Southern Nicola Project: Geochemistry of Volcanic Rocks of the Nicola Group West of the Boundary Fault (Parts of NTS 092H/02, 07 and 10)

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KEYWORDS: Quesnellia, Nicola Group, volcanic geochemistry, calcalkaline, Western Belt

INTRODUCTION

The Southern Nicola Project area covers about 850 km^2 of southern British Columbia, south and west of the town of Princeton (Figure 1). The project area stretches from the Copper Mountain and Wolfe Creek area southwest to the boundary of Manning Park and northwest to the Tulameen River. Tectonically, the project area lies at the western edge of Quesnellia – just east of the bounding Pasayten fault, and includes the southernmost exposures of the Late Triassic Nicola Group. Mapping by Rice (1947), Preto (1972), Monger (1989) and Massey *et al.* (2010) has outlined the essential distribution of Late Triassic Nicola Group strata in the Princeton area (92HSE) and their relationships to younger intrusive and volcano-sedimentary sequences.

The bulk of Princeton Group volcanic and sedimentary units in the central part of the project area accumulated within a half-graben bounded on its eastern side by the Boundary fault (Figure 1). This subvertical, east-side down fault was first identified by Preto (1972), and confirmed by Read (1987), to the north. Present mapping continues the trace of the fault to the south where it curves into the valley of Placer Creek. Although active during the Eocene, the Boundary fault is part of a larger system, mapped mainly to the north, suspected by Preto (1979) to have been established early in the geological history of the region, controlling facies distributions and pluton emplacement within the Nicola Arc.

The Nicola Group in southern British Columbia has been subdivided into a western calcalkaline belt and central and eastern alkaline (shoshonitic) belts (Preto, 1979; Mortimer, 1987) Within the project area, rocks of the Nicola Group east of the Boundary fault display an alkalic affinity and have been assigned to the "Eastern Belt" (Preto, 1979). They host the important porphyry and skarn deposits of the Copper Mountain area (Preto, 1972).

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However, prior to the present study, the designation of Nicola Group rocks west of the Boundary fault was uncertain. Mortimer (1987) suggested they may belong to the calcalkaline "Western Belt", though no geochemical data were presented from the area, while Monger (1989) referred to them as "undifferentiated". The "Central Belt" terminates north of Princeton (Preto, 1979) and does not extend into the project area.

This paper focuses on the results of geochemical analyses of samples of Nicola Group volcanic and volcaniclastic rocks collected in 2008 and 2009. These results confirm correlation of the Nicola Group rocks west of the Boundary fault with the "Western Belt" as suggested by Mortimer (1989).

GEOLOGY OF THE NICOLA GROUP WEST OF THE BOUNDARY FAULT

Rocks of the Nicola Group southwest of Princeton are divided into two informal lithologic units, a clastic sedimentary unit and a volcanic unit. These are lithologically similar to units to the east, but differ in details of the stratigraphic succession (Preto, 1972; Massey *et al.*, 2009; Massey and Oliver, 2010).

Clastic Sedimentary Unit

The clastic sedimentary unit is dominated by black argillite interbedded with grey to green-grey siltstone and sandstone and polymictic conglomerate. Finer grained beds are massive to laminated and may have a limy or siliceous matrix. Coarser beds can be massive, graded or laminated. Beds vary from millimetres to several centimetres thick. Layers of matrix supported, polymictic granule to pebble conglomerate are intercalated with the finer sedimentary rocks. The clasts are dominantly clastic sedimentary, but locally include limestone and volcanic material. The sedimentary rocks in the northwest corner of the map area are strongly metamorphosed in the aureole of the Eagle Plutonic Complex to produce a sequence of quartz ±feldspar-rich schists with variable proportions of biotite, actinolite, garnet, muscovite and magnetite. Chlorite and epidote may occur as secondary alteration minerals. Calcareous beds are recrystallized to buff weathering, medium to coarse grained white marble. The marbles are usually massive, but can display a weak foliation delineated by quartz, chlorite or minor calcsilicate minerals.

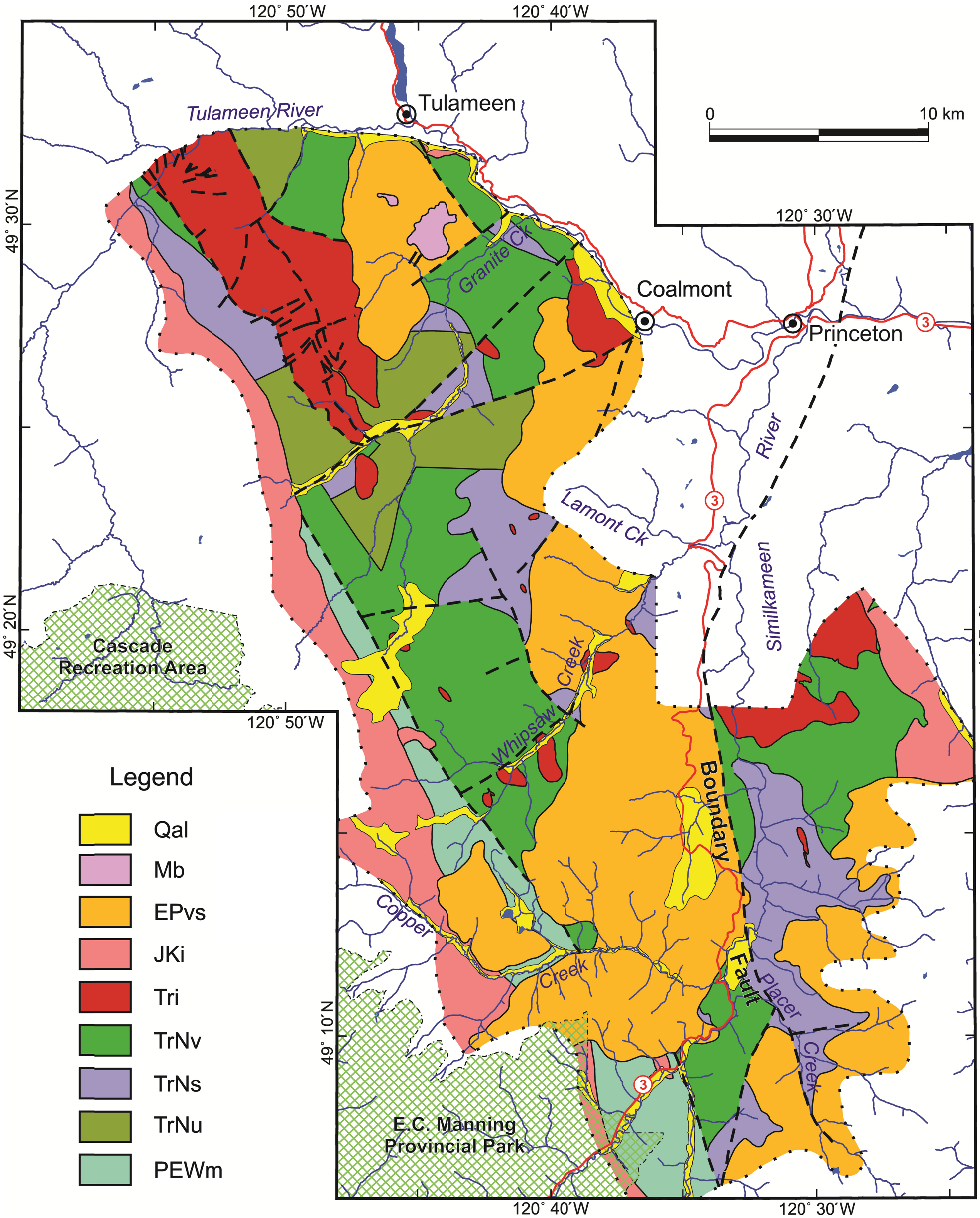

Figure 1. Simplified geology of the Southern Nicola Project area. Geology after Massey *et al.* (2010); extension of the Boundary fault outside the map area from Preto (1972) and Read (1987). Qal: Quaternary alluvium; Mb: Miocene basalt (?Chilcotin Group); EPvs: Eocene Princeton Group volcanic and sedimentary rocks; JKi Jurassic and Cretaceous felsic intrusions (including EP: the Eagle pluton , VC: Verde Creek pluton, and W: Whipsaw stock); Tri: Late Triassic ultramafite to diorite and syenite (including Tu: the Tulameen Complex, CM: Copper Mountain stock, V: Voigt stock, and R: Rice stock); TrNv: Nicola Group volcanic rocks; TrNs: Nicola Group sedimentary rocks, minor feldspathic volcaniclastic rocks; TrNu: undivided Nicola Group; PEWm: Permian Eastgate-Whipsaw metamorphic belt.

In the Lamont Main area, clastic sedimentary rocks are intercalated with feldspathic tuff, tuff breccia, tuffaceous sandstone, pebbly sandstone and fine grained cherty siltstone. Pyroxene is rare to absent in these beds. The clastic sediment and feldspathic volcaniclastic unit passes westwards, and probably upwards, into typical Nicola pyroxene-feldspar tuffs, lapilli tuffs and breccias of the volcanic unit.

Volcanic Unit

The volcanic unit includes interbedded pyroxene-feldspar tuffs, lapilli tuffs, breccias, agglomerates and tuffaceous sedimentary. They are light grey in colour, weathering to green-grey with orange stained fracture surfaces. Lithic clasts vary from angular to subrounded and are typically 3-5 cm across, ranging up to 20-25 cm in breccias and agglomerates. They are dominantly pyroxene feldspar porphyritic basalts and basaltic andesites, showing a wide variation in proportions and sizes of phenocrysts. Fragments of aphyric basalt are also present. The clasts are usually matrix supported. The matrix is medium to coarse sand sized, containing feldspar and pyroxene crystals as well as small lithic clasts. Epidote, chlorite and calcite occur as alteration minerals in clasts and matrix, and also in veins. Quartz veins are also common.

A sequence of massive feldspar phyric basalt flows occurs in the area southeast of the Granite Creek campsite. These are massive, fine grained, medium grey to green in colour. Feldspar phenocrysts are lath shaped, 1 to 3 millimetres in size and comprise 5 to 10% of the rock. One flow also contained subhedral pyroxene phenocrysts, 2 to 3 millimetres in size, with distinct blue-green feldspars in a bluish grey groundmass. Epidote and chlorite alteration is common, both in the matrix and in veins.

The volcanic rocks become progressively schistose from east to west. The tuffs and lapilli tuffs look massive in outcrop but display a weak foliation on broken surfaces. This foliation becomes progressively more penetrative to the west. Finer grained tuffs produce bluish green-grey chlorite schists. Relict pyroxenes are chloritized and vary from euhedral shapes to smeared blebs along the schistosity. Clasts in lapilli tuffs and breccias are undeformed to slightly flattened. Chloritic rims may develop around the clasts with feathering of their terminations along the foliation. Actinolite and biotite are developed in metavolcanic rocks in the aureole of the Eagle Plutonic Complex.

GEOCHEMISTRY OF THE VOLCANIC ROCKS

Thirty eight samples from the Nicola Group were analyzed for whole rock major, minor and trace elements. These are predominantly volcaniclastic rocks and some massive flows of the volcanic unit, but include three samples of volcaniclastic rocks interbedded with the clastic sediments. Results are summarized in Table 1. Samples range in composition from basalt to andesite (Figures 2 and 3). They show some mobility of alkalis but generally all preserve a subalkalic, medium-K calcalkaline character (Figures 2-5). They compare closely with the type 2 calcalkaline lavas of Mortimer (1987), which he collected from the Nicola Group in the "Western Belt" in the Merritt area and to the west of the Guichon batholith. They differ significantly from the shoshonitic type 1 lavas that are characteristic of the "Central" and "Eastern" belts (Mortimer, 1987; Preto, 1979).

Extended trace element spidergrams show typical calcalkaline patterns with the negative Nb-Ta anomaly characteristic of volcanic arcs (Figure 6). Minor and trace element petrotectonic discrimination diagrams are primarily designed for use with aphyric basaltic flows rather than porphyritic or volcaniclastic rocks. However, these plots support the formation of the Nicola Group volcanic rocks in an arc environment, though not all diagrams successfully discriminate them as calcalkaline (Figures 7-10). A few massive flows have higher P_2O_5 (>0.4 %), Zr (150 – 200 ppm) and Ti/V ratios (10 – 50), that compare with Mortimer's type 3 lavas. These latter are intermediate between arc and intra-plate character and occur in all three belts.

REGIONAL CORRELATIONS

The lithogeochemical data presented here support the correlation of Nicola Group volcanic rocks in the project area, west of the Boundary fault, with the "Western Belt" to the north, as originally proposed by Mortimer (1987). However, dacitic to rhyolitic rocks which are fairly common in the "Western Belt" to the north, are apparently absent within the project area. No paleontological or geochronological data are available on these rocks within the project area. Scattered fossil ages to the north are mainly late Carnian to early Norian (Monger and McMillan, 1989; Preto, 1979) and felsic volcanic rocks in the Merritt area yield late Triassic (Carnian) ages of 224.6 ±0.9 Ma and 224.5 ±0.3 Ma (Diakow and Barrios, 2009).

Correlation with the "Western Belt" may have implications for mineralization in the project area. Felsic volcanic rocks in the "Western Belt" are potential hosts to volcanic-hosted massive sulphide deposits. However, felsic volcanic rocks have not yet been identified in the project area.

Conversely, alkalic porphyry-copper deposits, like that at Copper Mountain, are hosted within, and probably consanguineous with, the shoshonitic "Eastern Belt" of the Nicola Group. Such mineralization is less likely to occur within the calcalkaline Western Belt. However, there are no geochemical or geochronological data from the diorite-pyroxenite stocks and minor intrusions of the project area, *e.g.* the Rice stock, which may test this.

Table 1. Whole rock chemical analyses for Nicola Group volcanic rocks. Major elements and Rb, Sr, Ba, Y, Zr, Nb, V, Ni, Cr determined by XRF (majors on fused disc, traces on pressed powder pellet) by Teck (Global Discovery) Labs. REEs, Th, Ta, Hf determined by peroxide fusion-ICPMS by Memorial University of Newfoundland. Dashes indicate element determinations below detection limit; blank values indicate element not analyzed. Map unit is as on Massey *et al.* (2010).

Sample	09SOL02-04	09SOL02-05-02	08NMA35-10	08NMA21-03	09NMA14-13	09NMA14-14	09NMA14-03	09NMA14-04	09NMA18-10
Lithology	px relics in act-qz-fsp-bio-chl-epid schist	px-phyric chl-act-bio-musc schist	fsp tuffs massive, some small lapilli	px-fsp porphyry, massive	fsp basalt, strong epidote alteration	blue-green fsp-px basalt, massive	massive vesicuar basalt	fsp basalt	massive aphyric basalt, sparse vesicles
Map Unit	TrNs	TrNs	TrNsv	TrNv	TrNvm	TrNvm	TrNv	TrNv	TrNv
SiO_2	49.61	49.21	57.17	46.68	48.41	47.28	45.49	54.47	54.20
TiO_2	0.79	0.62	0.64	0.65	1.72	1.13	1.11	1.34	1.34
Al_2O_3	17.38	13.37	17.44	14.60	15.56	17.99	16.24	16.31	14.34
Fe_2O_3t	10.03	10.23	7.39	10.10	11.99	9.73	9.74	7.14	10.86
MnO	0.17	0.17	0.14	0.15	0.17	0.17	0.16	0.11	0.15
MgO	5.43	10.73	3.25	8.77	4.50	4.91	9.80	3.25	3.53
CaO	9.83	11.38	5.94	13.00	7.41	10.13	8.25	5.74	6.00
Na_2O	4.18	1.90	3.56	1.46	4.37	3.07	1.52	4.47	3.68
K_2O	0.79	0.82	0.79	0.46	1.16	1.78	2.66	1.89	2.77
P_2O_5	0.15	0.11	0.23	0.13	0.47	0.30	0.58	0.38	0.51
BaO	0.02	0.02	0.03	0.01	0.03	0.03	0.08	0.04	0.07
LOI	1.30	1.40	2.66	3.92	3.70	3.20	4.40	3.20	2.00
Total	99.68	99.95	99.24	99.93	99.51	99.77	99.96	98.30	99.41
Ba	175	243	293	109	345	346	791	368	674
Rb	21	17	13	14	25	32	54	38	58
Sr	287	417	155	397	688	330	348	585	460
Y	16	16	27	18	24	23	26	26	42
Nb	-3	-3	16	7	4	4	9	8	5
Zr	34	30	104	52	69	116	166	192	180
V	279	251	133	257	236	287	144	320	255
Ni	43	129	-3	122	31	12	16	-3	34
Co			18	52					
Cr			18	351					
La			20.703			13.153	34.449		
Ce			34.497			28.624	70.060		
Pr			4.236			3.888	8.607		
Nd			16.432			17.235	34.722		
Sm			3.421			4.369	6.939		
Eu			1.245			1.243	2.043		
Gd			3.455			4.524	5.908		
Tb			0.579			0.709	0.847		
Dy			3.485			4.473	4.649		
Ho			0.731			0.883	0.806		
Er			1.993			2.415	2.116		
Tm			0.315			0.354	0.296		
Yb			2.359			1.975	1.739		
Lu			0.338			0.275	0.245		
Hf			2.446			1.714	3.505		
Ta			0.238			0.329	0.502		
Th			5.218			1.834	6.746		
Latitude (N)	49.493688	49.497555	49.391573	49.155825	49.493416	49.497105	49.491525	49.491832	49.443818
Longitude(W)	120.905837	120.906923	120.710806	120.586382	120.668382	120.668910	120.694723	120.693914	120.682400
Zone	10	10	10	10	10	10	10	10	10
Northing	5484447	5484874	5473506	5447582	5484922	5485331	5484653	5484689	5479377
Easting	651648	651557	666115	675980	668842	668791	666941	666999	667997

Table 1. (continued)

09NMA10-05	09NMA13-10	08NMA26-01-02	08SOL25-04	08SOL25-05	08NMA31-02-01	08NMA31-02-02	08JVI29-03	08JVI29-04	08JVI29-14
vesicular basalt	px-fsp basalt	green-grey tuffaceous sandstone, silt	px meta lapilli tuff,	px meta tuff,	px-fsp tuff, lap tuff; w eak foliation	px-fsp lap tuff; moderate foliation	massive tuffaceous sandstone and px crystal tuff	tuffaceous sandstone	tuffaceous sandstone
TrNv	TrNv	TrNv	TrNv	TrNv	TrNv	TrNv	TrNv	TrNv	TrNv
48.295	47.92	46.41	50.37	49.54	47.92	50.34	51.55	48.73	48.96
0.81	0.97	0.79	0.69	0.67	0.65	0.65	0.80	0.84	0.78
17.085	18.79	15.22	14.28	12.94	14.78	15.20	16.46	18.04	15.80
10.96	10.08	10.52	9.54	9.70	9.85	9.28	8.38	9.32	9.96
0.15	0.16	0.14	0.12	0.14	0.13	0.09	0.12	0.14	0.16
6.22	4.72	14.29	9.42	13.48	11.17	9.07	6.65	6.83	8.07
8.795	10.25	3.50	9.29	5.26	7.24	8.86	11.51	9.54	9.96
3.81	1.76	3.26	1.55	2.56	2.29	1.48	1.17	1.91	2.65
0.065	1.82	0.41	1.06	1.38	1.59	0.98	0.61	0.95	0.78
0.15	0.28	0.07	0.28	0.19	0.26	0.15	0.29	0.37	0.23
0.01	0.02	0.01	0.06	0.03	0.06	0.03	0.02	0.04	0.01
3.4	3.20	5.00	2.90	3.80	3.80	3.67	2.26	2.91	2.56
99.735	100.00	99.66	99.60	99.68	99.74	99.81	99.82	99.62	99.92
71.5	244	130	588	337	600	351	165	416	129
9	36	9	25	18	33	25	13	26	17
253	640	90	443	103	332	505	294	380	343
11	18	13	17	13	22	16	24	24	24
-3	6	-3	-3	-3	8	5	10	11	5
33.5	59	62	77	52	87	60	144	123	70
292.5	208	270	224	233	270	249	238	306	255
24	32	136	156	189	186	115	75	43	96
					47		32	30	46
					436		177	98	259
3.083					25.783		39.949	34.495	8.822
7.871					51.091		80.436	72.890	19.641
1.295					6.348		9.750	9.114	2.719
6.614					25.324		38.717	38.133	12.443
2.075					4.771		6.897	6.926	3.285
0.777					1.447		1.866	2.016	1.071
2.475					3.831		4.963	5.826	3.656
0.443					0.540		0.612	0.768	0.552
2.736					2.954		3.336	4.142	3.445
0.567					0.524		0.620	0.822	0.670
1.686					1.494		1.795	2.250	1.937
0.266					0.203		0.254	0.312	0.269
1.496					1.420		1.708	2.096	1.952
0.203					0.238		0.242	0.335	0.286
0.899					1.818		3.409	2.979	1.623
0.073					0.082		0.116	0.136	0.038
0.475					4.310		8.277	5.835	1.436
49.522734	49.473473	49.296624	49.279527	49.296584	49.323464	49.324289	49.365568	49.364846	49.381870
120.810926	120.687642	120.657719	120.678707	120.658002	120.692235	120.691125	120.748600	120.732478	120.746621
10	10	10	10	10	10	10	10	10	10
5487871	5482662	5463070	5461122	5463065	5465976	5466070	5470533	5470488	5472350
658426	667516	670295	668827	670274	667694	667772	663458	664631	663548

Table 1. (continued)

09NMA10-01	09NMA13-13	08NMA31-08	08NMA28-13-01	08NMA28-13-02	08NMA28-14	08NMA29-04	08NMA29-11	08NMA34-09	08SOL25-01
fsp-px lithic tuff	px-fsp crystal lapilli tuff	medium-coarse grained, px-fsp tuff	fsp-phyric chloritic meta-tuff	fine grained chloritic meta-tuff	px-fsp chlorite schist	px-phyric, chlorite schist	px-fsp chlorite schist	px chlorite schist	px-fsp phyric meta-tuff
TrNv	TrNv	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'
46.81	42.45	46.14	48.95	50.63	46.58	47.29	47.65	44.17	48.01
1.26	0.81	0.77	0.85	0.98	0.69	0.66	0.63	0.66	0.57
16.96	16.62	16.57	20.23	18.33	14.67	15.35	14.51	15.99	11.71
10.32	10.31	9.50	10.25	8.93	9.18	8.71	8.78	9.59	9.87
0.14	0.15	0.13	0.15	0.18	0.14	0.14	0.09	0.13	0.16
3.13	7.76	8.86	3.94	2.98	9.64	10.14	6.84	9.37	12.87
8.56	11.01	8.70	8.40	9.51	10.75	8.94	7.79	8.18	11.81
4.90	2.40	2.79	3.04	3.00	2.26	2.53	3.20	1.54	1.17
1.04	1.46	0.92	0.65	0.91	0.68	1.01	0.51	0.71	0.69
0.40	0.13	0.33	0.10	0.12	0.17	0.19	0.18	0.18	0.12
0.03	0.03	0.03	0.02	0.02	0.02	0.05	0.02	0.03	0.02
6.00	6.80	4.78	3.30	4.00	4.90	4.80	9.70	9.10	2.80
99.53	99.94	99.52	99.91	99.62	100	99.79	99.93	99.59	99.79
308	302	336	168	161	157	472	230	289	197
27	19	21	18	19	17	25	16	22	16
458	350	601	173	175	387	473	426	636	369
27	15	20	16	23	17	15	17	18	18
9	-3	6	-3	-3	-3	-3	-3	-3	-3
138	36	106	36	49	32	46	61	55	25
284	222	285	250	200	235	213	242	248	206
16	111	72	6	6	147	181	90	111	199
		39							
		161							
34.821	8.043	28.230							
74.539	17.356	56.949							
9.386	2.411	7.033							
36.888	10.791	29.179							
7.045	2.752	5.524							
2.094	0.921	1.746							
6.383	3.060	4.540							
0.843	0.465	0.650							
4.959	2.929	3.835							
0.935	0.583	0.721							
2.528	1.700	1.954							
0.346	0.229	0.293							
2.063	1.420	1.937							
0.290	0.209	0.298							
2.430	0.886	2.376							
0.465	0.150	0.088							
3.862	1.461	4.535							
49.523798	49.481554	49.319200	49.280177	49.280177	49.288021	49.303283	49.301167	49.339825	49.296099
120.799553	120.704556	120.693300	120.736689	120.736689	120.736050	120.690157	120.683841	120.722864	120.739422
10	10	10	10	10	10	10	10	10	10
5488013	5483523	5465500	5461067	5461067	5461940	5463737	5463516	5467727	5462830
659246	666263	667631	664609	664609	664629	667914	668380	665414	664357

Table 1. (continued)

08SOL25-03	09NMA08-13	09NMA02-03	09NMA02-04	09NMA03-03-01	09SOL01-12	09SOL02-07	09NMA01-09-03	09NMA07-01
px meta-tuff	feldspathic tuffs w ith minor px	px-act schist; minor calcite	schistose px-phyric lapilli tuffs (act-chlor)	px-act-chlor schist	fsp-chlor schist, epidote	px-phyric chl-bio-act schist	chlor-bio-act schist (relict px)	chlor mafic meta-tuffs, fsp xst tuff
TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'	TrNv'
49.25	47.66	47.30	48.33	48.29	47.98	47.64	49.38	48.14
0.67	0.92	0.65	0.60	0.69	0.63	0.58	0.58	0.77
14.42	18.55	13.78	12.16	14.89	19.80	11.65	12.54	16.32
9.51	8.63	9.90	9.68	9.74	9.96	10.07	9.58	9.27
0.15	0.16	0.17	0.17	0.14	0.16	0.16	0.16	0.15
8.77	5.59	11.41	12.53	10.52	5.68	12.94	11.69	9.03
10.89	9.72	11.00	13.25	10.37	9.69	11.38	11.75	7.63
2.69	3.61	2.51	1.49	1.97	2.62	1.81	1.78	3.61
0.42	0.96	0.44	0.23	1.18	0.49	0.47	0.73	0.97
0.13	0.21	0.15	0.13	0.17	0.07	0.11	0.12	0.20
0.01	0.02	-0.01	-0.01	0.02	0.02	0.01	0.02	0.02
2.60	3.80	2.60	1.30	1.90	2.80	3.00	1.50	3.90
99.48	99.81	99.94	99.85	99.86	99.88	99.84	99.81	99.96
117	164	37	12	216	164	110	167	158
13	22	14	10	27	15	15	15	22
499	379	273	335	433	359	210	283	354
20	15	14	16	12	9	10	17	14
-3	-3	-3	-3	-3	-3	4	-3	-3
28	33	48	41	39	33	38	44	60
218	245	233	230	265	217	223	225	233
88	27	176	182	145	16	203	153	66
49.245159	49.474289	49.370972	49.372289	49.380612	49.494517	49.505620	49.512924	49.410049
120.695089	120.740078	120.806183	120.808296	120.815929	120.898125	120.910815	120.922770	120.780393
10	10	10	10	10	10	10	10	10
5457265	5482637	5471011	5471153	5472062	5484554	5485763	5486551	5475409
667752	663715	659260	659103	658522	652203	651250	650362	661005

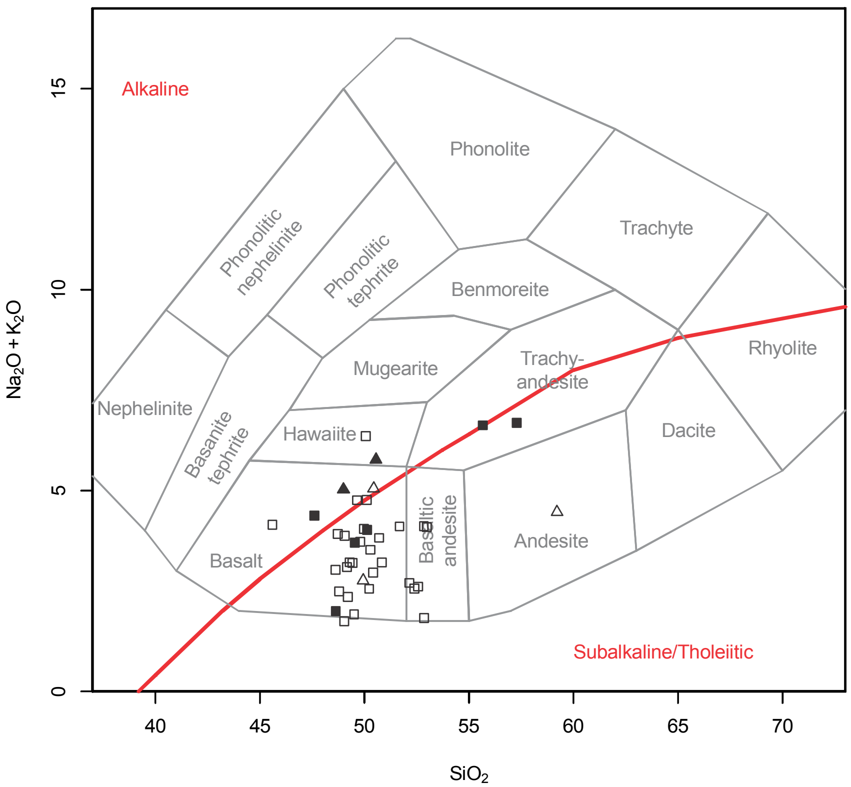

Figure 2. Total alkali vs SiO_2 (anhydrous weight %) plot for Nicola Group volcanic rocks. Classification fields and nomenclature after Cox *et al.* (1979). The alkaline-subalkaline dividing line after Irvine and Baragar (1971). Massive flows: closed symbols (squares: interbedded with volcaniclastic rocks; triangles: from massive subunit SE of Granite Creek); volcaniclastic rocks: open symbols (squares: from volcanic unit; triangles from sedimentary unit).

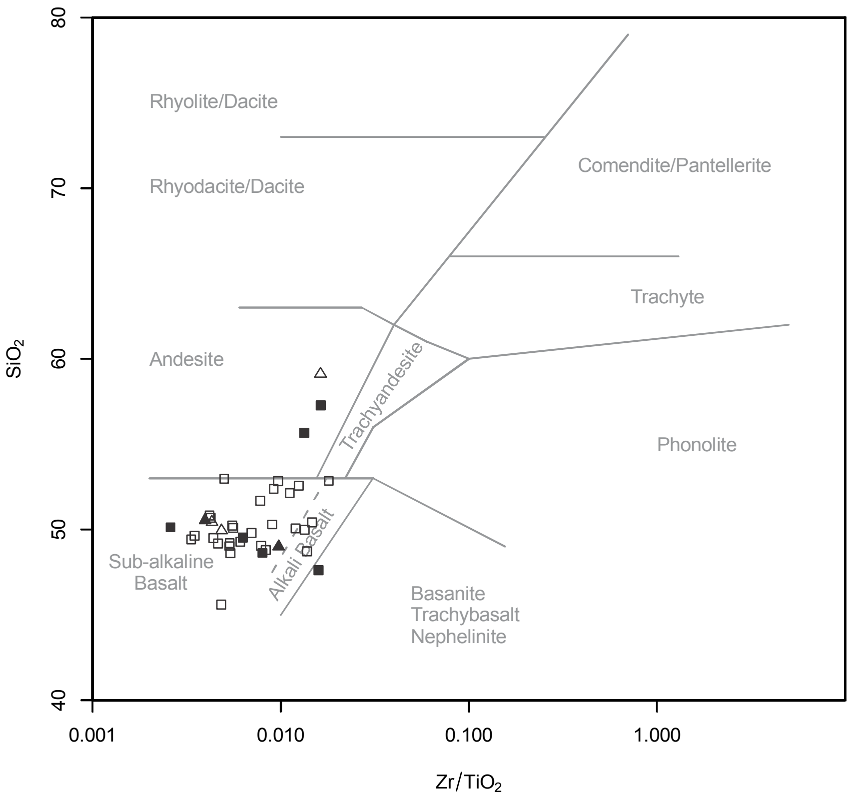

Figure 3. Zr/TiO_2 vs SiO_2 (anhydrous weight %) plot for Nicola Group volcanic rocks. Classification fields and nomenclature after Winchester and Floyd (1977). Symbols as in Figure 2.

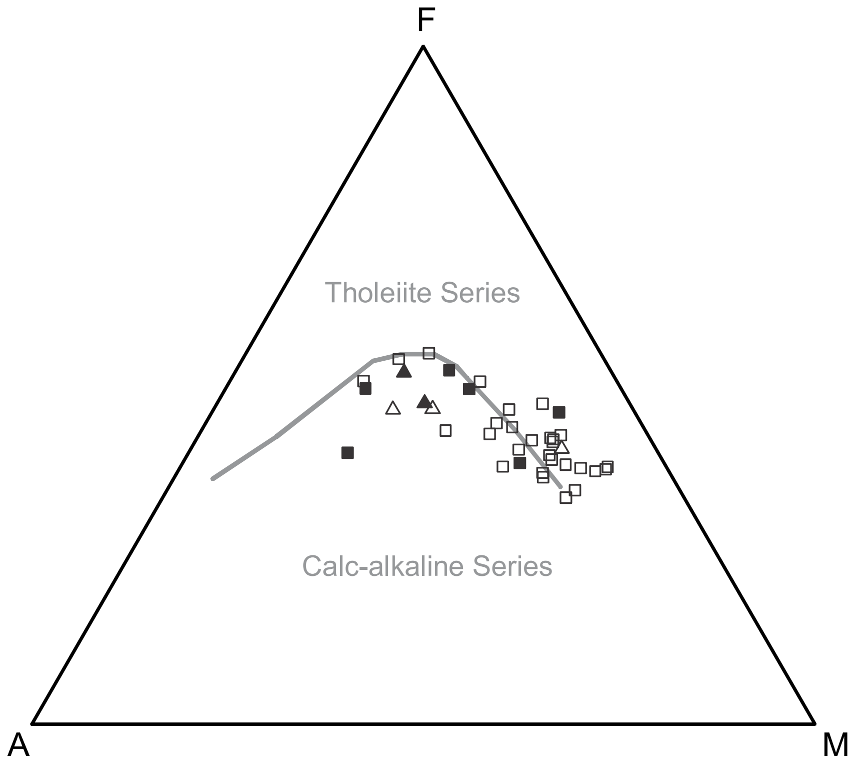

Figure 4. AFM diagram for Nicola Group volcanic rocks after Irvine and Baragar (1971). A = $Na_2O + K_2O$; F = FeO_{total}; M = MgO, all as anhydrous weight percents. Symbols are as in Figure 2.

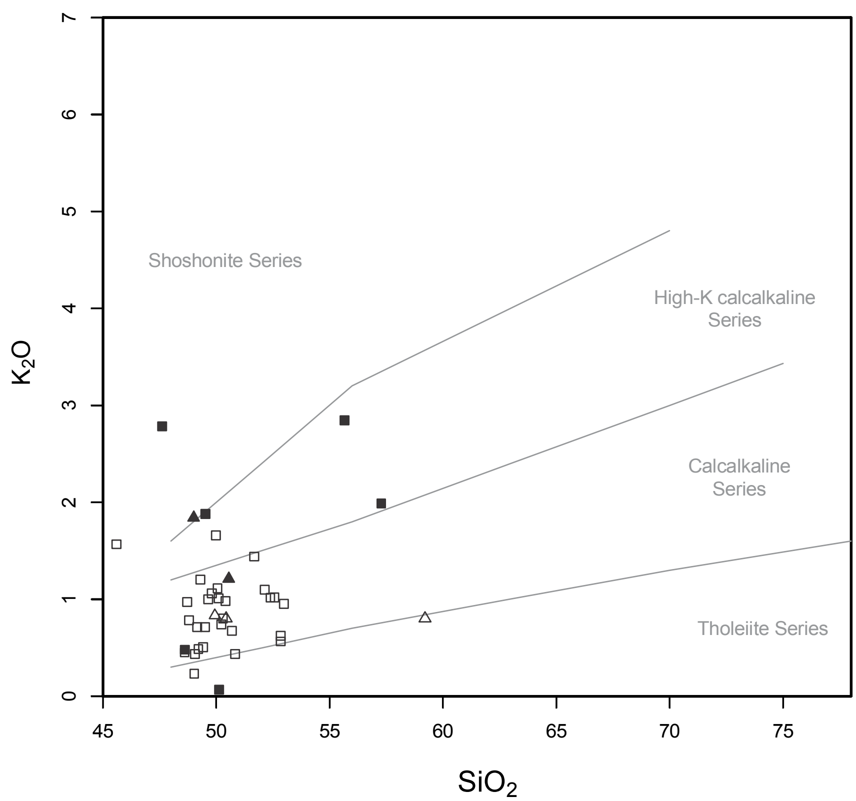

Figure 5. K_2O vs SiO_2 (anhydrous weight %) plot for Nicola Group volcanic rocks. Classification fields and nomenclature after Peccerillo and Taylor (1976). Symbols as in Figure 2.

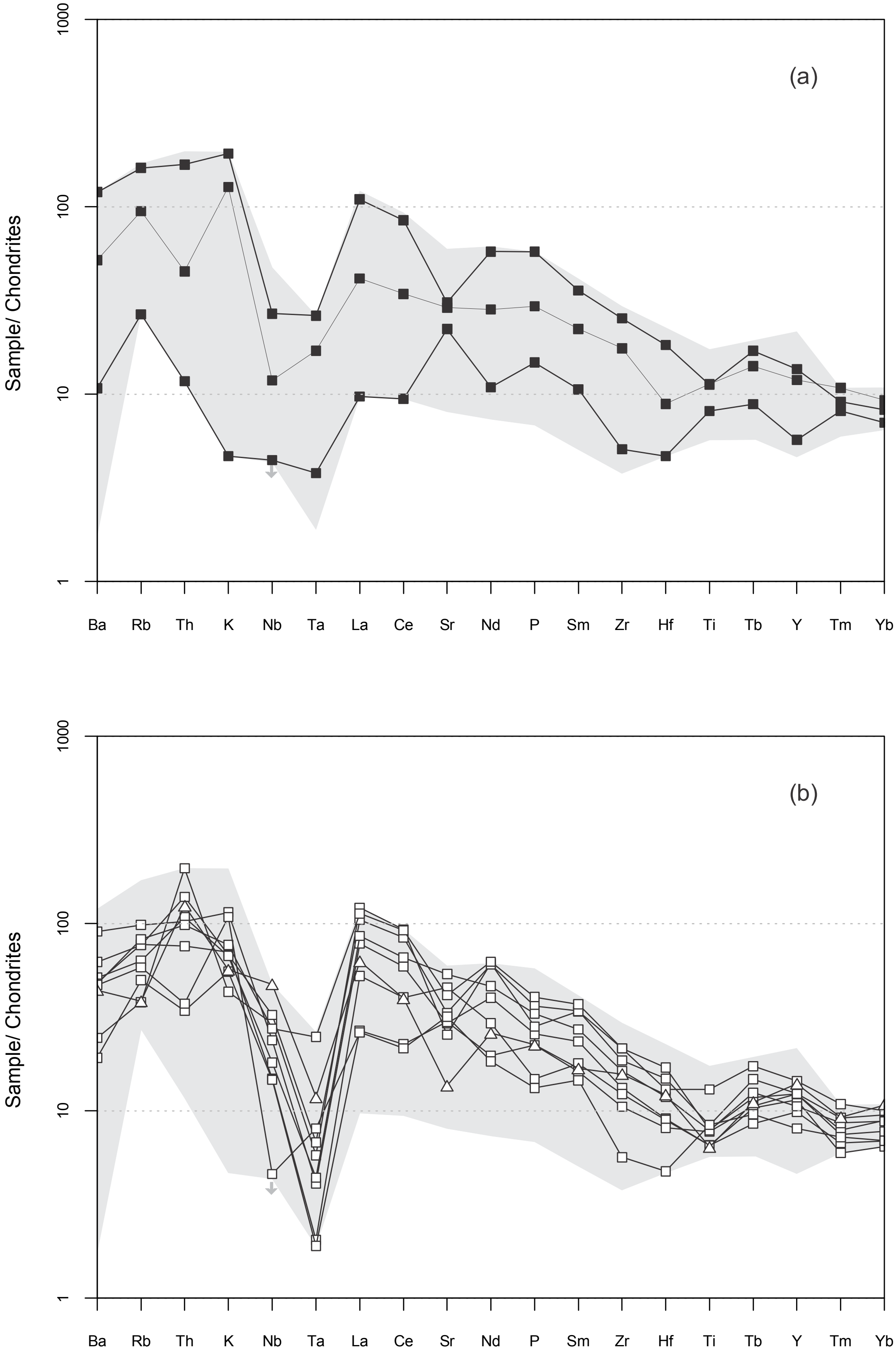

Figure 6. Trace element concentrations normalized to chondrite, after Thompson (1982). a) massive flows; b) volcaniclastic rocks. Symbols as in Figure 2. Only samples with the complete range of determined elements are plotted. The shaded field shows the range for all samples; arrow indicates that many samples have Nb values below the detection limit (3 ppm).

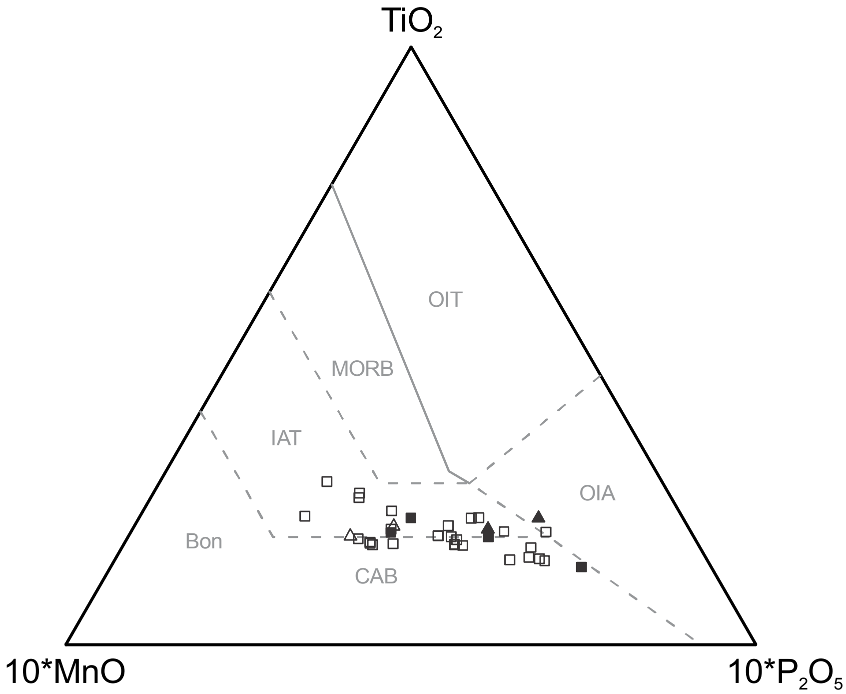

Figure 7. MnO-TiO_2-P_2O_5 (anhydrous weight %) discrimination diagram for Nicola Group volcanic rocks after Mullen (1983). OIT: ocean-island tholeiite; OIA: ocean-island alkali basalt; MORB: mid-ocean ridge basalt; IAT: island-arc tholeiite; CAB: calcalkaline basalt; Bon: boninite. Symbols are as in Figure 2. Only samples with 45<SiO_2<54 are shown.

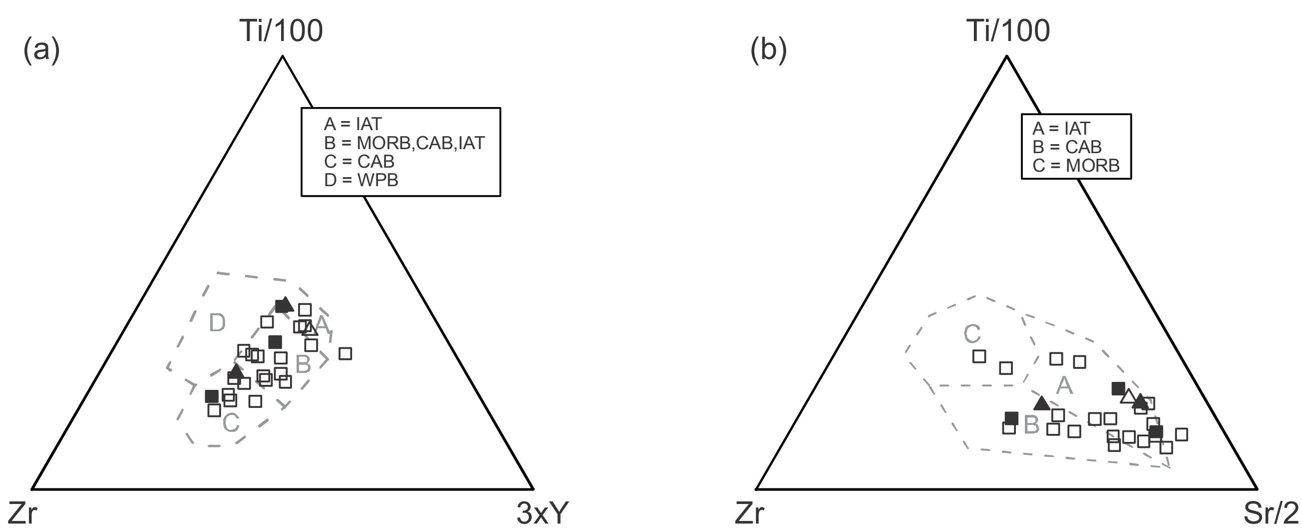

Figure 8. Trace element discrimination diagrams for Nicola Group volcanic rocks after Pearce and Cann (1973). a) Ti-Zr-Y diagram, A: island-arc tholeiites; B: mid-ocean ridge basalts, island-arc tholeiites and calcalkaline basalts; C: calcalkaline basalts; D within-plate basalts. b) Ti-Zr-Sr diagram, A: island-arc tholeiites; B: calcalkaline basalts; C: mid-ocean ridge basalts. Symbols are as in Figure 2. Only basaltic samples with 12<CaO + MgO<20 are shown.

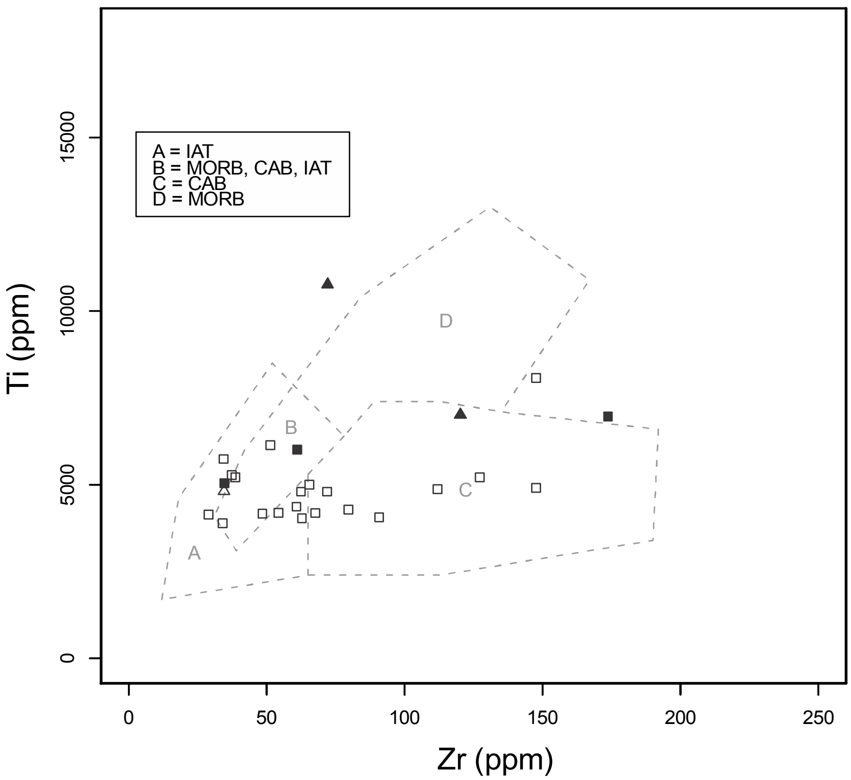

Figure 9. Ti-Zr (anhydrous parts per million) discrimination diagram for Nicola Group volcanic rocks after Pearce and Cann (1973). A: island-arc tholeiites; B: mid-ocean ridge basalts, island-arc tholeiites, calcalkaline basalts; C: calcalkaline basalts; D: within-plate basalts. Symbols are as in Figure 2. Only basaltic samples with 12<CaO + MgO<20 are shown.

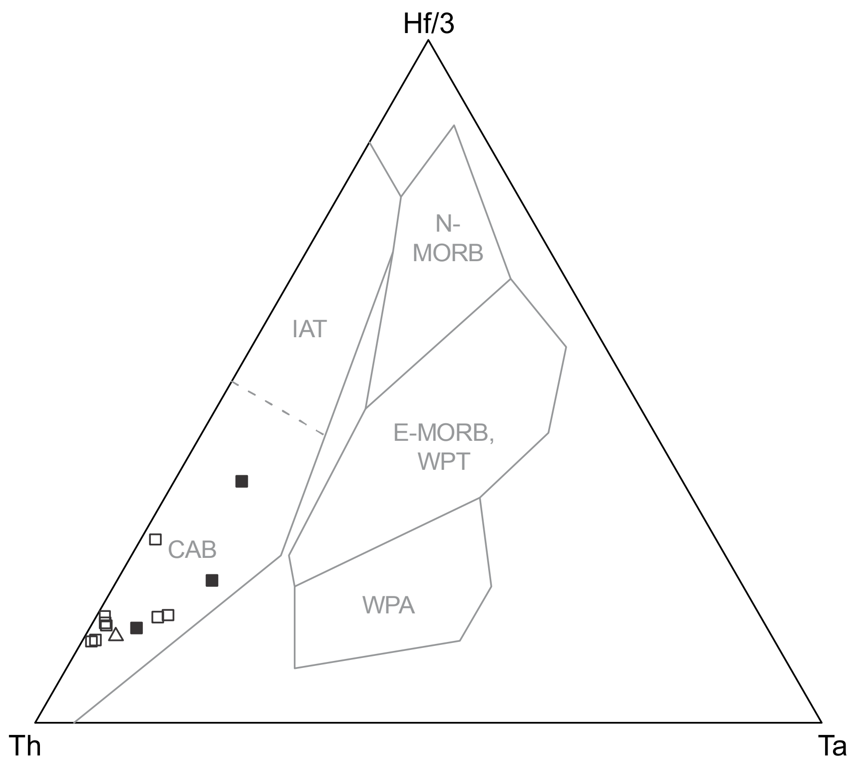

Figure 10. Th-Hf-Ta discrimination diagram for Nicola Group volcanic rocks after Wood (1980). IAT: island-arc tholeiite; CAB: calcalkaline basalt; N-MORB: normal-type mid-ocean ridge basalts; E-MORB: enriched-type mid-ocean ridge basalts; WPT: within-plate tholeiite; WPA: within-plate alkali basalt. Symbols are as in Figure 2.

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