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Title of article Tectonothermal Evolution of Contrasting Metamorphic Complexes in Northwest Spitzbergen (Biskayerhalvoya): Evidence from 49Ar/39Ar and Rb-Sr Mineral Ages

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Table 1. $^{40}Ar/^{39}Ar$ Analytical Data For Incremental Heating Experiments On Amphibole Concentrates From The Richarddalen Group And Montblanc Formation; Biskayerhalvøya, Spitsbergen, Svalbard.

Release temp (°C)	$(^{40}Ar/^{39}Ar)^*$	$(^{36}Ar/^{39}Ar)^*$	$(^{37}Ar/^{39}Ar)^c$	^{39}Ar % of total	%^{40}Ar non-atmos.$^+$	$^{36}Ar_{Ca}$ %	Apparent Age (Ma)**
				Montblanc Formation			
Sample 6A: J = 0.007653							
550	53.43	0.08870	4.733	2.78	51.65	1.45	346.6 ± 7.6
600	52.00	0.08043	2.378	1.65	54.65	0.80	355.5 ±13.3
625	62.29	0.08852	1.807	0.74	58.23	0.56	442.4 ±21.5
660	51.99	0.06388	3.528	1.05	64.22	1.50	411.3 ±23.6
695	42.85	0.02556	4.927	2.30	83.28	5.24	436.8 ± 7.2
725	40.93	0.02396	6.291	3.29	83.92	7.14	422.5 ± 3.8
750	39.20	0.01722	6.775	4.44	88.40	10.70	426.0 ± 5.3
775	39.52	0.01454	7.194	7.26	90.58	13.46	438.6 ± 3.8
800	37.25	0.00729	7.371	19.95	95.79	27.51	437.4 ± 1.2
825	37.01	0.00515	7.679	24.01	97.54	40.56	442.0 ± 1.6
850	43.75	0.02372	7.687	3.81	85.38	8.81	445.6 ± 3.1
875	37.57	0.00749	7.461	21.11	95.69	27.08	440.3 ± 1.2
900	43.37	0.02532	7.533	4.34	84.13	8.09	446.2 ± 5.2
Fusion	101.80	0.22359	7.504	3.26	35.68	0.91	444.4 ± 7.0
Total	41.41	0.02189	7.119	100.00	89.42	23.54	435.4 ± 3.2
Total without 550-750°C, 900°C and fusion				76.02			442.1 ± 2.3
Sample 8: J = 0.007882							
550	41.67	0.05959	5.309	4.55	58.75	2.42	319.3 ± 9.6
600	39.34	0.03560	1.837	3.20	73.62	1.40	371.3 ± 8.8
650	44.51	0.04715	1.904	2.61	69.03	1.10	391.6 ±11.6
700	40.63	0.01487	3.528	2.81	89.87	6.45	457.2 ± 8.8
725	37.30	0.00839	4.745	7.80	94.36	15.39	442.9 ± 2.7
750	37.44	0.00955	5.012	5.61	93.53	14.28	441.0 ± 3.4
775	36.27	0.00598	5.146	14.62	96.25	23.40	439.8 ± 1.8
800	36.14	0.00544	5.154	17.85	96.68	25.78	440.1 ± 3.1
825	35.32	0.00412	5.166	29.46	97.72	34.15	435.3 ± 1.1
850	37.39	0.00838	5.127	8.68	94.47	16.65	444.4 ± 3.9
875	51.80	0.05611	5.156	1.53	68.78	2.50	447.8 ±18.8
Fusion	61.94	0.09210	5.175	1.28	56.72	1.53	442.3 ±22.9
Total	37.46	0.01252	4.885	100.00	92.06	21.95	430.9 ± 3.7
Total without 550-700°C, 875°C and fusion				84.01			439.1 ± 2.2

Table 1. Continued (page 2).

Richarddalen Group

Sample 1: J = 0.007955

550	103.85	0.08888	3.763	0.92	74.99	1.15	871.5 ±20.9
600	56.33	0.07392	1.647	0.57	61.44	0.61	439.1 ±29.9
625	65.60	0.11783	3.131	0.40	47.30	0.72	398.7 ±33.8
660	56.48	0.05799	5.576	0.57	70.44	2.62	497.6 ±25.2
695	49.51	0.01831	4.868	3.20	89.85	7.23	548.0 ± 4.7
730	45.04	0.00569	3.876	17.39	96.94	18.52	538.9 ± 1.9
755	44.86	0.00572	3.660	15.74	96.87	17.40	536.7 ± 2.4
780	44.51	0.00482	3.561	24.65	97.43	20.11	535.8 ± 2.0
805	44.79	0.00535	3.583	14.32	97.10	18.23	537.1 ± 2.3
830	48.36	0.01497	3.608	4.85	91.44	6.56	544.9 ± 3.2
855	52.95	0.03210	3.525	4.71	82.61	2.99	539.7 ± 4.1
900	46.42	0.00934	3.520	6.83	94.65	10.25	541.8 ± 2.1
Fusion	52.72	0.03024	3.512	5.83	83.57	3.16	543.1 ± 4.5
Total	46.82	0.01111	3.672	100.00	94.22	15.13	540.3 ± 3.1
Total without 550-695°C				94.34			538.3 ± 2.4

Sample 2A: J = 0.007965

550	222.58	0.12637	2.972	0.48	83.33	0.64	1638.5 ±11.3
600	84.03	0.13141	2.522	0.27	54.02	0.52	557.5 ±50.2
625	176.84	0.46387	3.761	0.22	22.65	0.22	500.7 ±50.9
660	62.02	0.06710	4.529	0.45	68.61	1.84	527.8 ±23.6
695	43.84	0.01284	3.698	3.80	92.01	7.83	503.6 ± 5.5
720	42.15	0.00802	3.396	8.72	95.01	11.52	500.4 ± 2.6
740	41.93	0.00563	3.239	13.13	96.64	15.64	505.5 ± 1.6
760	41.91	0.00492	3.151	14.56	97.12	17.41	507.5 ± 1.6
780	41.88	0.00547	3.075	14.08	96.72	15.29	505.3 ± 2.1
800	42.40	0.00604	3.005	16.28	96.34	13.52	509.0 ± 1.6
820	43.63	0.00821	3.014	7.94	94.98	9.98	515.4 ± 4.3
840	45.16	0.01227	2.977	4.60	92.48	6.60	518.9 ± 5.4
860	48.37	0.02063	3.011	1.92	87.88	3.97	527.0 ± 7.3
880	46.55	0.01518	3.039	2.70	90.88	5.45	524.7 ± 7.7
900	47.37	0.01662	3.014	2.40	90.13	4.93	529.0 ± 6.1
Fusion	60.48	0.06029	2.936	8.44	70.92	1.32	531.1 ± 2.7
Total	45.68	0.01420	3.129	100.00	92.91	11.81	516.5 ± 3.2
Total without 550-695, 820-900°C and fusion				66.77			506.1 ± 2.1

Table 1. Continued (page 3).

Sample 5B: J = 0.007565

550	91.87	0.15467	2.176	0.57	50.44	0.38	542.8 ±30.2
600	91.49	0.17472	1.486	0.30	43.69	0.23	477.0 ±45.3
650	81.63	0.17676	4.308	0.41	36.43	0.66	366.9 ±77.0
685	61.66	0.07954	5.620	0.62	62.61	1.92	463.7 ±72.6
710	50.09	0.02590	4.188	1.83	85.38	4.40	506.8 ±13.9
730	45.20	0.00906	3.693	7.29	94.72	11.09	507.2 ± 2.3
750	43.87	0.00555	3.578	13.98	96.91	17.55	504.0 ± 2.9
765	43.84	0.00557	3.561	14.99	96.88	17.38	503.6 ± 2.3
780	43.76	0.00584	3.535	20.50	96.69	16.45	501.9 ± 1.9
800	43.71	0.00460	3.533	20.76	97.53	20.88	505.2 ± 1.5
820	44.25	0.00619	3.629	5.50	96.51	15.94	506.1 ± 5.5
840	44.75	0.00776	3.760	4.68	95.54	13.18	506.5 ± 4.5
865	44.73	0.00612	3.622	6.09	96.59	16.09	511.2 ± 3.9
890	49.89	0.02423	3.596	1.94	86.22	4.04	509.3 ±14.5
Fusion	60.06	0.05685	3.492	0.53	72.49	1.67	514.6 ±60.2
Total	45.02	0.00937	3.592	100.00	95.29	16.24	504.2 ± 4.3
Total without 550-710°C, 890°C, and fusion				93.80			504.7 ± 2.5

Sample 7: J = 0.007950

550	75.00	0.06793	2.542	1.33	73.50	1.02	656.5 ±17.5
600	60.77	0.08711	1.444	0.61	57.83	0.45	444.8 ±72.4
625	56.36	0.07912	2.165	0.43	58.81	0.74	422.4 ±71.5
675	53.97	0.06275	5.306	0.92	66.42	2.30	453.7 ±34.3
710	50.63	0.02443	5.879	2.41	86.67	6.55	541.6 ±11.8
730	47.50	0.01318	5.345	5.69	92.70	11.03	543.1 ± 5.7
750	47.39	0.01016	5.147	9.03	94.52	13.77	551.0 ± 2.0
765	46.73	0.00819	4.948	15.42	95.66	16.43	550.0 ± 2.2
780	47.26	0.00918	4.937	12.70	95.09	14.63	552.6 ± 3.1
800	47.32	0.00915	4.881	19.25	95.10	14.51	553.2 ± 2.2
820	47.85	0.01091	4.838	13.28	94.06	12.06	553.2 ± 2.5
840	47.92	0.00940	4.820	6.82	95.00	13.94	558.7 ± 5.9
860	48.72	0.01244	4.775	3.66	93.23	10.44	557.6 ± 4.9
880	51.98	0.02159	4.758	2.20	88.45	5.99	563.4 ± 8.1
Fusion	113.85	0.22150	4.742	6.24	42.84	0.58	592.7 ± 8.5
Total	52.28	0.02563	4.888	100.00	90.24	12.36	554.0 ± 4.9
Total without 550-730°, 840-880°, and fusion				69.69			552.6 ± 2.7

Table 1. Continued (page 4).

Sample 10: J = 0.007811

550	116.90	0.17730	2.674	0.42	55.36	0.41	739.0 ± 46.2
600	71.72	0.11435	2.585	0.31	53.17	0.61	470.9 ± 47.5
650	71.62	0.12187	6.359	0.44	50.42	1.42	449.8 ± 24.5
685	47.52	0.01597	3.785	3.33	90.70	6.45	524.5 ± 3.6
710	44.50	0.00565	3.222	7.82	96.82	15.51	524.2 ± 2.2
730	44.12	0.00434	3.070	16.48	97.64	19.24	524.1 ± 1.9
750	44.18	0.00297	2.959	25.86	98.54	27.08	528.8 ± 0.9
770	44.42	0.00274	2.882	27.93	98.69	28.64	532.0 ± 2.3
785	45.02	0.00371	2.888	12.44	98.06	21.15	535.3 ± 1.6
800	46.24	0.00601	3.489	3.89	96.76	15.80	541.7 ± 3.2
820	55.06	0.02798	8.994	0.34	86.29	8.74	572.1 ± 42.5
840	54.20	0.04411	10.157	0.38	77.45	6.26	514.4 ± 57.4
865	62.56	0.06507	6.403	0.28	70.07	2.68	533.0 ± 43.1
Fusion	129.25	0.23927	3.653	0.10	45.52	0.42	683.4 ±153.5
Total	45.28	0.00623	3.086	100.00	97.12	22.92	530.4 ± 2.9
Total without 550-685°C, 800-865°C, and fusion				90.53			529.4 ± 1.7

*measured

[c]corrected for post-irradiation decay of ^{37}Ar (35.1 day 1/2-life).

+$[^{40}Ar_{tot.} - (^{36}Ar_{atmos.})\ (295.5)]\ /\ ^{40}Ar_{tot.}$

**calculated using correction factors of Dalrymple et al. (1981); two sigma, intralaboratory errors.

Table 2. $^{36}Ar/^{40}Ar$ vs. $^{39}Ar/^{40}Ar$ Isotope Correlations Using Plateau Analytical Data From Incremental Heating Experiments On Amphibole Concentrates From The Richarddalen Group And Montblanc Formation, Biskayerhalvøya, Spitsbergen, Svalbard.

Sample	Isotope Correlation Age (Ma)*	$^{40}Ar/^{36}Ar$ Intercept**	MSWD	% of Total ^{39}Ar	Caluclated $^{40}Ar/^{39}Ar$ Plateau Age (Ma)***
		Richarddalen Group			
1A	536.0 ± 1.6	317.5 ± 1.8	1.47	94.34	538.3 ± 2.4
2A	504.3 ± 1.2	321.9 ± 19.2	1.99	66.77	506.0 ± 1.8
5B	499.5 ± 2.3	382.1 ± 13.6	1.87	93.80	504.7 ± 2.5
7	542.4 ± 2.3	388.7 ± 26.5	1.21	69.69	552.1 ± 2.3
		Montblanc Formation			
6A	437.1 ± 0.8	335.3 ± 10.7	1.32	76.05	442.1 ± 2.3
8	429.2 ± 0.5	446.2 ± 12.5	1.31	84.01	439.1 ± 2.2

* Calculated using the inverse abscissa intercept ($^{40}Ar/^{39}Ar$ ratio) in the age equation.

** Inverse ordinate intercept.

*** Table 1.

Table 3. Electron microprobe analyses of representative grains within muscovite concentrates from rocks within the Richarddalen Group and Montblanc Formation, Biskayerhalvøya, Spitsbergen, Svalbard.[+]

	Sample 2B*				Sample 5B*		
SiO_2	48.69	48.52	49.71	48.00	48.35	48.03	47.74
Al_2O_3	28.71	28.68	30.11	29.98	28.67	28.47	28.53
TiO_2	1.76	1.54	1.46	1.11	1.44	1.57	1.33
FeO^t	2.51	2.64	2.55	2.50	2.47	2.67	3.03
MnO	-	-	0.03	-	-	0.06	-
MgO	2.31	2.38	2.32	2.09	2.63	2.50	2.29
CaO	-	-	0.02	0.01	-	0.04	-
Na_2O	0.18	0.29	0.16	0.21	0.50	0.49	0.52
K_2O	10.36	10.39	8.70	9.36	9.92	10.15	10.36
Cl	-	-	-	-	-	-	-

Numbers Of Ions On The Basis Of 22 Oxygens

Si	6.567	6.559	6.580	6.517	6.552	6.532	6.524
Al	4.563	4.569	4.698	4.796	4.579	4.563	4.596
Ti	0.179	0.157	0.145	0.114	0.146	0.161	0.136
Fe^t	0.283	0.299	0.283	0.284	0.280	0.304	0.346
Mn	-	-	0.003	-	-	0.007	-
Mg	0.465	0.479	0.458	0.423	0.530	0.508	0.467
Ca	-	-	0.003	0.001	-	0.006	-
K	1.782	1.792	1.469	1.621	1.715	1.760	1.806
Na	0.048	0.076	0.042	0.055	0.132	0.131	0.138
(Na/Na+K)100	2.62	4.05	2.65	3.26	7.15	6.90	7.10
Fe/Fe+Mg	0.379	0.384	0.384	0.402	0.345	0.380	0.426

Table 3. Continued (page 2).

	Sample 9B*				Sample 6B**			
SiO_2	48.66	46.91	48.58	49.54	48.57	47.47	47.86	47.17
Al_2O_3	30.23	30.64	30.72	29.42	29.90	32.45	31.13	31.85
TiO_2	0.23	0.94	0.70	1.36	0.59	0.76	0.76	0.75
FeO^t	2.23	2.37	2.11	2.31	1.44	1.65	1.63	1.47
MnO	-	0.04	-	0.02	-	-	-	-
MgO	2.15	1.96	1.97	2.24	2.55	1.80	2.32	1.80
CaO	-	-	-	-	0.05	0.05	-	-
Na_2O	0.24	0.23	0.22	0.19	1.18	1.11	1.41	1.41
K_2O	10.74	10.85	10.05	9.50	8.93	9.14	8.77	8.75
Cl	-	-	-	-	0.02	-	0.07	-

Numbers Of Ions On The Basis Of 22 Oxygens

Si	6.555	6.391	6.522	6.616	6.563	6.350	6.431	6.381
Al	4.800	4.919	4.860	4.632	4.762	5.116	4.929	5.078
Ti	0.023	0.096	0.070	0.137	0.060	0.076	0.077	0.076
Fe^t	0.252	0.270	0.237	0.258	0.163	0.185	0.184	0.167
Mn	-	0.005	-	0.002	-	-	-	0.001
Mg	0.432	0.398	0.395	0.446	0.514	0.359	0.465	0.362
Ca	-	-	-	-	0.007	0.007	-	-
K	1.847	1.885	1.721	1.618	1.539	1.560	1.504	1.511
Na	0.062	0.061	0.058	0.049	0.311	0.288	0.367	0.371
(Na/Na+K)100	3.23	3.13	3.27	2.91	16.77	15.60	19.63	19.71
Fe/Fe+Mg	0.368	0.408	0.374	0.368	0.241	0.339	0.283	0.316

+ Separate analyses of different grains within each concentrate.

* Richarddalen Group.

** Montblanc Formation.

Table 4. $^{40}Ar/^{39}Ar$ Analytical Data For Incremental Heating Experiments On Muscovite Concentrates From The Richarddalen Group and Montblanc Formation; Biskayerhalvøya, Spitsbergen, Svalbard.

Release temp (°C)	$(^{40}Ar/^{39}Ar)^*$	$(^{36}Ar/^{39}Ar)^*$	^{39}Ar % of total	%^{40}Ar non-atmos.+	Apparent Age (Ma)**
			Montblanc Formation		
Sample 6B: J = 0.007621					
480	39.93	0.02028	2.23	84.98	414.9 ± 4.0
510	38.72	0.00980	8.36	92.50	435.3 ± 1.0
540	36.64	0.00491	29.79	96.02	428.4 ± 0.6
590	36.54	0.00393	22.03	96.80	430.6 ± 0.8
650	36.86	0.00437	12.38	96.48	432.6 ± 1.4
710	37.03	0.00480	11.97	96.15	433.1 ± 0.8
780	36.99	0.00470	9.00	96.22	432.9 ± 1.6
Fusion	43.45	0.02384	4.23	83.76	441.6 ± 1.3
Total	37.26	0.00615	100.00	95.22	431.2 ± 1.0
Total without 480, 510°C and fusion			85.18		430.7 ± 0.9
			Richarddalen Complex		
Sample 2B: J = 0.00775					
480	40.92	0.02535	1.42	81.63	415.4 ± 2.3
510	39.17	0.00687	3.97	94.81	456.6 ± 1.9
550	38.42	0.00428	20.53	96.69	456.7 ± 0.7
610	38.09	0.00342	21.66	97.32	455.9 ± 0.8
680	38.20	0.00384	17.88	97.02	455.8 ± 0.7
750	38.58	0.00625	26.32	95.20	452.1 ± 0.6
810	39.84	0.00770	5.92	94.27	461.1 ± 0.8
Fusion	54.26	0.05187	2.30	71.73	475.8 ± 2.1
Total	38.86	0.00623	100.00	95.49	455.2 ± 0.8
Total without 480, 510, 810°C and fusion			90.37		454.9 ± 0.7

Table 4. Continued (page 2).

Sample 5B: J = 0.007455

480	48.35	0.03824	1.03	76.63	440.0 ± 7.6
510	41.53	0.01140	5.45	91.87	451.6 ± 1.2
550	39.71	0.00748	24.12	94.41	444.6 ± 0.6
610	38.81	0.00583	34.91	95.54	440.3 ± 0.5
680	39.29	0.00586	17.50	95.58	445.3 ± 0.8
750	39.08	0.00500	16.28	96.20	445.7 ± 0.9
Fusion	43.65	0.01923	0.72	86.99	449.7 ± 8.2
Total	39.44	0.00683	100.00	94.93	443.8 ± 0.8
Total without 480, 510°C and fusion			92.80		443.3 ± 0.6

Sample 9B: J = 0.007952

480	45.65	0.04038	0.73	73.84	428.3 ± 7.2
500	45.18	0.02973	0.47	80.70	459.5 ±15.6
525	40.46	0.00852	2.98	93.77	475.6 ± 3.8
575	40.04	0.00483	10.94	96.41	483.0 ± 0.4
625	39.77	0.00402	10.61	96.98	482.5 ± 0.7
690	39.64	0.00331	9.57	97.51	483.5 ± 0.7
740	39.30	0.00295	12.12	97.77	481.0 ± 0.7
Fusion	40.05	0.00611	52.59	95.47	478.9 ± 0.7
Total	39.96	0.00553	100.00	95.93	479.8 ± 0.9
Total without 480 and 500°C			95.82		480.5 ± 0.6

*measured

+$[{}^{40}Ar_{tot.} - ({}^{36}Ar_{atmos.})\ (295.5)]\ /\ {}^{40}Ar_{tot.}$.

**calculated using correction factors of Dalrymple et al. (1981); two sigma, intralaboratory errors; ${}^{37}Ar/{}^{39}Ar$ corrected ratio < 0.020 in all analyses.

Table 5. $^{36}Ar/^{40}Ar$ vs. $^{39}Ar/^{40}Ar$ Isotope Correlations Using Plateau Analytical Data From Incremental Heating Experiments On Muscovite Concentrates From The Richarddalen Group And Montblanc Formation, Biskayerhalvøya, Spitsbergen, Svalbard.

Sample	Isotope Correlation Age (Ma)*	$^{40}Ar/^{36}Ar$ Intercept**	MSWD	% of Total ^{39}Ar	Caluclated $^{40}Ar/^{39}Ar$ Plateau Age (Ma)***
		Richarddalen Group			
2B	461.2 ± 1.3	169.3 ± 4.0	2.93	90.37	455.0 ± 0.8
5B	426.1 ± 0.9	542.3 ±32.4	15.01	92.80	443.3 ± 0.6
9B	481.6 ± 0.6	308.8 ± 9.3	7.73	95.82	480.5 ± 0.7
		Montblanc Formation			
6B	426.7 ± 1.1	316.5 ±12.2	3.66	85.18	430.7 ± 0.9

* Calculated using the inverse abscissa intercept ($^{40}Ar/^{39}Ar$ ratio) in the age equation.

** Inverse ordinate intercept.

*** Table 4.

Table 6. Rb-Sr Analytical Data For Biotite And Muscovite Concentrates And Corresponding Whole-Rocks From The Richarddalen Group And Montblanc Formation, Biskayerhalvøya, Spitsbergen, Svalbard.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$*	Age (Ma)
			Richarddalen Group		
3					
muscovite	308	122	7.32	0.75395 ± 6	418**
4					
whole-rock	221	478	1.34	0.71976 ± 5	
muscovite	323	140	6.71	0.75211 ± 4	423 ± 11
5C					
whole-rock	29.7	338	0.255	0.70887 ± 4	
muscovite	441	176	7.27	0.75181 ± 5	430 ± 9
9A					
whole-rock	67.2	218	0.894	0.72403 ± 5	
biotite	381	28.3	39.8	0.95143 ± 7	410 ± 8
muscovite	237	130	5.30	0.75038 ± 5	420 ± 10
11					
whole-rock	46.3	237	0.566	0.71466 ± 5	
biotite	290	26.6	32.1	0.92355 ± 9	465 ± 9
			Montblanc Formation		
6A					
whole-rock	30.4	190	0.463	0.71693 ± 3	
biotite	421	21.2	59.4	1.05446 ± 7	402 ± 8
6B					
whole-rock	93.8	278	0.978	0.73120 ± 8	
biotite	529	17.1	94.4	1.28023 ± 9	413 ± 8
muscovite	298	183	4.72	0.75401 ± 4	428 ± 11

* ± 2 m.

** Model age based on a 0.710 intial $^{87}Sr/^{86}Sr$ ratio.