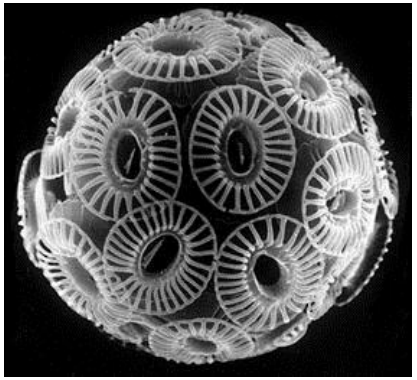
V. 古温度計による太古の地球の古気候変動の復元

＊アルケノン古水温指標（$U^{K'}_{37}$）

E.huxleyi



$U^{K'}_{37}$（C_{37} alkenoneの不飽和比）

$$U^{K'}_{37} = \frac{C_{37:2}}{(C_{37:2} + C_{37:3})} \; alkenone \qquad U^{k'}_{37} = 0.034T + 0.039$$

Prahl et al. (1988)

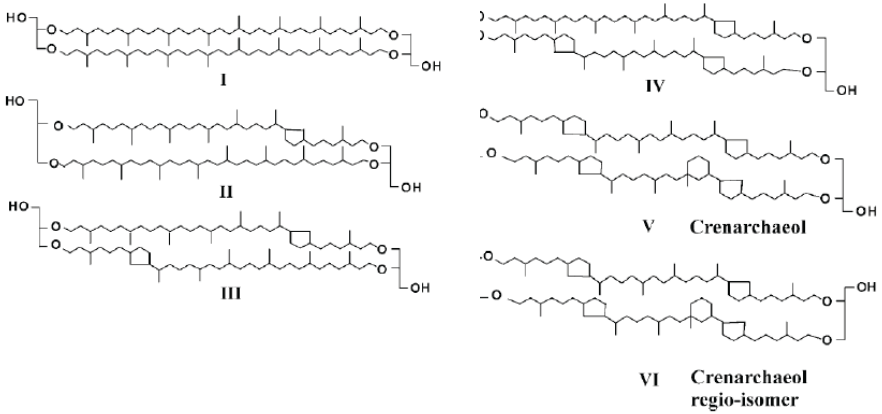
・長鎖アルケノンはハプト藻の円石藻に由来する

・春～初夏の温度を主に記録

＊GDGT古水温指標（TEX_{86}）

$$TEX_{86} = \frac{III + IV + VI}{II + III + IV + VI}$$

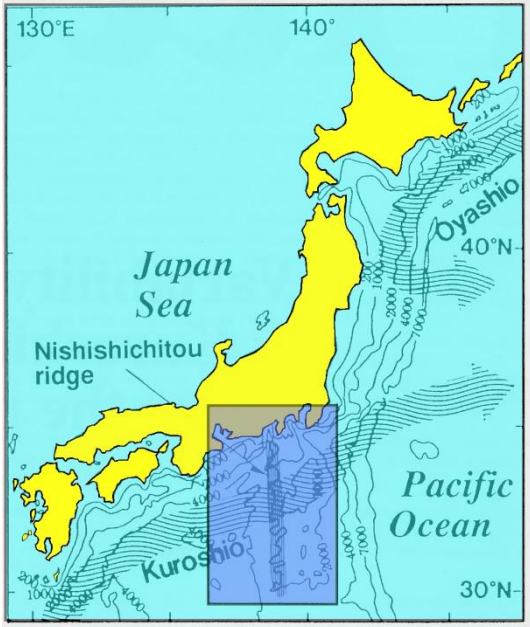
Schouten et al. (2002)

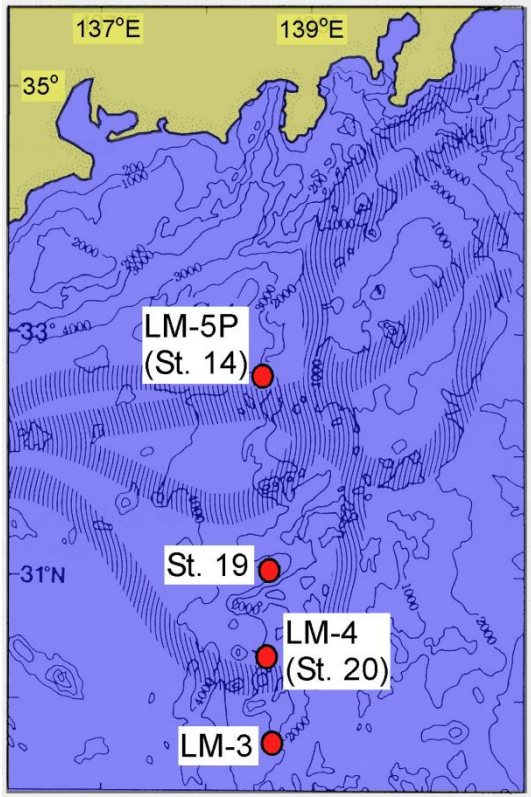


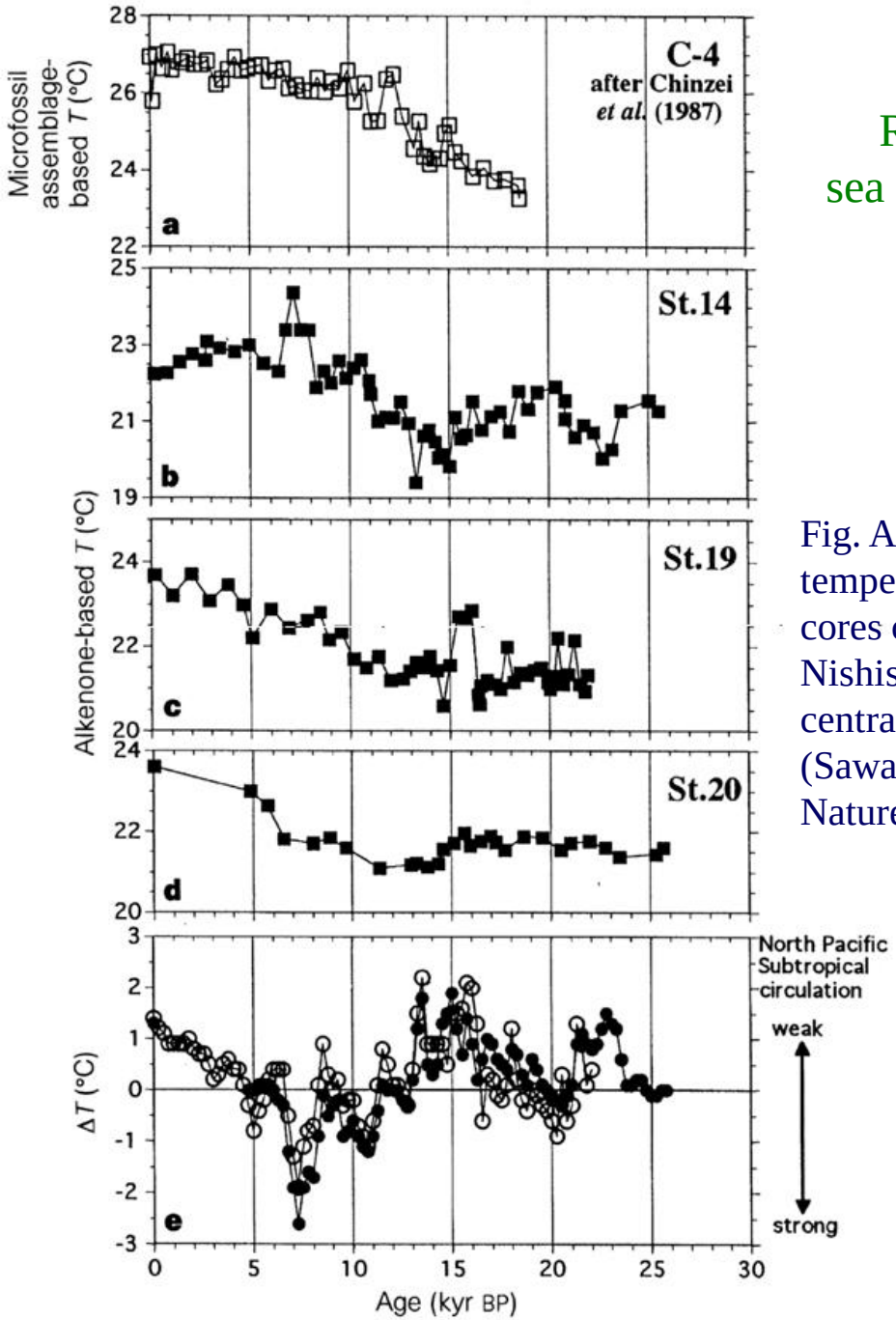
・古細菌由来のGDGT

・古細菌は海洋表層から中層まで分布？

起源となる生物の生態によって記録される温度に偏り（季節性など）
→複数の古水温指標の必要性







Reconstruction of sea surface temperature by alkenone thermometry

Fig. Alkenone-based temperature in sediment cores collected from the Nishishichitou Ridge off central Japan. (Sawada & Handa,1998, Nature)

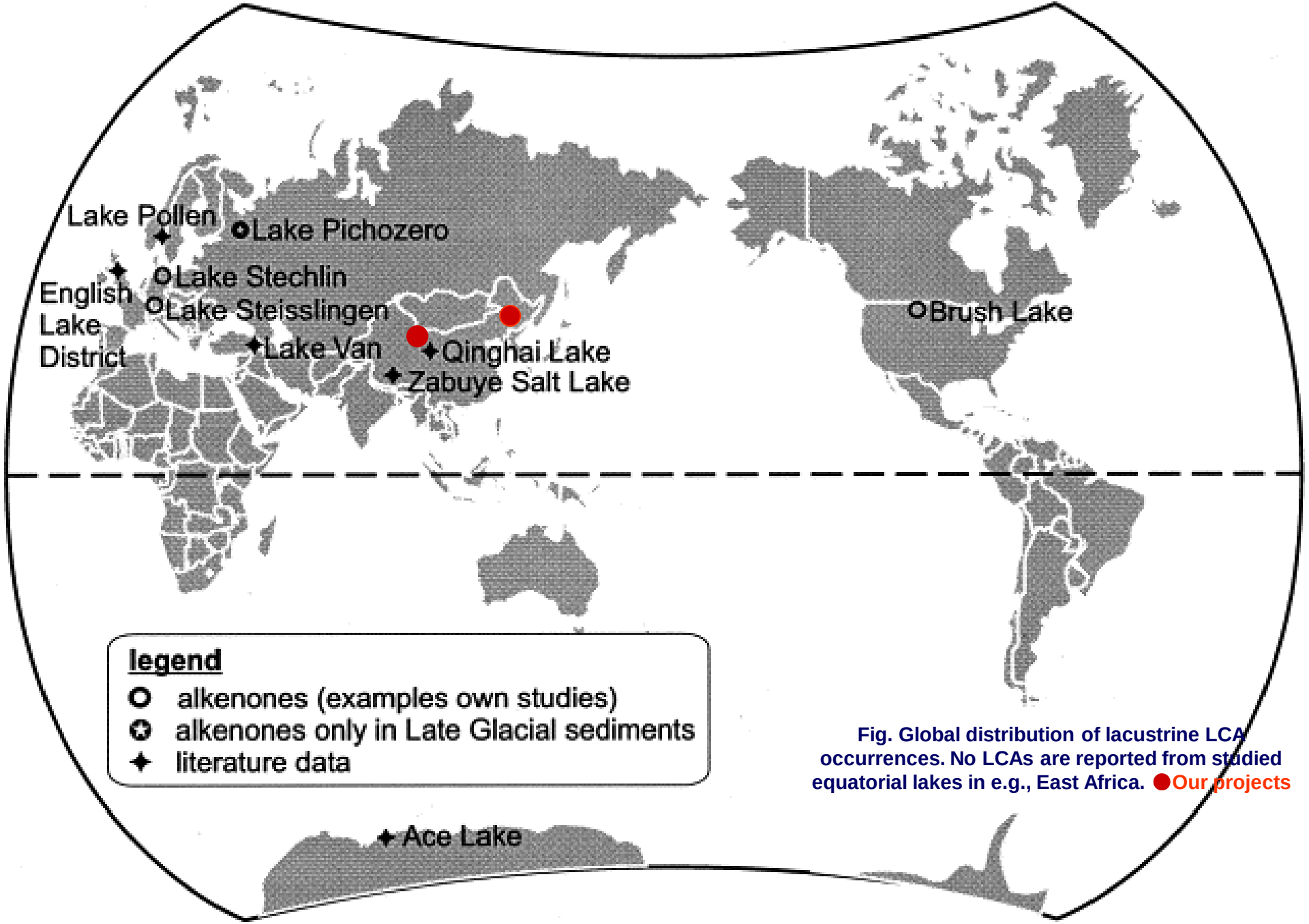


Fig. Global distribution of lacustrine LCA occurrences. No LCAs are reported from studied equatorial lakes in e.g., East Africa. ● Our projects

Zink et al.(2001)

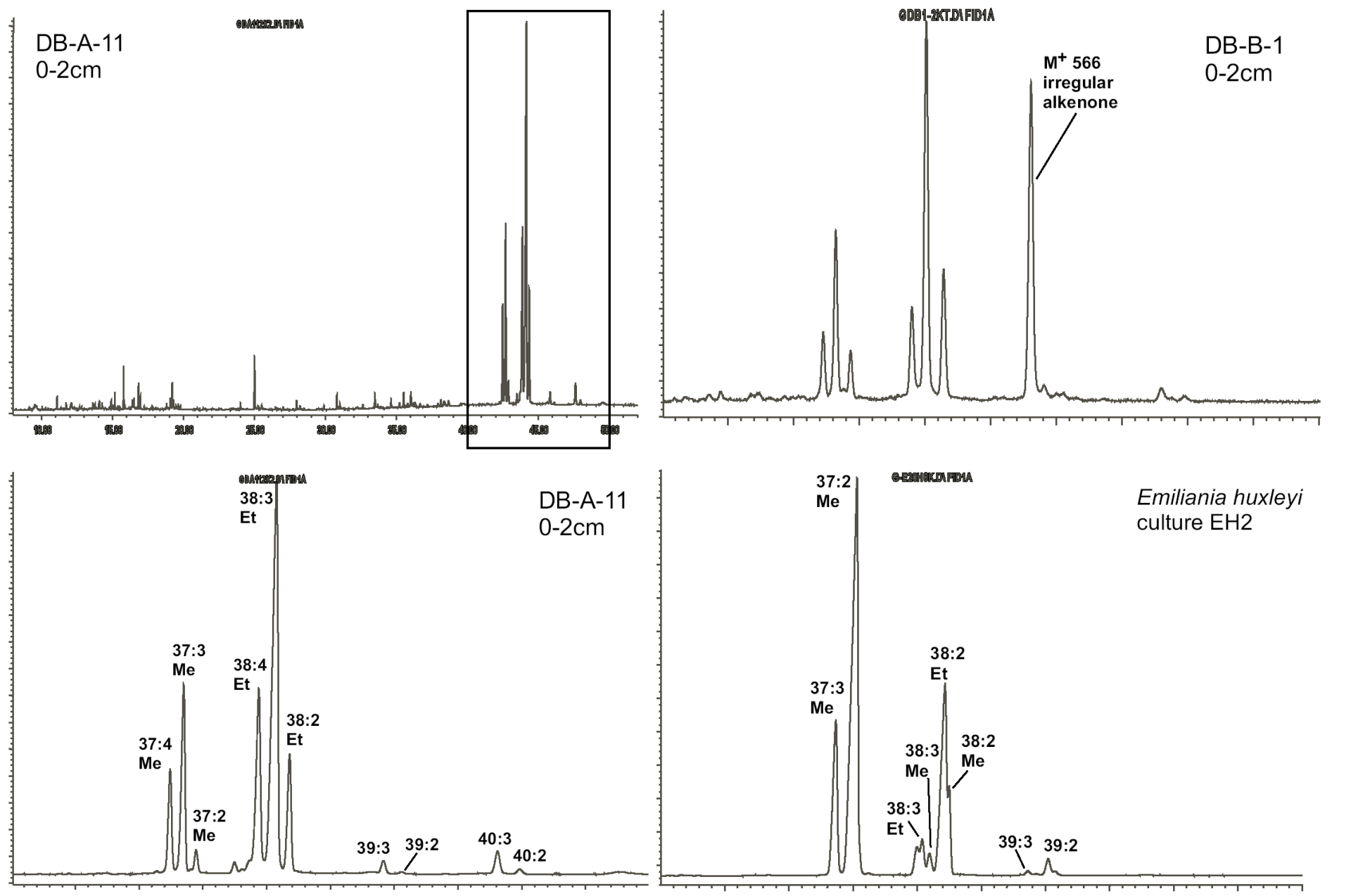
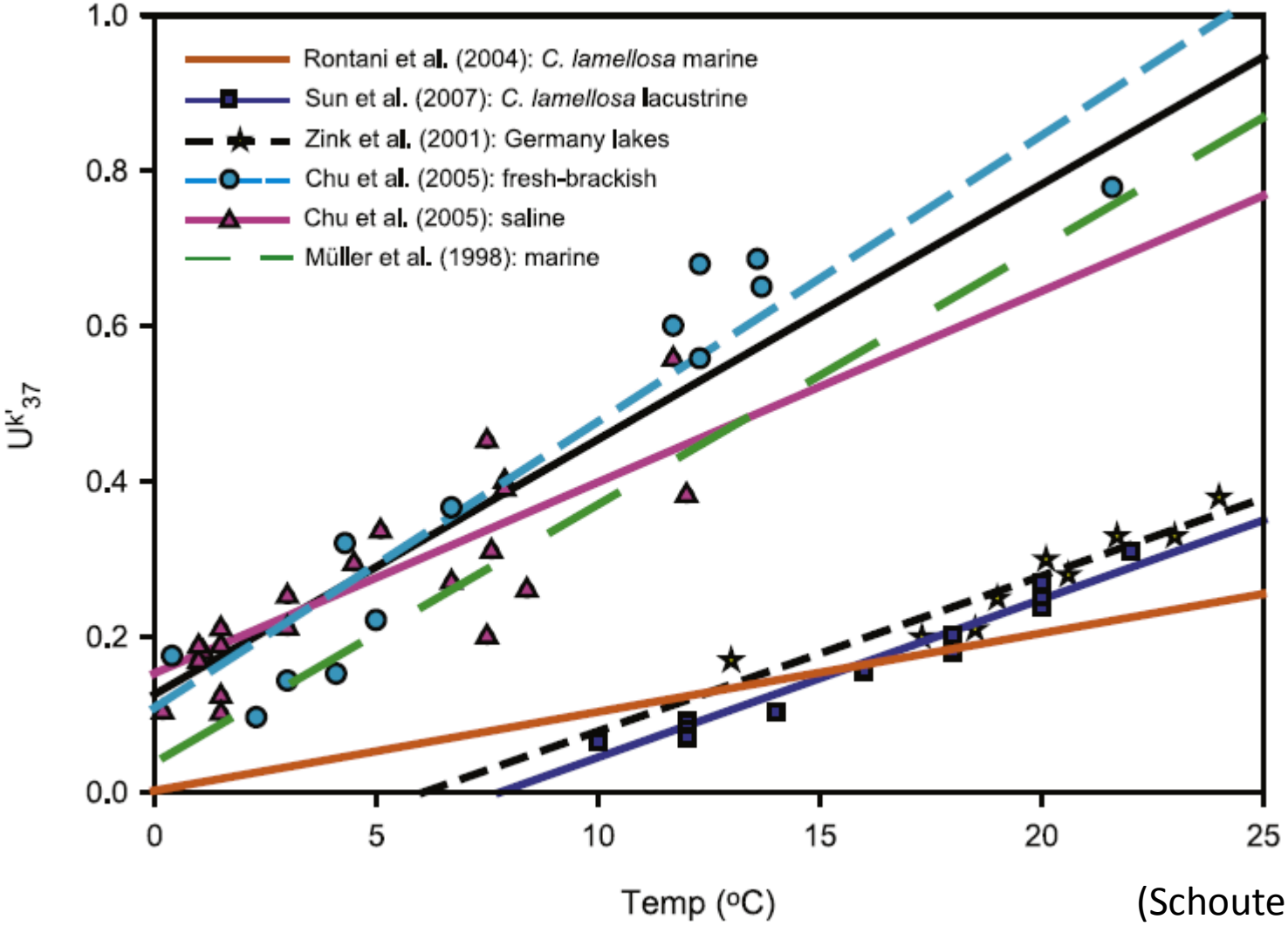


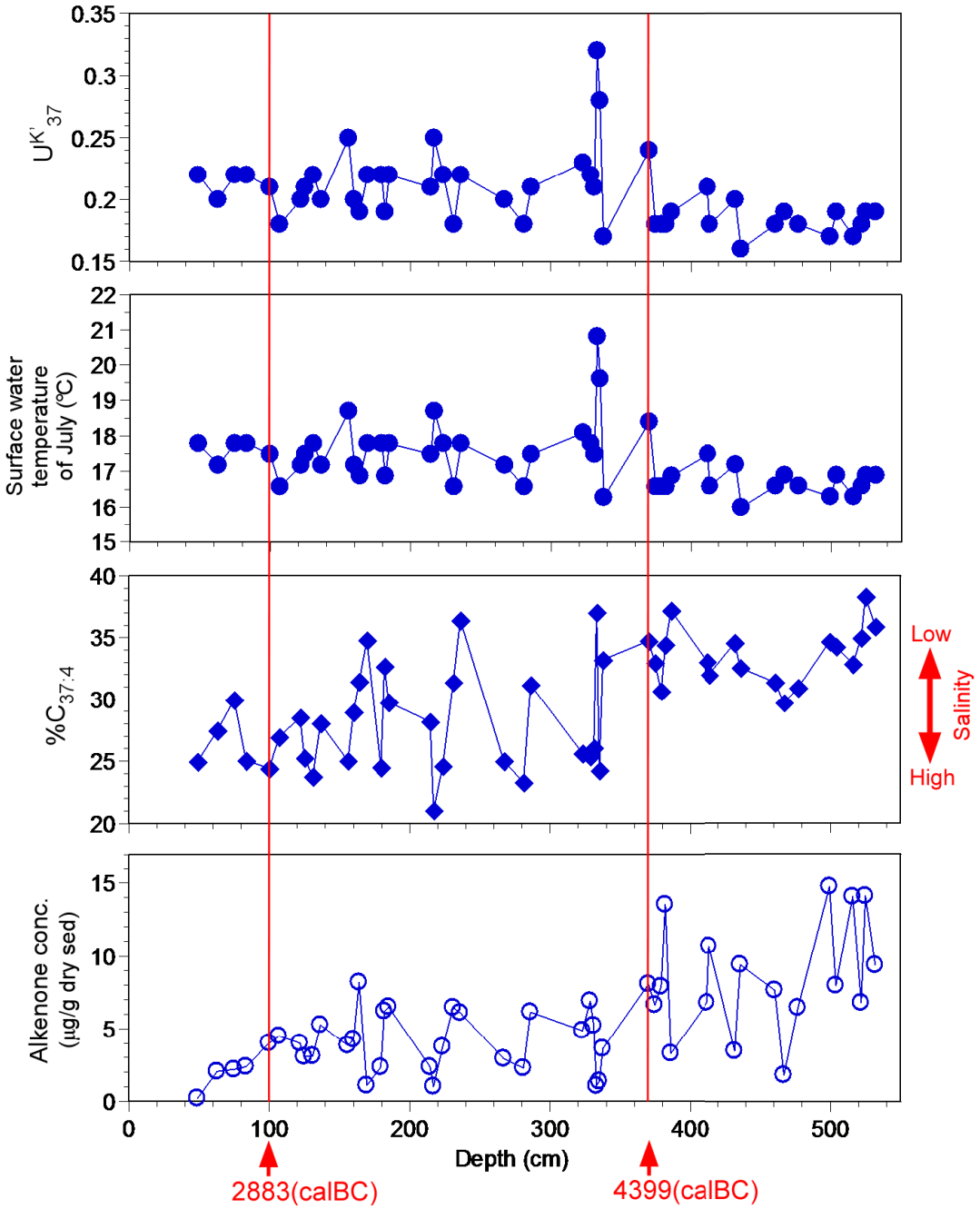
Fig. Gas chromatograms of ketone fractions in sediments of Dabusu Lake.

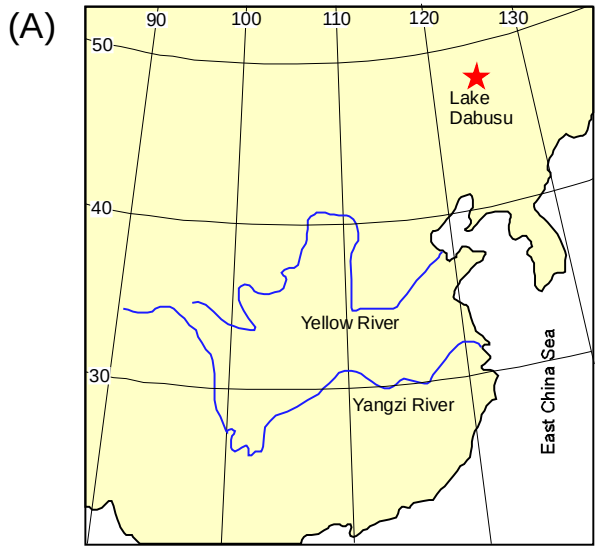
Relationship between $U^{k'}_{37}$ and temperature

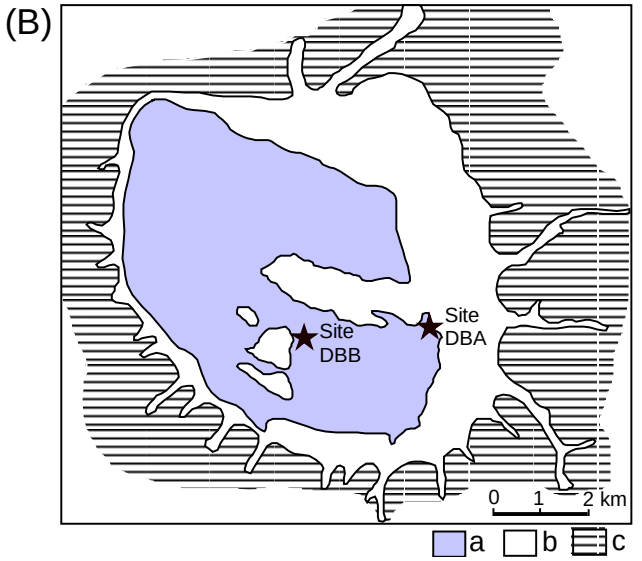


(Schouten et al., 2012)

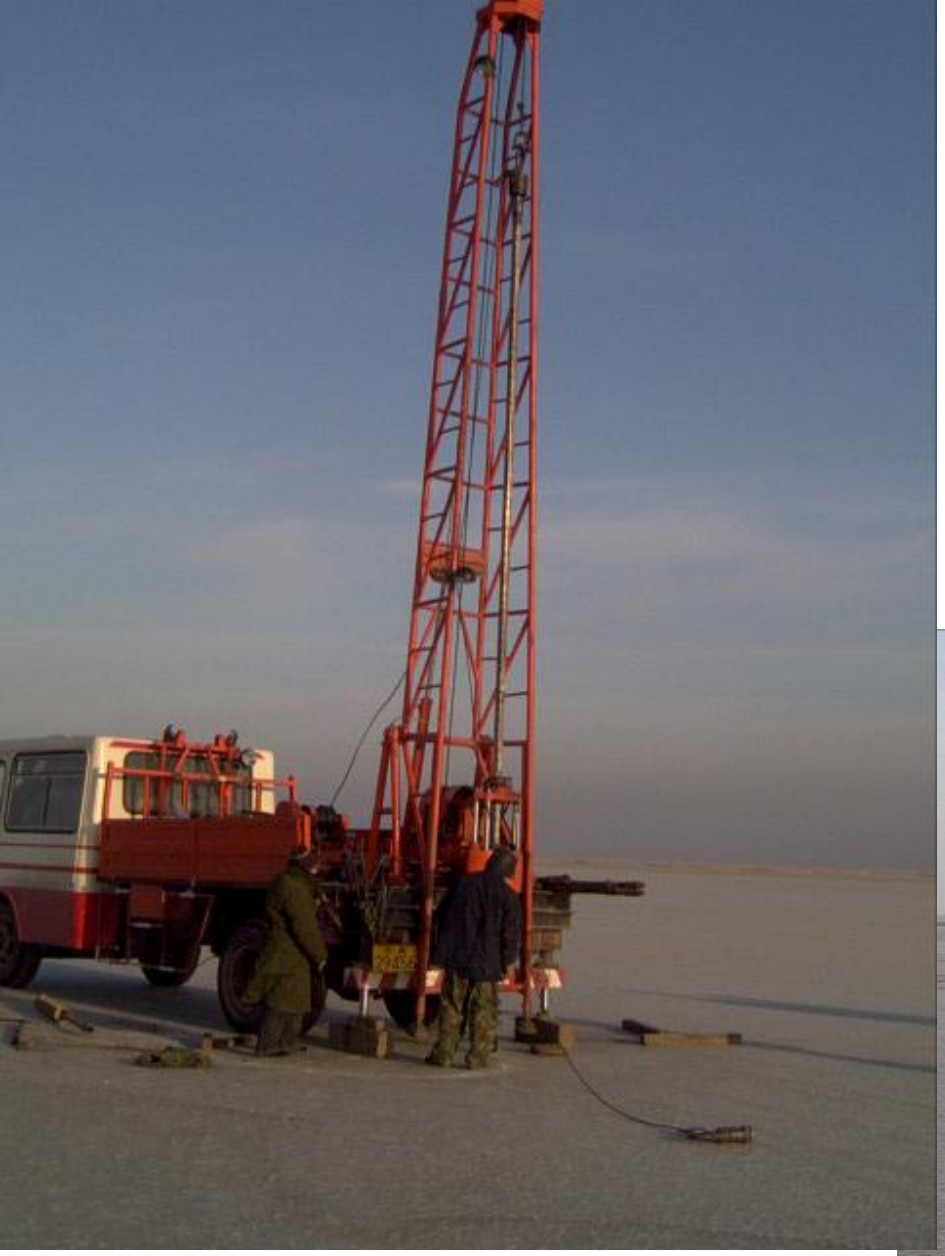
Fig. Comparison of lacustrine alkenone calibration equations for the $U^{K'}_{37}$ Index. The marine calibrations of *Emiliania huxleyi* (Prahl andWakeham,1987) and *Chrysotila lamellosa* (Conte et al., 1994) are shown for comparison.







Sawada, Ono et al. (2012) Org. Geochem.



Dabusu Lake (northeastern China) DB-B core site

TEX_{86} paleoceanography: Cretaceous paleotemperature.

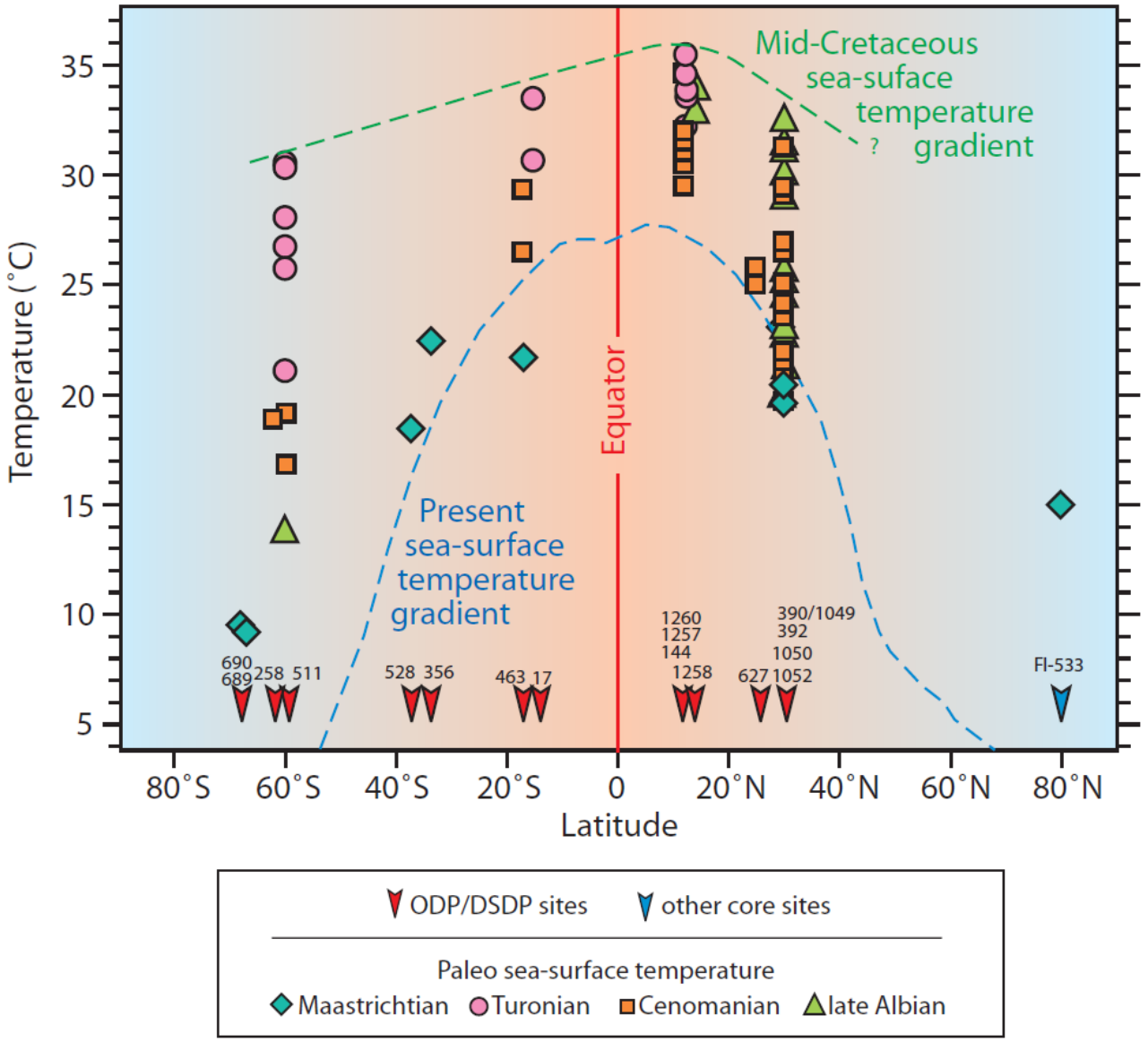
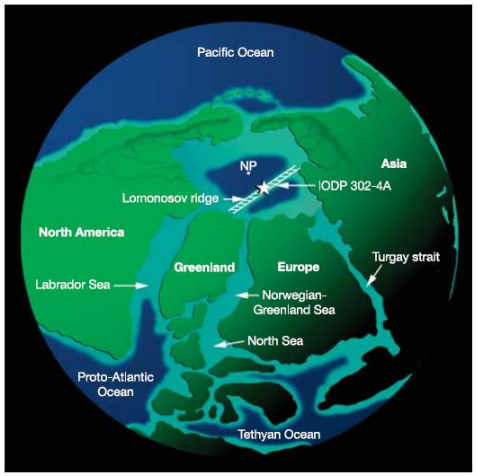


Fig. Latitudinal variations of surface ocean temperatures from planktonic foraminiferal $\delta^{18}O$ and TEX_{86} (Takashima et al., 2006). Modified from Bice et al. (2003), Huber et al. (2002) and Jenkyns et al. (2004).

TEX_{86} paleoceanography

暁新世/始新世最温暖期（Paleocene Eocene Thermal Maximum)）における北極海の古水温変動の復元



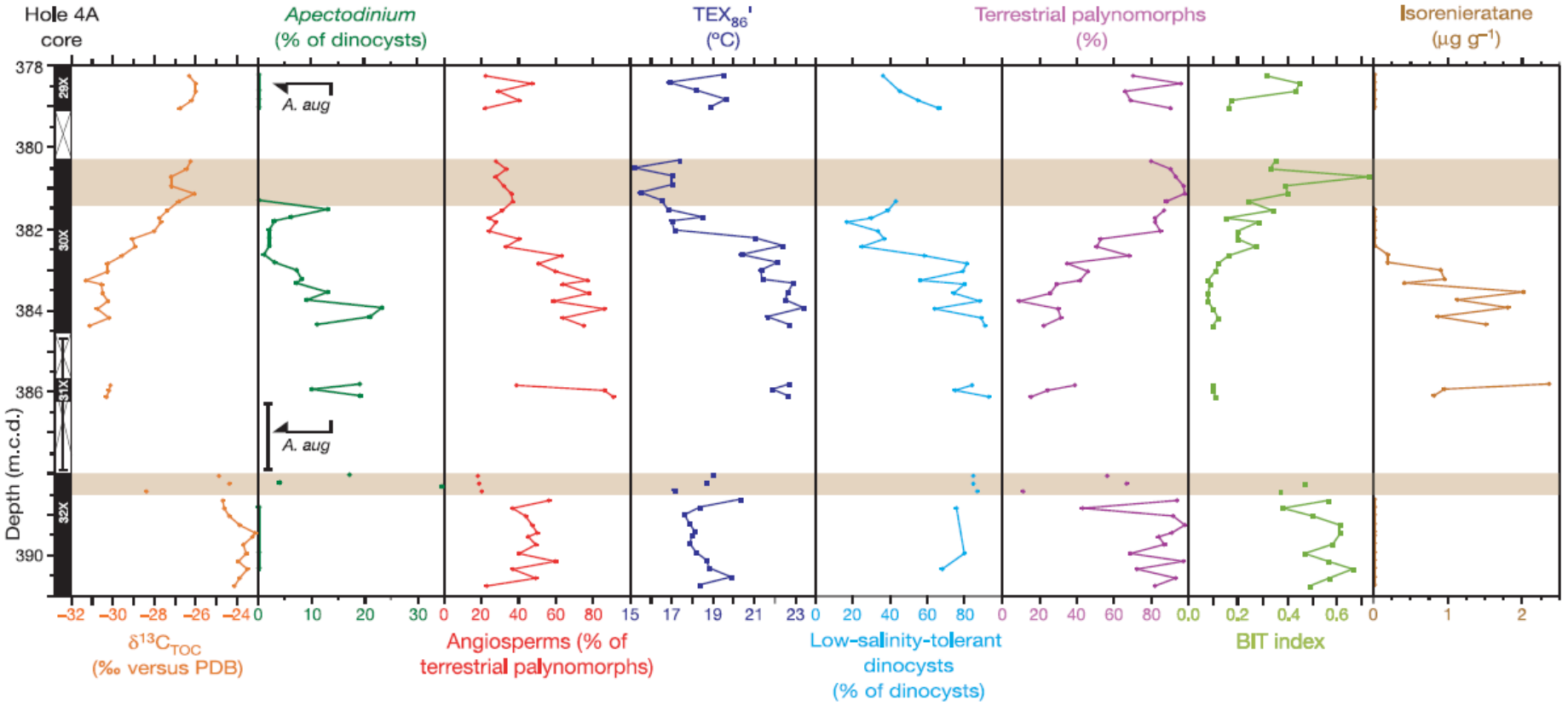
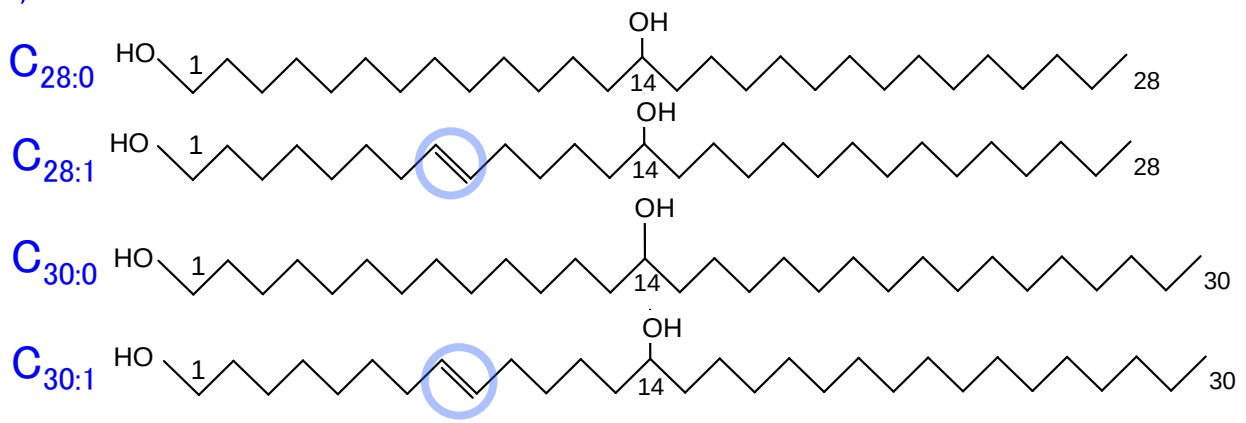


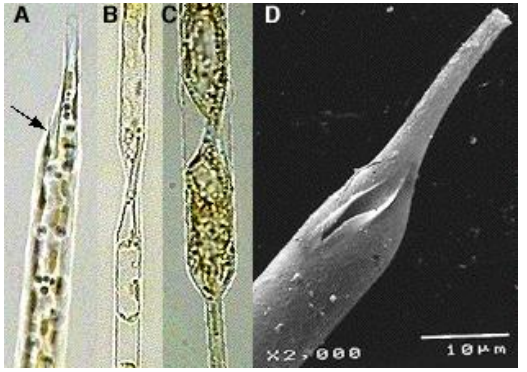
Fig. Palynology and geochemical results across the PETM of the IODP Hole 302-4A (Sluijs et al., 2006, Nature, 441, 610)

新たな古水温指標[1] 珪藻由来バイオマーカー

（1,14-diol & 12-OH m.a.）

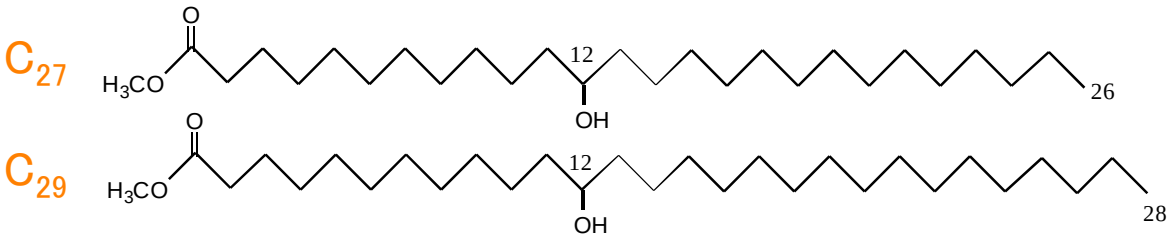
1,14-diol

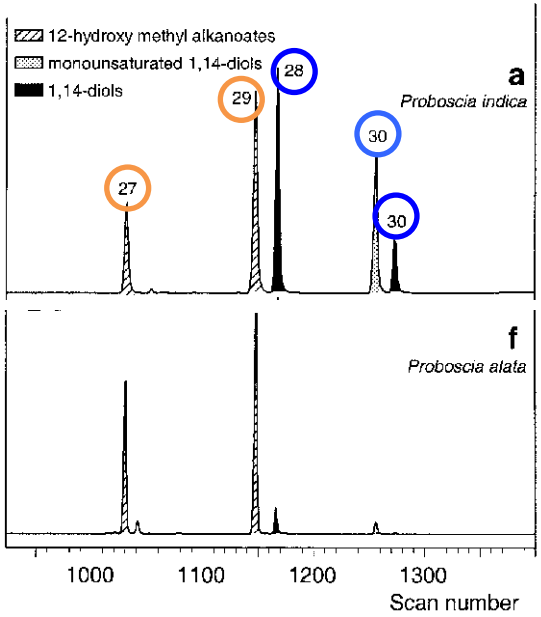




Proboscia alata

12-hydroxy methyl alkanoate（12-OH m.a.）





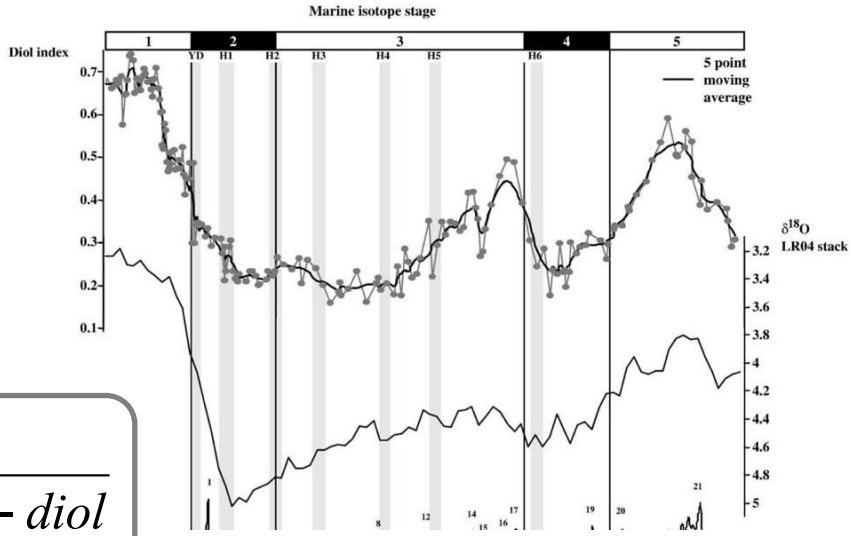
（Shinninghe Damste et al., 2003）

- 第四紀の海洋堆積物中でよく見られる（Versteegh *et al.*, 1997）
- 珪藻の*Proboscia*属に由来（Shinninghe Damste *et al.*, 2003）

・湧昇流発達の指標として研究・利用される

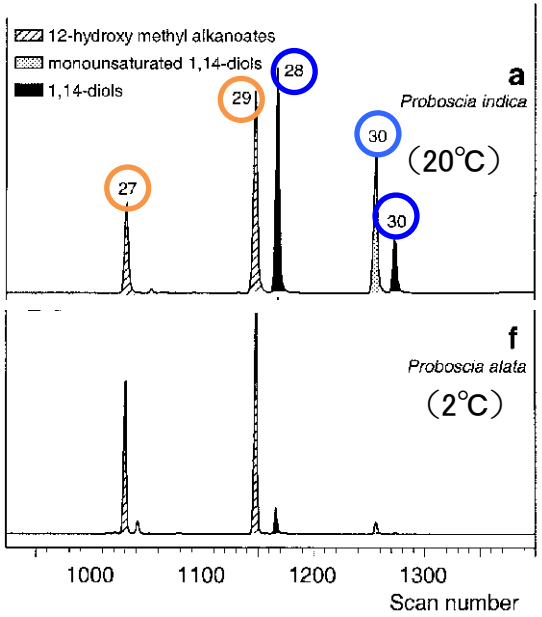
＊Rampen *et al.* (2008)
*Proboscia*による生産は湧昇流増大の初期に増加することから、1,14-diolと1,15-diolの比は湧昇流強度の指標となる

$$\text{Diol index} = \frac{(C_{28}+C_{30})1,14\text{-}diol}{(C_{28}+C_{30})1,14\text{-}diol + C_{30}1,15\text{-}diol}$$



・培養試料の生育温度（種）によって
1,14-diolおよび12-OH m.a.の組成に違い

→古水温指標となり得る可能性？



(Shinninghe Damste et al., 2003)

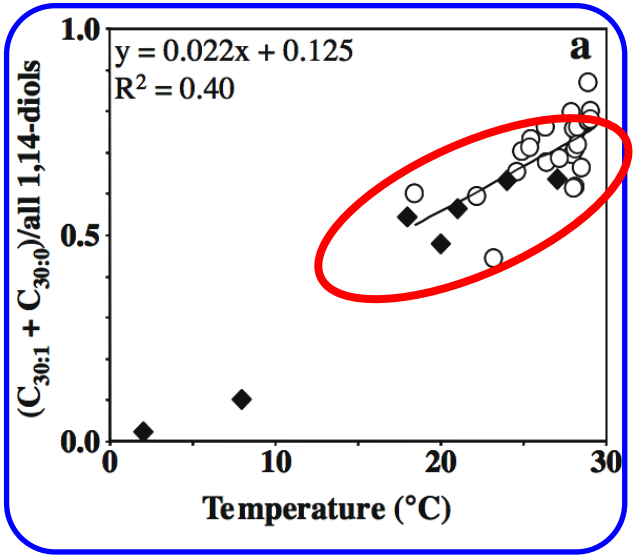
Introduction　新たな古水温指標[1] 珪藻由来バイオマーカー

（1,14-diol & 12-OH m.a.）

＊ Rampen *et al.*（2009）

1,14-diolの炭素鎖の長さ変化

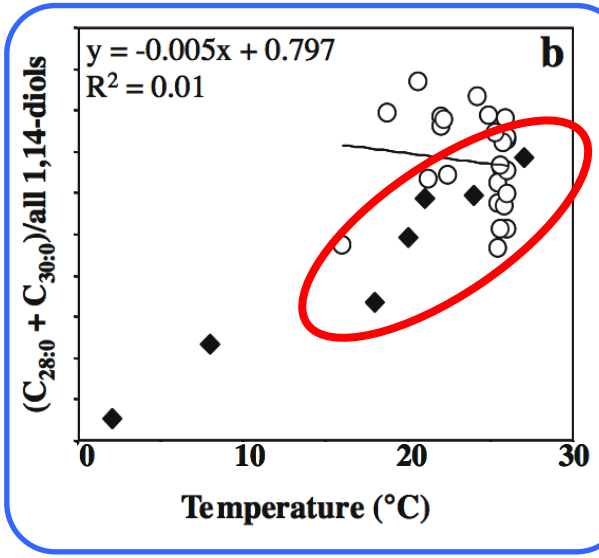
$$\frac{(C_{30:0}+C_{30:1})}{(C_{28:0}+C_{28:1})+(C_{30:0}+C_{30:1})}\ 1,14\text{-}diol$$



・相関あり？
・特に2月の水温と相関◎

1,14-diolの不飽和比

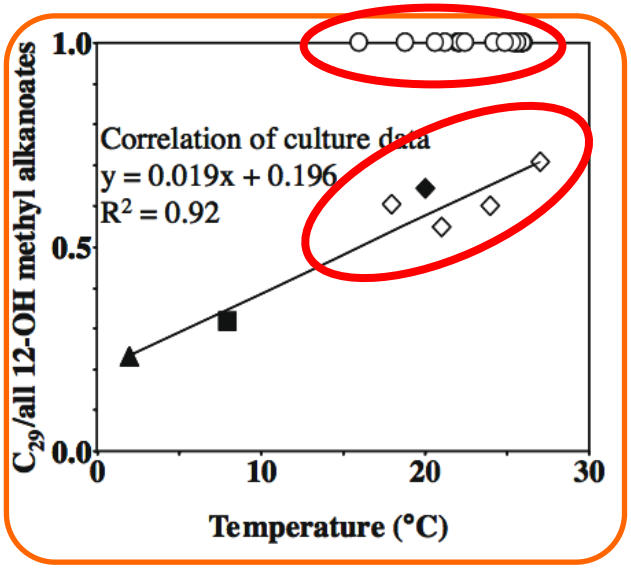
$$\frac{(C_{28:0}+C_{30:0})}{(C_{28:1}+C_{30:1})1+(C_{28:0}+C_{30:0})}\ 1,14\text{-}diol$$



・相関はみられなかった

12-OH m.a. の炭素鎖の長さ変化

$$\frac{C_{29}}{C_{27}+C_{29}}\ 12\text{-OH m.a.}$$



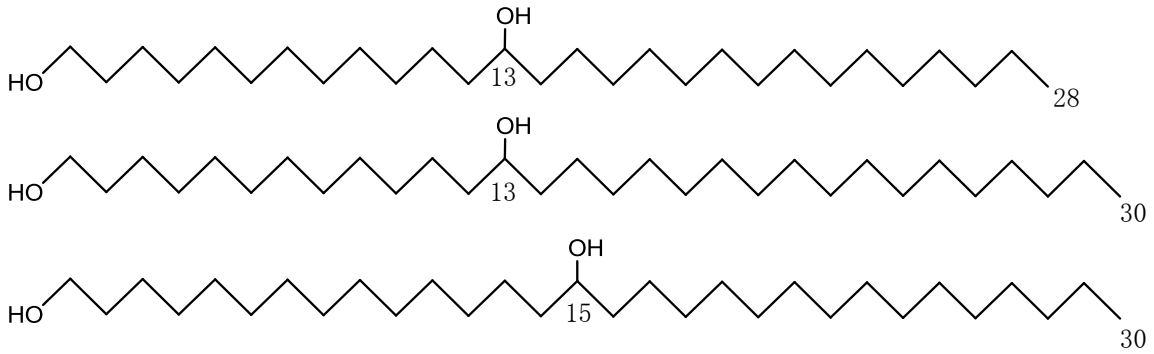
・C27が検出されなかった
→指標として利用できない

・培養試料　→生育温度と相関（同じ種でも生育温度により違い）
・アラビア海の表層堆積物を分析

Introduction　新たな古水温指標[2] 2種類のジオールの量比

(1,13-diol & 1,15-diol)

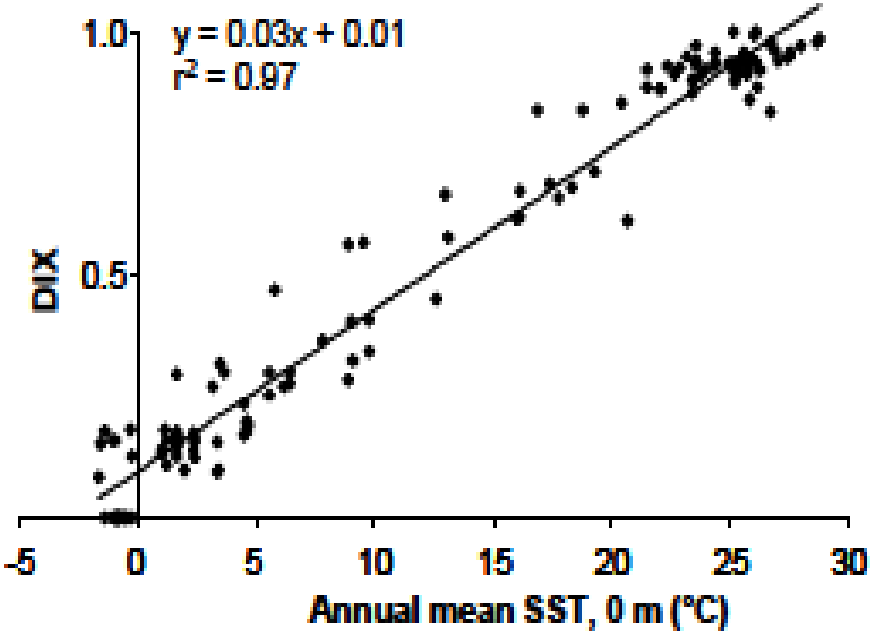
1,13-diol＆1,15-diol



C_{28} 1,13-diol

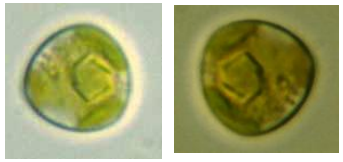
C_{30} 1,13-diol

C_{30} 1,15-diol



・第四紀の海洋堆積物中でよく見られる
（Versteegh et al., 1997）

・真正眼点藻から検出される
（Volkman et al., 1992）

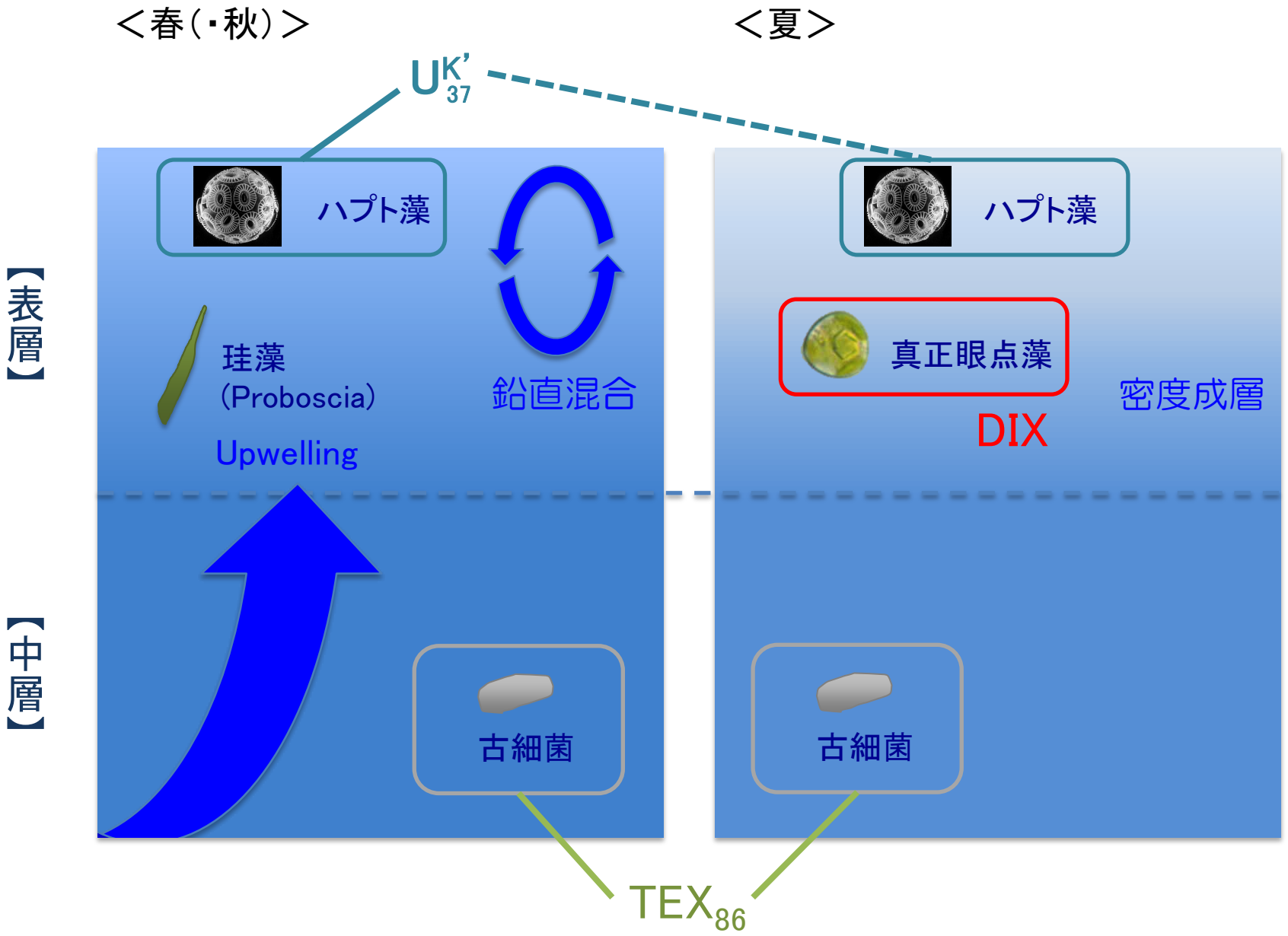


・表層水温に相関（Rampen et al., 2011）

DIX（Diol Isomer Index）：1,13-diolと1,15-diolの量比

$$DIX = \frac{C_{30}1,15\text{-}diol}{(C_{28}+C_{30})1,13\text{-}diol + C_{30}1,15\text{-}diol}$$

ジオール古水温計と他の古水温指標との関係



Introduction　藻類バイオマーカーを用いた新たな古水温指標

DCI（Diol Chain length Index）：1,14-diolの炭素鎖の長さ

$$DCI = \frac{(C_{30:0} + C_{30:1})}{(C_{28:0} + C_{28:1}) + (C_{30:0} + C_{30:1})} 1,14\text{-}diol$$

UD（Unsaturated Diol Index）：1,14-diolの不飽和比

$$UD = \frac{(C_{28:0} + C_{30:0})}{(C_{28:0} + C_{30:0}) + (C_{28:1} + C_{30:1})} 1,14\text{-}diol$$

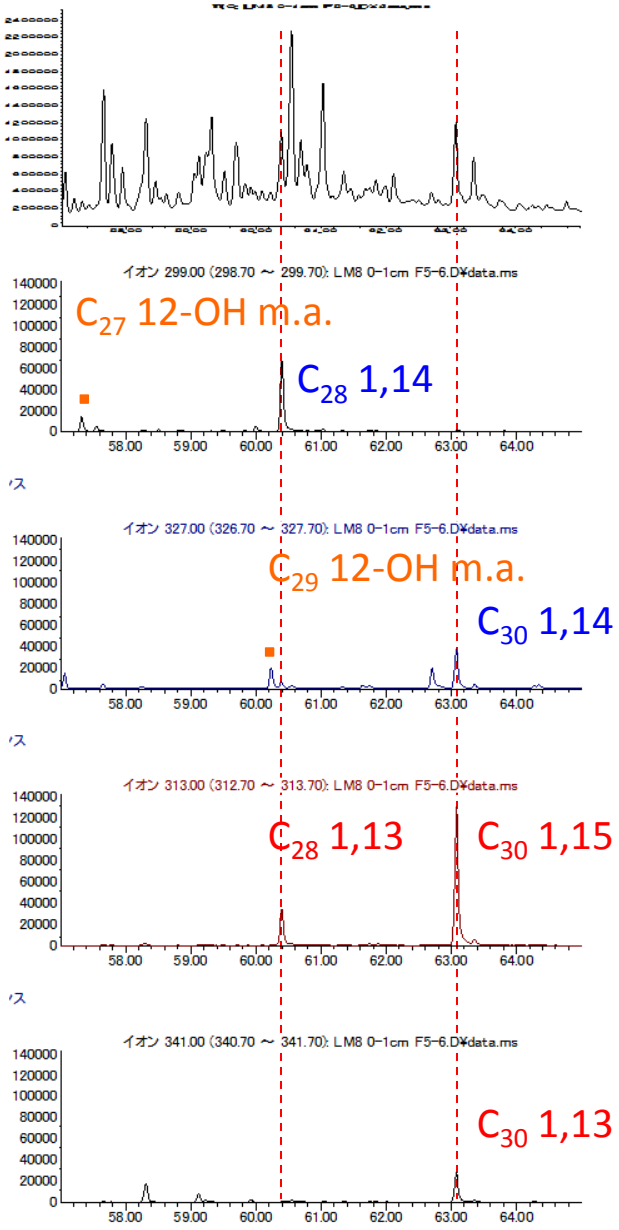
MA_{12}（12-OH M.A. ratio）：12-OH m.a. の炭素鎖の長さ

$$MA_{12} = \frac{C_{29}}{C_{27} + C_{29}} \text{12-OH m.a.}$$

本研究で新たに設定

DIX（Diol Isomer Index）：1,13-diolと1,15-diolの量比

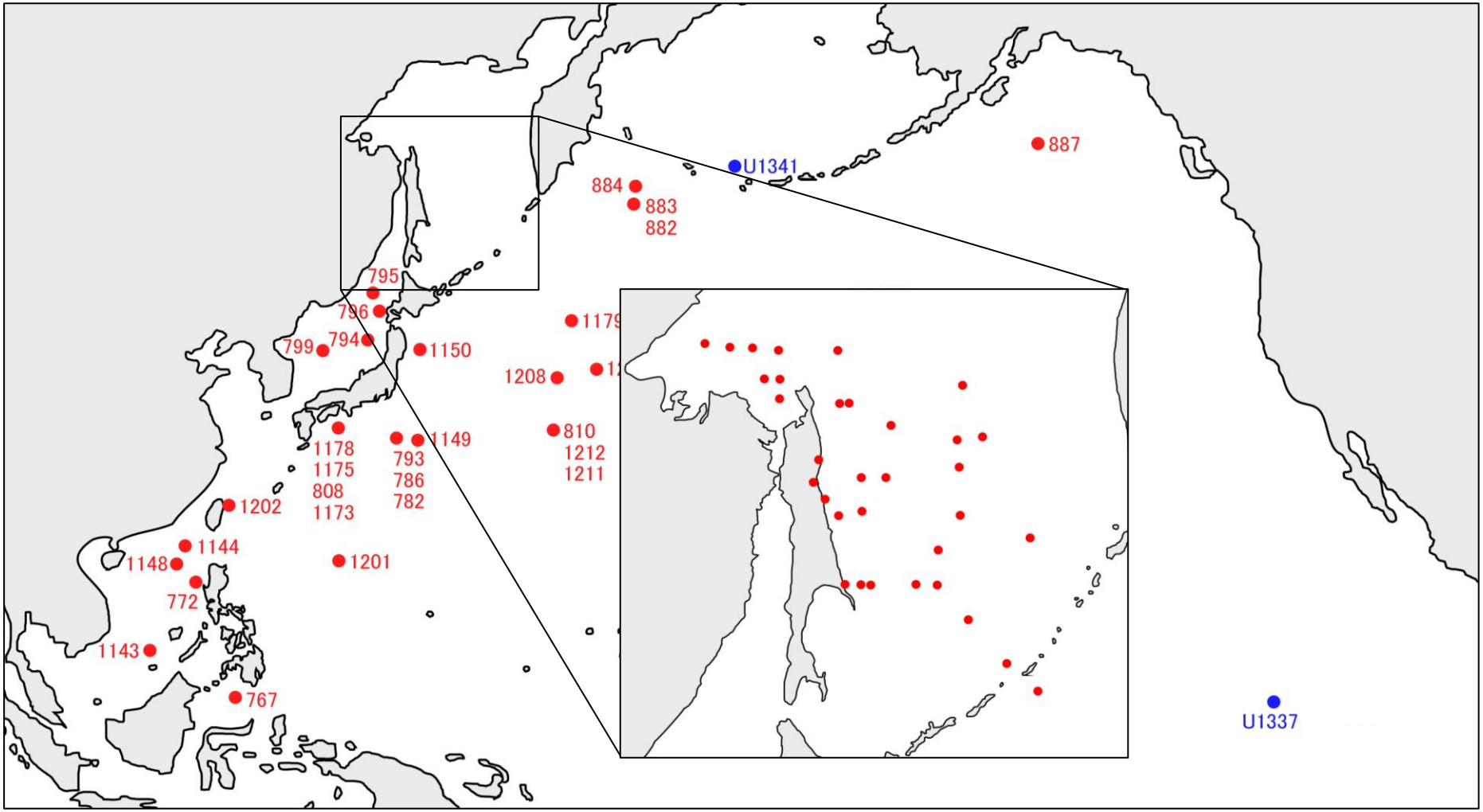
$$DIX = \frac{C_{30}1,15\text{-}diol}{(C_{28} + C_{30})1,13\text{-}diol + C_{30}1,15\text{-}diol}$$



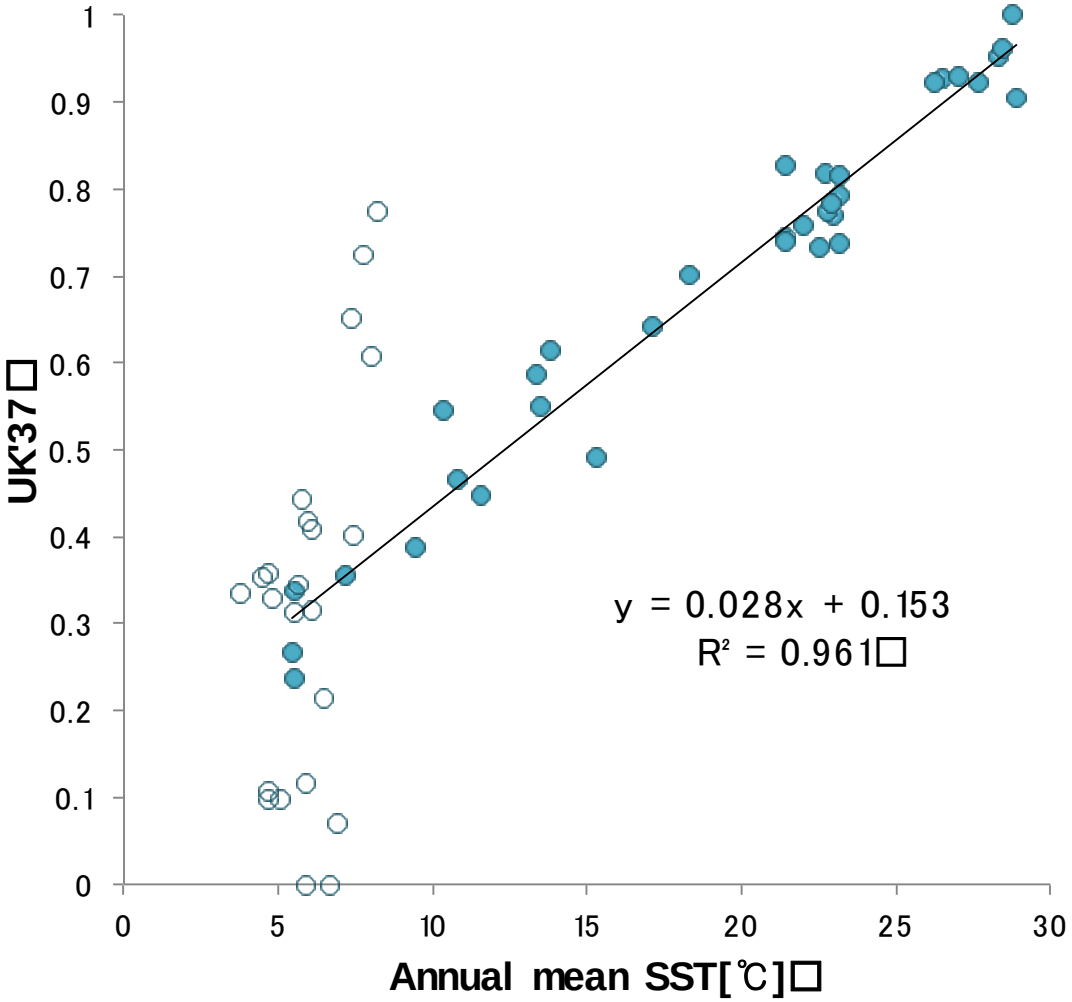
・各指標について、太平洋の堆積物コアに適用
→太平洋でも利用可能であるか検討する

(小林, 沢田. 未公表データ)

Samples 北太平洋表層堆積物＆深海掘削コア



Result 北太平洋表層堆積物中のアルケノン古水温指標



(小林, 沢田. 未公表データ)

$U^{K'}_{37}$（C_{37} alkenoneの不飽和比）

$$U^{K'}_{37} = \frac{C_{37:2}}{(C_{37:2} + C_{37:3})} alkenone$$

- 北大低温研究所 関宰博士による分析データ
- 表層水温（横軸）はWorld Ocean Atlas 2005のデータを使用
- オホーツク海ではアルケノンは表層水温に相関を持たない

Result 北太平洋表層堆積物中のジオール古水温計

DCI：1,14-diolの炭素鎖の長さ

$$DCI = \frac{(C_{30:0} + C_{30:1})}{(C_{28:0} + C_{28:1}) + (C_{30:0} + C_{30:1})} 1,14\text{-}diol$$

UD：1,14-diolの不飽和比

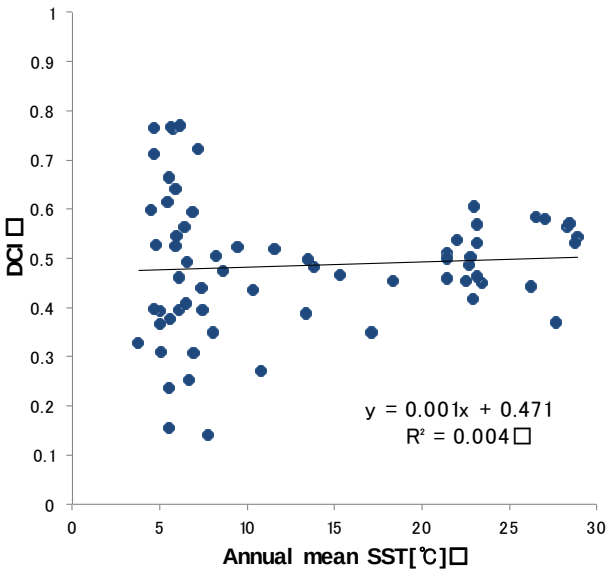
$$UD = \frac{(C_{28:0} + C_{30:0})}{(C_{28:0} + C_{30:0}) + (C_{28:1} + C_{30:1})} 1,14\text{-}diol$$

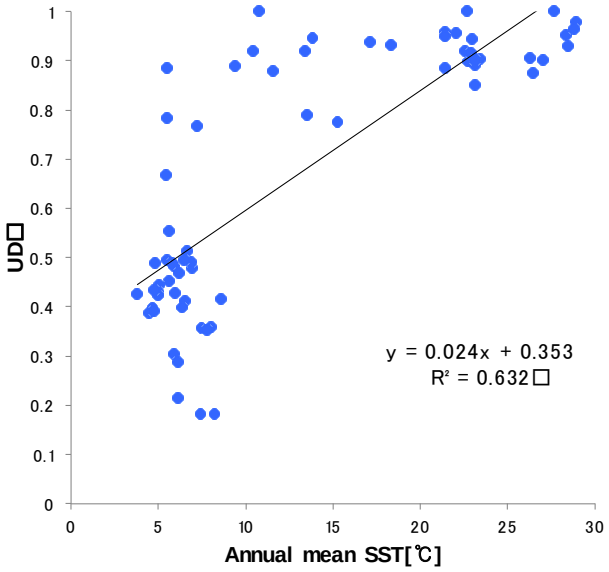
MA_{12}：12-OH m.a. の炭素鎖の長さ

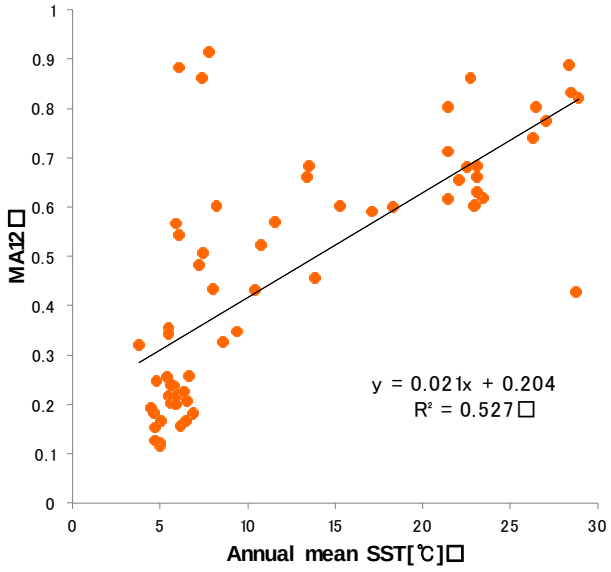
$$MA_{12} = \frac{C_{29}}{C_{27} + C_{29}} 12\text{-OH m.a.}$$

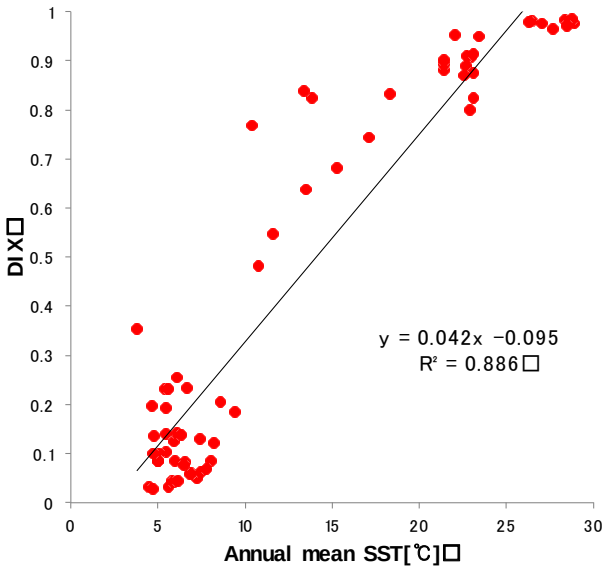
DIX：1,13-diolと1,15-diolの量比

$$DIX = \frac{C_{30} 1,15\text{-}diol}{(C_{28} + C_{30}) 1,13\text{-}diol + C_{30} 1,15\text{-}diol}$$



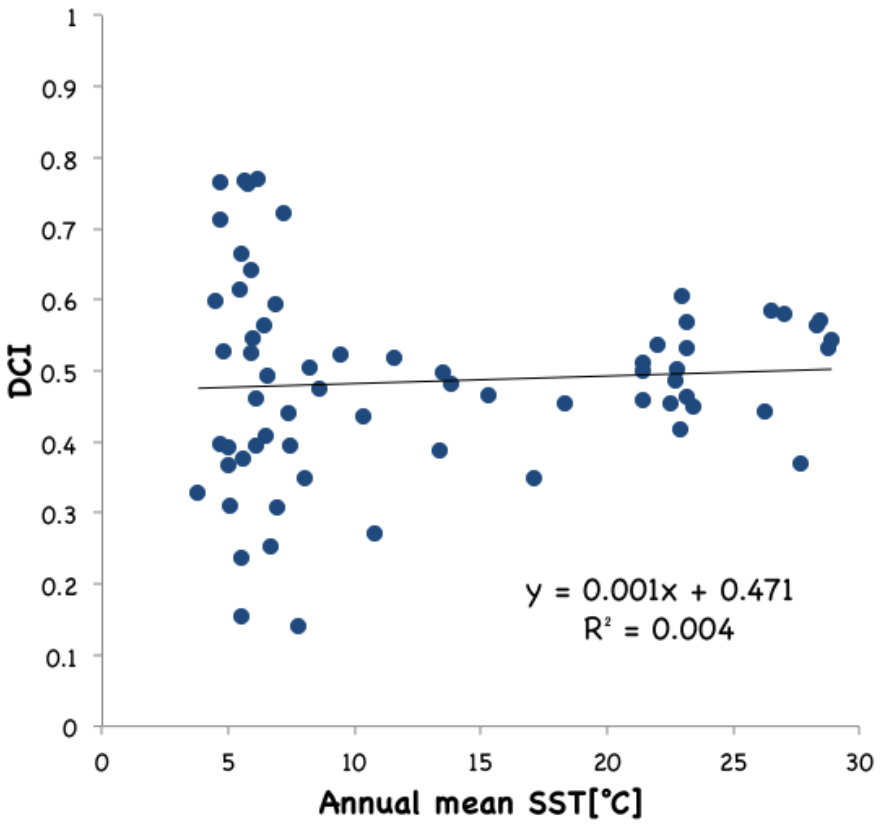


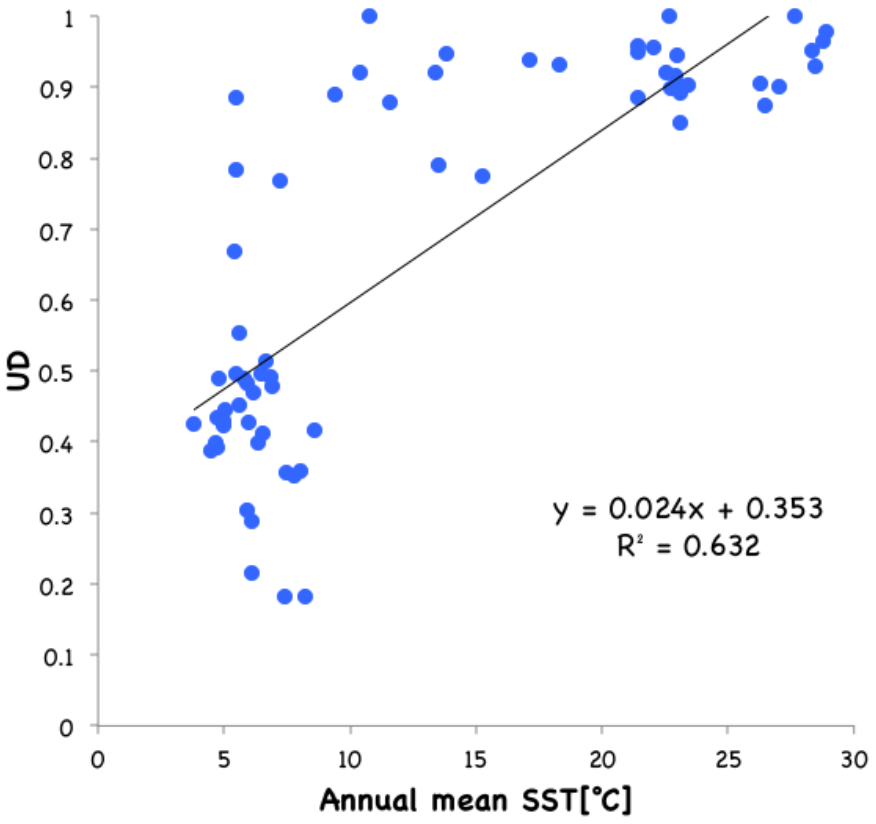




(小林, 沢田. 未公表データ)

Result 表層堆積物中のジオール古水温計（DCI, UD）





DCI：1,14-diolの炭素鎖の長さ

$$DCI = \frac{(C_{30:0} + C_{30:1})}{(C_{28:0} + C_{28:1}) + (C_{30:0} + C_{30:1})} 1{,}14\text{-}diol$$

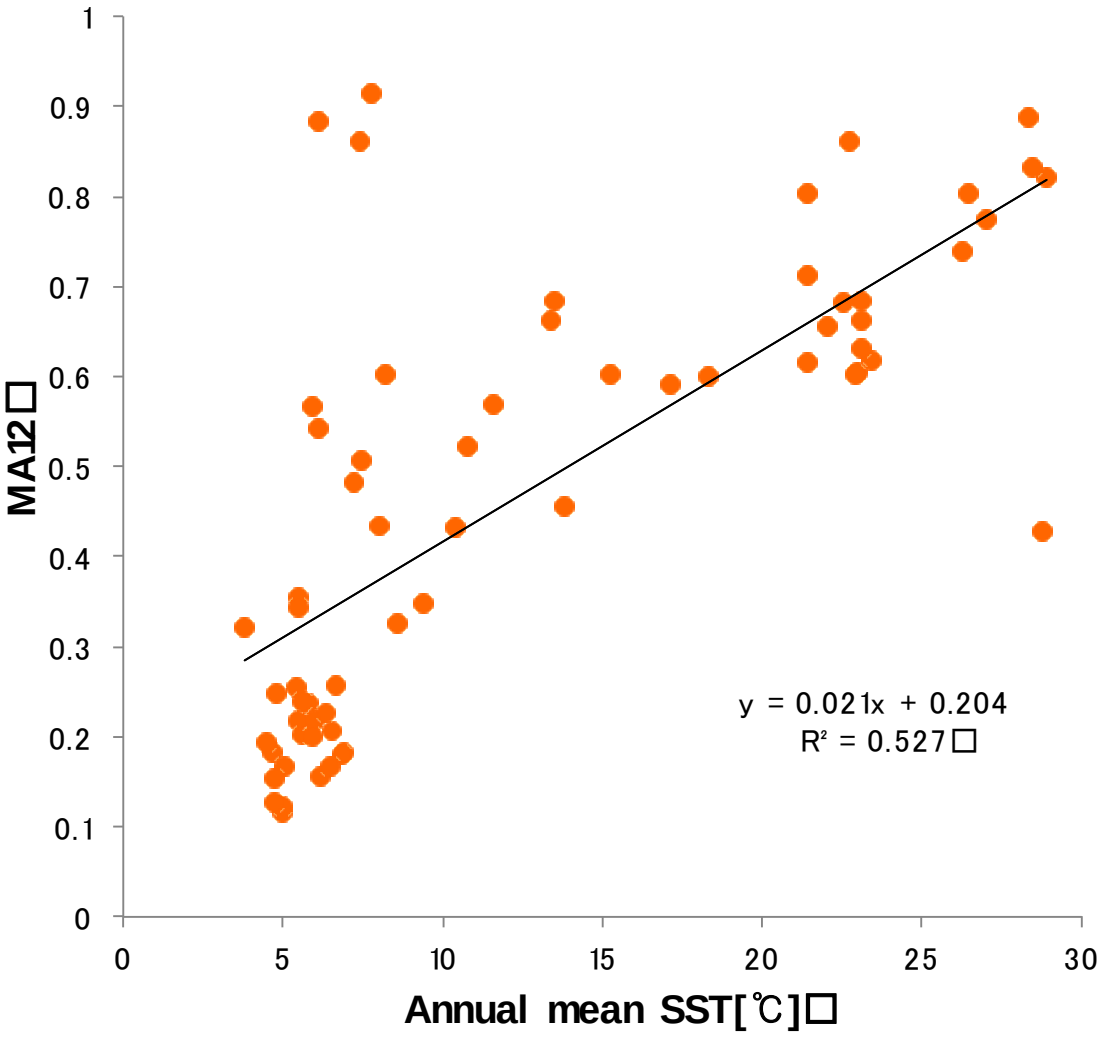
UD：1,14-diolの不飽和比

$$UD = \frac{(C_{28:0} + C_{30:0})}{(C_{28:0} + C_{30:0}) + (C_{28:1} + C_{30:1})} 1{,}14\text{-}diol$$

1,14-diolを用いた指標→明瞭な相関はみられない

(小林, 沢田. 未公表データ)

Result 表層堆積物中のジオール古水温計（MA_{12}）



(小林, 沢田. 未公表データ)

MA_{12}：12-OH m.a. の炭素鎖の長さ

$$MA_{12} = \frac{C_{29}}{C_{27} + C_{29}} \text{ 12-OH m.a.}$$

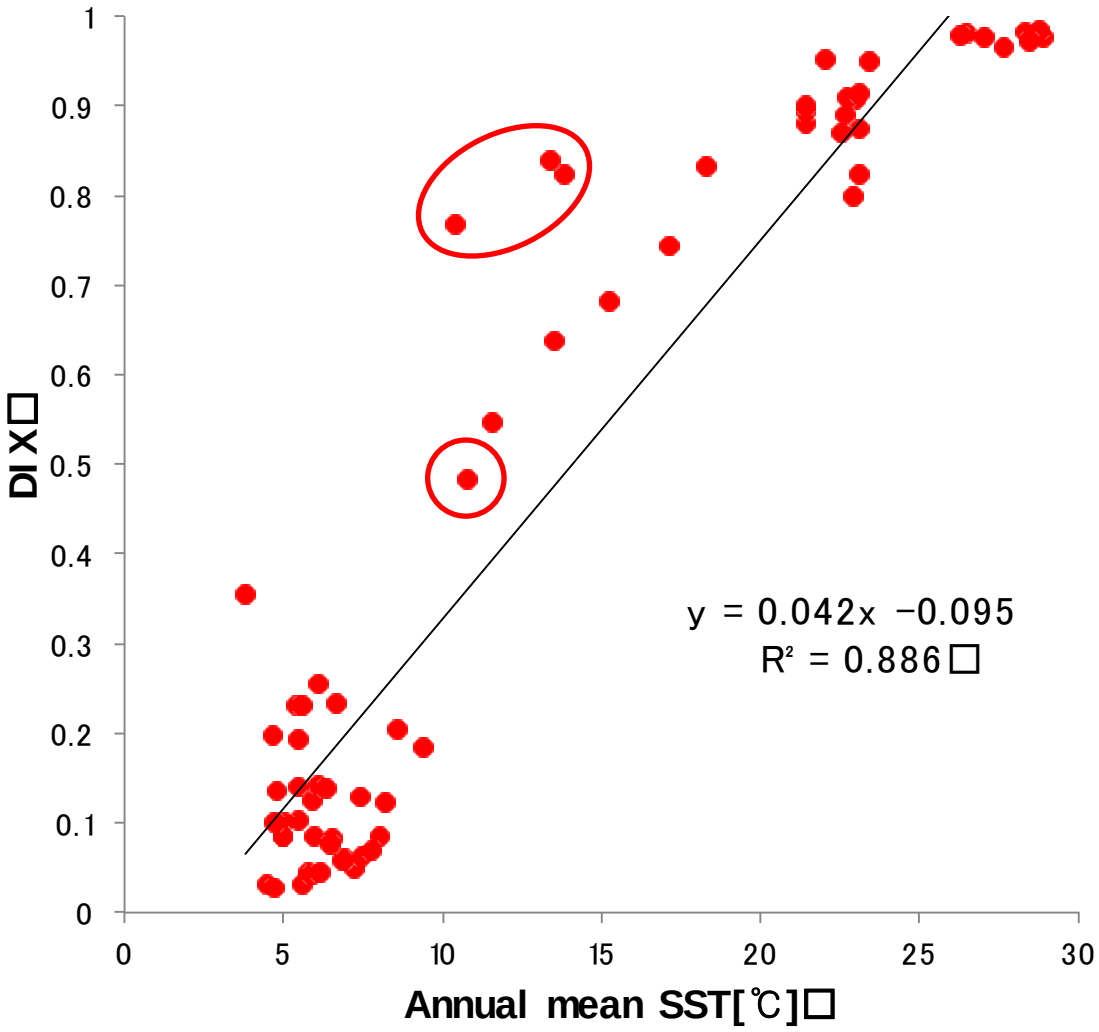
大きく外れた点

- 12-OH m.a.が微量しか検出されていない

- 水温以外の要素の影響

- *Proboscia*（珪藻）以外にも12-OH m.a.を生産する生物が存在する可能性も

Result 表層堆積物中のジオール古水温計（DIX）



(小林, 沢田. 未公表データ)

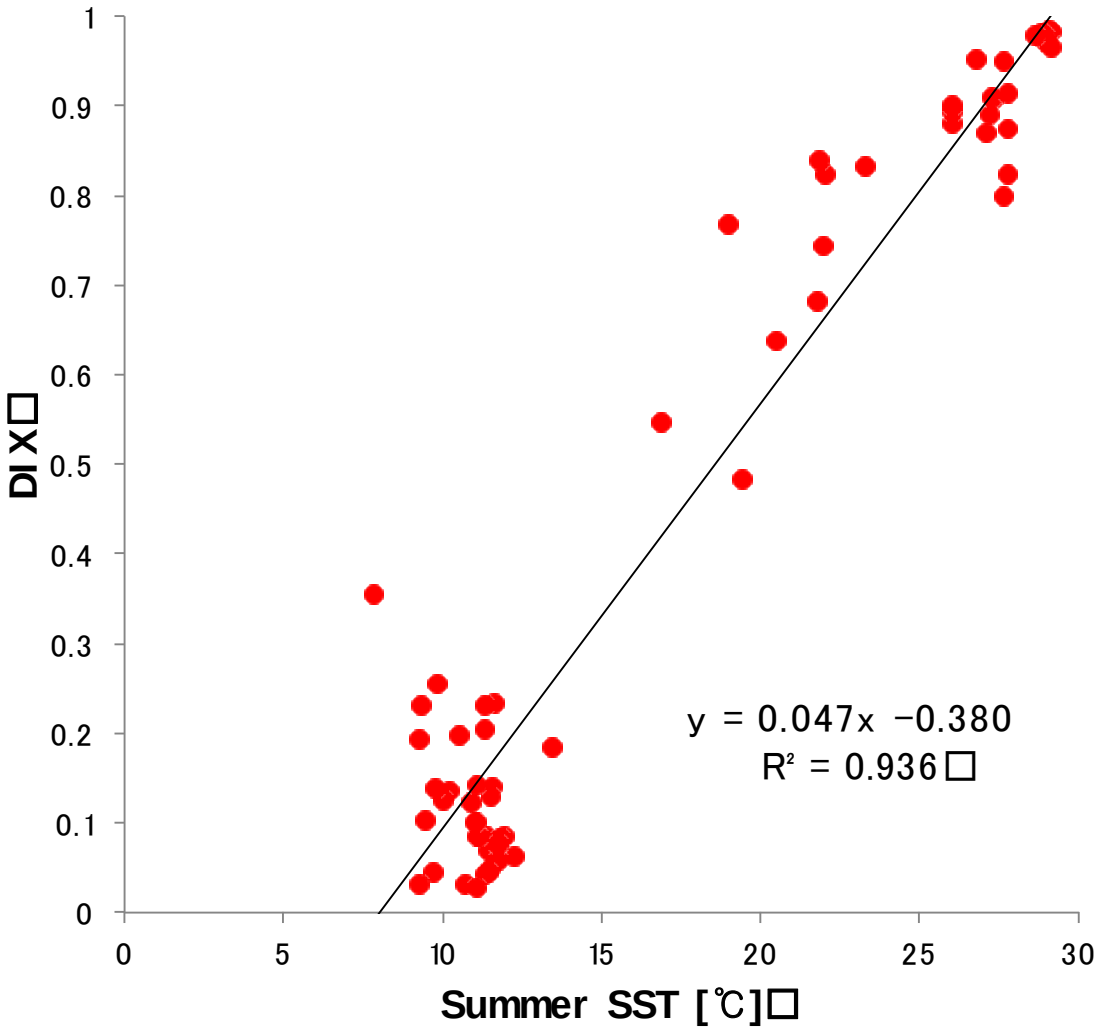
DIX：1,13-diolと1,15-diolの量比

$$DIX = \frac{C_{30}1,15\text{-}diol}{(C_{28}+C_{30})1,13\text{-}diol + C_{30}1,15\text{-}diol}$$

・大きく外れているのは日本海

・淡水の影響の大きい
場所では外れた値になる
(Rampen et al., 2011)

Result 表層堆積物中のジオール古水温計（DIX）



（夏季の表層水温）

(小林, 沢田. 未公表データ)

DIX：1,13-diolと1,15-diolの量比

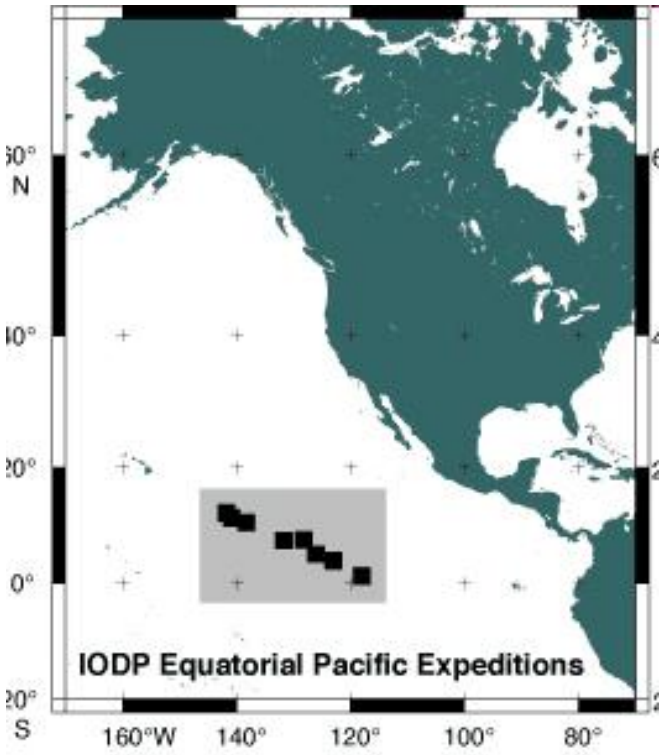
$$DIX = \frac{C_{30}1,15\text{-}diol}{(C_{28}+C_{30})1,13\text{-}diol + C_{30}1,15\text{-}diol}$$

・横軸の季節や水深(SST,10m,20m,30m,50m)を変えて比較

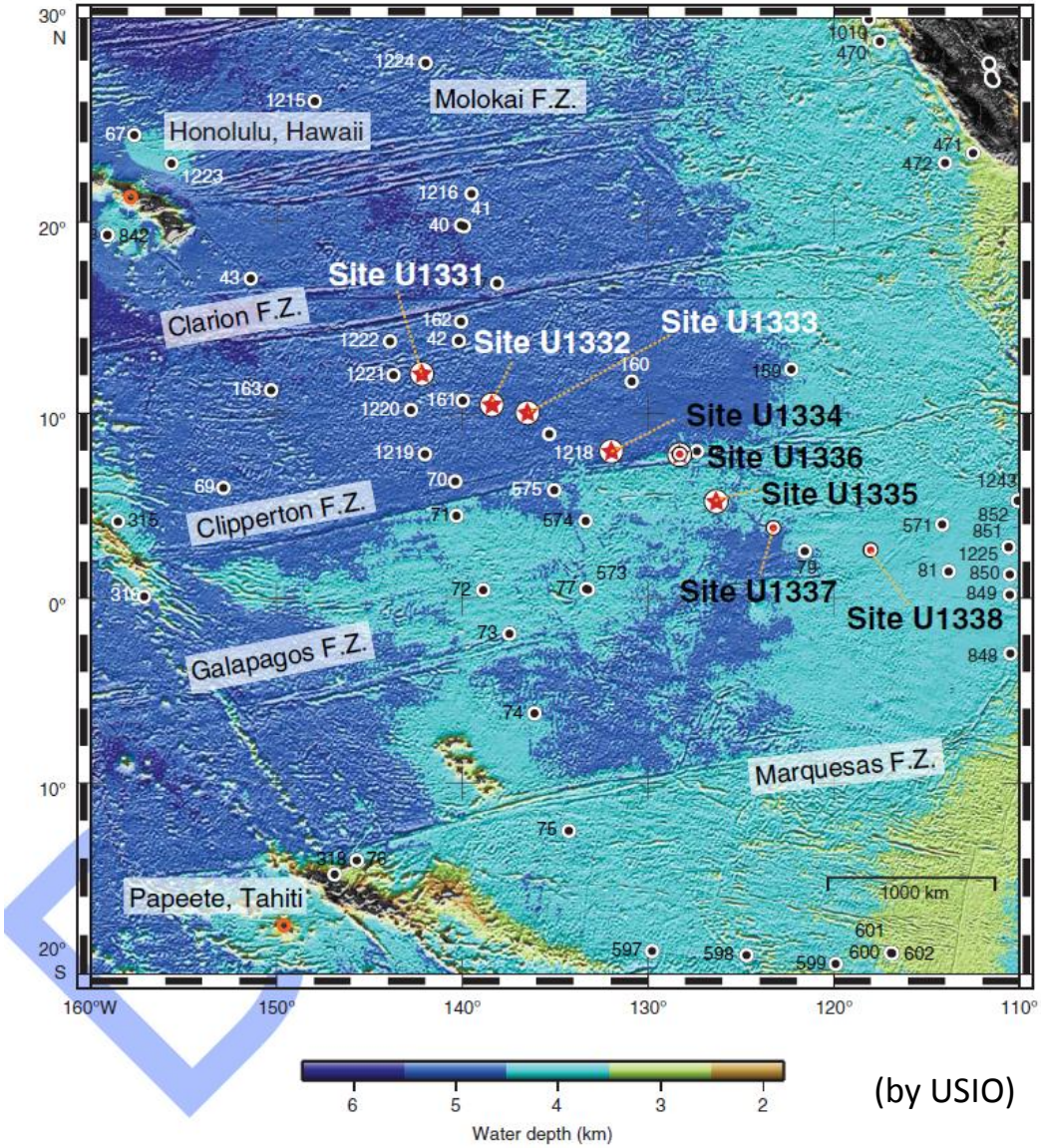
↓

・夏季の表層水温に対して特に良い相関を示す

Expedition 320/321 Pacific Equatorial Age Transect (PEAT)



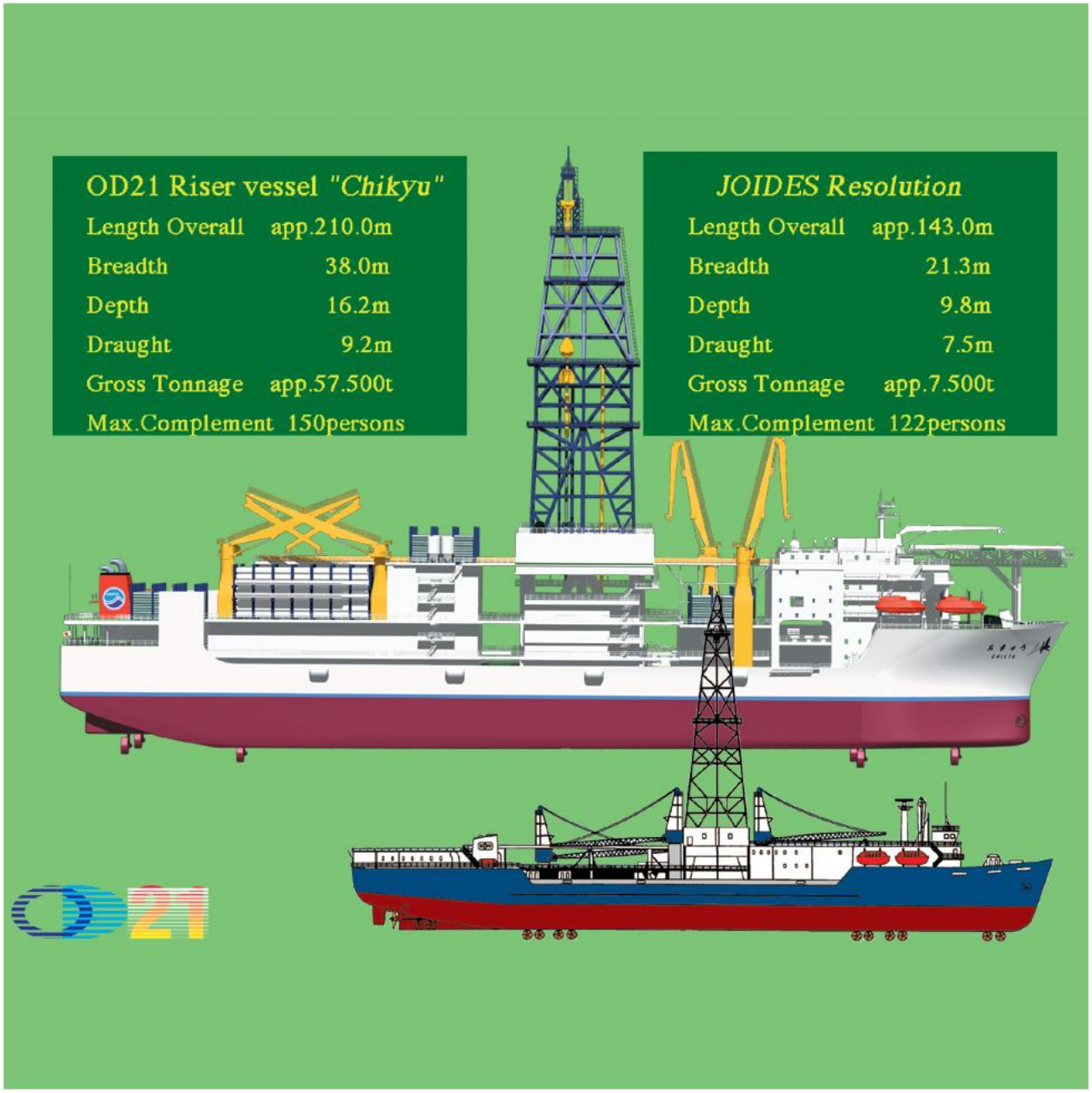
(by USIO)



(by USIO)


(by USIO)

Chikyu *vs.* JR

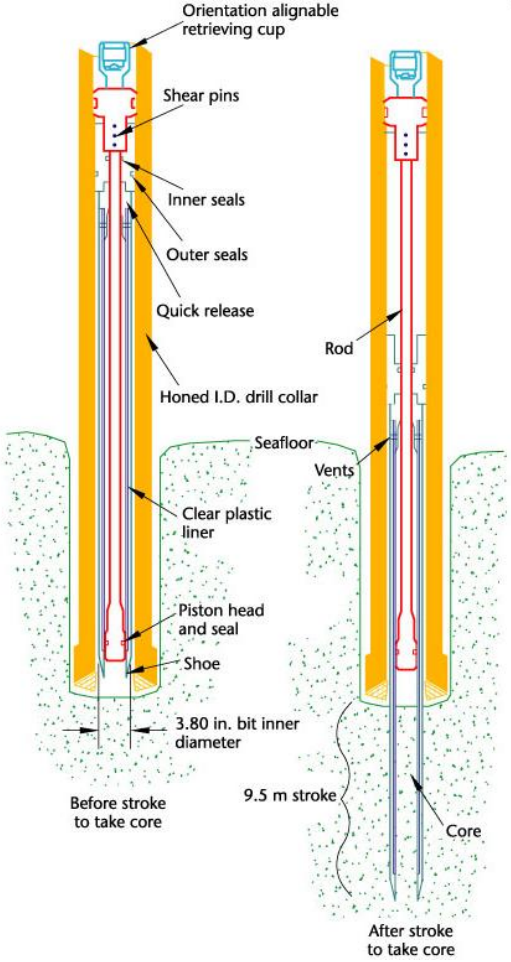


最大掘削深度

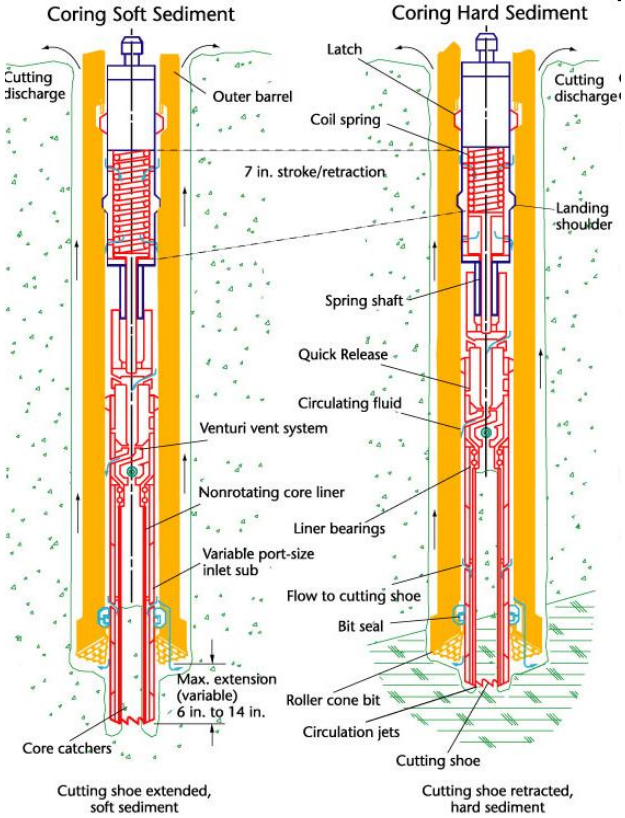
7000m

2111m

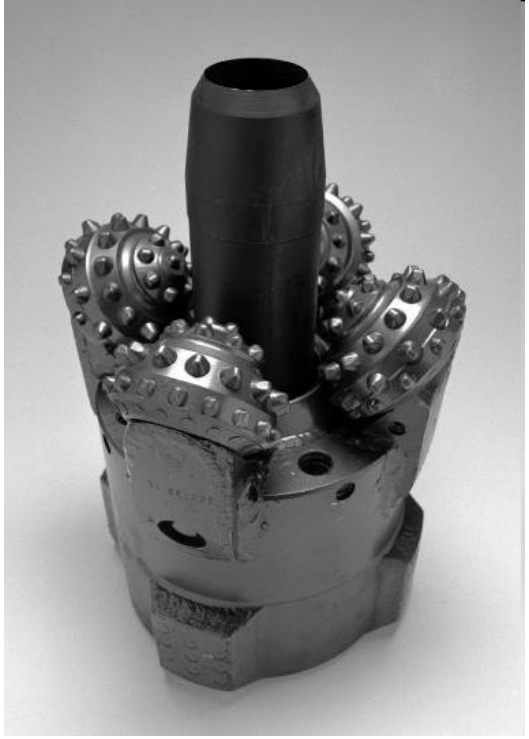
by JAMSTEC



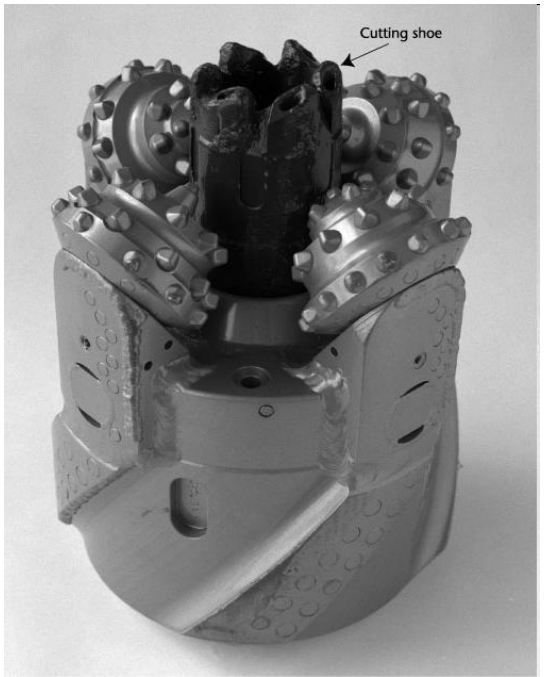
APC



XCB



APC



XCB

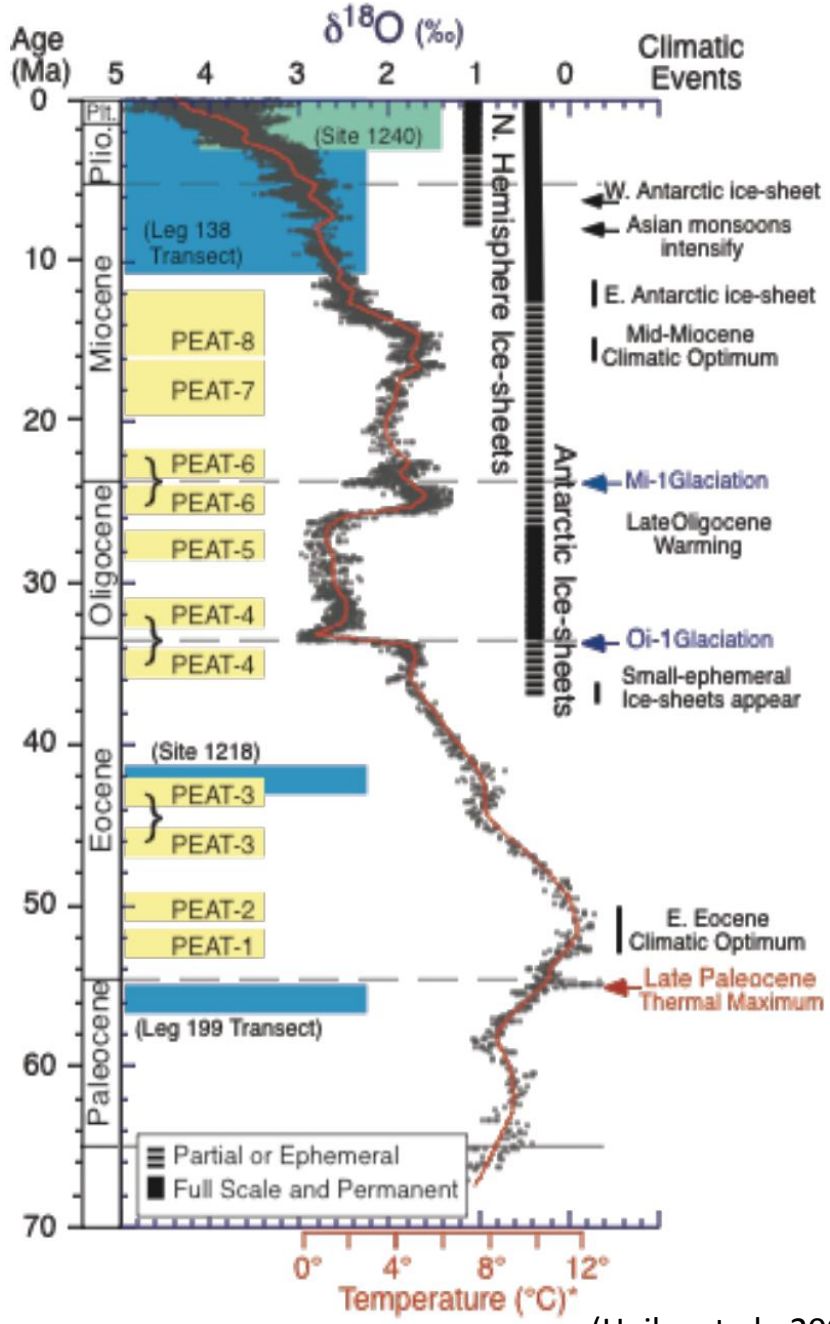
Fig. PC piston shoe extending through APC/XCB bit.
APC: advanced piston corer, RCB: Rotary core barrel, XCB: extended core barrel

(by USIO)

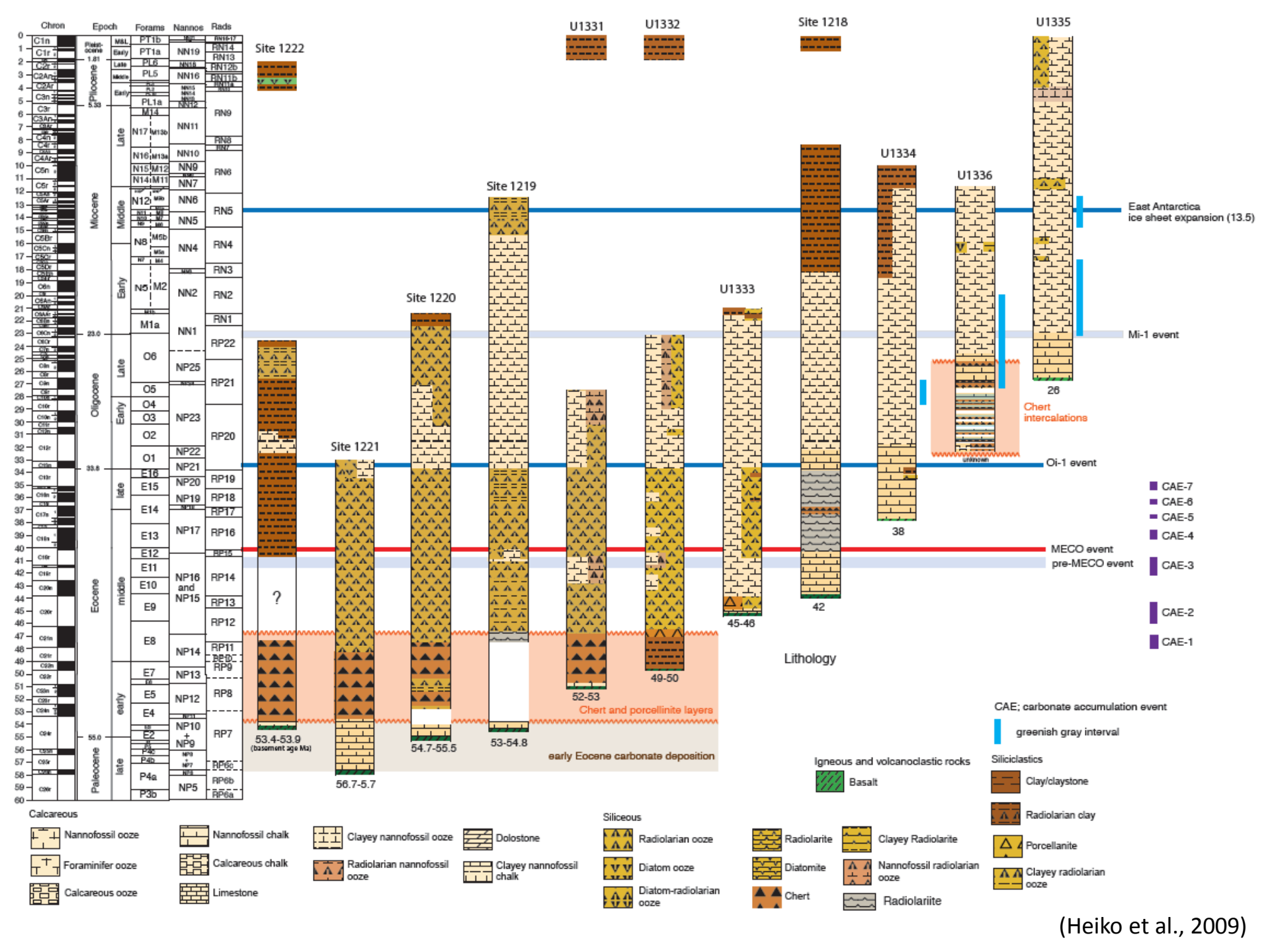

TREVOR
ACETONE


95 cm
WHITEST POSS.
EP SAMPLES 10 cm APART
PLS USE THIS
ORDER
CLINGWRAP

- Early Eocene climatic optimum.
- Middle Eocene (little high-resolution data for detailed time scales and hunt for PETM like events); interaction between carbonate and silicous deposits.
- Eocene/Oligocene transition, including first "two-step" lock-step change in $\delta^{18}O$ and CCD.
- Pre-Oligocene transition.
- late Oligocene climatic evolution.
- Oligocene/Miocene biotic turnover.
- Mid-Miocene climatic optimum
- Early Miocene carbon cycle.
- Targets Oligocene/Miocene boundary and subsequent events includes the "Mi-1" glacial events, on a background of strong ~400 kyr eccentricity cycles in $\delta^{18}O$ and $\delta^{13}C$.
- Recovery of mid-Miocene climatic optimum, and formation of East Antarctic ice-sheet.

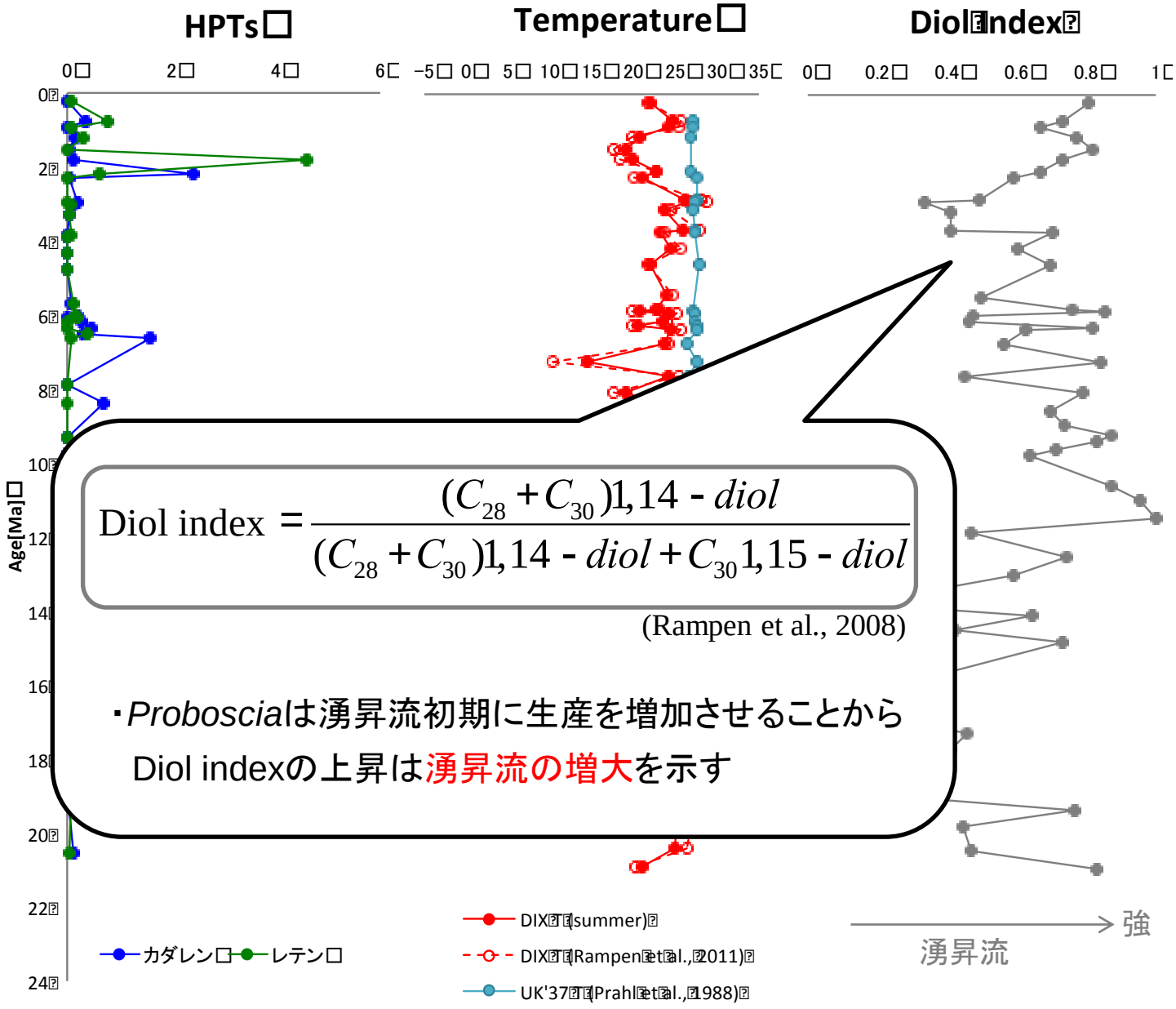


(Heiko et al., 2009)



(Heiko et al., 2009)

Discussion 赤道太平洋コア中のHPTと古水温変動



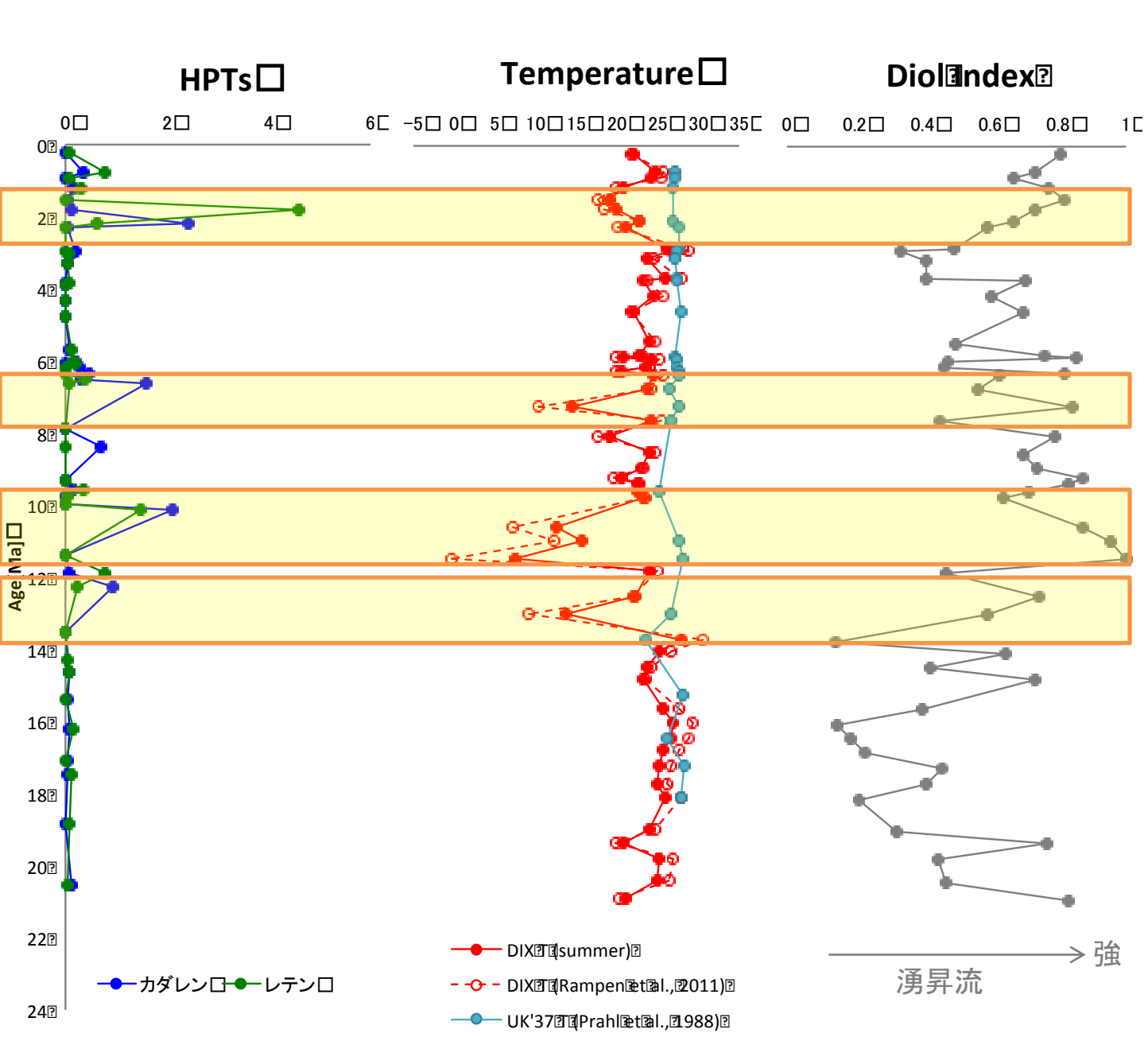
$$\text{Diol index} = \frac{(C_{28}+C_{30})1,14\text{-}diol}{(C_{28}+C_{30})1,14\text{-}diol + C_{30}1,15\text{-}diol}$$

(Rampen et al., 2008)

・*Proboscia*は湧昇流初期に生産を増加させることから
Diol indexの上昇は湧昇流の増大を示す

(小林, 沢田. 未公表データ)

Discussion 赤道太平洋コア中のHPTと古水温変動



HPTの増加
水温の低下
湧昇流の増大

←2-3Ma
…NHG
（北半球に氷床発達）

←7Ma
…風成循環の強化

←13.5Ma
…南極氷床の拡大

(小林, 沢田. 未公表データ)

参考文献

- Bice, K.L., B.T. Huber, and R.D. Norris., Extreme polar warmth during the Cretaceous greenhouse?: Paradox of the Late Turonian δ18O record at DSDP Site 511. *Paleoceanography* 18:1029/2002PA000848, 2003.
- M. H. Conte, A. Thompson, and G. Eglinton, Primary production of lipid biomarker compounds by *Emiliania huxleyi*: Results from an experimental mesocosm study in fjords of southwestern Norway, *Sarsia*, *79*, 319-331, 1994.
- Huber, B.T., R.D. Norris, and K.G. MacLeod., Deep-sea paleotemperature record of extreme warmth during the Cretaceous. *Geology* 30:pp. 123–126, 2002.
- Jenkyns, H.C., A. Forster, S. Schouten, and J.S. Sinninghe Damsté., High temperatures in the Late Cretaceous Arctic Ocean, *Nature* 432, pp. 888–892, 2004.
- Prahl F. G., Muehlhausen L. A., and Zahnle D. L., Further evaluation of long-chain alkenones as indicators of paleoceanographic conditions, Geochimica et Cosmochimica Acta, vol. 52, Issue 9, pp.2303-2310, 1988.
- Prahl and Wakeham, Calibration of unsaturation patterns in long-chain ketone compositions for palaeotemperature assessment, *Nature* 330, 367 – 369, 1987.
- Rampen, Sebastiaan W. Schouten, Stefan Koning, Erica Brummer, Geert-Jan A. Sinninghe Damsté, Jaap S., A 90 kyr upwelling record from the northwestern Indian Ocean using a novel long-chain diol index, Earth and Planetary Science Letters, Volume 276, Issue 1-2, pp. 207-213, 2008.

参考文献

- Rampen, Sebastiaan W., Stefan Schouten, Ellen C. Hopmans, Ben Abbas, Anna A.M. Noordeloos, Judith D.L. van Bleijswijk, Jan A.J. Geenevasen, Jaap S. Sinninghe Damsté, Diatoms as a source for 4-desmethyl-23,24-dimethyl steroids in sediments and petroleum, 2009.
- Rampen, Sebastiaan W., Stefan Schouten, Jaap S. Sinninghe Damsté, Occurrence of long chain 1,14-diols in *Apedinella radians, Org. Geochem.* 42 Volume 42, issue 5, pp. 572–574. 2011.
- Sawada, K. and Handa, N., Variability of the path of the Kuroshio ocean current over the past 25,000 years. *Nature*, 392, 592-595, 1998.
- Schouten S., Hopmans E.C., Schefusz E., and Sinninghe Damste J.S., Distributional variations in marine crenarchaeotal membrane lipids: a new tool for reconstructing ancient sea water temperatures?, Earth and Planetary Science Letters, Vol. 204, Issue 1-2, pp. 265-274. 2002.
- Sinninghe Damsté J.S., Kuypers M.M.M., Schouten S., Schulte S., Rullkötter J., The lycopane / C31 n-alkane ratio as a proxy to assess palaeoxicity during sediment deposition. Earth and Planetary Science Letters 209, pp. 215-226, 2003.
- Sluijs, A., Schouten, S., Pagani, M., Woltering, M., Brinkhuis, H., Sinninghe Damsté, J.S., Dickens, G.R., Huber Matthew, Reichart G.-J., Stein R., Matthiessen J., Lourens L.J., Pedentchouk N., Backman J., Moran K., Subtropical Arctic Ocean temperatures during the Palaeocene/Eocene thermal maximum. Nature. 441, pp. 610–613. 2006.

参考文献

- Takashima R., Nishi H., Huber B.T., and Reckie M., Greenhouse world and the Mesozoic ocean, Oceanography Vol. 19, No. 4, 2006.
- Versteegh G. J. M., Bosch H.-J., and De Leeuw J. W., Potential palaeoenvironmental information of C24 to C30 mid-chain diols, keto-ols and mid-chain hydroxy fatty acids; A critical review. *Org. Geochem.* 27, pp. 1–13. 1997.
- Volkman J. K., Barrett S. M., Dunstan G. A., and Jeffrey S. W., C30–C32 alkyl diols and unsaturated alcohols in microalgae of the class Eustigmatophyceae. *Org. Geochem.* 18**,** pp. 131–138, 1992.
- K. G. Zink, D. Leythaeuser, M. Melkonian, and L. Schwark., Temperature dependency of long-chain alkenone distributions in recent to fossil limnic sediments and in lake waters 1, Geochimica et Cosmochimica Acta, vol. 65, Issue 2, pp.253-265, 2001.