Tectonic origins of Precambrian Granitic Gneisses & Amphibolites from the Spanish Peaks-Gallatin Mountain range, SW Montana

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Abstract

The Big Sky Orogeny affected rocks of the Spanish Peaks and Gallatin Mountain ranges in southwest Montana 1.7 billion years ago. This orogenic event caused widespread deformation and metamorphism and largely obliterated earlier evidence for the origin of granite bodies within the range. As a result of a younger tectonic event, the Laramide Orogeny, these ancient rocks were uplifted and exposed during the Cretaceous and Tertiary time. Samples were collected from Lone Mountain, Beehive Basin, and the Spanish Peak in the vicinity of the town of Big Sky in an effort to unravel the earlier tectonic origins of these rocks using whole-rock and trace element geochemistry.

Rocks with these ranges are dominated by a unit of grey gneiss with interlayered amphibolites which are adjacent with meta-supracrustal lithologies such as quartzite, schists, banded iron formation, and marble in varying proportions. Several granitic bodies intruded these pre-existing lithologies and have either post-dated them or intruded syntectonically. We will use x-ray fluorescence of granitic and amphibolite units to investigate the nature and origin of these granite bodies.

Project Objectives

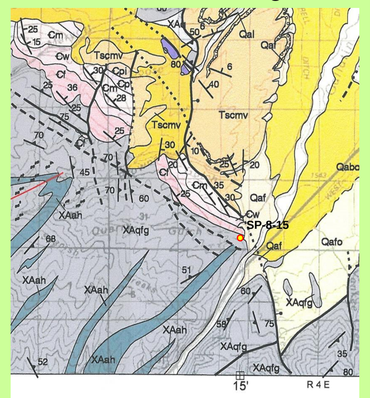
- Compare and contrast the geochemical signature of granitic and amphibolite gneisses from the Spanish Peaks and Gallatin mountain ranges
- Use geochemical data to determine the protolith of granitic gneisses and tectonic affinity in which they were produced
- Use geochemical discrimination diagrams to determine the protolith and tectonic origins of amphibolite layers in the Spanish Peak and Gallatin ranges

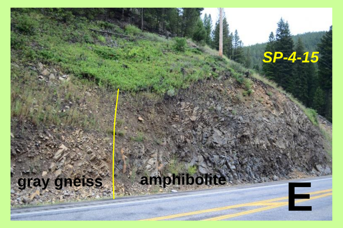
View from Beehive Basin to the southeast

Geologic Setting

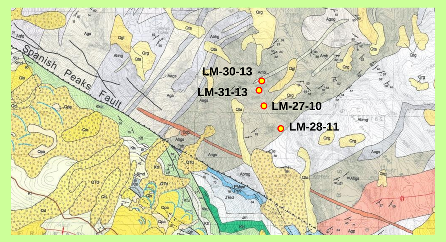
The North American continent is comprised of Archean-aged blocks of crust that subsequently collided during a Proterozoic tectonic event called the "Big Sky Orogeny" between 1.78 and 1.71 Ga. The result was tectonic uplift and high-grade metamorphism that became exposed during Late Cretaceous-Tertiary time in southwestern Montana. The Spanish Peak-Gallatin ranges extends approximately 60 km along its NE-trend and 20 km across in an E-W direction. The nature of the tectonic origins of granitic and amphibolitic rocks is unknown and is the focus of this research.

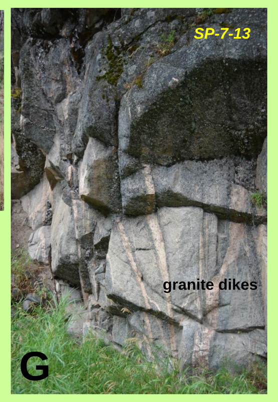
Geologic Map of northern end of Gallatin Mountain range

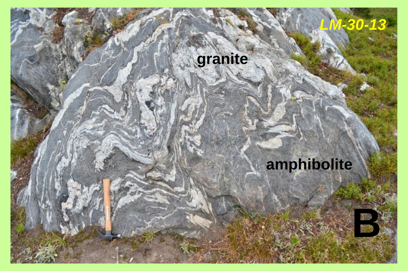




Geologic Map of Beehive Basin within the Spanish Peaks showing representative rock types and contact relations (A-C)



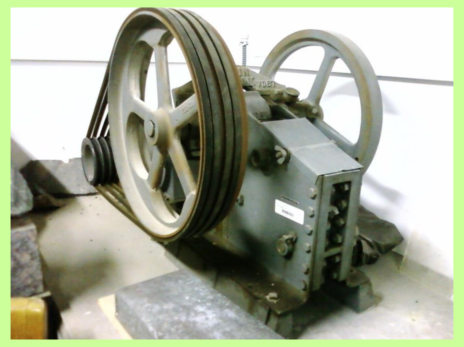




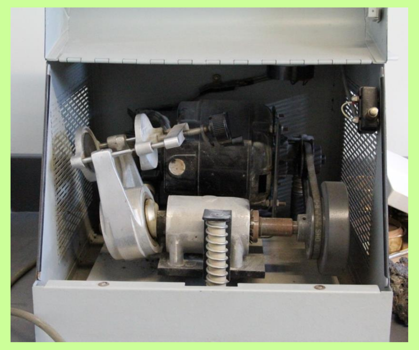
Representative sample locations (D-G) in the Gallatin Range

Sample Preparation & Analytical Methods

Samples were prepared for geochemical analysis using a jaw crusher to grind samples into smaller pieces. Samples were ground using a ball mill for a duration of 40 to 60 minutes to further reduce the grain size to a fine powder. The powder was split into 2 different aliquots; 1) used to make a fusion bead for the major oxides and 2) used to make a pressed pellet for trace element analysis.



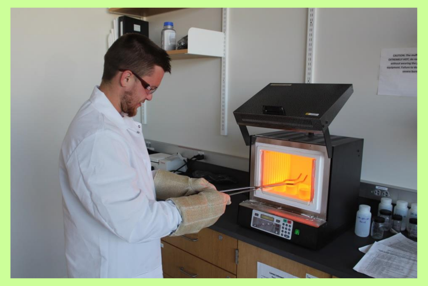
Jaw Crusher

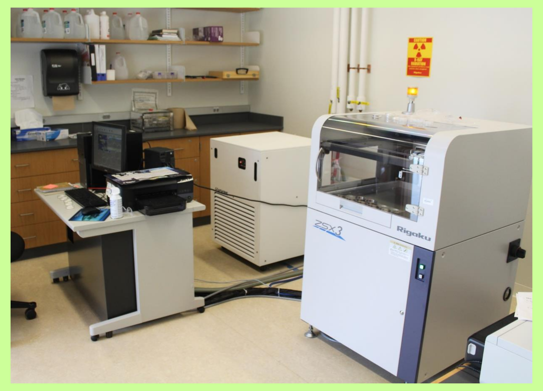


Ball Mill

Powder samples used for major oxide analysis were heated in a muffle furnace to 1000°C for 20 minutes. Samples were stirred in order to homogenize the melt. Once samples were adequately melted, they cool to room temperature and finally hand polished.

Powders for the trace element analysis were made into pressed pellets using a lithium borate binder and a 25 ton press.





Samples were analyzed using a Rigaku ZSX-3 X-ray fluorescence instrument for major oxides (in weight percent) and trace elements (in parts per million, ppm).

Standards were used to calibrate and daily drift corrections were made to ensure analytical accuracy and precision.

Geochemical Results

Spanish Peaks

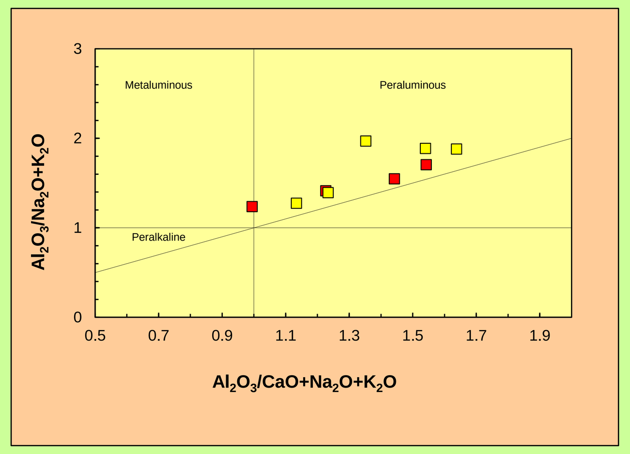
	SP-4A-15 Amphibolite	SP-4B-15 Amphibolite	SP-4C-15 Amphibolite	SP-4D-15 Amphibolite	SP-4E-15 Amphibolite	SP-8A-15 Amphibolite	SP-1-09 Granite	SP-6-13 Granite	SP-8-15 Granite	SP-8B-15 Granite
SiO_2	45.72	48.90	48.15	46.22	49.22	44.14	71.56	75.63	78.00	68.18
TiO_2	1.66	1.24	1.15	1.17	1.18	2.90	0.08	0.03	0.04	0.20
Al_2O_3	11.24	13.86	13.89	12.87	11.84	10.68	16.82	14.91	14.36	12.48
FeO_T	17.43	14.85	14.67	14.76	13.49	20.15	0.83	0.24	0.27	
MnO	0.16	0.17	0.17	0.16	0.15	0.18	0.01	0.01	0.00	0.01
MgO	4.59	6.09	6.13	6.46	7.41	6.36	0.16	0.01	0.07	1.00
CaO	9.33	10.23	10.29	9.84	10.10	9.35	1.01	0.39	0.49	1.36
Na_2O	2.18	2.50	2.45	1.93	1.82	2.53	4.58	2.63	2.12	5.17
K_2O	0.45	0.39	0.38	0.46	0.38	1.02	4.02	4.91	4.56	1.47
P_2O_5	0.25	0.14	0.13	0.13	0.12	0.36	0.03	0.02	0.00	0.07
Totals	93.00	98.36	97.41	93.99	95.71	97.66	99.10	98.75	99.91	89.93
V	354.2	344	322	334	355	686	10	1	5	9
Rb	9.7	10	10	15	9	22	137	368	144	65
Sr	147.9	195	137	288	160	110	787	50	228	336
Y	44.1	25	25	29	26	34	8	28	6	36
Zr	128.5	78	81	94	81	109	62	12	43	136
Zn	138.5	139	118	135	135	149	21	15	9	41
Ba	132.5	119	69	110	82	178	1953	80	1078	289
Co	53.6	48	49	60	62	51	47	86	51	
Cr	99.7	331	287	153	169	3	14	21	17	18
Cu	95.7	156	168	182	208	47	13	7	8	14
Nb	6.9	5	5	6	5	5	2	3	0	2
Ni	55.5	118	132	133	146	65	3	4	1	3
Mn	1577.5	1670	1675	1600	1489	1825	64	46	11	149
Mo	0	0	0	0	0	0	0	0	0	0
Pb	3	7	2	6	4	4	54	127	72	11
Ti	9954	7425	6915	7015	7051	17365	486	156	252	1185

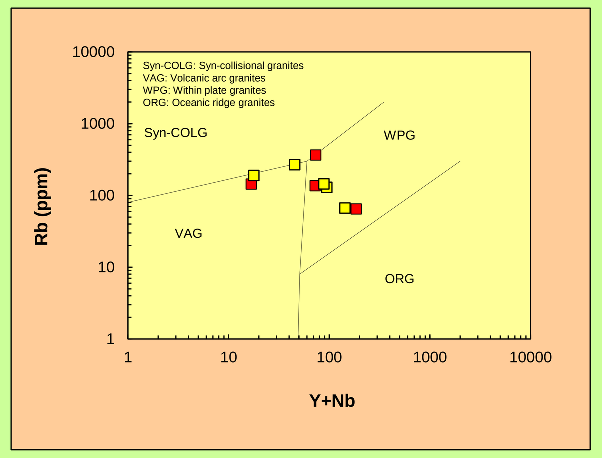
Beehive Basin

	LM-27-10 Granite	LM-28A-11 Granite	LM-30-13 Granite	LM-31-13 Granite	LM-31A-13 Granite	LM-27A-10 Amphibolite	LM-30A-13 Amphibolite	LM-31B-13 Mafic Gneiss
SiO_2	72.56	74.69	73.28	72.30	68.80	55.63	44.89	56.37
TiO_2	0.04	0.05	0.03	0.07	0.03	0.76	2.46	0.63
Al_2O_3	16.93	14.70	15.44	17.21	16.25	15.73	11.28	15.00
FeO_T	0.57	0.46	0.41	0.92	0.41	6.13	22.19	6.34
MnO	0.01	0.01	0.01	0.02	0.00	0.11	0.24	0.12
MgO	0.30	0.17	0.24	0.44	0.12	5.47	3.94	4.67
CaO	1.11	0.80	0.67	2.20	0.84	8.20	11.61	6.89
Na_2O	2.90	3.58	2.67	3.68	3.14	3.45	1.57	5.44
K_2O	3.89	5.21	3.52	2.48	5.99	2.45	0.55	2.03
P_2O_5	0.06	0.04	0.04	0.09	0.03	0.74	0.18	0.54
Totals	98.38	99.70	96.31	99.40	95.61	98.66	98.89	98.03
V	25	19	22	23	21	142	438	118
Rb	130	269	145	67	191	59	7	39
Sr	1597	888	1512	1535	1807	1893	355	1465
Y	7	8	8	5	2	32	46	32
Zr	228	100	658	188	45	155	155	252
Zn	12	6	11	17	7	101	129	113
Ba	4442	2287	4589	2336	6018	1504	68	909
Co	8	5	10	22	8	34	62	30
Cr	247	55	14	29	232	282	125	219
Cu	21	12	27	9	18	20	11	7
Nb	0	1	0.3	1	0	13	9	21
Ni	10	5	6	8	6	103	23	91
Mn	88	37	81	139	16	1076	1621	1089
Mo	4	0	0	0	2	0	0	0
Pb	44	28	50	32	50	25	6	27
Ti	258	294	204	390	192	4532	14736	3801

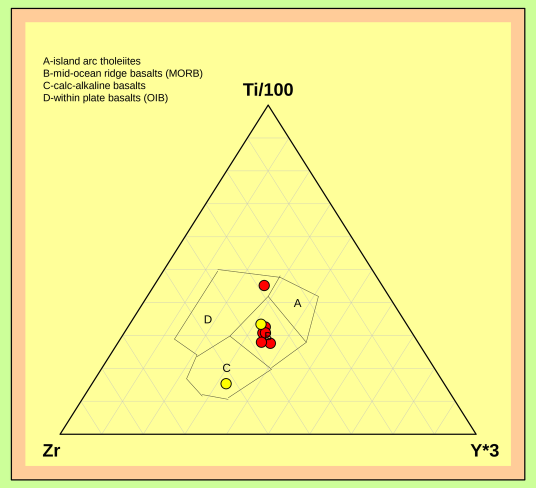
Geochemical Results

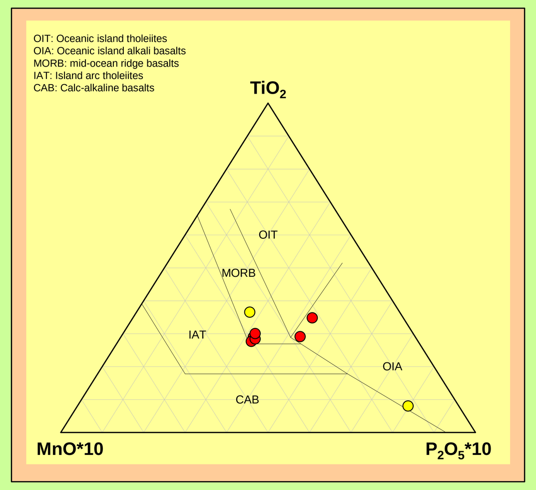
Granitic Gneiss Data

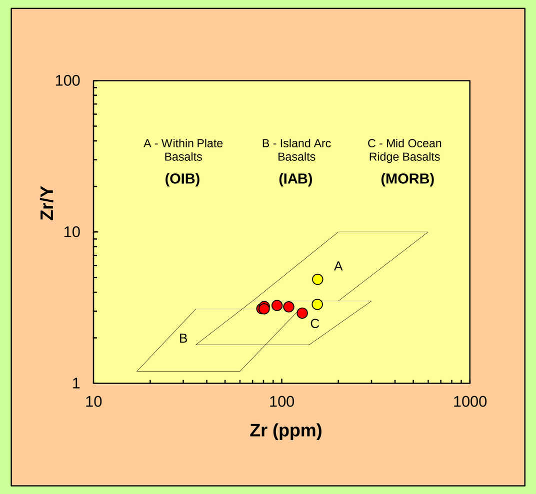




Amphibolite Data







Granitic gneisses from both parts of the ranges are largely S-type granites that formed as within-plate rift related tectonic setting or a volcanic arc setting.

Amphibolite data are more scattered in terms of their tectonic affinities. The majority of the Spanish Peak amphibolite's fall within the field of Mid-Ocean Ridge basalts (MORB), whereas the Gallatin Range amphibolite's are scattered in the MORB, Oceanic island arc, or the calc-alkaline subduction fields.

Red squares and circles: Beehive Basin

Yellow squares and circles: Spanish Peak Range

Summary

A rift related setting for a few granite samples and the MORB signature for amphibolites is in agreement with formation of both in an extensional tectonic environment.

Some of the granites and amphibolite's also indicate a volcanic arc setting.

A possible explanation for the two settings may suggest the Precambrian margin was in transition from one of convergence and subduction to one of crustal extension and rifting.

However, the ages of these units is not known making a definitive interpretation difficult at this time.

Acknowledgements

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