Supplementary Information (SI) for Analytical Methods.
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Supplementary information for

Comparison of neutron activation analysis, X-ray fluorescence spectrometry and inductively-coupled plasma mass spectrometry for the determination of rare earth element concentrations in Jordanian monazite ore

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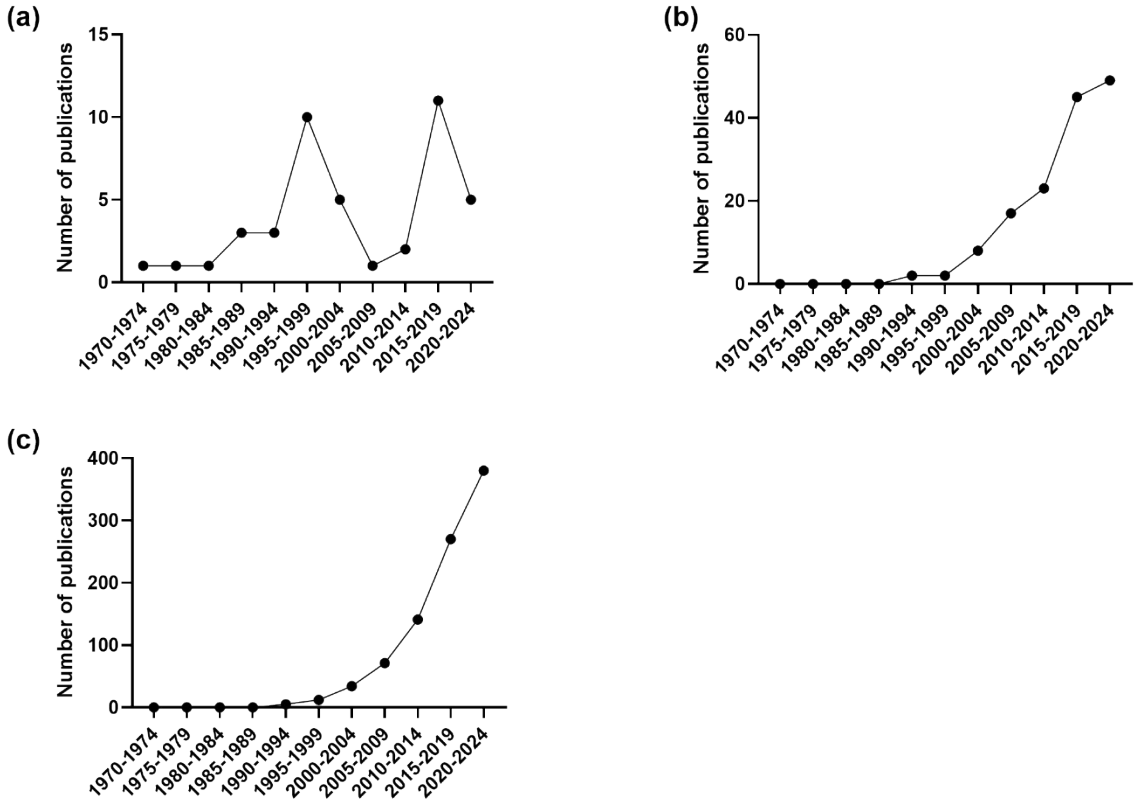

Figure S1: Publication data (*Web of Science,* accessed 1st October 2024) for different analytical techniques applied to monazite: (a) "neutron activation analysis" and "monazite", (b) "X-ray fluorescence" and "monazite" and (c) "ICP-MS" and "monazite"

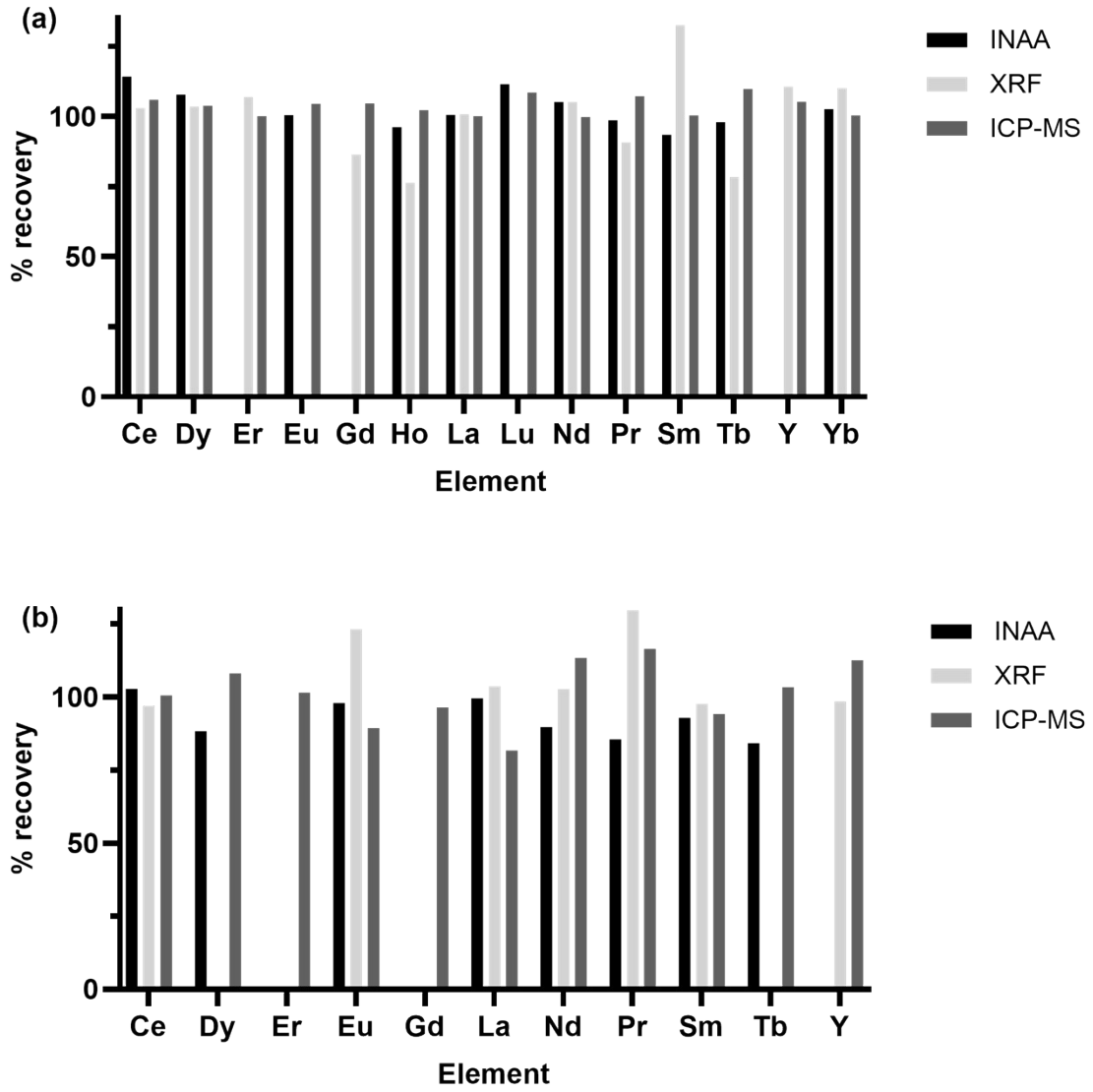

Figure S2: Percentage recoveries for certified reference materials (a) REE-1 and (b) REE-2 for INAA, XRF, and ICP-MS.

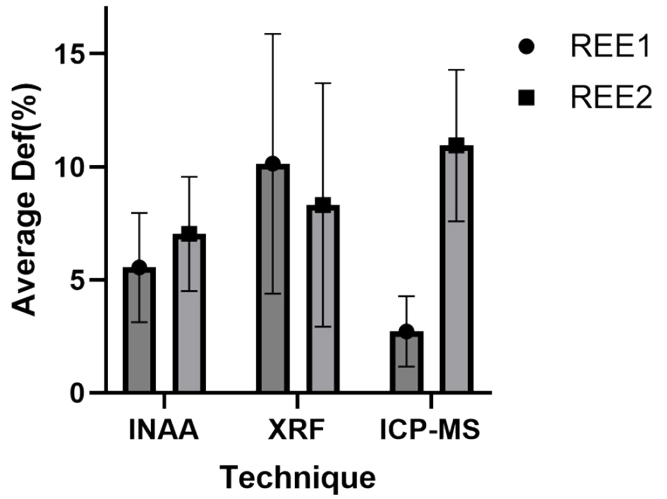

Figure S3: Comparison of value deflections (Def) for La, Ce, Pr, Nd, and Sm for INAA, XRF and ICP-MS measurements of certified reference materials REE-1 and REE-2. Error bars represent standard error of the mean.

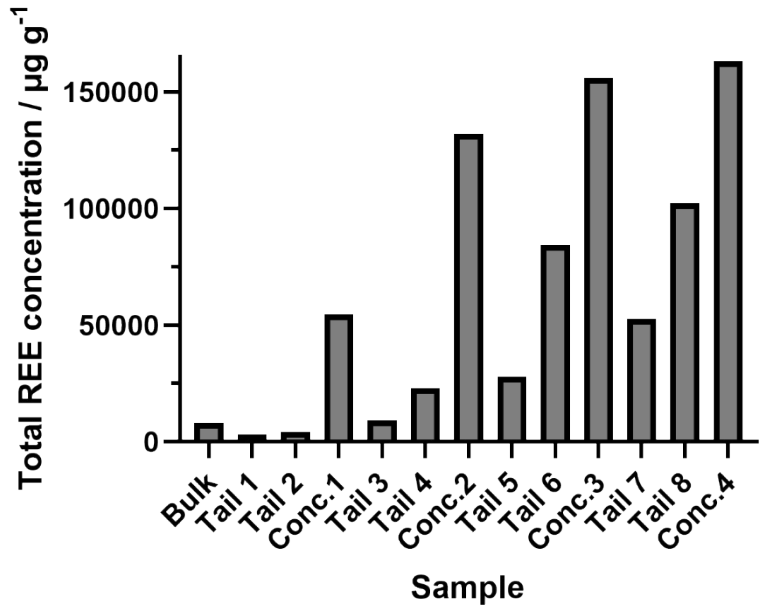

Figure S4: Total rare earth element content of different monazite samples, determined by ICP-MS.

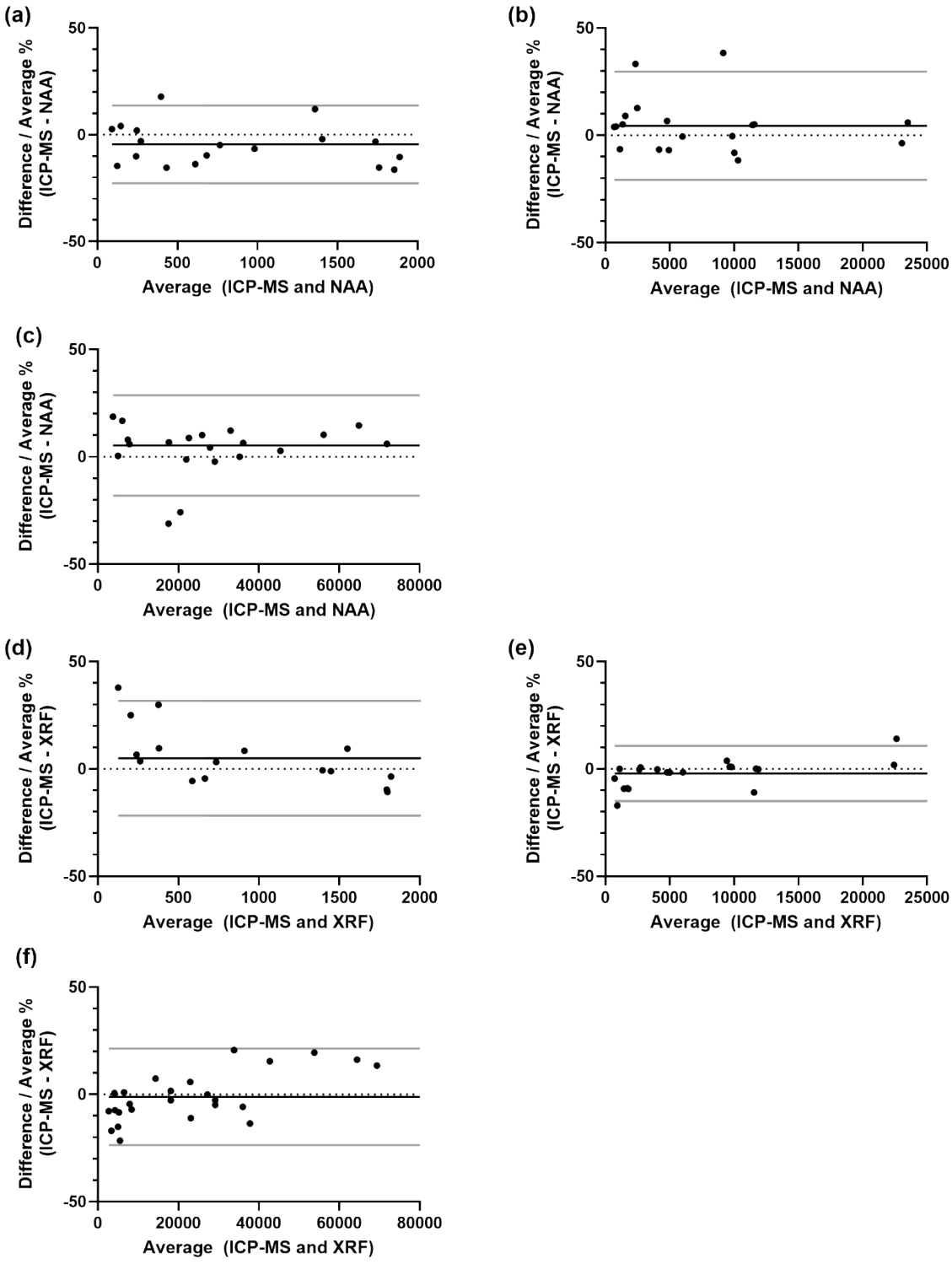

Figure S5: Bland-Altman plots for analysis of La, Ce, Nd, Pr, and Sm in monazite samples using ICP-MS, INAA, and XRF. Black line indicates bias, gray lines indicate limits of agreement. (a) and (d) are low concentration monazite samples (Bulk, Tail 1, Tail 2, Tail 3); (b) and (e) are medium concentration samples (Tail 4, Tail 5, Tail 7, Conc. 1); (c) and (f) are high concentration samples (Tail 6, Tail 8, Conc. 2, Conc. 3, Conc. 4).

Supplementary Tables

Table S1: Statistical analysis of differences between Def values for the three techniques for analysis of REE-1 and REE-2. Student's t-test (two-tailed, heteroscedastic).

		***p*-values**	
Sample	**INAA *vs* XRF**	**INAA *vs* ICP-MS**	**XRF *vs* ICP-MS**
REE-1	0.047*	0.43	0.017*
REE-2	0.78	0.86	0.86

***** significance determined as $p < 0.05$

Table S2: Elemental concentrations of monazite samples determined by ICP-MS, INAA and XRF

	Ce			La			Nd		
Sample	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]
Bulk	3631.12	3595.67	3767.5	1709.09	1765.62	1881.82	1440.26	1277.59	1455.76
Tail 1	1391.04	1419.86	1400.2	650.04	716.55	679.57	569.75	653.9	602.71
Tail 2	1702.77	2006.58	1895.96	949	1014.2	872.27	746.55	783.89	722.74
Conc.1	24200.2	22809.1	21028.1	11712.2	11166.4	11695.0	9619.67	10432.5	9264.4
Tail 3	3829.27	3970.14	4032.07	1789.68	1986.91	1853.68	1624.47	1894.41	1477.19
Tail 4	9843.81	9880.14	9746.83	4767.13	5105.66	4842.26	4029.88	4305.33	4039.78
Conc.2	59045.4	53281.0	48590.8	28484.8	27280.0	29899.3	23617.9	21627.6	22281.3
Tail 5	11876.7	11283.2	11890.2	5973.27	6004.23	6066.68	4951.74	4631.82	5033.44
Tail 6	37324.6	34988.5	30345.1	18260.2	17059.0	17971.5	14837.4	20301.4	13786.8
Conc.3	69652.5	60157.1	59185.9	34991.3	30965.9	37083.0	27235.9	24603.1	27240.2
Tail 7	22637.3	23468.9	22221.5	10910.6	7397.6	12180.2	9714.67	10912.2	9612.48
Tail 8	46045.2	44778.6	39452.1	21832.0	22092.3	24378.4	17854.6	23150.3	18340.1
Conc.4	74036.3	69700.0	64710.1	35255.1	35245.0	40373.4	28773.89	29427.16	29558.47

	Pr			Sm			Y		
Sample	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]
Bulk	398.22	465.05	361.7	248.73	243.97	232.84	365.56	-	507.13
Tail 1	149.41	143.48	101.8	91.57	89.21	BDL	161.45	-	214.19
Tail 2	229.95	254.44	178.78	114.81	132.97	BDL	225.38	-	326.8
Conc.1	2629.62	2315.87	2636.15	1619.77	1479.7	1771.3	2129.85	-	2321.44
Tail 3	432.96	362.23	320.31	267.46	275.73	257.85	640.66	-	863.85
Tail 4	1100.01	1173.4	1099.98	695.23	668.15	726.97	1320.63	-	1707.22
Conc.2	6564.72	5547.66	6499.75	4086.83	3464.59	4401.52	4480.79	-	3996.38
Tail 5	1375.18	1306.19	1508.03	841.72	807.75	998.62	1442.09	-	1723.76
Tail 6	4105.39	3404.45	4081.28	2585.87	2085.45	2796.65	3360.7	-	3167.97
Conc.3	7718.68	7128.71	8069.03	4641.49	4040.4	5401	4893.88	-	4490.12
Tail 7	2734.76	1953.63	2715.61	1698.38	843.36	1864.44	2175	-	2336.4
Tail 8	5009.76	4987.82	5447.77	3081.55	2971.17	3652.12	3844.82	-	3708.95
Conc.4	8083.75	7613.73	8670.75	4914.35	4658.13	6102.97	4985.58	-	4703.52

	Dy			Er			Eu		
Sample	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]
Bulk	94.85	88.5	-	94.85	88.5	-	13.19	12.32	-
Tail 1	37.35	39.55	-	37.35	39.55	-	-	6.75	-
Tail 2	50.15	49.78	-	50.15	49.78	-	-	7.77	-
Conc.1	585.5	684.65	-	585.5	684.65	-	75.43	70.69	-
Tail 3	130.88	144.07	-	130.88	144.07	-	16.6	17.93	-
Tail 4	289.22	286.9	-	289.22	286.9	-	36.46	36.51	-
Conc.2	1359.97	1303.85	1025.53	1359.97	1303.85	1025.53	175.58	159.37	-
Tail 5	333.94	342.72	-	333.94	342.72	-	43.61	43.82	-
Tail 6	902.67	817.72	709.24	902.67	817.72	709.24	113.81	109.38	-
Conc.3	1586.91	1405.38	1241.61	1586.91	1405.38	1241.61	198.76	173.98	-
Tail 7	557	554.47	-	557	554.47	BDL	74	73.46	-
Tail 8	1045.95	1145.14	879.15	1045.95	1145.14	879.15	136.4	137.13	-
Conc.4	1650.66	1455.77	1315.67	1650.66	1455.77	1315.67	218.76	200.42	-

	Gd			Yb			Ho		
Sample	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]
Bulk	190.32	-	-	37.69	36.99	-	14.45	14.58	-
Tail 1	71.09	-	-	18.65	29.07	-	-	6.47	-
Tail 2	93.66	-	-	31.16	36.7	-	-	9.41	-
Conc.1	1243.72	-	1466.25	196.98	243.98	-	79	59.36	-
Tail 3	219.56	-	-	97.49	107.46	-	24.18	23.59	-
Tail 4	538.26	-	600.38	168.35	204.71	-	48.82	36.42	-
Conc.2	3018.26	-	3693.39	234.36	175.52	-	132.52	102.69	-
Tail 5	642.19	-	754.82	160.7	198.71	-	54.96	35.95	-
Tail 6	1919.14	-	2313.9	310.76	345.82	318.78	127.66	92.23	-
Conc.3	3565.3	-	4537.57	323.06	405.99	-	192.17	174.01	-
Tail 7	1390.55	-	1496.62	190.66	156.96	-	84.68	33.92	-
Tail 8	2206.25	-	3173.69	332.01	403.1	374.11	151.49	107.22	-
Conc.4	3667.96	-	4908.9	313.1	412.18	320.54	217.23	151.71	-

	Lu			Tb			Sc		
Sample	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]	ICP-MS [µg/g]	INAA [µg/g]	XRF [µg/g]
Bulk	-	6.18	-	22.35	18.64	-	-	16.54	-
Tail 1	-	4.08	-	8.69	8.68	-	-	17.91	-
Tail 2	-	6.07	-	11.04	12.29	-	-	12.94	-
Conc.1	36.9	32.78	-	141.4	118.76	-	-	54.59	-
Tail 3	17.07	18.52	-	27.36	25.4	-	-	38.69	-
Tail 4	32.14	35.54	-	65.36	62.38	-	-	53.04	-
Conc.2	41.66	38.7	-	256.35	282.23	-	-	63.7	-
Tail 5	31.06	31.99	-	77.55	70.56	-	-	56.03	-
Tail 6	58.72	74.53	-	219.86	184.59	-	-	78.17	-
Conc.3	54.37	49.76	-	385.41	316.23	-	-	56.96	-
Tail 7	34.62	36.39	-	142.73	132.42	-	-	56.22	-
Tail 8	70.34	74.54	-	259.52	229.87	-	-	80.46	-
Conc.4	54.05	47.97	-	432.95	356.13	-	-	56.76	-