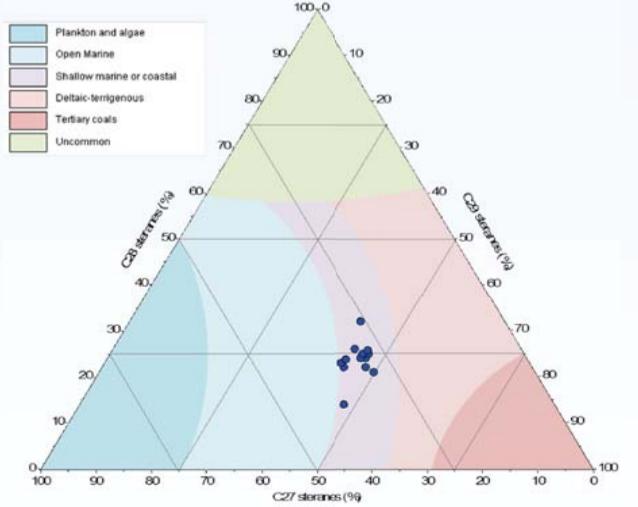
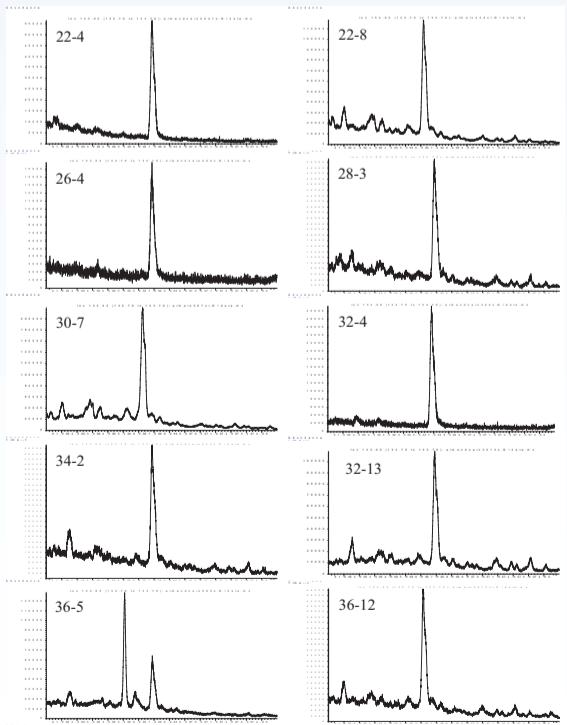
- Free H₂S in anoxic photic zone
- Phototrophic sulphur bacteria
- Strict anaerobes that need light



- Distinct biomarker composition



GC-MS m/z 133 Depositional Environment Milankovitch cycles Lithology Colour Scale



Modified from Albert Wegener Institute based on Bassinot et al., 1994.