Geochemistry of Volcanic and Plutonic Rocks of the Sitlika Assemblage, Takla Lake Area, Central British Columbia (NTS 093N/04, 05, 12, 13)

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INTRODUCTION

The Sitlika assemblage comprises a belt of Permo-Triassic volcanic, sedimentary and plutonic rocks, which crop out in the Takla Lake area of central British Columbia. It includes rocks that correlate with the Kutcho assemblage of northern BC, which hosts the Kutcho Creek Cu-Zn volcanogenic massive sulphide deposit. The Sitlika belt was mapped by the BC Geological Survey between 1995 and 1998, as part of the Nechako NATMAP federal-provincial geoscience program. Samples of representative volcanic and plutonic rocks were analyzed for whole-rock geochemistry during this program, but only some of this data has previously been presented (Childe and Schiarizza, 1997; Schiarizza and Massey, 2000). In this paper, we present, and briefly discuss, the geochemistry of the full suite of Sitlika samples collected during the NATMAP program.

The Takla Lake map area is located along the western edge of NTS map sheet 093N. The most direct access is via networks of logging and forest service roads that originate near the town of Fort St. James, which is located 125 km southeast of Takla Narrows. Access from Fort St. James is also provided by the CN Rail line which, in part, follows the eastern shore of Takla Lake.

REGIONAL GEOLOGY

The Sitlika assemblage is generally included in the oceanic Cache Creek terrane. It comprises a Permo–Triassic volcanic unit and an overlying Late Triassic–Early Jurassic (?) clastic sedimentary unit, and two small tonalite to diorite plutons of Early Triassic age (Figure 1). The main stratigraphic units of the Sitlika assemblage are folded and structurally overlain by higher elements of the Cache Creek terrane across a system of mainly east-dipping, Early–Middle Jurassic thrust faults (Struik et al., 2001). These higher units of the Cache Creek terrane include, in ascending order, a tectonically disrupted Late Paleozoic ophiolite succession and a structurally imbricated assemblage of Carboniferous–Early Mesozoic chert, argillite, phyllite, limestone and basalt (Figures 1, 2). All units of the Cache Creek terrane, including the Sitlika assemblage, commonly display a penetrative foliation and lower greenschist-facies metamorphic mineral assemblages.

The Sitlika assemblage is flanked to the west by rocks of the Stikine terrane, which includes arc-derived volcanic and sedimentary rocks of the Late Paleozoic Asitka Group, the Late Triassic Takla Group, the Early–Middle Jurassic Hazelton Group and Late Triassic–Middle Jurassic arc-related plutonic suites (MacIntyre et al., 2001). These rocks are separated from the Sitlika assemblage mainly by a system of steeply dipping, north-striking faults, which are, at least in part, related to a regional dextral strike-slip fault system of Late Cretaceous–Early Tertiary age. Older, east-dipping thrust faults are preserved locally within the Stikine terrane and relationships beyond the Takla Lake area suggest that Stikine terrane was the footwall to the Early–Middle Jurassic west-directed thrust system documented in the adjacent Cache Creek terrane (Struik et al., 2001).

Younger rocks exposed in the Takla Lake map area include several large granitic plutons in the southeast and Late Cretaceous sedimentary rocks of the Sustut Group along the western boundary of the area. The mainly Early Cretaceous granitic plutons cut various units of the Cache Creek terrane and the thrust faults separating them. The Sustut Group comprises conglomerate and sandstone that is in fault contact with various units of the Stikine terrane (Figure 1).

THE SITLIKA ASSEMBLAGE

The Sitlika assemblage was named by Paterson (1974) for greenschist-facies metavolcanic and metasedimentary rocks on the eastern side of Takla Lake, which had previously been included in the Cache Creek and Takla groups by Armstrong (1949). He subdivided the assemblage into three divisions: a central volcanic division, a greywacke division to the east and a narrow argillite division to the west. Monger et al. (1978) correlated the Sitlika assemblage with the Kutcho Formation, host to the Kutcho Creek volcanogenic massive sulphide deposit, which occurs in the eastern part of the King Salmon allochthon in northern BC. They suggested that the Kutcho and Sitlika assemblages might have been contiguous prior to dispersion along Late Cretaceous or Early Tertiary dextral strike-slip faults.

The distribution and subdivisions of the Sitlika assemblage shown on Figure 1 are based on 1995–1998 geological mapping by the BC Geological Survey (Schiarizza and Payie, 1997; Schiarizza et al., 1998; Schiarizza and MacIntyre, 1999). This continuous belt is offset by a northeast-striking fault about 7 km northwest of Mount Olson, but a narrow sliver of volcanic and sedimentary rocks correlated with the Sitlika assemblage extends an additional 35 km

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northwestward into the southern part of the McConnell Creek map area (Monger, 1977; Richards, 1990). The southern end of the belt is likewise truncated by a northeast-striking fault just beyond the southern boundary of Figure 1, although several fault-bounded blocks of sedimentary rocks correlated with the Sitlika clastic sedimentary unit have been mapped southward from there to the vicinity of Babine Lake (MacIntyre and Schiarizza, 1999). A belt of

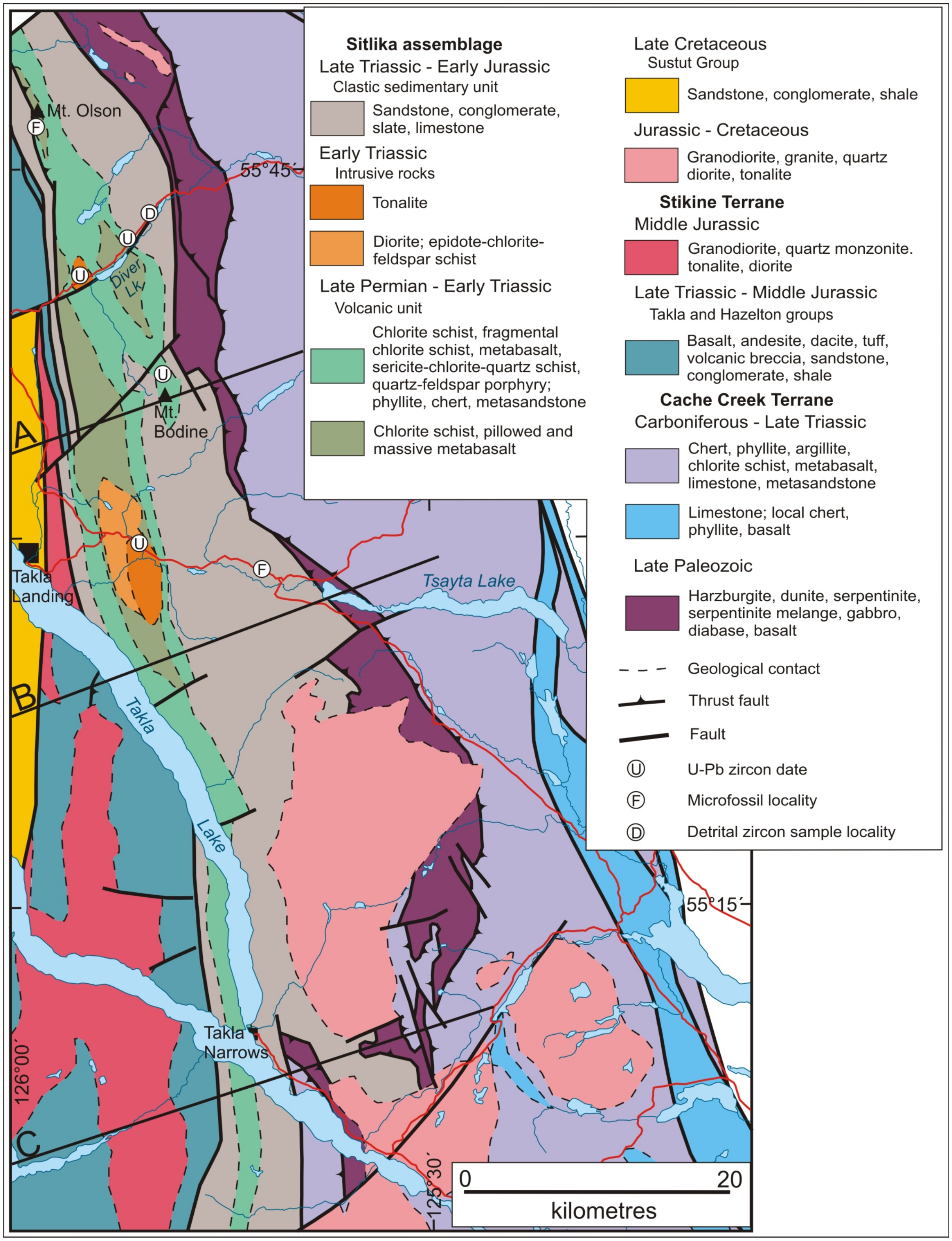

Figure 1. Generalized geology of the Takla Lake area, central British Columbia (after Schiarizza, 2000; Schiarizza et al., 2000).

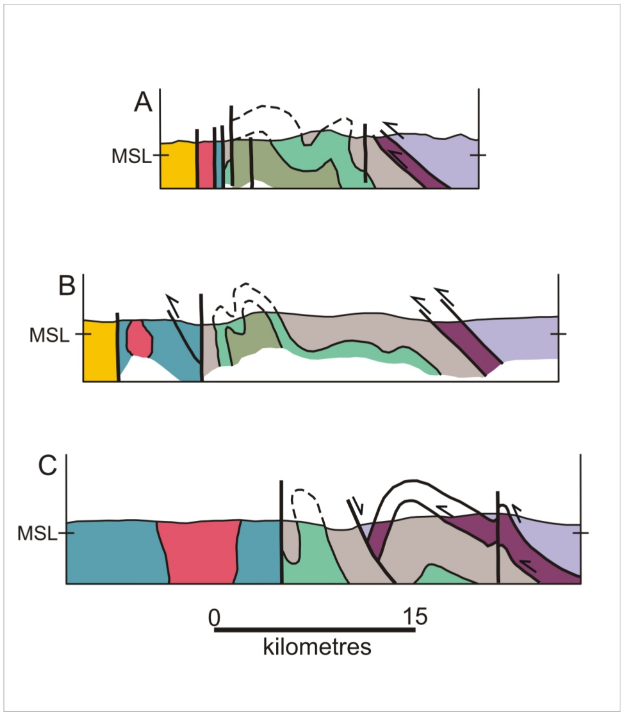

Figure 2. Schematic vertical cross-sections through the western part of the Takla Lake area, central British Columbia. See Figure 1 for legend and location of section lines. Abbreviation: MSL, mean sea level.

volcanic rocks exposed near Cunningham Lake in this southern area was provisionally correlated with the Sitlika volcanic unit, but subsequently yielded a Middle Jurassic U-Pb zircon date, which demonstrates that it is not actually part of the Sitlika assemblage (Mihalynuk et al., 2008).

The Sitlika assemblage is currently divided into two main units: a volcanic unit and an unconformably overlying clastic sedimentary unit. The volcanic unit corresponds to the volcanic division originally defined by Paterson (1974). The clastic sedimentary unit forms a wide belt to the east of the volcanic unit, where it corresponds to the greywacke division of Paterson. The clastic sedimentary unit is structurally repeated as a narrow belt to the west of the volcanic unit (Figure 2), where it corresponds, in part, to Paterson's argillite division. However, part of Paterson's argillite division has been reassigned to the adjacent Stikine terrane, where it is included in a sedimentary unit in the upper part of the Takla Group (Schiarizza and MacIntyre, 1999).

Volcanic Unit

The volcanic unit of the Sitlika assemblage is separated into two subunits: a mafic volcanic subunit and an overlying mixed volcanic subunit. The mafic volcanic subunit comprises a monotonous succession of plagioclase-epidote-actinolite-chlorite schist, semischist and greenstone that locally displays relict volcanic features such as pillows, pillow breccias, amygdules and relict phenocrysts of plagioclase, and, less commonly, pyroxene. The mixed volcanic subunit includes similar mafic schist, intercalated with felsic volcanic rocks and sedimentary rocks. The felsic units include quartz-sericite schist, with or without relict quartz and feldspar phenocrysts, and massive to flow-banded feldspar porphyry and quartz-feldspar porphyry. Fragmental sericite-chlorite schist is also common and contains flattened fragments of felsic and mafic volcanic rock, locally accompanied by relict crystals of feldspar, quartz and pyroxene, and, rarely, clasts of dioritic to tonalitic plutonic rock. Sedimentary rocks within the mixed volcanic subunit include black phyllite, siltstone, feldspathic sandstone, green siliceous phyllite and chert.

A massive, quartz-plagioclase–phyric rhyolite unit within the mixed volcanic subunit on the northeastern flank of Mount Bodine has yielded a U-Pb zircon date of 258 +10/-1 Ma (Childe and Schiarizza, 1997). A sample of flow-banded rhyolite from near the top of the mixed volcanic subunit northeast of Diver Lake appears to be from about the same stratigraphic level (Figure 1), but yielded a younger U-Pb zircon date of 248.4 ±0.3 Ma (M. Villeneuve, *in* Struik et al., 2007). Despite the range, both samples indicate a Late Permian age, which is corroborated by Permian radiolarians (*Latentibifistula* sp.) extracted from a narrow chert interval intercalated with volcanic rocks of the mixed subunit south of Mount Olson (F. Cordey, *in* Struik et al., 2007).

Intrusive Rocks

Dikes and sills of variably foliated diorite, feldspar-chlorite schist and quartz-feldspar porphyry are widespread within the Sitlika volcanic unit, which also hosts two mappable plutons. The composite Maclaing Creek pluton, east of Takla Landing, includes a mafic component consisting of foliated diorite and epidote-chlorite-feldspar schist, and a younger felsic component consisting of massive to weakly foliated chlorite-epidote–altered tonalite (Schiarizza et al., 1998). The smaller Diver Lake stock, west of Diver Lake, consists mainly of massive to weakly foliated tonalite, which displays several textural variations (Schiarizza and Payie, 1997). Zircons from the Diver Lake pluton yielded a U-Pb date of 241 ±1 Ma (Childe and Schiarizza, 1997) and tonalite from the Maclaing Creek pluton yielded a U-Pb zircon date of 243 3 Ma (M. Villeneuve, *in* Struik et al., 2007). These dates indicate that magmatism within the Sitlika assemblage continued into the Early Triassic.

Clastic Sedimentary Unit

The clastic sedimentary unit of the Sitlika assemblage consists of slate, siltstone and sandstone, with local intercalations of conglomerate and limestone. Where observed, the base of the unit is in abrupt stratigraphic contact with the volcanic unit, and commonly includes a basal conglomerate that contains clasts of felsic to mafic volcanic and plutonic rocks, which may have been derived from the underlying volcanic unit (Schiarizza and Payie, 1997; Schiarizza et al., 1998). Higher stratigraphic levels consist largely of thin-bedded slate and siltstone, commonly intercalated with thin to thick, massive to graded beds of fine- to coarse-grained sandstone and granule conglomerate. Sandstones range from schistose wacke, containing quartz, feldspar and lithic grains, to quartz-rich wacke and arenite. Calcareous rocks, including thin layers and lenses of calcareous sandstone, calcarenite and impure marble, are scattered throughout the unit, but may be most common in the lower part.

The clastic sedimentary unit is dated at a single locality, 3 km west of Tsayta Lake, where Late (?) Norian conodonts were extracted from a schistose calcarenite bed (M.J. Orchard, *in* Struik et al., 2007). In addition, a sandstone sample from northeast of Diver Lake was analyzed for detrital zircons (Figure 1) and yielded grains as young as 202 Ma (latest Triassic; M. Villeneuve, *in* Struik et al., 2007).

GEOCHEMISTRY OF THE SITLIKA ASSEMBLAGE

The samples analyzed from the Sitlika assemblage are listed in Table 1 and their locations are shown on Figure 3. The geochemical data are listed in Tables 2, 3 and 4. Major elements and Rb, Sr, Ba, Y, Zr, Nb, V, Cr, Ni, Cu and Zn were determined by X-ray fluorescence (majors on fused disc, traces on pressed powder pellet) at McGill University. Rare earth elements (REE), Hf, Ta and Th were determined by peroxide-fusion inductively coupled plasma–mass spectrometry at the Memorial University of Newfoundland, except for samples PSC95-16-4 and PSC95-18-6-1, (originally reported by Childe and Schiarizza, 1997), which were determined by instrumental neutron activation analysis at Activation Laboratories Ltd.

The Sitlika rocks have been subject to varying degrees of chemical alteration accompanying low-grade metamorphism, a process which particularly affects the alkali and alkaline earth elements. Despite this alteration, the mafic volcanic rocks can be shown to consist of three geochemically distinct types, which define two belts within the Sitlika volcanic unit: an eastern belt containing type 1 volcanic rocks, of mid-ocean-ridge basalt (MORB) affinity, and a western belt containing a mixture of type 2 volcanic rocks, of volcanic-arc affinity, and type 3 volcanic rocks, of alkaline within-plate character. Felsic samples are mainly from the eastern belt and show an affinity with the type 1 mafic volcanic rocks. A single felsic sample that comes from the western belt is geochemically similar to the type 2 mafic volcanic rocks. A dividing line between the eastern and western belts is shown on Figure 3, based purely on geochemistry as there is no mapped structural or stratigraphic

Table 1. Geochemical samples from the Sitlika volcanic unit and associated intrusions. Easting and northing refer to UTM Zone 10 coordinates (NAD 83). Abbreviations: v1, mafic volcanic subunit; v2, mixed volcanic subunit; M, Maclaing Creek pluton; D, Diver Lake stock; d, diorite; t, tonalite; f, felsic.

Sample	Easting	Northing	Unit	Type	Description
96GPA-9-6-1	318924	6176524	v1	1	pillowed metabasalt
96GPA-14-1-1	318279	6168448	v2	1	pale greenstone
96GPA-14-4	317641	6168228	v2	1	feldspar-phyric chloritic schist
96GPA-14-10	316121	6168238	v1	2	feldspar-phyric chloritic schist
96GPA-18-3-1	319810	6158630	v1	2	amygdaloidal chloritic schist
96GPA-21-5	313882	6186742	v1	1	pillowed chloritic semischist
96PSC-7-9	315726	6174187	v1	3	chloritic greenstone; possible pillows
96PSC-7-11	315835	6174040	v1	1	greenstone; possible pillows
96PSC-15-14	320165	6172334	v1	1	epidote-chlorite semischist; pillows
97NMA-8-14	321280	6144558	v1	2	massive feldspar-phyric greenstone
97NMA-14-1-4	326233	6131109	v1	3	pillowed chlorite schist
97NMA-14-7-2	325314	6132537	v1	2	weakly foliated pyroxene-phyric metabasalt
97NMA-17-4	324212	6136182	v2	2	massive pyroxene (?)-feldspar phyric metabasalt
97NMA-23-16	326557	6113236	v1	2	massive feldspar-phyric greenstone; up to 50% 1–2 mm phenocrysts
97NMA-24-8-1	321719	6140425	v2	3	aphyric weakly foliated greenstone; hints of pillows
97NMA-28-4-2	318304	6146063	v2	3	massive feldspar basalt
PSC95-16-9-3	318986	6174937	v2	1	massive pyritic metavolcanic; pillows
PSC95-17-7-2	321478	6172109	v2	1	chlorite schist with relict feldspar and mafic phenocrysts
PSC95-17-11	320711	6171937	v1	1	calcite-epidote-chlorite schist; hints of pillows
PSC95-18-6-1	319514	6175597	v1	1	pillowed metabasalt
PSC95-22-3	320530	6176518	v2	1	pillowed calcite-epidote-chlorite schist
96PSC-15-15-3	320005	6172450	v1	f1	massive quartz porphyry; grades to sericite-quartz semischist; dike?
96PSC-18-17	315627	6184358	v2	f1	feldspar-phyric siliceous semischist; thick flow or sill
96PSC-28-1-1	322188	6163803	v2	f1	fragmental felsic semischist with quartz, feldspar and felsic lithic fragments
96PSC-31-8	321569	6166314	v2	f1	quartz-feldspar-phyric semischist
97NMA-25-6-2	319790	6143795	v2	f2	quartz-feldspar crystal tuff
97PSC-22-2	320395	6176435	v2	f1	flow-banded quartz-feldspar–phyric rhyolite
PSC95-22-2	320459	6176430	v2	f1	chlorite-sericite-quartz semischist; rare tiny feldspar phenocrysts
96PSC-12-1	319072	6154388	M	d	epidote-chlorite-feldspar semischist (metadiorite)
96PSC-12-3-1	317636	6154515	M	d	epidote-chlorite-feldspar semischist (metadiorite)
97PSC-2-3-1	319393	6152476	M	t	medium-grained, weakly foliated, chlorite-epidote–altered tonalite
97PSC-2-6	319923	6153763	M	t	medium-grained, massive, chlorite-epidote–altered tonalite
97NMA-30-2	317864	6153531	M	d	chlorite-feldspar semischist (metadiorite)
PSC95-16-1-1	316835	6174320	D	t	quartz-phyric tonalite
PSC95-16-1-2	316835	6174320	D	t	quartz-feldspar porphyry; more mafic, older phase than 16-1-1
PSC95-16-2	316686	6174143	D	t	crowded feldspar porphyry
PSC95-16-4	316721	6173971	D	t	medium-grained tonalite

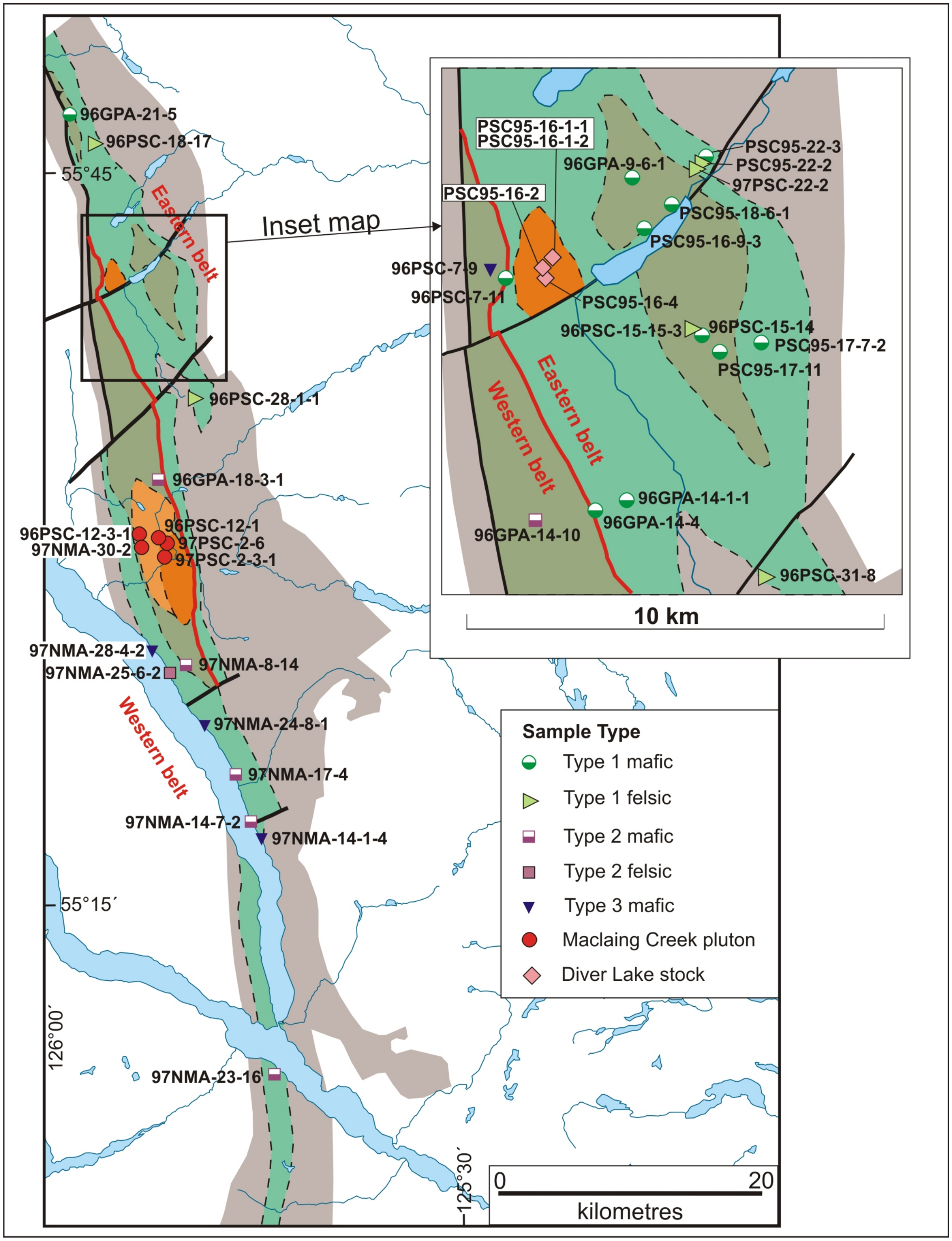

Figure 3. Locations of samples listed in Table 1. See Figure 1 for legend.

divide between the two belts. There is little lithological difference between mafic volcanic rocks in the two belts, although relict pyroxene phenocrysts are more common, and locally very abundant, within western belt basalt.

Type 1 volcanic rocks are a subalkaline, bimodal basalt and rhyolite series (Figures 4a, c). Rare earth element (REE) patterns are mid-ocean-ridge basalt (MORB)-like light rare earth element (LREE)-depleted for mafic rocks (Figure 5a) and flat for felsic rocks (Figure 5d). Similar MORB characteristics are seen for both mafic and felsic rocks in the various tectonic discrimination diagrams (Figures 6–8).

Type 2 volcanic rocks are subalkaline, basalt to dacite (Figures 4b, d). Rare earth element patterns show a moder-

Table 2. Whole-rock chemical analyses for Sitlika volcanic rocks of the eastern belt. Dashes indicate element determinations below detection limit; blank values indicate elements not analyzed. Abbreviation: LOI, loss-on-ignition.

		Mafic intermediate											Felsic					
Sample	**Units**	**PSC95-16-9-3**	**PSC95-17-7-2**	**PSC95-17-11**	**PSC95-18-6-1**	**PSC95-22-3**	**96PSC-7-11**	**96PSC-15-14**	**96GPA-9-6-1**	**96GPA-14-1-1**	**96GPA-14-4**	**96GPA-21-5**	**97PSC-22-2**	**PSC95-22-2**	**96PSC-31-8**	**96PSC-18-17**	**96PSC-28-1-1**	**96PSC-15 15-3**
SiO_2	%	49.00	62.09	46.98	49.89	43.91	47.90	49.38	50.77	47.05	49.13	49.63	83.12	74.14	72.90	73.98	76.62	82.16
TiO_2	%	2.17	1.38	1.53	1.42	1.35	1.29	1.58	1.58	1.35	1.51	1.40	0.09	0.12	0.50	0.56	0.35	0.21
Al_2O_3	%	16.40	15.02	16.15	15.64	17.13	16.59	17.34	14.65	15.00	17.02	18.86	9.48	14.68	13.63	13.32	11.42	7.48
$Fe_2O_3^t$	%	12.62	8.18	12.36	13.91	11.78	8.66	10.34	14.47	9.79	13.16	9.79	0.81	1.29	4.09	3.23	3.16	2.30
MnO	%	0.19	0.17	0.19	0.22	0.18	0.13	0.20	0.23	0.19	0.22	0.14	0.02	0.04	0.08	0.07	0.06	0.06
MgO	%	4.79	2.53	5.04	4.92	6.84	8.80	6.29	6.39	9.23	3.99	5.05	0.29	0.35	1.19	0.26	0.86	0.49
CaO	%	5.08	2.68	9.05	7.70	7.89	11.78	7.04	4.45	13.17	8.94	7.09	0.09	0.31	0.44	0.50	0.82	5.08
Na_2O	%	5.38	7.23	4.24	4.38	4.20	2.97	5.01	5.76	1.95	3.95	5.03	4.68	7.05	6.18	7.13	5.31	0.67
K_2O	%	0.04	0.18	0.07	0.12	0.22	0.20	0.10	0.08	0.04	0.16	0.47	0.73	1.28	0.20	0.37	0.37	0.17
P_2O_5	%	0.24	0.20	0.28	0.14	0.18	0.08	0.22	0.17	0.09	0.21	0.28	0.01	0.02	0.09	0.12	0.06	0.02
LOI	%	3.85	0.98	4.70	2.56	6.68	2.17	3.12	2.25	2.82	2.50	3.00	0.42	0.82	1.19	0.75	1.18	1.51
Total	%	99.76	100.64	100.59	100.90	100.36	100.58	100.61	100.80	100.68	100.78	100.74	99.74	100.10	100.49	100.29	100.21	100.15
Rb	ppm	-	1	-	-	3	3	1	-	1	2	6	5	9	1	2	3	1
Sr	ppm	106	74	133	125	74	212	194	38	257	94	71	22	26	28	48	31	41
Ba	ppm	191	132	135	138	119	125	139	129	100	158	198	80	125	63	87	78	77
Y	ppm	44	53	38	37	28	26	40	27	26	30	28	48	86	51	53	51	57
Zr	ppm	121	268	110	107	75	76	146	73	99	87	71	155	234	220	331	183	242
Nb	ppm	4	4	3	3	4	2	4	3	2	4	4	8	8	4	4	4	3
V	ppm	402	164	253	391	288	221	227	368	192	326	302	-	-	38	20	32	13
Cr	ppm	66	-	217	-	271	436	288	62	553	31	320	-	-	-	19	-	-
Ni	ppm	11	-	45	3	62	169	137	17	254	5	37	-	9	5	-	3	-
Cu	ppm	46	12	27	53	89	30	45	63	13	48	13	12	23	31	14	29	6
Zn	ppm	136	111	118	126	124	85	118	158	96	139	121	24	60	75	106	89	85
Hf	ppm				2.9		2.240	3.703	2.000			2.043				7.374	4.362	
Ta	ppm				0.3		1.054	1.214	1.257			1.252				4.486	5.120	
Th	ppm						0.089	0.247	0.226			0.152				1.320	1.020	
La	ppm				4.3		1.944	5.975	2.637			3.967				10.662	8.154	
Ce	ppm				1.0		7.443	19.316	8.962			11.606				29.756	21.658	
Pr	ppm						1.423	3.291	1.617			1.968				4.369	3.256	
Nd	ppm				16.0		8.069	16.534	8.819			10.496				20.920	15.524	
Sm	ppm				3.6		2.985	5.061	3.111			3.471				6.418	4.816	
Eu	ppm				1.4		1.083	1.752	1.093			1.380				1.496	1.084	
Gd	ppm						3.817	6.443	3.930			4.534				7.497	6.100	
Tb	ppm				0.9		0.645	1.091	0.672			0.783				1.260	1.045	
Dy	ppm						4.205	7.062	4.507			4.906				8.548	7.262	
Ho	ppm						0.839	1.463	0.932			1.040				1.866	1.661	
Er	ppm						2.565	4.470	2.770			3.129				5.631	5.365	
Tm	ppm						0.333	0.629	0.394			0.423				0.845	0.804	
Yb	ppm				3.6		2.218	4.190	2.546			2.508				5.924	5.584	
Lu	ppm				0.5		0.329	0.656	0.372			0.390				0.965	0.855	

Table 3. Whole-rock chemical analyses for Sitlika volcanic rocks of the western belt. Dashes indicate element determinations below detection limit; blank values indicate elements not analyzed. Abbreviation: LOI, loss-on-ignition.

		Type 2 mafic - intermediate						Type 2	Type 3 mafic			
Sample	**Units**	**97NMA-8-14**	**96GPA-14-10**	**96GPA-18-3-1**	**97NMA-14-7-2**	**97NMA-17-4**	**97NMA-23-16**	**97NMA-25-6-2**	**97NMA-24-8-1**	**97NMA-28-4-2**	**97NMA-14-1-4**	**96PSC-7-9**
SiO_2	%	56.53	63.80	46.94	51.89	48.60	48.66	66.00	46.51	51.70	40.41	47.08
TiO_2	%	0.84	0.55	1.08	0.71	1.01	0.75	0.48	2.31	1.04	1.97	2.29
Al_2O_3	%	17.08	16.97	18.81	14.11	18.03	22.02	15.37	17.50	19.14	15.45	16.81
$Fe_2O_3^t$	%	7.66	5.69	11.92	10.02	9.46	8.56	4.21	9.08	8.21	8.52	9.29
MnO	%	0.17	0.10	0.16	0.17	0.16	0.19	0.09	0.15	0.16	0.15	0.14
MgO	%	4.23	1.69	6.84	6.91	6.68	3.88	1.37	8.75	3.15	3.60	7.87
CaO	%	6.20	3.53	4.85	8.74	10.86	9.48	4.36	5.69	8.81	14.27	10.32
Na_2O	%	5.20	5.80	4.16	3.14	2.32	3.54	3.32	4.10	3.14	4.18	3.36
K_2O	%	0.36	0.61	1.24	1.27	0.04	0.39	1.91	0.91	0.83	1.01	0.36
P_2O_5	%	0.12	0.12	0.17	0.36	0.15	0.12	0.10	0.50	0.22	0.45	0.31
LOI	%	2.20	1.55	4.52	2.67	3.66	3.22	2.96	4.77	3.70	9.79	2.83
Total	%	100.59	100.40	100.70	99.99	100.97	100.81	100.24	100.27	100.10	99.80	100.66
Rb	ppm	6	10	17	25	3	7	33	11	13	18	5
Sr	ppm	173	106	151	283	480	416	265	179	344	276	164
Ba	ppm	102	178	239	358	-	248	506	200	283	157	297
Y	ppm	30	22	21	23	23	20	19	31	24	28	38
Zr	ppm	114	100	46	70	71	51	119	259	135	214	233
Nb	ppm	6	6	4	4	7	4	7	25	13	28	6
V	ppm	161	111	263	225	273	197	79	220	180	212	248
Cr	ppm	105	24	285	337	143	17	22	188	29	259	222
Ni	ppm	18	6	42	64	19	7	4	72	6	135	100
Cu	ppm	93	22	52	338	25	197	32	53	71	40	9
Zn	ppm	67	69	124	64	68	91	39	68	67	58	75
Hf	ppm				2.152		1.374	2.707	5.015		4.224	
Ta	ppm				0.153		0.182	0.511	1.587		1.807	
Th	ppm				1.333		0.424	2.266	1.422		2.137	
La	ppm				9.200		4.476	9.088	20.290		15.952	
Ce	ppm				20.205		10.473	18.423	46.763		34.939	
Pr	ppm				2.756		1.490	2.206	5.907		4.445	
Nd	ppm				12.547		7.349	8.798	24.724		18.916	
Sm	ppm				2.987		2.028	1.952	5.155		4.349	
Eu	ppm				0.895		0.809	0.701	1.726		1.463	
Gd	ppm				3.405		2.615	2.240	5.536		4.274	
Tb	ppm				0.494		0.419	0.346	0.791		0.669	
Dy	ppm				3.121		2.740	2.271	4.726		4.126	
Ho	ppm				0.696		0.615	0.515	0.993		0.945	
Er	ppm				2.183		1.931	1.638	2.934		2.916	
Tm	ppm				0.300		0.259	0.235	0.379		0.392	
Yb	ppm				1.898		1.665	1.600	2.319		2.465	
Lu	ppm				0.283		0.239	0.241	0.336		0.332	

Table 4. Whole-rock chemical analyses for intrusive rocks from the Diver Lake stock and the Maclaing Creek pluton. Dashes indicate element determinations below detection limit; blank values indicate elements not analyzed. Abbreviation: LOI, loss-on-ignition.

		Maclaing Creek pluton					Diver Lake stock			
Sample	Units	96PSC-12-1	96PSC-12-3-1	97PSC-2-3-1	97PSC-2-6	97NMA-30-2	PSC95-16-1-1	PSC95-16-1-2	PSC95-16-2	PSC95-16-4
SiO_2	%	60.68	54.58	61.81	67.91	53.42	74.47	66.42	48.53	74.43
TiO_2	%	0.72	1.00	0.68	0.42	1.05	0.30	0.65	1.81	0.31
Al_2O_3	%	16.60	16.59	16.34	15.60	16.37	13.45	16.01	14.64	13.92
$Fe_2O_3^t$	%	5.75	9.04	5.54	3.80	9.26	2.55	4.72	15.65	2.09
MnO	%	0.08	0.16	0.09	0.07	0.18	0.05	0.11	0.24	0.03
MgO	%	2.59	3.62	2.74	1.34	3.60	0.65	1.35	5.56	0.71
CaO	%	6.59	6.96	5.30	4.43	5.18	1.95	3.66	6.37	2.45
Na_2O	%	4.99	4.55	4.32	4.22	4.98	5.09	5.56	3.79	5.16
K_2O	%	0.25	0.18	1.17	0.45	0.49	0.69	0.30	0.45	0.62
P_2O_5	%	0.15	0.18	0.13	0.09	0.16	0.06	0.18	0.11	0.06
LOI	%	1.93	3.72	1.85	1.45	5.81	0.99	1.34	3.42	0.87
Total	%	100.32	100.57	99.97	99.78	100.50	100.25	100.30	100.57	100.65
Rb	ppm	5	4	20	7	10	9	3	6	5
Sr	ppm	146	266	161	256	149	133	200	119	111
Ba	ppm	110	69	360	702	169	181	170	257	258
Y	ppm	33	33	30	19	34	27	40	31	29
Zr	ppm	156	104	130	135	106	139	131	47	127
Nb	ppm	6	5	7	7	5	4	4	3	4
V	ppm	108	184	115	63	209	25	56	490	27
Cr	ppm	28	63	72	25	23	-	-	35	-
Ni	ppm	10	14	15	7	7	-	-	-	-
Cu	ppm	21	76	33	26	104	5	4	32	4
Zn	ppm	17	61	27	7	92	57	60	117	43
Hf	ppm									4.5
Ta	ppm									1.6
La	ppm									5.8
Ce	ppm									1.0
Nd	ppm									16.0
Sm	ppm									2.3
Eu	ppm									0.9
Tb	ppm									0.6
Yb	ppm									3.1
Lu	ppm									0.5

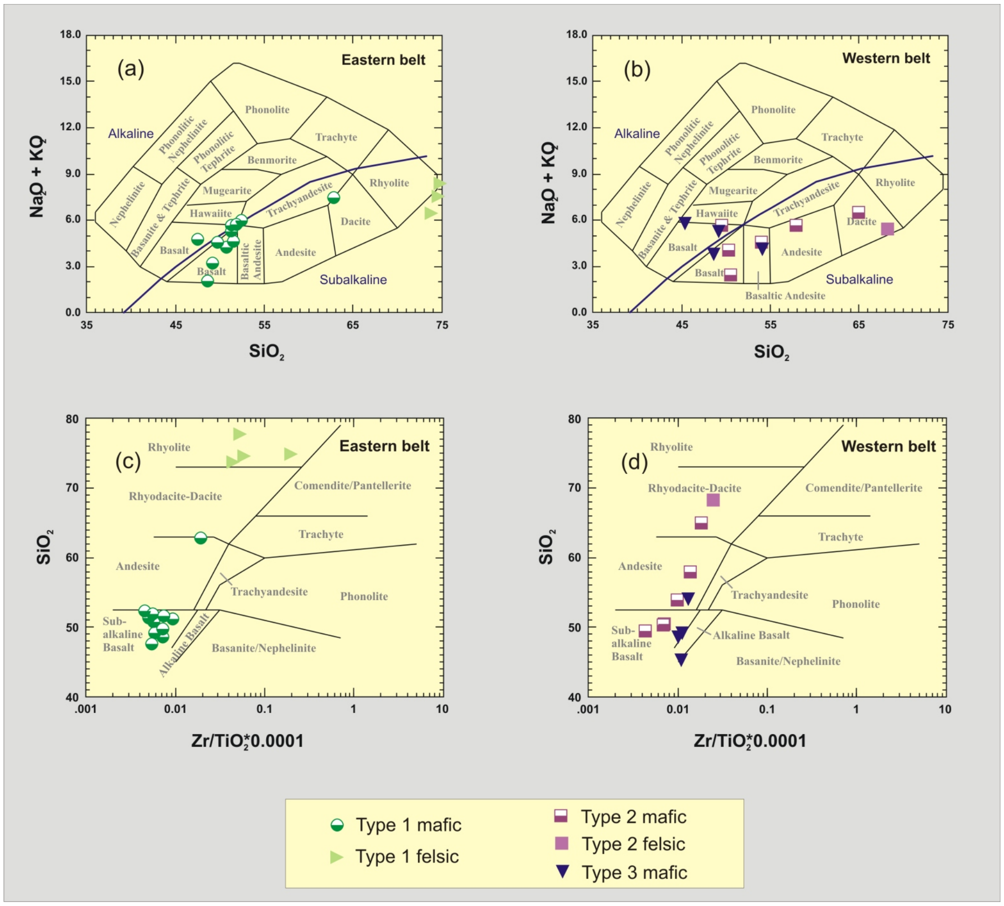

Figure 4. Geochemical classification of Sitlika volcanic rocks from the eastern and western belts: **a)** and **b)** alkali-silica diagrams, fields after Cox et al. (1979), with alkaline-subalkaline dividing line after Irvine and Baragar (1971); **c)** and **d)** silica versus zirconium-titania ratio, fields after Winchester and Floyd (1977).

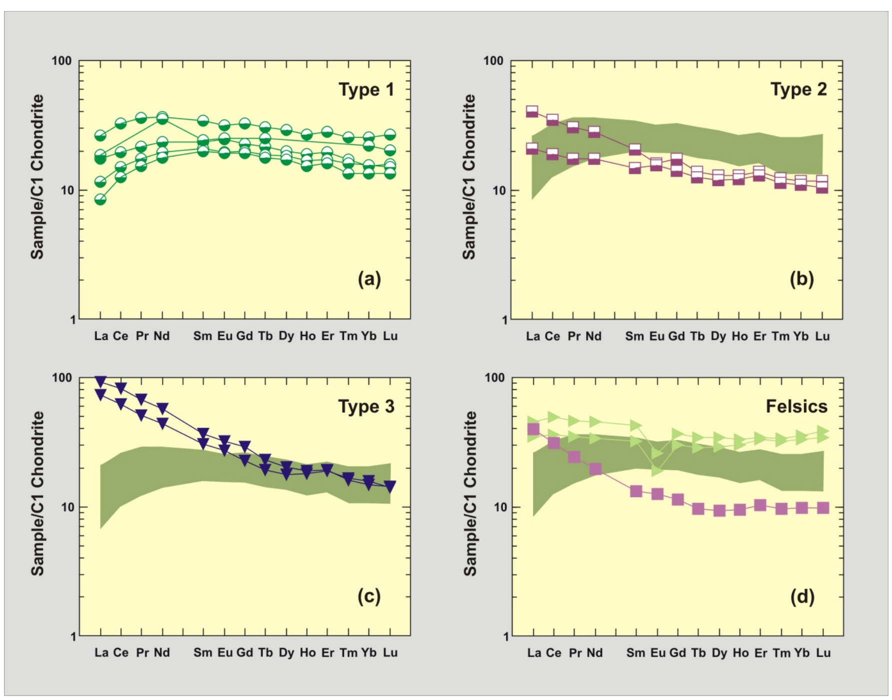

Figure 5. Rare earth element plots for Sitlika volcanic rocks. Normalizing values from Sun and McDonough (1989). Type 1 basalt in a) is repeated as the shaded area in b)–d) for reference. Symbols as in Figure 4.

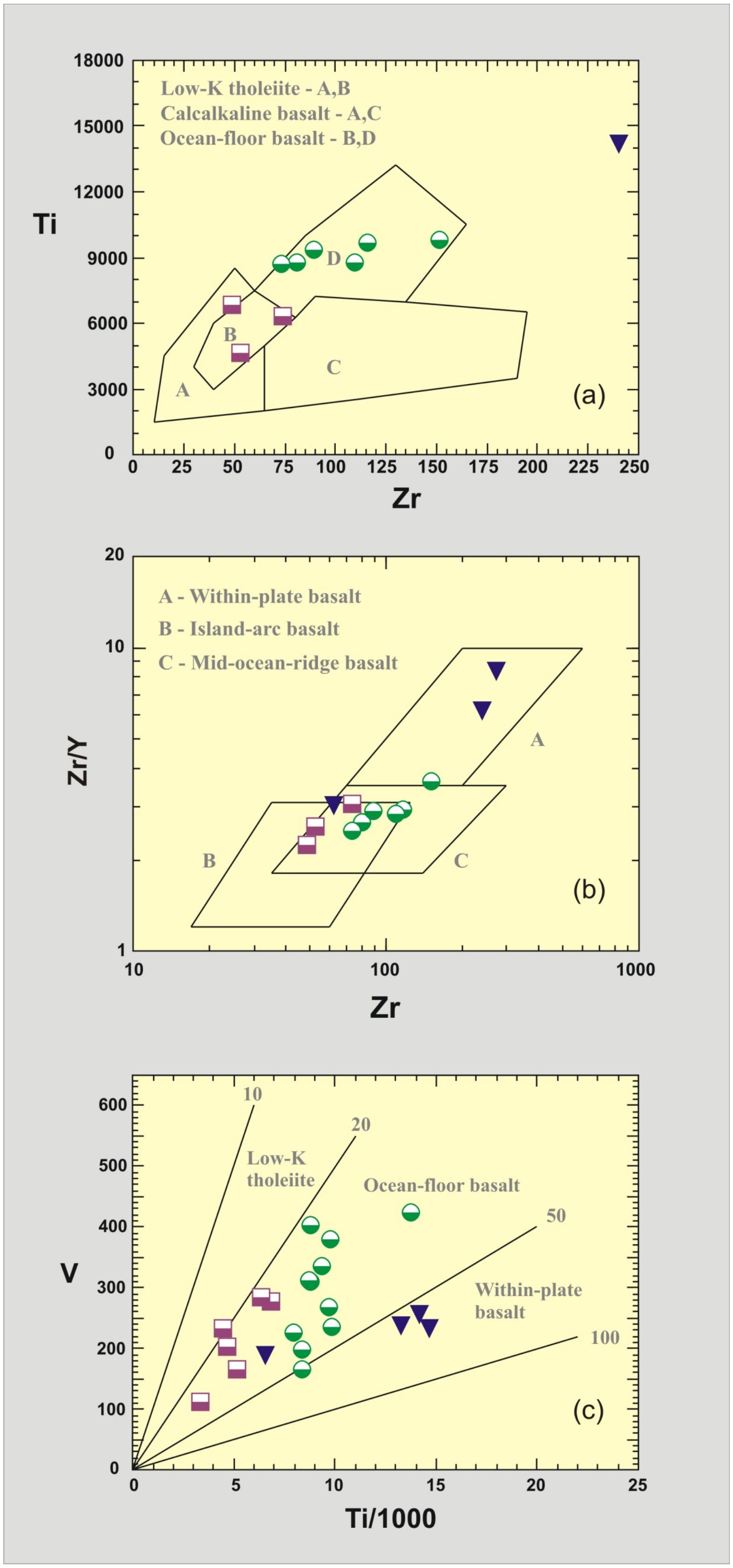

Figure 6. Tectonic discrimination diagrams for Sitlika basalts: **a)** Ti-Zr diagram, fields after Pearce and Cann (1973); **b)** Zr/Y-Zr diagram, fields after Pearce and Norry (1979); **c)** Ti-V diagram, fields after Shervais (1982). Symbols as in Figure 4.

ate LREE enrichment for both mafic and felsic rocks (Figures 5b, d). Heavy rare earth elements (HREE) have lower concentrations than in type 1 basalt. An oceanic-arc signature is apparent in the various tectonic discrimination diagrams (Figures 6–8).

Type 3 volcanic rocks are alkaline in character (Figures 4b, d). Only mafic rocks have been analyzed and it is unclear if felsic members are present. Rare earth element patterns in these rocks show much more LREE enrichment than in type 2 samples, and HREE have higher concentrations than in type 2 samples, comparable to those in type 1 basalt (Figure 5c). A within-plate character is suggested by discrimination diagrams (Figures 6, 7).

Intrusive rocks from the Diver Lake stock and the Maclaing Creek pluton are calcalkaline intermediate to felsic (Figure 9). They plot in the volcanic-arc field on discrimination diagrams (Figure 8) and are similar to the type 2 felsic volcanic sample. They are inferred to be related to the type 2 volcanic rocks, although the Diver Lake stock is located in the eastern belt (but at its western edge).

DISCUSSION

The volcanic rocks of the Sitlika assemblage have an oceanic signature. The western belt includes mafic and felsic rocks with a volcanic-arc signature, but also includes alkaline basalt of within-plate character. Intrusive rocks of the Maclaing Creek pluton and Diver Lake stock have a volcanic-arc signature, consistent with their location within and along the margin of the western belt. In contrast, volcanic rocks in the eastern belt have MORB characteristics. They may have formed in a back-arc setting, behind the western belt arc.

Comparison to the Kutcho Assemblage

The Sitlika volcanic unit is reasonably correlated with the Kutcho assemblage (Childe and Thompson, 1997) on the basis of general mafic to felsic volcanic character, the presence of associated tonalitic intrusive units, the age of the volcanic and intrusive units, comparable primitive Nd-isotopic signatures, and structural and tectonic setting (Monger et al., 1978; Childe et al., 1998). Although they both represent intraoceanic arc systems (and probably parts of the same system), there are distinctions between volcanic rocks of the Kutcho assemblage, as represented by analyses presented by Barrett et al. (1996) and Childe et al. (1998), and the Sitlika volcanic unit. Kutcho volcanic rocks are tholeiitic, with characteristics of low-K island-arc basalt. Contents of the immobile

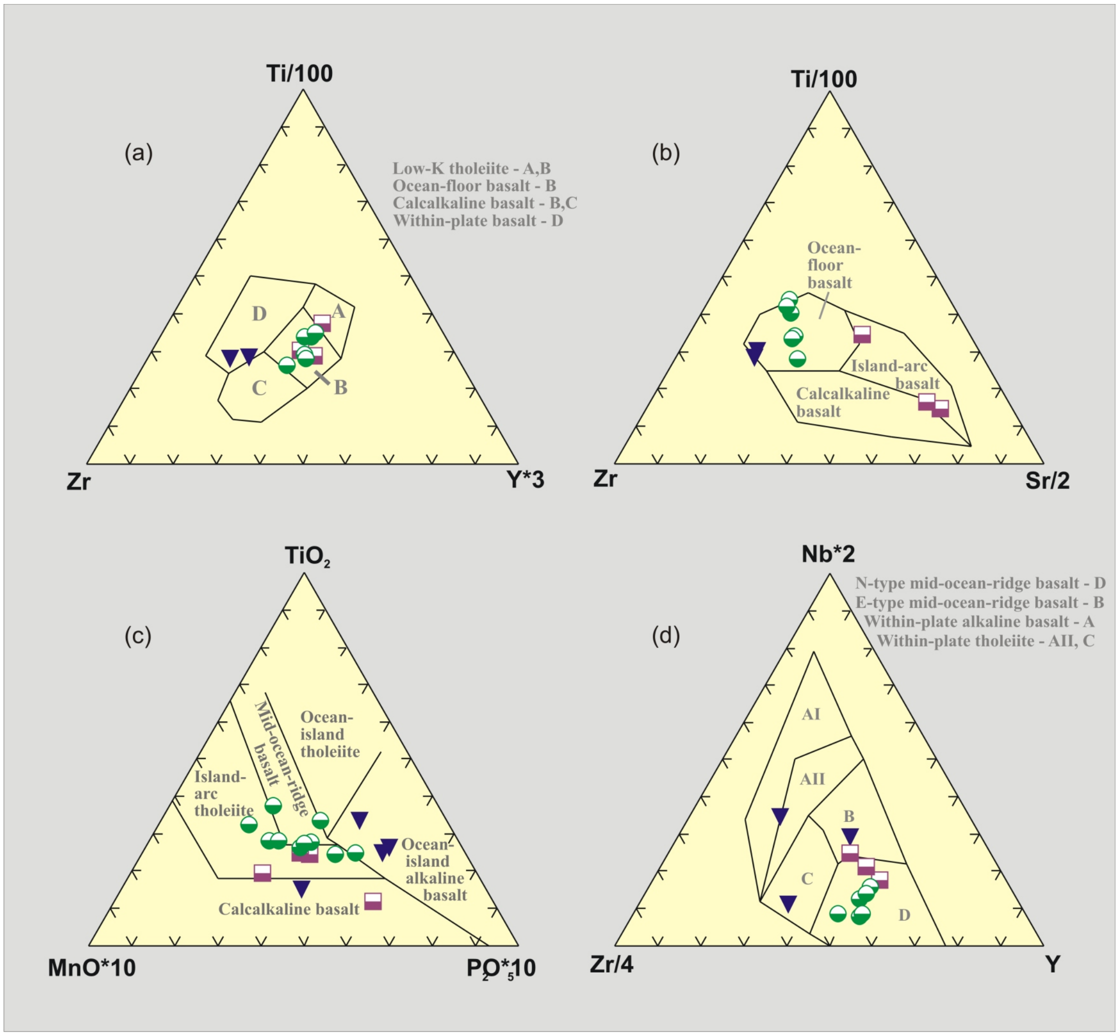

Figure 7. Triangular tectonic discrimination diagrams for Sitlika basalts: **a)** Ti-Zr-Y diagram, fields after Pearce and Cann (1973); **b)** Ti-Zr-Sr diagram, fields after Pearce and Cann (1973). **c)** Ti-Mn-P diagram, fields after Mullen (1983). **d)** Nb-Zr-Y diagram, fields after Meschede (1986). Symbols as in Figure 4.

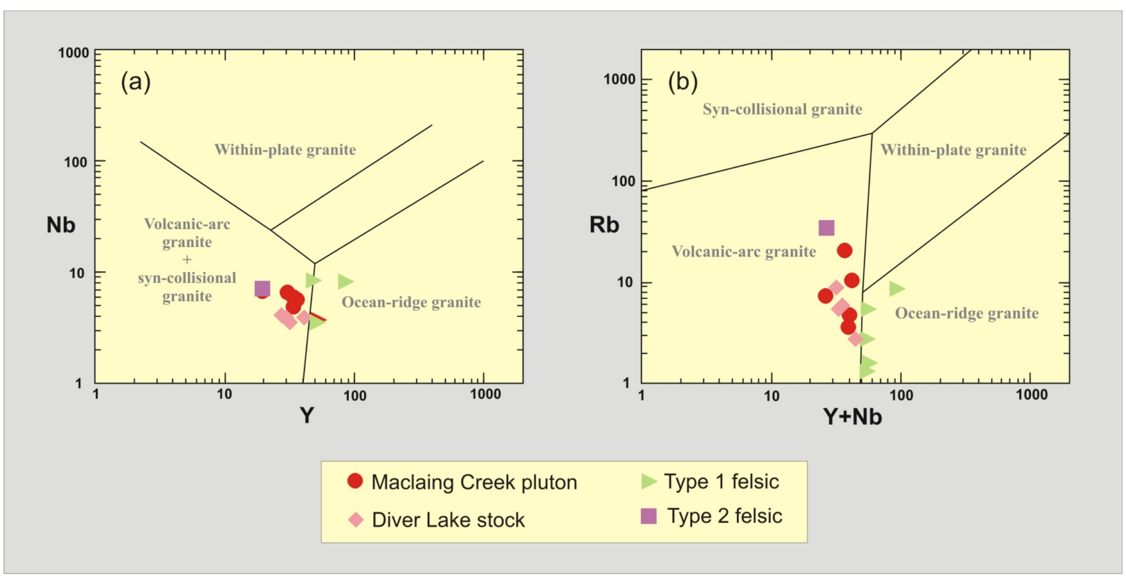

Figure 8. Tectonic discrimination diagrams for Sitlika intrusive and felsic volcanic rocks: **a)** Nb-Y tectonic discrimination diagram, fields after Pearce et al. (1984); **b)** Rb-(Y+Nb) tectonic discrimination diagram, fields after Pearce et al. (1984).

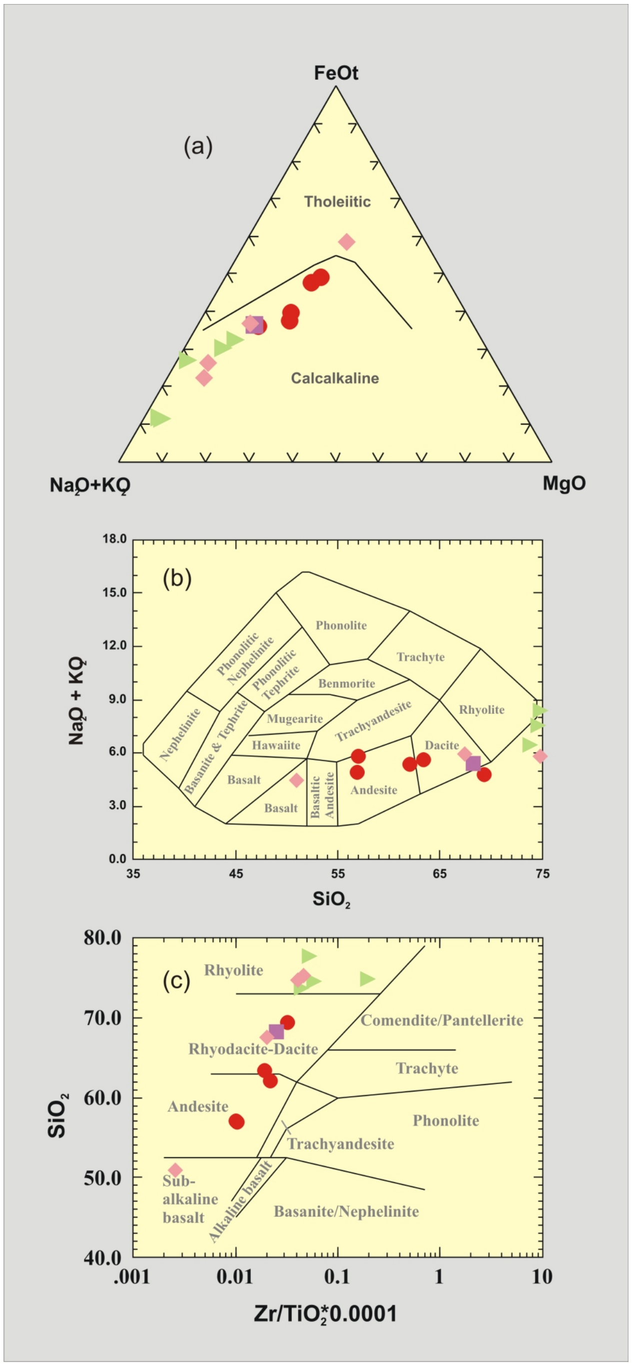

Figure 9. Geochemical classification of rocks from the Maclaing Creek pluton and the Diver Lake stock, with Sitlika felsic volcanic rocks included for comparison: **a)** AFM triangle diagram, tholeiitic-calcalkaline divide after Irvine and Baragar (1971); **b)** alkali-silica diagram, fields after Cox et al. (1979); **c)** silica versus zirconium-titania ratio, fields after Winchester and Floyd (1977). Symbols as in Figure 8.

high-field strength elements, such as Zr and Y, and the rare-earth elements, are significantly lower in the Kutcho basalt than in the Sitlika lavas, even the similarly LREE-depleted type 1 flows. The LREE-enriched patterns of types 2 and 3 Sitlika flows are not reported from the Kutcho area. However, gabbro intrusions within the Kutcho assemblage are calcalkaline in character, with REE patterns showing moderate LREE enrichment very similar to that of the Sitlika type 2 volcanic rocks.

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