Heat flow of the Norwegian continental shelf

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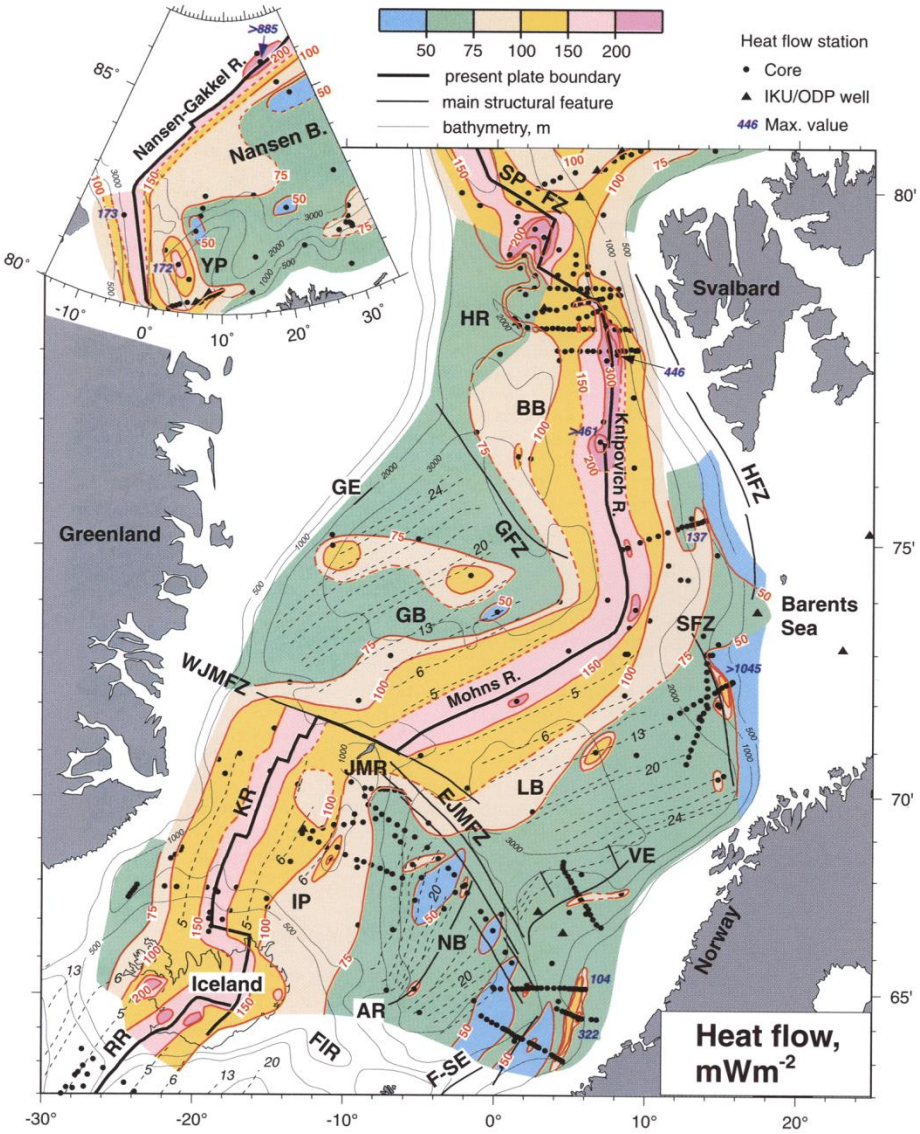
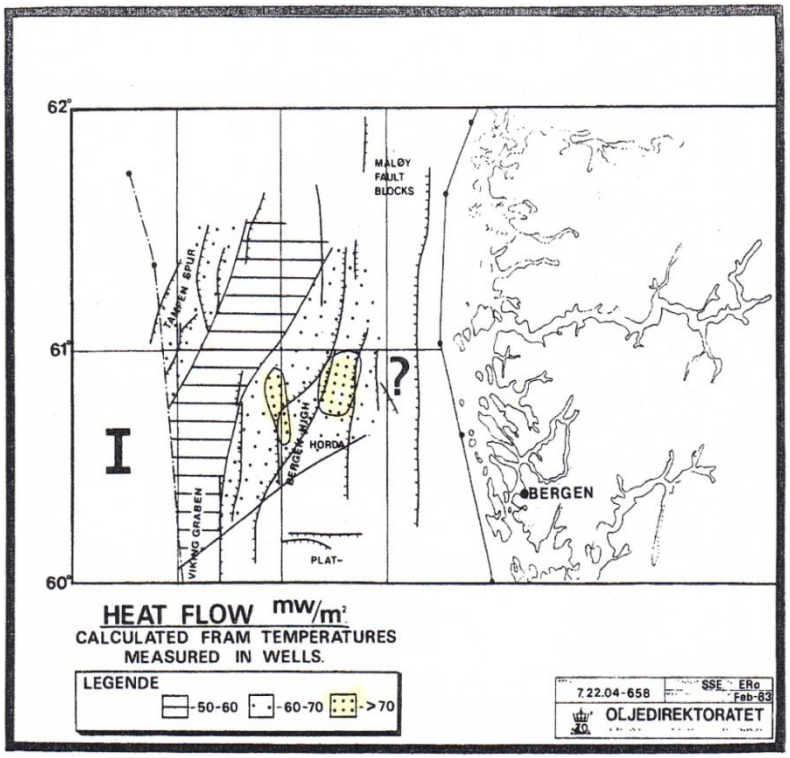


Marine heat flow data compilation
(Sundvor et al. 2000)



Heat flows derived from exploration well data
in the North Sea (Eggen 1984)

1) Heat flow determinations from deep exploration drillholes have been published (from the North Sea) but unfortunately we do not know what holes have been used.

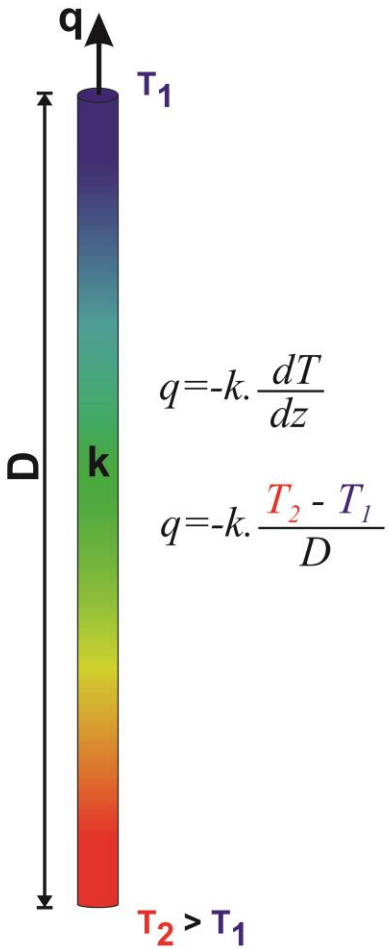
2) Marine heat flow data are available but unfortunately restricted to deep waters.

3) Comparison of data gathered using contrasting methods is always problematic (the classical fruit salad problem: do you prefer oranges or apples?).

A new heat flow study covering as much as possible all the continental shelf of Norway and using a consistent approach was definitively needed!

Heat flow determination

Theroretical problem



$$q = -k.\frac{dT}{dz}$$

$$q = -k.\frac{T_2 - T_1}{D}$$

Practically speaking...

T_1 = surface temp.
T_2 = temp. measured in the well
D = depth to measurement point

k = k(Φ, rock matrix litho, T)

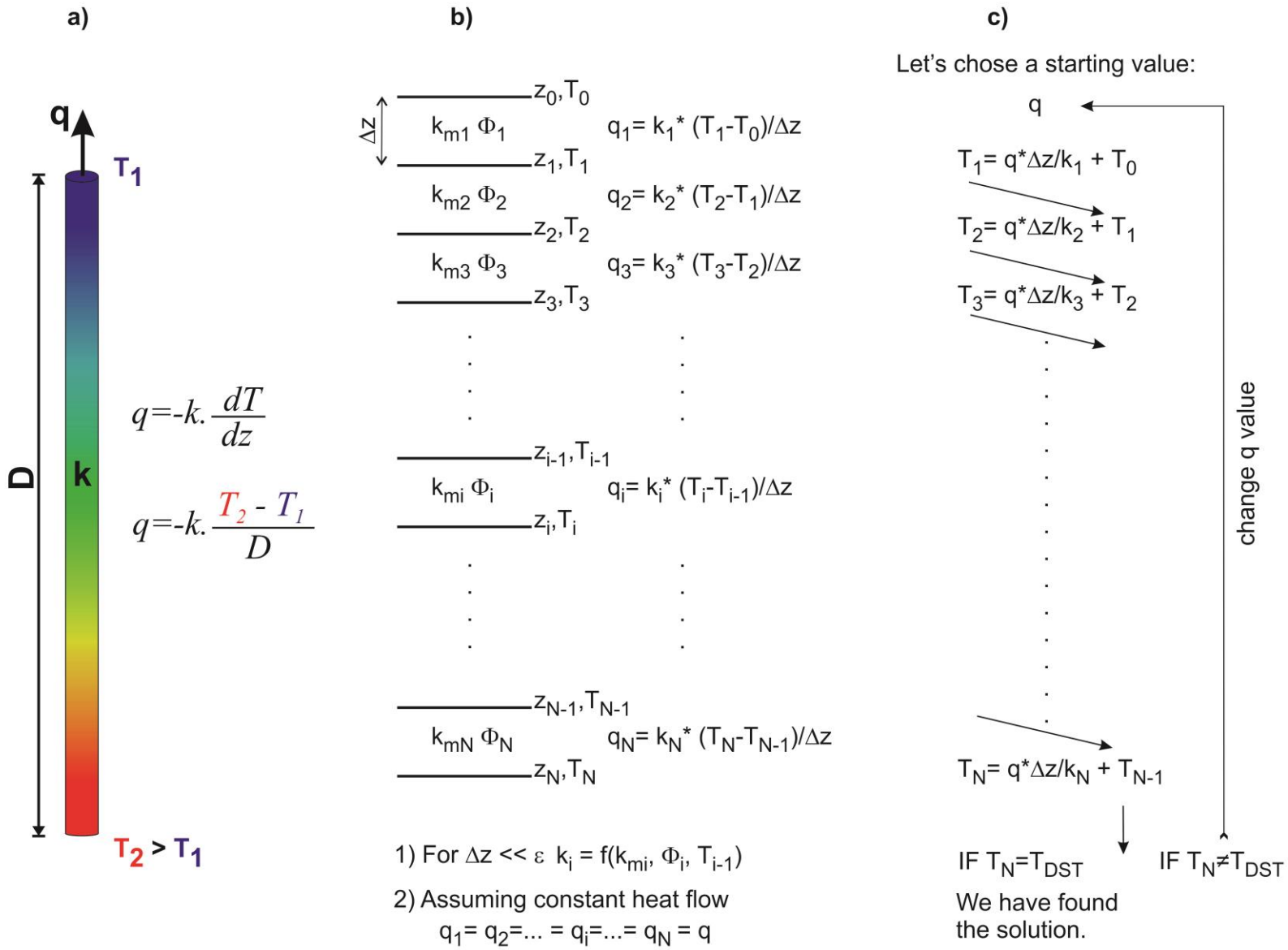
Sclater & Christie's laws (potentially adapted) → Φ

Fine description of drill cuttings → rock matrix litho

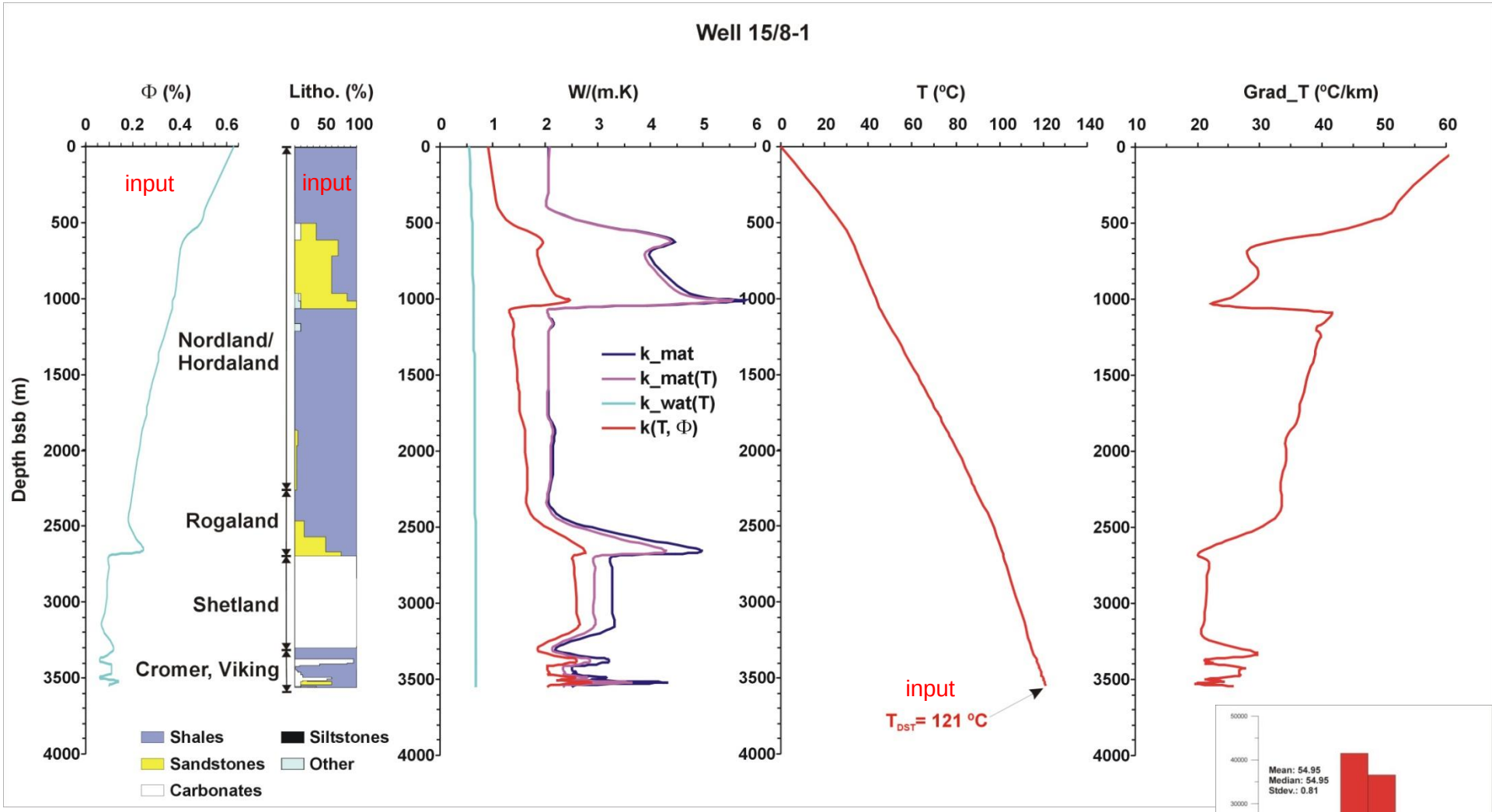
And last but not least: thermal conductivities of rock matrix lithologies are taken from Brigaud et al. (1992).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
	Well	x_ED50	y_ED50	UTM Zone	deepest form	TVD	KB	Wdepth	Depth b sb	BHT	DST	~TVD	Depth b.s.b	Depth b.s.l.	TDST	In all ~1400 wells visited!!				
0	6406/2-1 R	386574.4	7196390.67	32	ÅRE FM	5790	22	278	5490	194	y	5214	4914	5192	175	Six more DST temps (on front page only)				
1	6406/2-2	384741	7191848.6	32	ÅRE FM	5351	24	272	5055	183	y	4730	4434	4706	168	Litho in report (missing most of Naust Fm ~Sh)!! And another DST				
2	6406/2-3	377806.7	7208685.6	32	ÅRE FM	5256	24	372	4860	188	y	4820	4424	4796	167	Litho in report!! And another DST				
3	6406/2-4 SR	383212.3	7188560.78	32	ÅRE FM	5080	23	274	4783	177	y	4889	4592	4866	168	Litho in report!! And another DST but ~100 m dev. At bottom hole				
4	6406/2-5A	379444.9	7203444.56	32	ÅRE FM	5438	23	341	5074	190	y	4704	4340	4681	170	Litho in report!! But DST from sidetrack				
5	6406/2-6	375445.8	7184316.92	32	ÅRE FM	5257	23	302	4932	177	n					Litho in report!!				
6	6406/2-7	373929.1	7193415.64	32	TILJE FM	4977	24	293	4660	177	y	4565	4248	4541	164	DST temp on frontpage only! Litho in report				
7	6406/3-1	396410.1	7183474.26	32	LATE TRIASSIC	4896	22	256	4618	160	y	3785	3507	3763	140	Litho in report!!				
8	6406/3-2	397207.6	7195126.91	32	ÅRE FM	4522	22	300	4200	160	y	4319	3997	4297	146	Litho in report!! And another DST				
9	6406/3-3	400545.3	7209958.99	32	ÅRE FM	4416	29	302	4085		y	4007	3676	3978	136	Litho in report!! And another DST				
0	6406/6-1	390653.8	7180531.71	32	TILJE FM	4708	25	243	4440		n					Litho in report!!				
1	6406/8-1	376765.3	7140372.6	32	ÅRE FM	4910	27	348	4535	172	y	4433	4058	4406	166	DST temp on frontpage only! Litho in report (part) but too many "OTHE				
2	6406/9-1	394862.1	7148739.49	32	ÅRE FM	5077	24	308	4745	184	y	5009	4677	4985	182	DST temp on frontpage only! And another DST				
3	6406/11-1 S	383011.3	7104524.7	32	LATE TRIASSIC	4131	26	315	3790	150	y	4043	3702	4017	141	Litho in report!! And 2 other DST; 50m dev. At BH				
4	6406/12-1 S	389379.2	7106932.34	32	MELKE FM	3891	23	329	3539	147	n					Litho in report!! 70 m dev. At BH				
5	6407/1-1	406849.9	7187528.6	32	NAUST FM	900	29	273	598	27	n					Litho in report!!				
6	6407/1-2	406877.1	7187495.23	32	LATE TRIASSIC	4558	29	273	4256	149	y	3664	3362	3635	135					
7	6407/1-3	407531.5	7195989.53	32	LATE TRIASSIC	4467	29	286	4152	140	y	3667	3352	3638	132	Litho partially in report!! And another DST				Note that comp
8	6407/1-4	406280.1	7194806.98	32	NOT FM	3805	25	286	3494	141	y	3690	3379	3665	136	DST temp on frontpage only!				Note that comp
9	6407/2-1	427977.3	7205942.44	32	LATE TRIASSIC	3869	33	266	3570	101	n					Litho in report!! (part)				Note that comp
0	6407/2-2	430730.8	7208716.22	32	LATE TRIASSIC	3351	26	258	3067	91	y	2480	2196	2454	91	Litho partially in report!!				Note that comp
1	6407/2-3	436877.8	7201913.99	32	ÅRE FM	3050	26	250	2774	104	y	2513	2237	2487	92	DST temp on frontpage only! Another DST + some litho				
2	6407/4-1	411212.8	7164900.01	32	ÅRE FM	4835	22	225	4588	157	n					Litho in report!!				
3	6407/5-1	426984.9	7165626.69	32	GARN FM	4303	23	221	4059	155	n					Litho in report!!				
4	6407/6-1	446258.7	7169163.29	32	LATE TRIASSIC	2895	27	226	2642	93	n					Litho in report!!				
5	6407/6-3	436571.6	7176849.07	32	ÅRE FM	3215	29	222	2964	98	y	2550	2299	2521	98	Litho in report!! And 2 other DST				
6	6407/6-5	436337.5	7169519.03	32	TILJE FM	2758	25	225	2508	111	n					Litho in report!!				
7	6407/7-1 S	413114.3	7129107.11	32	LATE TRIASSIC	3925	23	328	3574	138	y	3107	2741	3084	115	Litho in report!! And 4 other DST and dev log				
8	6407/7-2	411732.2	7127130.16	32	LATE TRIASSIC	3320	23	338	2959	125	y	2826	2465	2803	113	This is a production test temp., two other DST				
9	6407/7-3	410422.7	7129582.24	32	LATE TRIASSIC	3220	23	332	2865	99	y	3057	2702	3034	116	2 other DST				
0	6407/7-4	413943.2	7127595.36	32	ÅRE FM	3204	23	329	2852	92	y	3132	2780	3109	118	2 other DST				
1	6407/7-6	408271.7	7131389.98	32	ÅRE FM	3971	26	336	3609	148	y	3728	3366	3702	136	DST on frontpage only				
2	6407/9-1	441548.4	7138488.3	32	LATE TRIASSIC	2500	25	248	2227	75	y	1635	1362	1610	68	Litho in report!!				
3	6407/9-2	442297.2	7142349.8	32	TILJE FM	1865	25	247	1593	50	y	1638	1366	1613	67	Temp reported in Well Resume file p 65				
4	6407/9-4	438354.8	7139103.84	32	TILJE FM	1820	32	244	1544	48	y	1665	1389	1633	71	on front page,and p. 68 of completion report of 6407/9-6				
5	6407/10-3	417314.2	7109795.67	32	BASEMENT	2972	24	324	2624	87	n					Some litho in report				
6	6506/11-1	390662	7231229.82	32	ÅRE FM	4672	29	246	4397	148	y	3736	3461	3707	122	Hum, stability problems during DST?				
7	6506/11-2	388157.3	7217095.51	32	ÅRE FM	4806	23	297	4486	160	y	4686	4366	4663	160	Litho in report!! And 4 other DST				
8	6506/11-3	377273.8	7237146.88	32	NOT FM	4346	24	328	3994	108	y	3132	2780	3108	108	Litho in report!!				
9	6506/11-4 S	387026.3	7214065.98	32	ÅRE FM	4907	22	303	4582	165	y	4856	4531	4834	163					
0	6506/11-6	378448.1	7213786.47	32	ÅRE FM	5273	23	380	4870	173	y	4844	4441	4821	173	Litho in report!! And 2 other DST; but on frontpage only; corrected for J				
1	6506/11-7	381477.2	7229792.83	32	ÅRE FM	4973	25	356	4592	175	y	4785	4404	4760	161	Litho in report!! And 2 other DST (but one aborted)				
2	6506/12-1	393591.7	7229359.52	32	ÅRE FM	4924	22	250	4652	156	y	4362	4090	4340	154	Litho in report!! And 7 DST; but on plots				
3	6506/12-3	400646.8	7213112.8	32	TILJE FM	4359	22	301	4036	130	y	4230	3907	4208	150	Litho in report!! And 5 other DST; but on frontpage only				
4	6506/12-4	393591.3	7234298.14	32	ÅRE FM	4455	25	257	4173	99	?	3141	2859	3116	106	Litho in report!! Not clear that it is DST temp!!!				
5	6506/12-5	404557.6	7214766.4	32	ÅRE FM	4587	29	301	4257	149	y	4032	3702	4003	141	Litho in report!! And 3 other DST				
6	6506/12-6	395911.3	7228967.74	32	ÅRE FM	4738	29	272	4437	167	y	4332	4031	4303	154	And 3 other DST				
7	6506/12-7	402108	7228966.15	32	TILJE FM	4840	29	267	4544	167	y	4744	4448	4715	164	And 2 other DST				
8	6506/12-8	403380.4	7212038.59	32	TILJE FM	4334	29	296	4009	134	y	4241	3916	4212	148	And 1 other DST				
9	6506/12-9 S	394568.5	7223265.37	32	ÅRE FM	4903	23	294	4586	166	y	4820	4503	4797	163	And 1 other DST but on frontpage only				

Compiled after oil industry reports available on npd.no
(63 drillholes were selected)



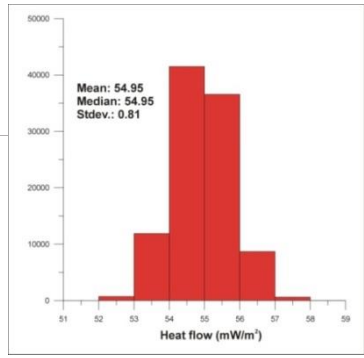
Pascal 2015, Mar. Pet. Geol.



Example of heat flow determination

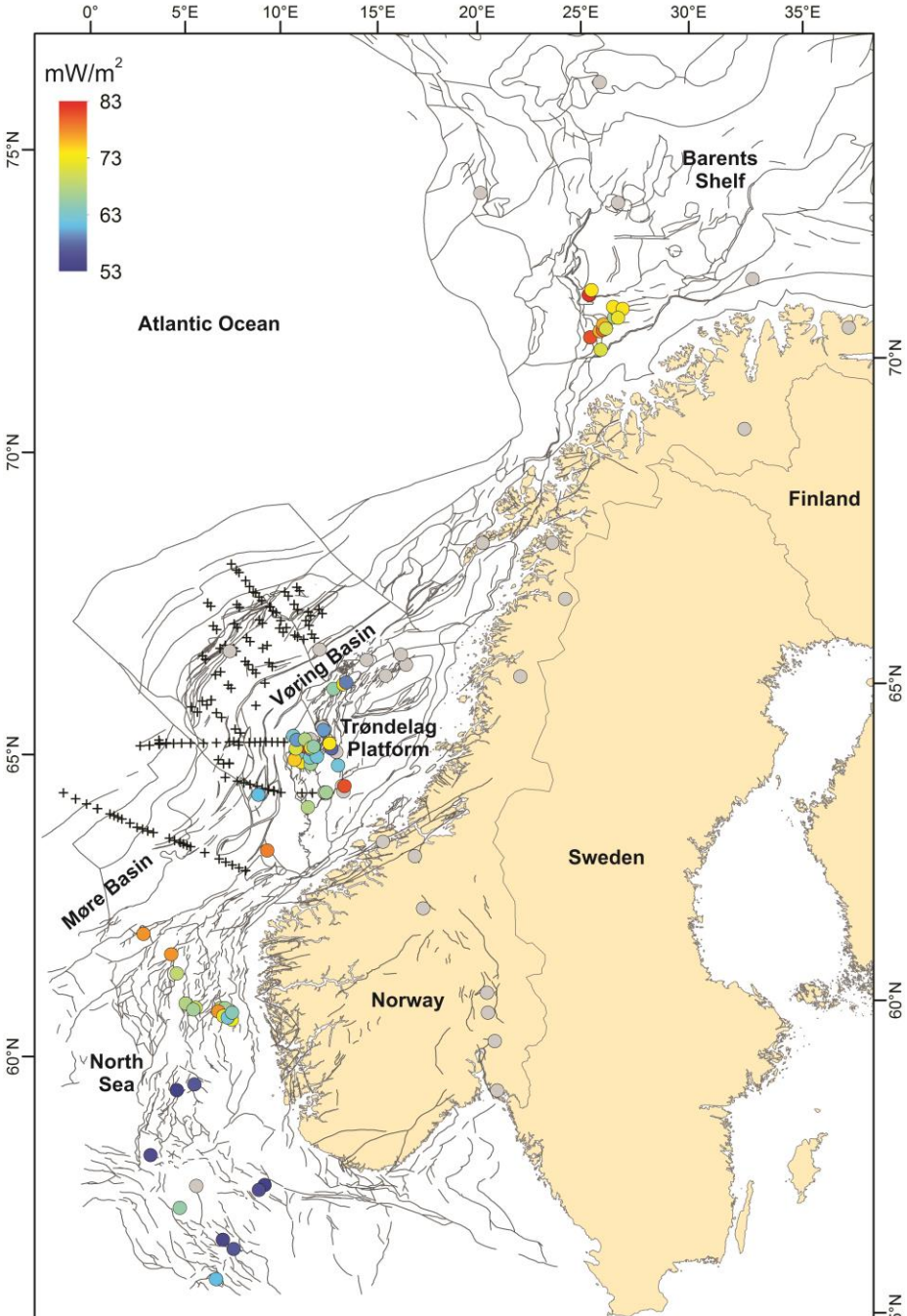
Pascal 2015, Mar. Pet. Geol.

Distribution of heat flow values:
10^5 Monte Carlo simulations

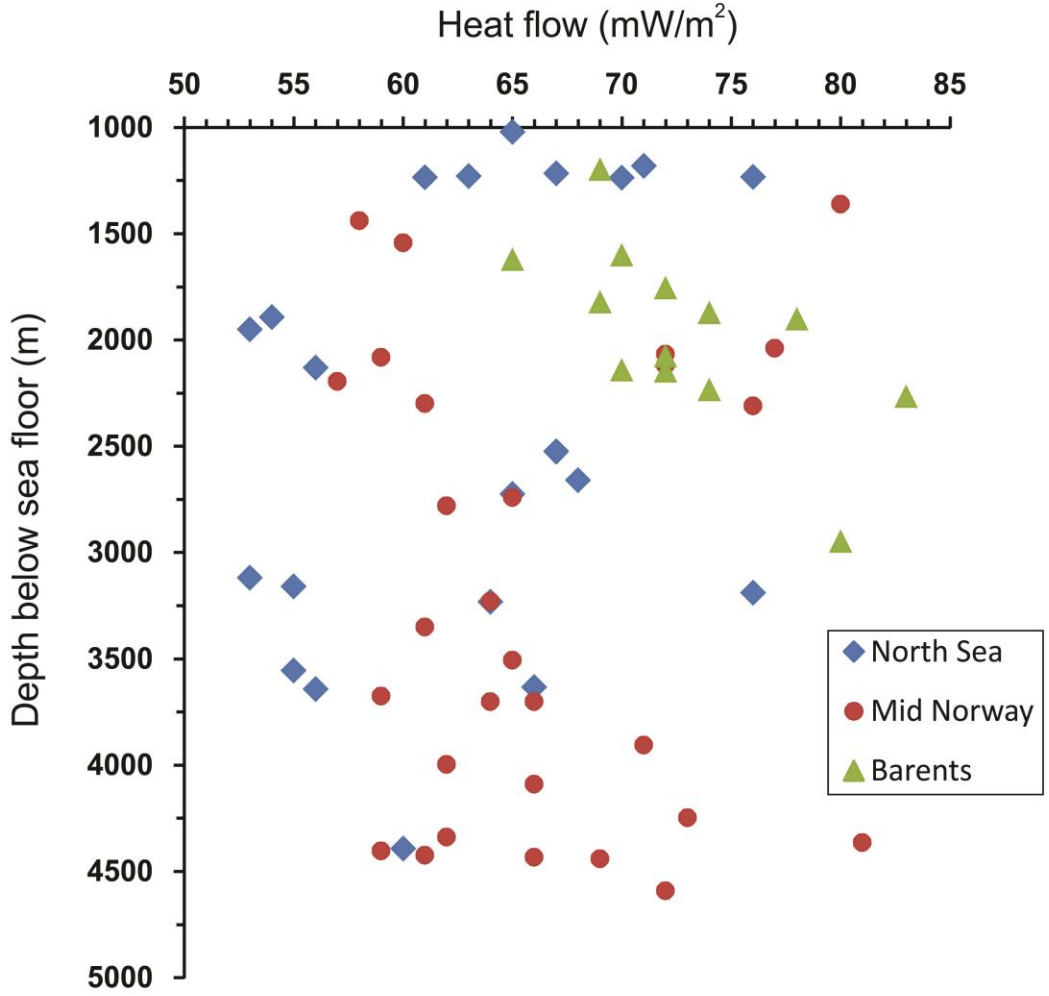


Heat flow of the Norwegian shelf

Calculated heat flows



Pascal 2015, Mar. Pet. Geol.

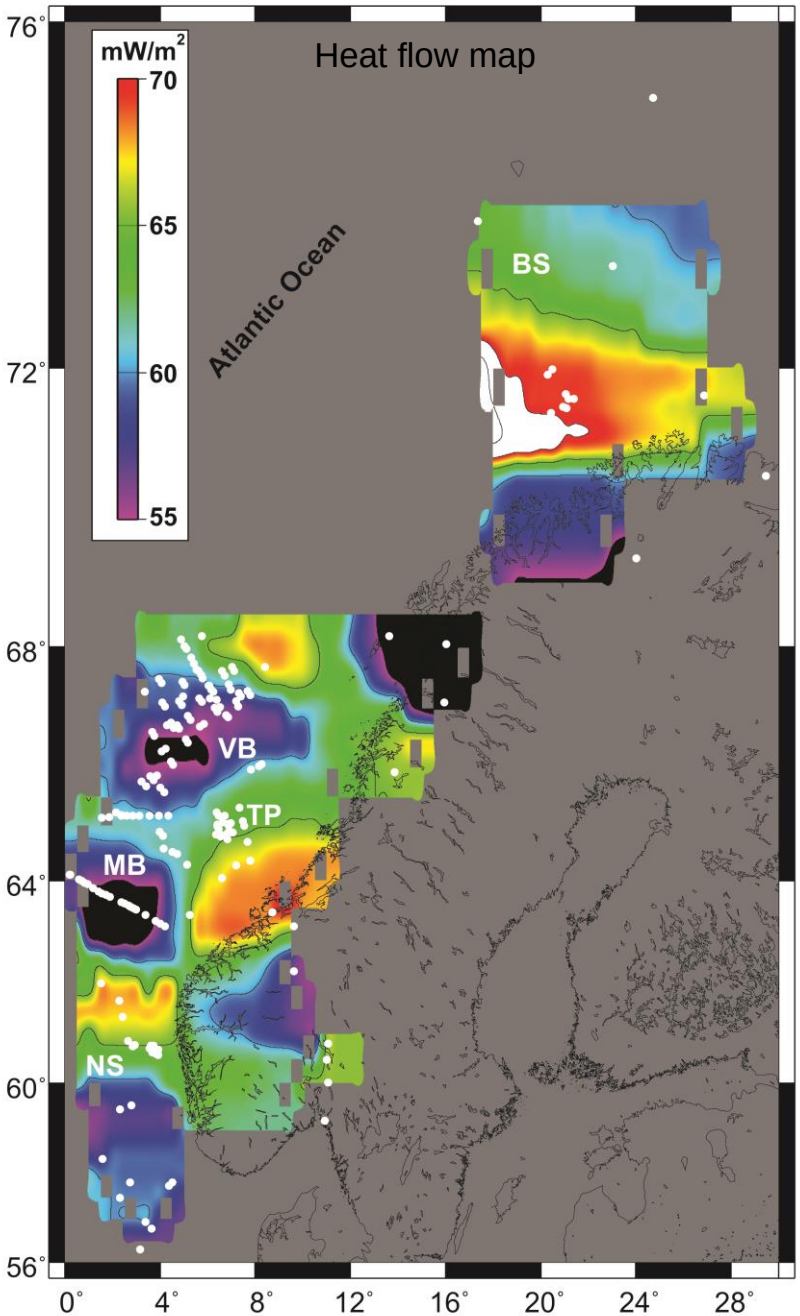


Median heat flows
North Sea: 64 mW/m²
Mid Norway: 65 mW/m²
Barents: 72 mW/m²

Estimated perturbation by Quaternary sedimentation/erosion: ± 4 to 10 mW/m²

Calculated heat flows

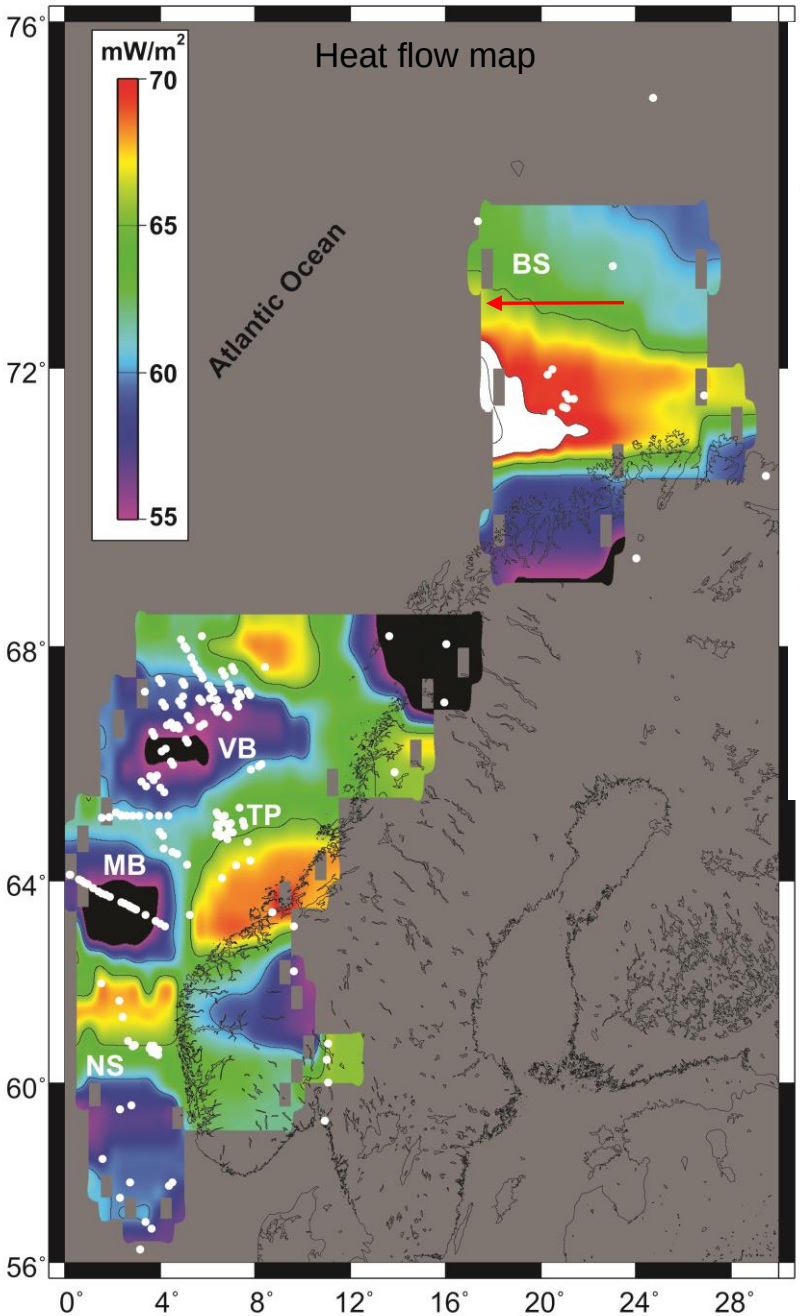
Pascal 2015, Mar. Pet. Geol.

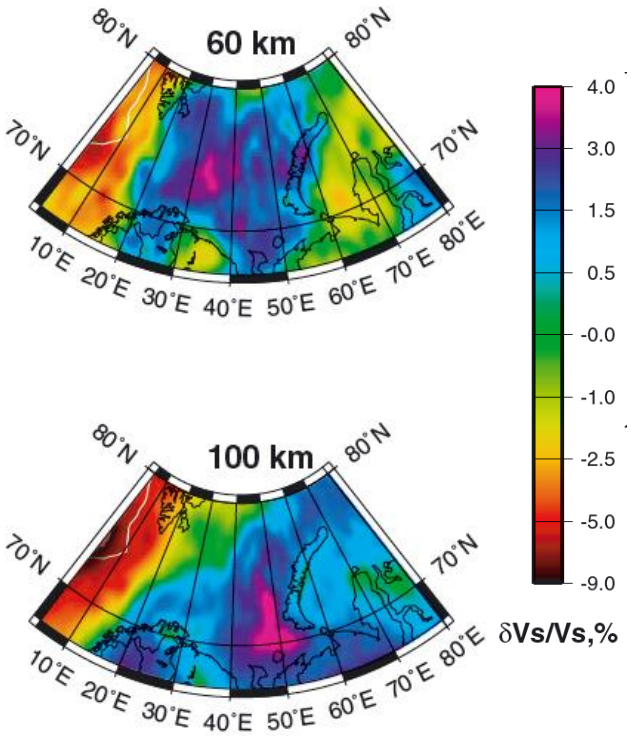


This study + published marine and onshore heat flow results + 5 shallow offshore drillholes.

Pascal 2015, Mar. Pet. Geol.

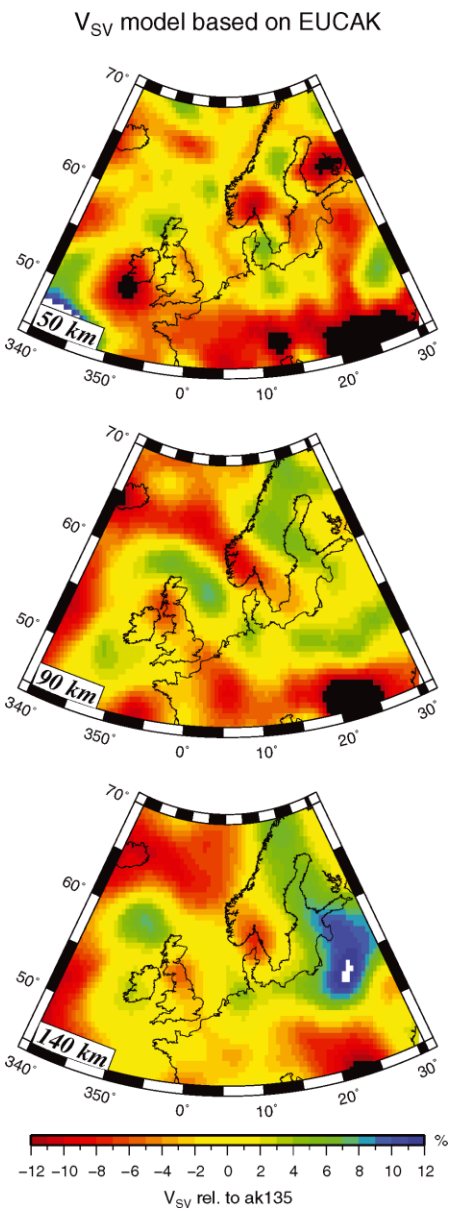
Heat flow of the Norwegian shelf



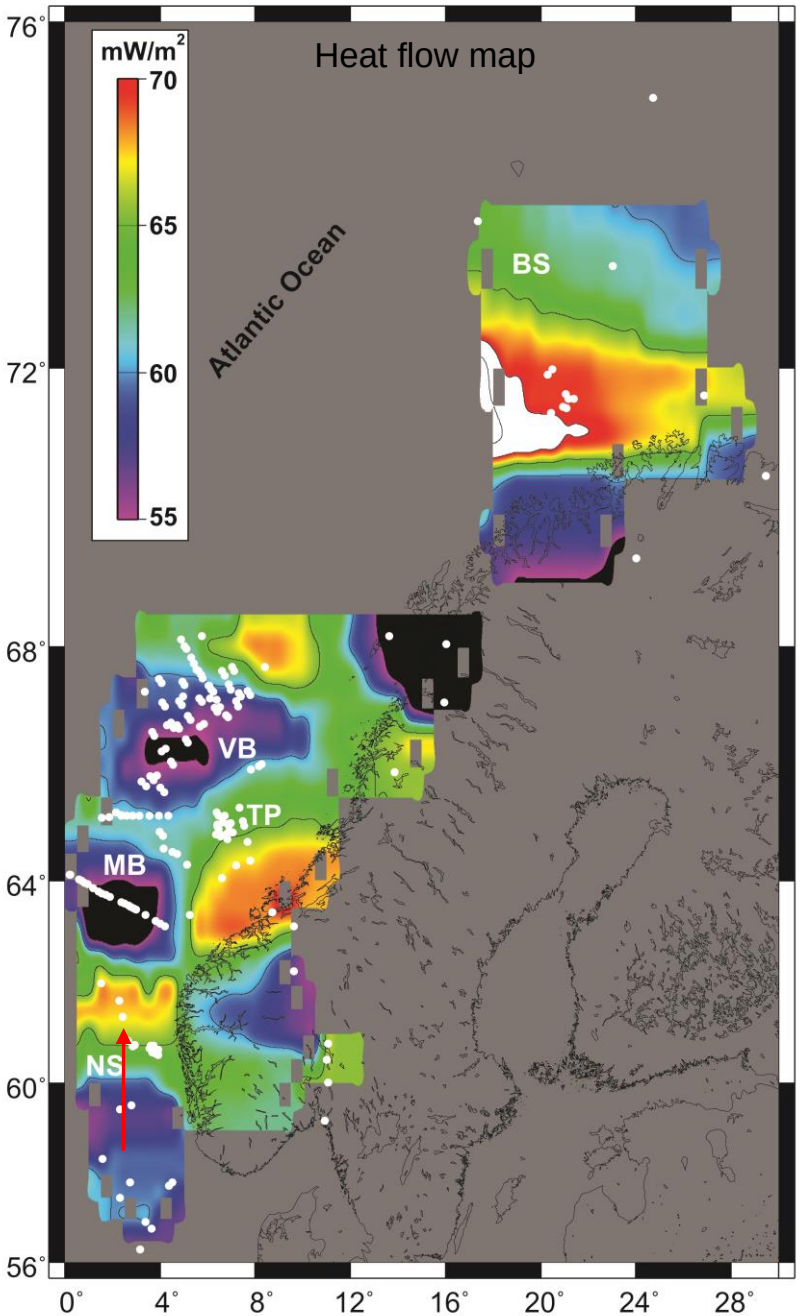


Levshin et al. (2007)

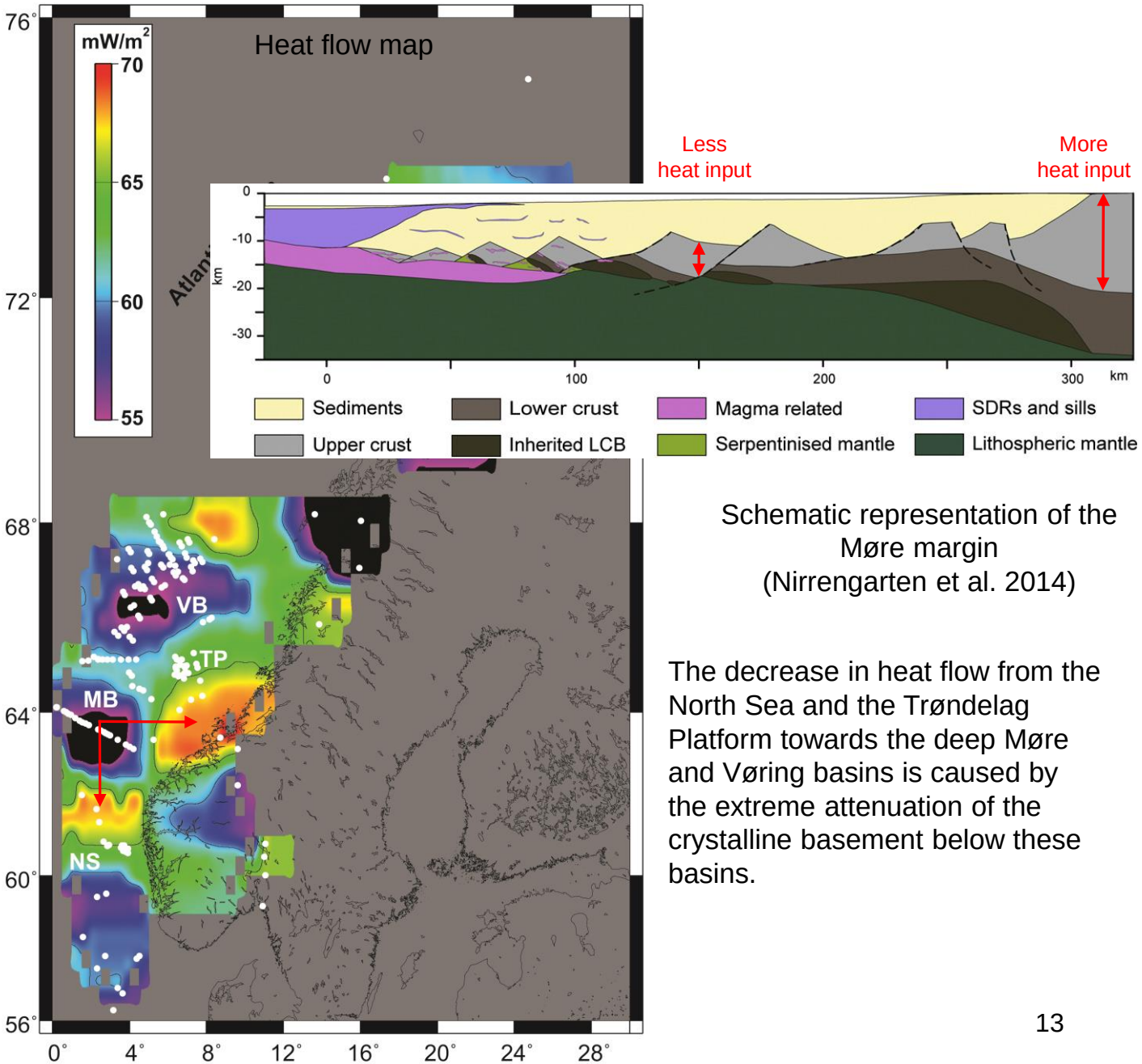
The relatively high heat flow of the SW Barents Shelf is due to lateral heat transfer from the warmer oceanic lithosphere.



Weidle and Maupin (2008)



The N-S increase in heat flow in the North Sea reflects gradual thinning of the lithosphere.



Schematic representation of the Møre margin (Nirrengarten et al. 2014)

The decrease in heat flow from the North Sea and the Trøndelag Platform towards the deep Møre and Vøring basins is caused by the extreme attenuation of the crystalline basement below these basins.

1) According to our results, median heat flow values are 64 mW/m^2, 65 mW/m^2 and 72 mW/m^2 for the North Sea, the Mid Norway Margin (Trøndelag Platform) and the SW Barents Shelf respectively.

2) Heat flow increases by ~ 10 mW/m^2 from the southern Norwegian North Sea towards the Mid Norway Margin.

3) Heat flow decreases from both the North Sea and the Trøndelag Platform towards the centres of the deep Møre and Vøring basins.

4) Heat flow in the SW Barents Shelf increases westwards.

Only 63 drillholes have been considered.

There is an enormous potential for improvements in quantity and quality if e-logs (e.g. porosity, shale fraction logs) and reports on measured BHT are made available!

THANK YOU FOR YOUR ATTENTION

Special thanks to Therese Rudlang (MSc 2011) and Khadija Darwich (MSc 2013), and to all sponsors and organisations that have supported this work.