

Supplementary Material

for

Mass occurrence of echinoids in an Oligocene hydrocarbon-seep limestone from the Olympic Peninsula, Washington State, USA

Sandro P. Müller¹, Andreas Kroh², Daniel Birgel¹, James L. Goedert³, Steffen Kiel⁴, Jörn Peckmann¹

¹Institute for Geology, Center for Earth System Research and Sustainability, Universität Hamburg, 20146 Hamburg, Germany

²Natural History Museum Vienna, Geological-Palaeontological Department, 1010 Vienna, Austria

³Burke Museum of Natural History and Culture, University of Washington, Seattle, Washington 98195, USA

⁴Swedish Museum of Natural History, Department of Palaeobiology, 10405, Stockholm, Sweden

Supplementary Table S1 Biomarker inventory of the Bullman Creek echinoid seep deposit – Hydrocarbon fraction

Compound	Peak area (%)	$\delta^{13}\text{C}$ (‰)	Putative source	Precursor lipid
phytane + crocetane	45.4	-103	ANME	archaeol derivatives/ unsaturated crocetenes
PMI	9.3	-106	ANME	unsaturated PMIs
pristane	5.3	-86	ANME, Algae	archaeol, α -tocopherol, chlorophyll
acyclic biphytane	2.2	-97	ANME	GDGT-0, possibly cyclic GDGTs
monocyclic biphytane	0.5	n.m.	ANME	GDGT-1, -2
bicyclic biphytane	0.4	n.m.	ANME	GDGT-3
<i>n</i> -C ₁₆	2.0	n.m.	Algae	short-chain fatty acids
<i>n</i> -C ₁₇	1.5	n.m.	Algae, Cyanobacteria	heptadecenes, short-chain fatty acids
<i>n</i> -C ₂₃	1.3	-66	JS1?, unknown Bacteria	tricosenes
5 β (H)-Cholestane (20 <i>S</i>)	0.5	n.m.	Algae, Animals	cholesterol
5 β (H)-Ergostane	0.6	n.m.	?	?
5 α (H)-Ergostane	1.4	n.m.	Microalgae, Fungi	brassicasterol, ergostol
5 β (H)-Stigmastane	0.6	n.m.	?	?
5 α (H)-Stigmastane	2.5	-27	Microalgae, land plants	sitosterol
lanostane	0.7	n.m.	MOB	lanosterol, 4-methyl sterols
17 α (H),21 β (H)- <i>nor</i> -C ₃₀ -hopane	0.6	n.m.	Bacteria	C ₃₀ -hopenes
17 α (H),21 β (H)-C ₃₀ -hopane	0.9	-60	MOB?, Bacteria	BHPs
17 α (H),21 β (H)-C ₃₁ -hopane (22 <i>S</i>)	0.2	n.m.	Bacteria	BHPs
17 α (H),21 β (H)-C ₃₁ -hopane (22 <i>R</i>)	0.3	n.m.	Bacteria	BHPs
17 α (H),21 β (H)-C ₃₅ -hopane (22 <i>R</i>)	0.5	n.m.	Bacteria	BHPs
oleanane	0.9	n.m.	Land plants	taraxerol
gammacerane	0.4	n.m.	MOB, ciliates	tetrahymanol

ANME – anaerobic methane-oxidising archaea; *BHPs* – bacteriohopanepolyols; *GDGT* – glycerol dibiphytanyl glycerol tetraether; *JS1* – ‘Atribacteria’ (candidate phylum of bacteria); *MOB* – aerobic methane-oxidising bacteria; *PMI* – 2,6,10,15,19-pentamethylcosane; *n.m.* – not measured.

Supplementary Table S2 Biomarker inventory of the Bullman Creek echinoid seep deposit – Fatty acid fraction

Compound	Peak area (%)	$\delta^{13}\text{C}$ (‰)	Putative source	Precursor lipid
phytanoic acid	13.8	-97	ANME	archaeol
PMI acid	0.4	n.m.	halophilic (methanotrophic) Archaea	extended hydroxyarchaeol
<i>n</i> -C ₈₋₁₃ acid	1.5*	-36**	diverse marine sources	?
<i>n</i> -C ₁₄ acid	5.4	-59	SRB, diverse marine sources	MAGEs, DAGEs, fatty acids
<i>n</i> -C ₁₅ acid	3.0	-60	SRB, diverse marine sources	MAGEs, DAGEs, fatty acids
<i>n</i> -C ₁₆ acid	13.9	-72	SRB, diverse marine sources	MAGEs, DAGEs, fatty acids
<i>n</i> -C ₁₇ acid	1.7	-64	SRB, diverse marine sources	MAGEs, DAGEs, fatty acids
<i>n</i> -C ₁₈ acid	3.3	-59	SRB, diverse marine sources	MAGEs, DAGEs, fatty acids
<i>n</i> -C ₁₉₋₃₂ acid	1.2*	-34***	diverse marine sources, land plants	?
<i>iso</i> -C ₁₄ acid	1.4	-63	SRB, Bacteria	MAGEs, DAGEs, fatty acids
<i>anteiso</i> -C ₁₄ acid	0.3	n.m.	SRB, Bacteria, Eukaryota	MAGEs, DAGEs, fatty acids
<i>iso</i> -C ₁₅ acid	5.0	-72	SRB, Bacteria	MAGEs, DAGEs, fatty acids
<i>anteiso</i> -C ₁₅ acid	3.9	-79	SRB	MAGEs, DAGEs, fatty acids
<i>iso</i> -C ₁₆ acid	1.1	-68	SRB, Bacteria	MAGEs, DAGEs, fatty acids
<i>anteiso</i> -C ₁₆ acid	0.4	n.m.	SRB, Bacteria, Eukaryota	MAGEs, DAGEs, fatty acids
<i>iso</i> -C ₁₇ acid	1.4	n.m.	SRB, Bacteria	MAGEs, DAGEs, fatty acids
<i>anteiso</i> -C ₁₇ acid	0.9	n.m.	SRB, Bacteria, Eukaryota	MAGEs, DAGEs, fatty acids
17 α (H),21 β (H)-C ₃₂ -hopanoic (22 <i>R</i>) acid	1.3	-62	MOB?, Bacteria	BHPs
17 β (H),21 α (H)-C ₃₂ -hopanoic (22 <i>R</i>) acid	0.3	n.m.	Bacteria	BHPs
17 β (H),21 β (H)-C ₃₂ -hopanoic (22 <i>R</i>) acid	0.8	n.m.	Bacteria	BHPs

* mean value; ** mean value for C₁₁-C₁₃; *** Mean value for even-length C₂₀-C₃₀; ANME – anaerobic methane-oxidising archaea; BHPs – bacteriohopanepolyols; DAGE – dialkyl glycerol ether; MAGE – monoalkyl glycerol ether; MOB – aerobic methane-oxidising bacteria; PMI – 3,7,11,15,19-pentamethylcosane; SRB – sulphate-reducing bacteria; n.m. – not measured.