

APPENDIX 1A

Chemical composition of monazites, from Azov Sea black sand, in wt.%, EMPA measurements

No.	P ₂ O ₅	UO ₂	ThO ₂	Y ₂ O ₃	ΣREE	CaO	PbO	Sc ₂ O ₃	SiO ₂	As ₂ O ₅	SO ₃	Total	Comment
3	30.354	0.256	7.455	0.506	60.729	1.283	0.692	0.038	0.516	b.d.l.	0.017	101.846	1_mnz1/1/B
4	30.278	0.202	2.764	0.649	64.897	0.527	0.292	0.033	0.366	0.096	0.082	100.186	1_mnz1/2/B
5	30.456	0.193	3.092	0.668	65.198	0.522	0.361	0.038	0.412	0.033	0.056	101.029	1_mnz1/3/B
6	29.718	0.139	5.891	0.477	61.647	0.763	0.560	0.030	0.734	0.050	0.012	100.021	1_mnz1/4/B
7	30.515	0.134	2.363	0.64	61.647	0.406	0.286	0.022	0.287	0.131	0.052	100.282	1_mnz1/5/B
8	29.814	0.179	6.164	0.331	62.760	0.700	0.639	0.022	0.936	b.d.l.	0.017	101.562	1_mnz2/1
9	30.309	0.166	5.368	0.466	63.773	0.701	0.470	0.026	0.631	b.d.l.	0.064	101.974	1_mnz2/2
10	30.449	0.172	4.998	0.419	63.585	0.678	0.565	0.061	0.615	0.044	0.022	101.608	1_mnz2/3
11	30.103	0.252	6.301	0.490	62.192	0.851	0.684	0.062	0.727	0.059	0.076	101.797	1_mnz2/4
12	27.546	0.179	11.421	0.419	58.087	0.648	1.057	0.030	2.194	0.026	0.037	101.644	1_mnz3/1/D
13	28.391	0.195	10.249	0.477	58.550	0.657	0.985	0.040	1.860	0.041	b.d.l.	101.445	1_mnz3/2/D
14	28.197	0.251	10.842	0.473	58.426	0.809	0.941	0.027	1.856	0.063	b.d.l.	101.885	1_mnz3/3/D
15	28.608	0.249	10.083	0.432	58.998	0.908	0.955	0.043	1.585	0.039	0.017	101.917	1_mnz3/4/D
16	29.076	0.270	9.106	0.487	59.726	0.852	0.824	0.018	1.479	0.024	b.d.l.	101.868	1_mnz3/5/D
17	28.654	0.251	9.779	0.529	58.923	0.756	0.864	0.059	1.741	0.061	b.d.l.	101.617	1_mnz3/6/D
18	28.942	0.168	9.284	0.462	59.063	0.867	0.901	0.013	1.564	0.069	0.003	101.336	1_mnz3/7/D
19	27.637	0.199	10.721	0.441	58.016	1.214	0.929	0.048	2.043	0.044	0.050	101.342	1_mnz3/8/D
20	27.683	0.233	11.727	0.453	57.709	0.652	1.020	0.034	2.279	b.d.l.	0.014	101.804	1_mnz3/9/D
21	28.688	0.114	7.237	0.365	61.679	0.474	0.651	0.031	1.484	0.076	0.027	100.826	1_mnz4/1
22	28.716	0.216	7.252	0.395	61.772	0.469	0.660	0.034	1.559	0.061	0.014	101.148	1_mnz4/2
23	28.611	0.131	8.137	0.397	61.417	0.514	0.754	0.029	1.632	0.079	0.013	101.714	1_mnz4/3
24	28.663	0.183	7.949	0.439	61.397	0.523	0.706	0.039	1.555	0.075	0.050	101.579	1_mnz4/4
25	28.958	0.152	8.325	0.513	60.892	0.783	0.782	0.050	1.370	0.106	b.d.l.	101.931	1_mnz5/1/F
26	29.116	0.236	8.740	0.612	59.474	1.047	0.837	0.021	1.202	0.107	b.d.l.	101.392	1_mnz5/2/F
27	29.946	0.136	7.600	0.578	61.421	0.939	0.690	0.047	0.990	0.068	b.d.l.	102.425	1_mnz5/3/F
28	28.723	0.162	8.392	0.569	59.613	0.668	0.706	0.016	1.566	0.028	b.d.l.	100.443	1_mnz5/4/F
29	29.772	0.171	8.341	0.511	60.359	1.013	0.803	0.034	1.186	0.048	b.d.l.	102.238	1_mnz5/5/F
30	28.467	0.117	8.556	0.558	60.329	1.048	0.788	0.042	1.157	0.038	b.d.l.	101.1	1_mnz5/6/F

31	29.704	0.207	7.403	0.574	61.313	0.985	0.683	0.018	0.911	0.052	0.022	101.872	1_mnz5/7/F
32	29.363	0.19	7.043	0.551	60.877	0.934	0.682	0.025	0.922	0.140	0.005	100.732	1_mnz5/8/F
33	28.960	0.161	7.970	0.495	61.222	0.697	0.777	0.031	1.286	0.070	0.018	101.687	1_mnz5/9/F
34	27.753	0.142	8.237	0.460	61.368	0.698	0.765	0.054	1.808	0.055	0.271	101.611	1_mnz6/1
35	27.452	0.21	10.057	0.373	59.408	0.749	0.960	0.045	2.144	0.006	0.247	101.651	1_mnz6/2
36	26.568	0.214	12.21	0.391	56.423	0.791	1.123	0.053	2.666	0.037	0.204	100.68	1_mnz6/3
37	26.481	0.098	12.801	0.394	56.538	0.750	1.23	0.029	2.728	0.024	0.248	101.321	1_mnz6/4
38	25.491	0.316	12.72	0.399	56.951	0.822	1.068	0.043	2.714	0.031	0.205	100.760	1_mnz6/5
39	26.761	0.203	11.742	0.367	57.815	0.793	1.117	0.033	2.564	0.009	0.229	101.633	1_mnz6/6
40	26.992	0.192	10.384	0.316	59.022	0.840	0.975	0.042	2.242	0.034	0.296	101.335	1_mnz6/7
41	27.872	0.188	10.848	0.351	58.054	0.939	0.982	0.020	1.991	0.029	b.d.l.	101.274	2_mnz1/1
42	28.294	0.253	11.636	0.329	58.103	0.999	1.029	0.049	2.268	0.007	0.052	103.019	2_mnz1/2
43	27.965	0.144	10.498	0.278	58.531	0.817	0.993	0.058	2.017	0.022	0.018	101.341	2_mnz1/3
44	28.312	0.169	9.996	0.324	58.941	0.736	0.958	0.047	1.870	0.085	0.028	101.466	2_mnz1/4
45	28.342	0.197	9.901	0.309	59.148	0.781	0.910	0.019	2.008	0.038	0.032	101.685	2_mnz1/5
46	28.188	0.182	11.026	0.292	58.042	0.776	1.021	0.037	2.026	0.070	0.032	101.692	2_mnz1/6
47	27.508	0.240	11.269	0.339	57.584	0.787	1.060	0.034	2.163	0.068	b.d.l.	101.052	2_mnz1/7
48	29.863	0.315	9.761	0.794	57.187	1.609	0.934	0.048	0.950	0.046	b.d.l.	101.507	2_mnz2/1
49	29.747	0.303	10.126	0.794	56.990	1.634	0.99	0.016	1.024	0.085	b.d.l.	101.709	2_mnz2/2
50	27.551	0.243	10.135	0.370	58.655	0.737	0.903	0.052	1.998	b.d.l.	0.123	100.859	2_mnz3/1/H
51	27.300	0.270	10.227	0.319	58.821	0.812	0.881	0.045	2.154	0.027	0.161	101.017	2_mnz3/2/H
52	27.589	0.141	10.458	0.330	58.048	0.804	0.996	0.027	2.155	0.034	0.181	100.763	2_mnz3/3/H
53	26.877	0.343	11.282	0.487	57.551	0.674	1.053	0.035	2.421	0.089	0.109	100.921	2_mnz3/4/H
54	26.683	0.265	11.845	0.472	57.474	0.629	1.106	0.025	2.572	0.014	0.104	101.189	2_mnz3/5/H
55	26.459	0.361	12.060	0.527	57.019	0.621	1.198	0.039	2.705	b.d.l.	0.137	101.126	2_mnz3/6/H
56	26.608	0.377	12.918	0.463	57.029	0.637	1.205	0.042	2.859	0.088	0.123	102.349	2_mnz3/7/H
57	26.765	0.283	11.857	0.510	57.519	0.682	1.116	0.044	2.541	b.d.l.	0.155	101.481	2_mnz3/8/H
58	26.283	0.331	13.404	0.305	55.765	0.741	1.266	0.056	3.041	0.026	0.128	101.346	2_mnz3/9/H
59	29.344	0.176	7.664	0.607	60.446	0.832	0.714	0.031	1.228	0.084	0.013	101.139	2_mnz4/1
60	29.144	0.076	7.823	0.539	61.505	0.835	0.681	0.062	1.249	0.085	b.d.l.	102.009	2_mnz4/2
61	28.985	0.189	7.950	0.596	60.174	0.799	0.778	0.038	1.344	0.038	0.047	100.938	2_mnz4/3

62	29.457	0.094	7.764	0.523	60.004	0.866	0.741	0.028	1.221	0.078	0.013	100.789	2_mnz4/4
63	29.079	0.189	8.603	0.602	60.176	0.878	0.864	0.05	1.380	0.111	0.018	101.95	2_mnz4/5
Av.	28.461	0.206	9.144	0.468	59.606	0.803	0.855	0.037	1.651	0.052	0.063	101.408	n=61
S.d	1.249	0.066	2.473	0.116		0.225	0.218	0.013	0.695	0.034	0.08	0.554	n=61

APPENDIX 1B
REE concentrations in analysed monazites from the Azov Sea, in wt%

No.	La ₂ O ₃	Ce ₂ O ₃	Pr ₂ O ₃	Nd ₂ O ₃	Sm ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	Tb ₂ O ₃	Dy ₂ O ₃	Ho ₂ O ₃	Er ₂ O ₃	Tm ₂ O ₃	Yb ₂ O ₃	Lu ₂ O ₃	ΣREE	LREE	HREE
3	15.399	28.772	2.941	11.379	1.184	b.d.l.	0.669	0.106	0.139	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	60.729	60.374	0.355
4	17.333	30.870	3.100	11.015	1.346	0.062	0.712	0.121	0.199	b.d.l.	b.d.l.	b.d.l.	0.076	b.d.l.	64.897	64.438	0.459
5	17.921	30.855	2.967	10.973	1.320	0.075	0.624	0.123	0.165	b.d.l.	b.d.l.	b.d.l.	0.073	b.d.l.	65.198	64.735	0.463
6	15.957	29.283	2.962	11.068	1.296	0.067	0.544	0.098	0.107	b.d.l.	0.059	b.d.l.	0.068	b.d.l.	61.647	61.177	0.47
7	17.199	31.316	3.094	11.389	1.303	0.063	0.547	0.173	0.157	0.128	0.066	b.d.l.	b.d.l.	b.d.l.	61.647	64.911	0.535
8	18.010	30.070	2.770	10.107	0.976	0.060	0.476	0.126	0.113	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	62.760	62.469	0.291
9	17.966	30.254	2.926	10.458	1.200	0.058	0.542	0.102	0.106	b.d.l.	0.094	b.d.l.	b.d.l.	0.050	63.773	63.399	0.374
10	18.336	29.616	3.087	10.576	1.189	0.081	0.476	0.107	0.102	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	63.585	63.361	0.224
11	18.018	28.626	2.719	10.631	1.246	b.d.l.	0.518	0.059	0.142	b.d.l.	b.d.l.	0.056	b.d.l.	0.051	62.192	61.767	0.425
12	15.867	28.493	2.744	9.293	0.812	b.d.l.	0.362	0.068	0.138	0.124	b.d.l.	b.d.l.	0.124	b.d.l.	58.087	57.601	0.486
13	15.218	28.882	2.778	9.681	1.045	b.d.l.	0.551	0.089	0.118	b.d.l.	0.101	0.057	b.d.l.	b.d.l.	58.550	58.156	0.394
14	15.838	28.728	2.806	9.374	0.922	0.052	0.451	0.073	0.122	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	58.426	58.171	0.255
15	16.277	28.483	2.736	9.563	1.052	b.d.l.	0.551	0.059	0.025	b.d.l.	0.066	b.d.l.	0.064	0.063	58.998	58.711	0.287
16	16.309	28.880	2.803	9.890	0.981	b.d.l.	0.346	0.073	0.195	0.116	0.059	b.d.l.	0.065	b.d.l.	58.426	59.209	0.517
17	15.883	28.785	2.911	9.551	1.009	b.d.l.	0.459	0.098	0.152	b.d.l.	b.d.l.	b.d.l.	0.075	b.d.l.	58.998	58.598	0.325
18	15.475	29.186	2.823	9.549	1.067	b.d.l.	0.433	0.104	0.102	0.125	0.084	0.054	b.d.l.	b.d.l.	59.726	58.557	0.506
19	15.753	28.523	2.763	9.259	0.895	b.d.l.	0.393	b.d.l.	0.171	b.d.l.	b.d.l.	b.d.l.	0.066	b.d.l.	58.923	57.596	0.42
20	15.711	28.251	2.830	9.218	0.918	b.d.l.	0.405	0.069	0.134	0.094	0.067	b.d.l.	b.d.l.	b.d.l.	59.063	57.337	0.372
21	17.109	30.010	2.941	9.993	0.949	b.d.l.	0.387	0.091	0.094	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	58.016	61.389	0.29

22	17.299	30.207	2.709	9.897	0.961	b.d.l.	0.396	0.128	0.042	b.d.l.	0.056	b.d.l.	b.d.l.	b.d.l.	57.709	61.492	0.28
23	16.985	29.999	2.854	9.696	0.978	b.d.l.	0.547	0.146	0.069	b.d.l.	b.d.l.	b.d.l.	0.109	b.d.l.	61.679	61.059	0.358
24	16.476	30.308	2.832	9.901	0.984	b.d.l.	0.359	0.104	0.075	0.121	0.143	b.d.l.	b.d.l.	b.d.l.	61.772	60.898	0.499
25	14.551	29.454	2.977	11.483	1.329	b.d.l.	0.691	0.070	0.191	b.d.l.	b.d.l.	0.056	b.d.l.	b.d.l.	61.417	60.520	0.372
26	14.053	28.713	3.043	11.359	1.414	b.d.l.	0.604	0.051	0.167	b.d.l.	0.055	b.d.l.	b.d.l.	b.d.l.	61.397	59.186	0.288
27	14.969	29.306	3.066	11.574	1.426	b.d.l.	0.524	0.080	0.143	0.158	0.068	b.d.l.	b.d.l.	0.060	61.421	60.912	0.509
28	14.324	28.939	2.962	11.318	1.231	b.d.l.	0.545	0.102	0.084	b.d.l.	b.d.l.	b.d.l.	0.059	b.d.l.	59.474	59.319	0.294
29	14.203	28.654	2.847	12.019	1.444	0.102	0.727	0.016	0.106	b.d.l.	0.129	0.076	b.d.l.	b.d.l.	61.421	59.996	0.363
30	13.785	29.282	3.061	11.656	1.451	b.d.l.	0.753	0.120	0.055	b.d.l.	0.065	b.d.l.	b.d.l.	0.065	59.613	59.992	0.337
31	14.455	29.814	3.059	11.658	1.335	0.062	0.537	0.059	0.120	b.d.l.	0.076	0.056	b.d.l.	b.d.l.	60.359	59.992	0.393
32	14.682	29.162	3.052	11.558	1.335	b.d.l.	0.575	0.136	0.136	0.096	b.d.l.	0.083	0.053	b.d.l.	60.329	60.373	0.504
33	14.884	29.427	3.042	11.541	1.239	b.d.l.	0.669	0.122	0.200	b.d.l.	b.d.l.	0.052	b.d.l.	b.d.l.	61.313	60.820	0.402
34	17.483	30.008	2.846	9.381	0.799	b.d.l.	0.385	0.053	0.131	0.085	0.114	b.d.l.	b.d.l.	b.d.l.	60.877	60.942	0.426
35	16.999	28.759	2.717	9.344	0.836	b.d.l.	0.359	b.d.l.	0.185	b.d.l.	b.d.l.	0.084	b.d.l.	b.d.l.	61.222	59.018	0.39
36	15.871	27.353	2.586	9.149	0.902	b.d.l.	0.298	b.d.l.	0.080	0.102	b.d.l.	b.d.l.	0.063	b.d.l.	61.368	56.159	0.264
37	16.286	27.280	2.583	8.884	0.804	0.058	0.409	0.059	0.058	b.d.l.	0.090	b.d.l.	b.d.l.	b.d.l.	59.408	56.304	0.234
38	15.679	27.978	2.636	9.224	0.774	b.d.l.	0.420	0.068	0.112	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	56.431	56.740	0.211
39	16.422	28.168	2.552	9.203	0.804	b.d.l.	0.302	b.d.l.	0.087	0.123	0.055	b.d.l.	b.d.l.	b.d.l.	56.538	57.474	0.341
40	17.125	28.593	2.563	9.092	0.857	b.d.l.	0.514	0.097	0.074	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	56.951	58.782	0.24
41	17.297	28.113	2.770	8.529	0.767	b.d.l.	0.386	b.d.l.	0.098	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.007	57.815	57.862	0.192
42	17.098	28.253	2.631	8.756	0.845	b.d.l.	0.398	0.075	0.039	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	59.022	57.989	0.114
43	16.963	28.730	2.648	8.899	0.775	b.d.l.	0.328	0.062	0.041	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	58.531	58.343	0.188
44	17.049	29.269	2.688	8.471	0.797	b.d.l.	0.190	0.071	0.071	0.118	0.158	b.d.l.	b.d.l.	b.d.l.	58.941	58.476	0.465
45	17.471	28.993	2.722	8.604	0.663	b.d.l.	0.444	0.062	b.d.l.	b.d.l.	b.d.l.	b.d.l.	0.053	b.d.l.	58.531	58.901	0.247
46	16.543	28.339	2.474	9.253	0.758	0.075	0.313	0.087	0.079	b.d.l.	b.d.l.	0.067	b.d.l.	b.d.l.	58.941	57.755	0.287
47	16.464	28.244	2.612	8.902	0.807	b.d.l.	0.282	0.066	0.058	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	59.148	57.331	0.253
48	12.777	27.357	2.803	11.075	1.658	0.063	0.817	0.120	0.234	b.d.l.	0.102	0.063	b.d.l.	b.d.l.	58.042	56.550	0.637
49	12.443	27.262	3.048	11.325	1.760	b.d.l.	0.646	0.103	0.190	0.095	b.d.l.	b.d.l.	b.d.l.	0.051	57.584	56.484	0.506
50	16.328	28.810	2.701	9.263	0.821	b.d.l.	0.396	b.d.l.	0.098	b.d.l.	0.069	0.104	b.d.l.	b.d.l.	57.187	58.328	0.327
51	16.588	28.661	2.786	9.251	0.849	b.d.l.	0.397	0.069	0.110	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	56.990	58.532	0.289
52	16.344	28.567	2.732	8.876	0.806	b.d.l.	0.397	b.d.l.	0.172	b.d.l.	0.056	b.d.l.	b.d.l.	b.d.l.	58.655	57.770	0.278

53	14.749	28.510	2.760	9.602	1.087	0.087	0.354	0.107	0.147	b.d.l.	0.055	b.d.l.	b.d.l.	b.d.l.	58.821	57.149	0.402
54	14.745	28.699	2.829	9.337	1.062	b.d.l.	0.509	b.d.l.	0.089	b.d.l.	b.d.l.	0.096	b.d.l.	b.d.l.	58.048	57.197	0.277
55	14.631	28.133	2.768	9.519	0.965	0.075	0.514	0.120	0.110	b.d.l.	0.082	b.d.l.	b.d.l.	0.102	57.551	56.605	0.414
56	14.568	28.384	2.810	9.522	0.913	b.d.l.	0.536	0.061	0.109	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	57.029	56.746	0.283
57	14.822	28.392	2.800	9.708	0.962	b.d.l.	0.378	0.094	0.149	0.117	b.d.l.	0.062	b.d.l.	b.d.l.	57.019	57.062	0.457
58	15.19	27.822	2.331	8.875	0.846	0.117	0.267	0.076	0.116	b.d.l.	b.d.l.	b.d.l.	0.063	b.d.l.	57.029	55.448	0.317
59	16.193	29.463	2.823	10.114	1.009	b.d.l.	0.584	b.d.l.	0.090	b.d.l.	0.106	b.d.l.	b.d.l.	b.d.l.	57.519	60.206	0.24
60	16.589	29.867	2.870	10.102	1.082	b.d.l.	0.638	0.072	0.169	b.d.l.	b.d.l.	0.062	b.d.l.	b.d.l.	55.765	61.159	0.346
61	16.316	29.5	2.777	9.596	1.122	b.d.l.	0.488	0.076	0.123	b.d.l.	0.055	b.d.l.	0.060	b.d.l.	60.446	59.833	0.341
62	15.963	29.531	2.754	9.81	1.053	0.083	0.551	0.124	0.135	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	61.505	59.745	0.259
63	16.114	29.224	2.760	9.944	1.052	b.d.l.	0.550	0.116	0.117	b.d.l.	0.089	0.066	b.d.l.	0.073	60.174	59.69	0.486
Av.	15.989	28.974	2.813	9.971	1.05	0.032	0.482	0.082	0.118	0.04	0.046	0.029	0.028	0.014	59.606	58.180	0.356
S.d	1.284	0.873	0.164	0.975	0.24	0.03	0.132	0.034	0.046	0.047	0.039	0.028	0.03	0.025	n= 61		
CV	8.01	3.01	5.83	9.77	22.85	93.75	27.38	414.63	256.52	117.50	84.78	96.55	107.14	178.57	%		

CV-coefficient of variability, b.d.l.-below detection limit