Comparative geochemistry of pelitic schists as a function of metamorphic grade across the metamorphic high of central Massachusetts

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INTRODUCTION

The field of study for this project is across metamorphic zones of Central Massachusetts. The samples used in the study were pelitic schists of the Rangeley Formation (Silurian). The samples, collected from the Bronson Hill Anticlinorium and the Merrimac Synclinorium, varied in the amount of granitic material (melt). The purpose of the study was to determine if there was a variation in bulk chemistry of the rocks across zones. If bulk chemistry changes with zone, it would imply that melt was either introduced or taken from the rocks. To determine this, the rocks were prepared and sent to Professor Stan Mertzman at Franklin and Marshall College in Lancaster, PA , for XRF chemical analysis. Whole rock analyses of the samples are listed in Table 1.

PELITIC SCHIST NORMS

In order to compare the bulk chemistry of the different samples, a norm calculation for Pelitic schists was created. First, a standard composition for a shale was selected (Dietritch, Dutro, & Foose, 1982). Based on chosen pelitic composition, a set of normative minerals was specified: ilmenite, almandine, spessartine, biotite, K-spar, albite, anorthite, sillimanite, quartz and apatite.

- To calculate the norm for a sample, divide the weight percent of each oxide by the gram formula weight to determine molar amounts.
- Convert all Fe_2O_3 to FeO by multiplying the moles of Fe2O3 by 2 to convert to moles of FeO. Add this value to the analyzed FeO to get the new FeO.
- First form ilmenite by taking all TiO_2 and combining it with an equal amount of FeO.
- Combine the remaining FeO with an equal part of SiO_2 and one-third that value of Al_2O_3 to form almandine.
- Biotite is formed by taking the remaining MgO and combining it with an equal part of $Si0_2$ and one-sixth that value of Al_2O_3 and K_2O.
- Form K-spar by taking all remaining K_2O with an equal part of Al_2O_3 and six times that value of SiO_2.
- Albite is then formed by combining all Na_2O with an equal amount of Al_2O_3 and six times that amount of SiO_2.
- Anorthite is calculated by combining all CaO with equal parts Al_2O_3 and twice that amount of SiO_2.
- Sillimanite is calculated by taking the remaining Al_2O_3 and combining it with an equal amount of SiO_2.
- The remaining SiO_2 is then used to make quartz.
- Finally all P_2O_5 goes to form apatite.

Determine the moles of the norm mineral by multiplying the amount of the designated oxide in the formula by the number of moles of that oxide need to form one mole of the mineral. These weight norms are then converted to oxygen norms in order to approximate the volume percent-mode. Results of the norm calculations are in Table 2.

CONCLUSIONS

(1) The bulk composition of the rocks does not vary much with metamorphic zone. Therefore, the high grade and low grade rocks are isochemical.

(2) The observed chemical changes with metamorphic grade are not significant. However, they do suggest that melt from elsewhere may have entered some samples in small amounts in the higher grade rocks.

REFERENCES

Dietrich, R., Dutro, J., and Foose, R. 1982, AGI Data Sheets, American Geological Institute, p. 44.1

Specimen	2B	4	6A2	6PR	7K	8A	8B1	8B2	9A	9B3	9C	9D	9F	9G	9H	9Q2	9Q5	SLW	MH
SiO2	60.69	53.97	69.02	67.04	61.74	58.25	61.45	56.40	73.64	56.83	72.77	74.95	60.52	66.20	70.36	73.38	64.93	67.16	74.75
TiO2	1.19	1.41	1.01	0.97	1.15	1.23	0.96	1.30	0.74	1.28	0.63	0.62	1.25	1.20	0.89	0.03	0.76	1.04	1.00
Al2O3	18.24	22.26	16.41	16.35	17.52	19.28	18.57	20.05	13.18	19.81	12.77	10.65	19.95	19.20	14.71	14.67	17.51	16.74	12.38
Fe2O3	2.02	3.08	1.96	2.33	0.90	0.75	0.92	1.00	0.47	1.13	0.79	1.70	0.70	0.64	1.42	0.34	0.43	0.98	2.03
FeO	6.78	8.02	4.18	4.30	6.73	8.02	6.25	8.30	4.67	8.05	3.34	4.38	6.63	5.54	4.42	0.46	5.30	5.34	3.74
MnO	0.24	0.21	0.06	0.08	0.17	0.23	0.18	0.23	0.12	0.21	0.06	0.24	0.10	0.07	0.08	0.05	0.17	0.07	0.08
MgO	3.32	3.50	1.61	1.64	3.20	3.40	2.71	3.66	1.34	3.61	1.03	1.15	2.03	1.77	1.43	0.09	2.15	1.67	1.47
CaO	0.93	0.50	0.20	0.37	0.77	0.77	0.56	0.22	0.15	0.24	0.69	1.10	0.17	0.29	0.19	0.82	1.21	0.26	0.17
Na2O	0.87	0.89	0.59	1.42	1.80	1.07	1.05	0.20	0.40	0.42	1.56	1.85	0.54	0.49	0.53	2.32	1.88	0.76	0.46
K2O	3.41	4.38	2.78	2.97	3.21	4.18	3.98	4.38	3.62	4.58	4.24	1.84	5.11	2.91	3.76	6.83	3.39	3.18	2.87
P2O5	0.15	0.09	0.05	0.70	0.10	0.14	0.14	0.12	0.06	0.11	0.08	0.05	0.06	0.05	0.05	0.11	0.16	0.08	0.05
LOI	1.83	0.83	2.50	2.10	2.38	2.23	3.00	3.33	1.45	3.53	1.42	1.50	2.07	1.46	2.15	0.46	1.80	2.37	0.52
Total	**99.67**	**99.14**	**100.37**	**100.27**	**99.67**	**99.55**	**99.77**	**99.19**	**99.84**	**99.80**	**99.38**	**100.03**	**99.13**	**99.82**	**99.99**	**99.56**	**99.69**	**99.65**	**99.52**
Fe2O3T	9.55	11.99	6.61	7.11	8.38	9.66	7.87	10.22	5.66	10.08	4.50	6.57	8.07	6.80	6.33	0.85	6.32	6.91	6.19
Rb	129.1	138.0	121.2	137.8	150.4	197.0	173.5	218.0	162.4	212.4	154.6	147.1	242.6	157.7	169.8	110.8	132.9	146.3	106.4
Sr	129	159	88	121	115	85	107	15	47	36	103	174	45	61	43	72	158	71	85
Y	38	65	31	29	33	38	29	38	30	33	36	9	23	51	21	32	27	32	23
Zr	237	232	313	265	274	235	170	227	229	219	233	30	296	279	281	198	141	348	407
V	193	230	147	136	172	231	168	225	102	225	64	36	200	172	123	68	130	147	128
Ni	58	57	32	42	73	52	39	52	20	49	13	<1	35	32	22	13	31	45	65
Cr	100	134	129	129	176	185	120	140	64	135	50	31	113	110	78	45	73	131	81
Nb	19.4	22.1	17.3	16.6	18.2	21.7	17.4	21.4	16.7	20.3	18.3	2.9	25.1	23.4	18.9	17.8	13.8	18.1	15.9
Ga	24.0	29.3	19.0	18.1	20.4	27.1	23.8	28.5	16.6	28.6	13.8	9.3	31.1	24.2	23.4	12.7	19.4	19.7	16.3
Cu	30	10	21	20	11	54	24	24	12	19	14	3	9	7	16	31	35	18	41
Zn	138	147	96	87	111	146	106	144	97	137	77	11	155	106	107	78	88	96	85
Co	50	69	54	49	45	46	32	34	31	30	43	26	33	40	24	55	73	58	45
Ba	699	926	469	362	305	413	581	277	331	402	449	576	304	421	301	80	575	445	570
La	32	40	32	27	23	38	33	33	15	35	31	7	25	42	18	22	22	30	23
Ce	66	108	70	62	66	98	63	77	35	80	70	19	60	91	47	47	53	61	42
U	1.6	1.4	2.6	2.1	1.3	1.5	2.3	1.9	2.4	1.4	3.4	1.5	2.6	3.3	2.3	1.8	0.9	2.7	2.3
Th	10.5	14.7	11.7	8.3	10	13.8	10.5	14.2	7.9	14.6	14	2.5	12.8	14.7	10.4	9	8.2	13.1	11.5
Sc	14	25	14	17	20	21	16	21	17	20	14	4	20	20	17	19	15	16	7
Pb	16	31	17	24	17	14	20	3	18	7	34	61	14	10	15	15	28	14	19

Table 1. Whole rock XRF chemical data for metamorphic rocks of the Silurian Rangeley Formation, central Massachusetts.

Location	Sample	Zone	Ilmenite	Almandine	Spessartine	Biotite	K-Spar	Albite	Anorthite	Sillimanite	Quartz	Apatite
S Lake East	6A2	2	1.27	9.39	0.11	5.35	12.24	5.10	0.96	15.85	49.67	0.06
S Lake East	6PR	2	1.23	10.37	0.15	5.48	13.35	12.36	1.78	12.35	42.10	0.83
S Lake West	7K	3	1.49	12.52	0.33	10.98	11.53	16.06	3.80	11.06	32.11	0.12
S Lake West	SLW	3	1.32	9.98	0.13	5.62	14.56	6.65	1.26	15.03	45.36	0.10
Athol	8A	3	1.62	14.80	0.45	11.82	17.00	9.68	3.85	13.57	27.04	0.17
Athol	8B1	3	1.25	12.01	0.35	9.34	17.24	9.41	2.77	14.45	33.00	0.17
Athol	8B2	3	1.74	15.91	0.46	12.92	17.86	1.84	1.12	18.62	29.38	0.15
Templeton	9A	4	0.92	8.15	0.22	4.40	17.40	3.41	0.71	10.02	54.70	0.07
Templeton	9B3	4	1.71	15.64	0.42	12.71	19.13	3.85	1.21	17.19	28.02	0.14
Templeton	9C	4	0.79	6.49	0.11	3.42	21.80	13.47	3.29	4.40	46.13	0.09
Templeton	9D	4	0.77	9.87	0.45	3.78	7.83	15.82	5.20	1.57	54.64	0.06
Templeton	9F	4	1.64	11.90	0.20	7.02	25.56	4.86	0.84	17.55	30.37	0.07
Templeton	9G	4	1.51	9.38	0.13	5.88	12.62	4.23	1.38	20.18	44.63	0.06
Templeton	9H	4	1.12	9.15	0.15	4.76	18.27	4.59	0.91	11.64	49.34	0.06
Templeton	9Q2	4	0.04	1.36	0.09	0.30	38.24	19.85	3.88	2.59	33.52	0.13
Templeton	9Q5	4	0.97	9.47	0.33	7.25	14.74	16.50	5.87	10.17	34.52	0.19
Wales Rd	2B	5	1.55	14.49	0.47	11.39	12.43	7.77	4.59	13.15	33.98	0.18
McBride	4	6	1.87	18.75	0.42	12.28	18.11	8.12	2.52	18.27	19.54	0.11
Mt. Hitchcock	MH	6	1.23	8.53	0.15	4.79	12.81	3.90	0.80	9.59	58.16	0.06

Table 2. Pelitic schist norms of Rangeley Formation rocks arranged according to metamorphic zone.

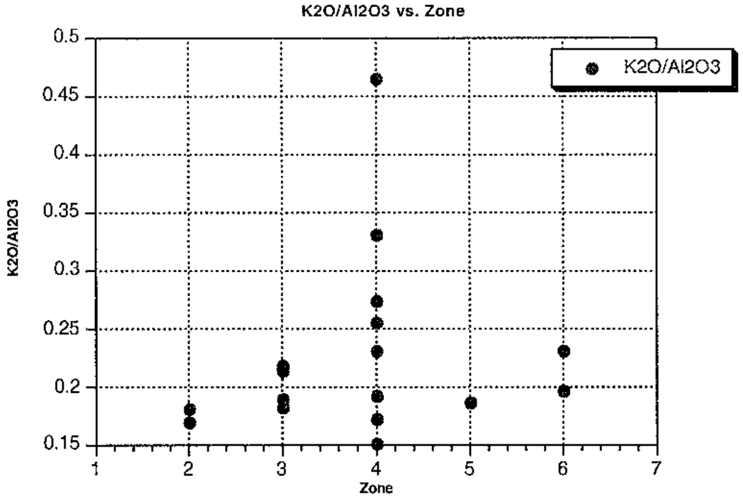

Figure 1. There is a slight increase of K2O/Al2O3 with zone, which implies that the rocks are becoming more K-spar rich with grade. This shows that with increasing grade there is less mica since the K-Al ratio of K-spar is larger than micas.

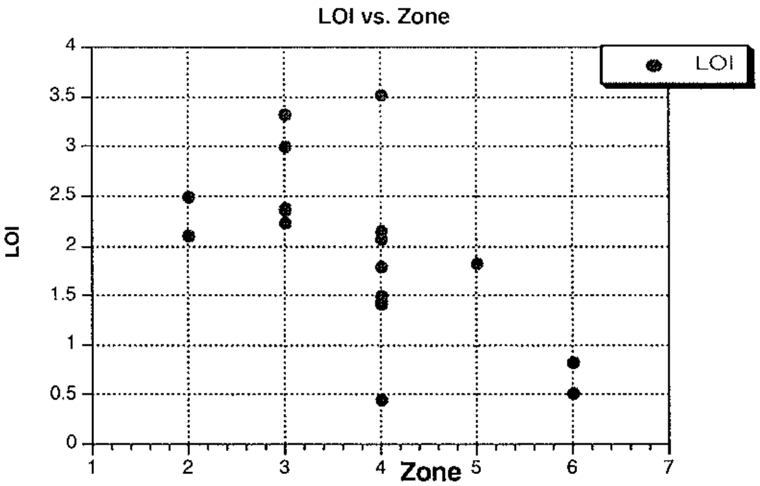

Figure 2. As hydrous minerals such as biotite and muscovite are removed from the system, the weight percent of water is thereby decreased. This shows that with increasing zone, the rocks become drier, correlating to theorized high temperature reactions.

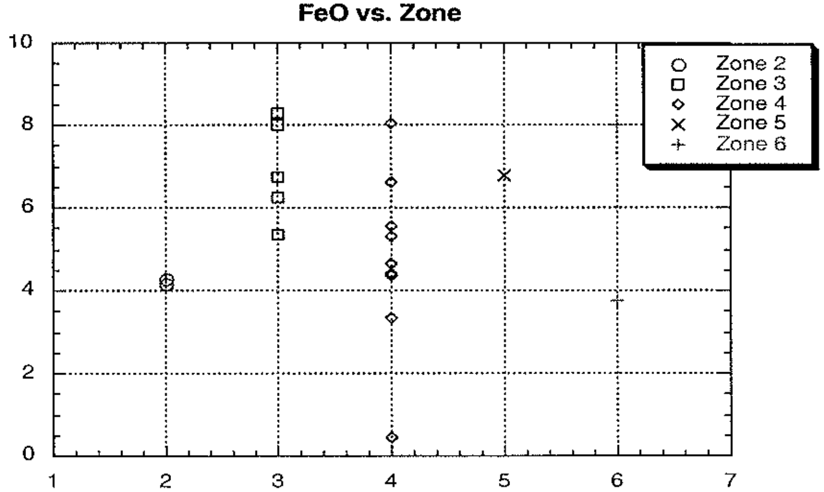

Figure 3. Iron preferentially enters melt. These graphs show that with increasing grade there is increasing iron content. This shows that some melt must be introduced, otherwise the composition would remain constant.

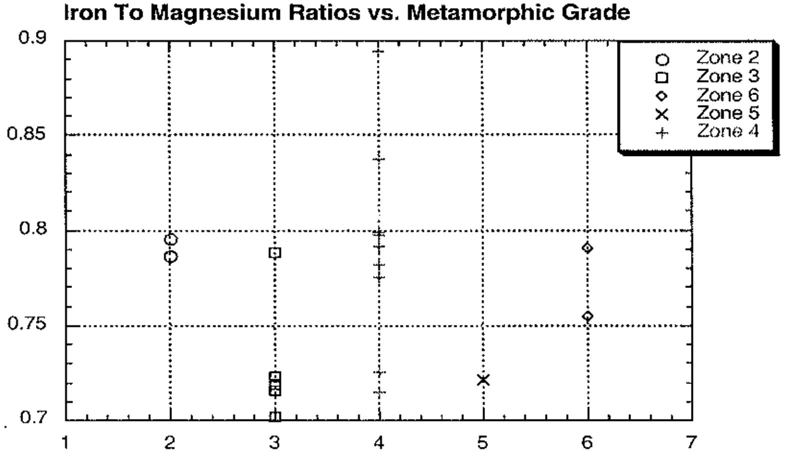

Figure 4. There is no variation of Fe/(Fe+Mg) with zone. This shows that if melt is being added from elsewhere, it is not much. Also, if there was melting within these rocks, not much melt has left.