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# Geochemistry of Diabase Dikes of the Silvretta (Switzerland)\*

by Barbara E. Hellermann<sup>1</sup>

## Abstract

In the Silvretta crystalline complex about 200 diabase dikes are known. The dikes intruded in post-Variscan time; they are not affected by Variscan metamorphism and tectonic movements. Primary mineral assemblages are commonly altered in response to Alpine very low grade metamorphism. Major and trace element geochemistry classify the dikes as tholeiitic basalts. Rare Earth element pattern reinforce the continental tholeiitic characteristics and suggest a crustal influence prior to magma intrusion.

*Keywords:* Diabase dikes, geochemistry, tholeiitic basalts, Silvretta nappe, Switzerland.

## 1. Introduction

In post-Variscan time about 200 diabase dikes intruded in the crystalline part of the Silvretta, a polymetamorphic complex of gneiss and amphibolite series.

The dikes have been mapped and described petrographically by BEARTH (1932). Beside the petrographic studies, no more than twelve chemical analyses were carried out by different authors (BEARTH, 1932; ESCHER, 1921; FLISCH, 1981; MICHAEL, 1985), which cannot give a complete picture of the mineralogical differences of the dikes, nor of their chemical affinities. The present study is based on 235 chemical analyses from 140 dikes (Fig. 1), including several vertical and horizontal profiles.

## 2. Field Relations and Petrography

In the Silvretta, mafic dikes intrude polymetamorphic gneisses and amphibolitic associations of the Variscan basement. The dikes are not affected by Variscan metamorphism and tectonic movements. They are not known from the triassic sedimentary cover of the Ducan- and Landwasser trough. From this geological setting, the dikes are assumed to have about Permian age. The dikes are widely metamorphosed with a maximum overprint by Alpine lower greenschist facies. Moreover many dikes display a weak foliation.

The dikes, which range in thickness from few centimeters to a maximum of 50 m, range from fine- to mediumgrained diabase with a sometimes well developed porphyritic texture. Primary magmatic minerals are plagioclase (An compositions from An<sub>40</sub> to An<sub>70</sub>) and clinopyroxene, in general augite or titanaugite. In some dikes orthopyroxene (enstatite-hyperstene) instead of augite is present. Both pyroxenes commonly show a subophitic intergrowth with plagioclase laths. In few specimens talc is present, possibly as a pseudomorph after olivine. Dikes from the eastern part of the investigated area bear in some cases primary brown hornblende. In the interstices quartz, ilmenite, chlorite and biotite crystallized. Apatite is present as primary mineral in interstices or crystallized arbitrary in response to metamorphic events. The Alpine overprint is visible in the following alterations of magmatic phases: plagioclase crystals are variably replaced by epidote-clinzoisite, quartz, calcite and ore replacing it from the center. Secondary albite forms at the rims of the plagioclase crystals. Augite is altered in a first stage to green amphibole and later to chlorite. Veinlets filled with late stage chlorite, epidote, quartz and calcite cut some dikes. Petrographically five groups could have been distinguished which represent the increasing influence of Alpine metamorphism. If the groups are transferred to the geological map they scatter all over the area. No reconstruction of a zonation from the Alpine metamorphism overprint is possible.

\* Extended abstract of a contribution presented at the annual meeting of the SSMP, Fribourg, October 13 and 14, 1989.

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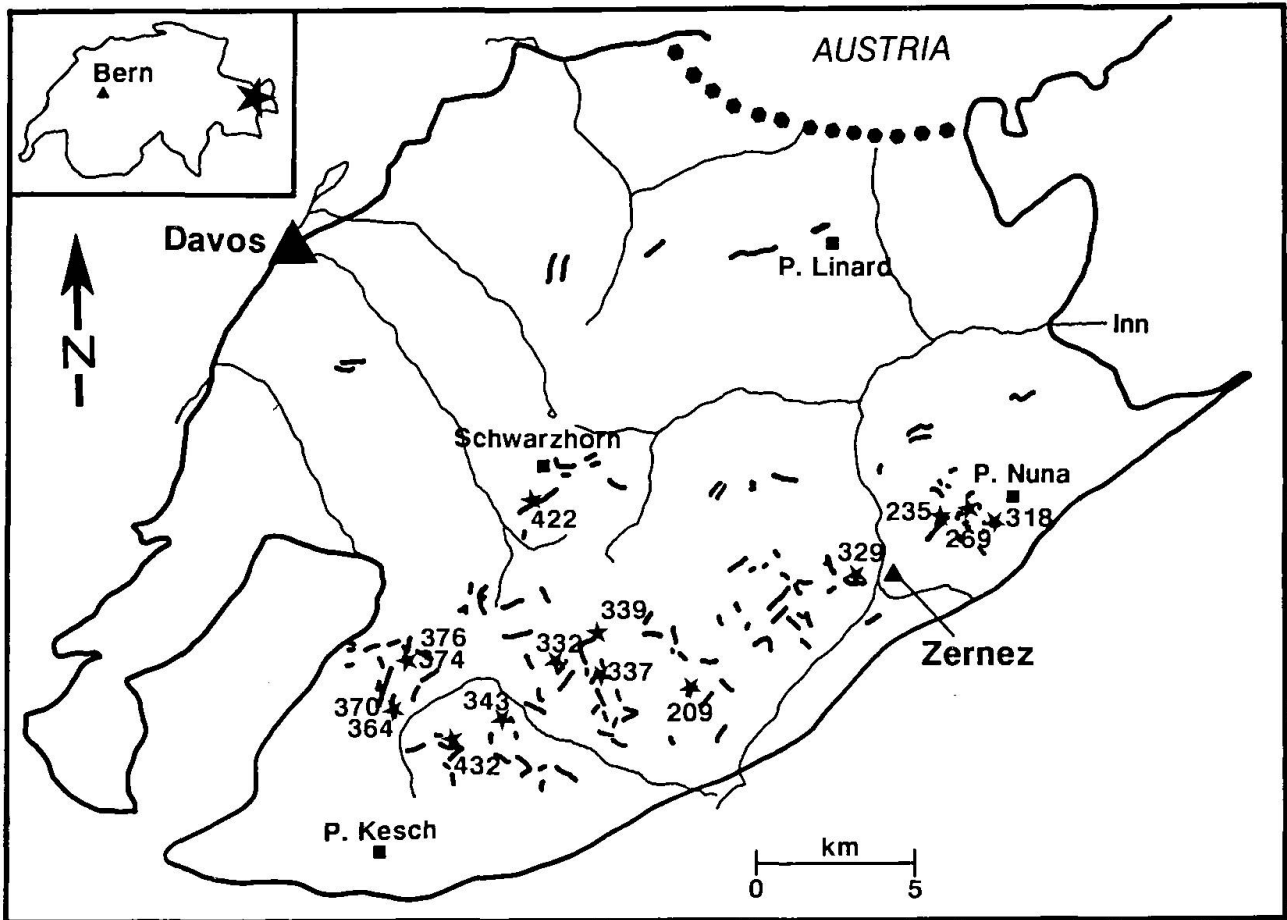


Fig. 1 Schematic map of the Swiss part of the Silvretta crystalline complex with the sampled diabase dikes in black (not to scale). Numbers refer to mentioned samples in the text. Map after BEARTH (1932).

Localities and sample coordinates:

BH 209	Val Barlas-ch	796 375 / 171 850
BH 235	Zernez	804 675 / 177 550
BH 269	Munt Baseglia	805 025 / 177 850
BH 318	Macun	806 675 / 177 850
BH 329	Zernez	802 075 / 175 450
BH 332	Vallorgia	792 100 / 172 025
BH 337	Vallorgia	793 075 / 172 625
BH 339	Vallorgia	793 050 / 172 750
BH 343	Val Müsella	790 600 / 169 625
BH 364	Platta Naira	786 625 / 170 925
BH 370	Platta Naira	786 550 / 171 150
BH 374	Sertigpass	787 070 / 172 700
BH 376	Sertigpass	787 000 / 172 755
BH 422	Rad. Rothorn	791 275 / 177 900
BH 432	Passhörel	787 875 / 170 175

### 3. Major and trace element geochemistry

Major and trace element analyses of some representative diabase dikes are given in Table 1. Major and trace elements of 135 samples were measured with XRF in Fribourg, the rest of 100 specimens was analysed for major, trace and rare earth elements by INAA at Nancy/France.

The analysed specimens show varying degrees of alteration, from those retaining original mineralogy to those in which the primary minerals have been completely replaced. Therefore some mobility of certain elements can be suspected. Secondary mobility is indicated, if the element is plotted against a differentiation index  $Mg'(Mg' = Mg/(Mg + Fe) \cdot 100)$  and proofs to show no more correlation (Fig. 2). This is especially evident for Si, Ca, Na, K, Ba, but also Ti, P and Zr reveal an influence of secondary processes, which might be of different origin as will be discussed later.

Overall major element compositions resemble broadly other continental tholeiitic basalts.  $SiO_2$  contents vary between 48.9 and 60.64 wt% with  $Mg'$ -values between 30 and 68, indicating a magma suite from fairly primitive basalts to more differentiated derivatives. A group of high  $P_2O_5$  and  $TiO_2$  contents is notable which might represent fractionation or variation in initial  $P_2O_5$  ( $TiO_2$  resp.) contents. They show no regional or metamorphic zonation and plot in the  $Zr/P_2O_5$  vs.  $TiO_2$  discrimination diagram from FLOYD and WINCHESTER (1975) in the field of alkali basalts.

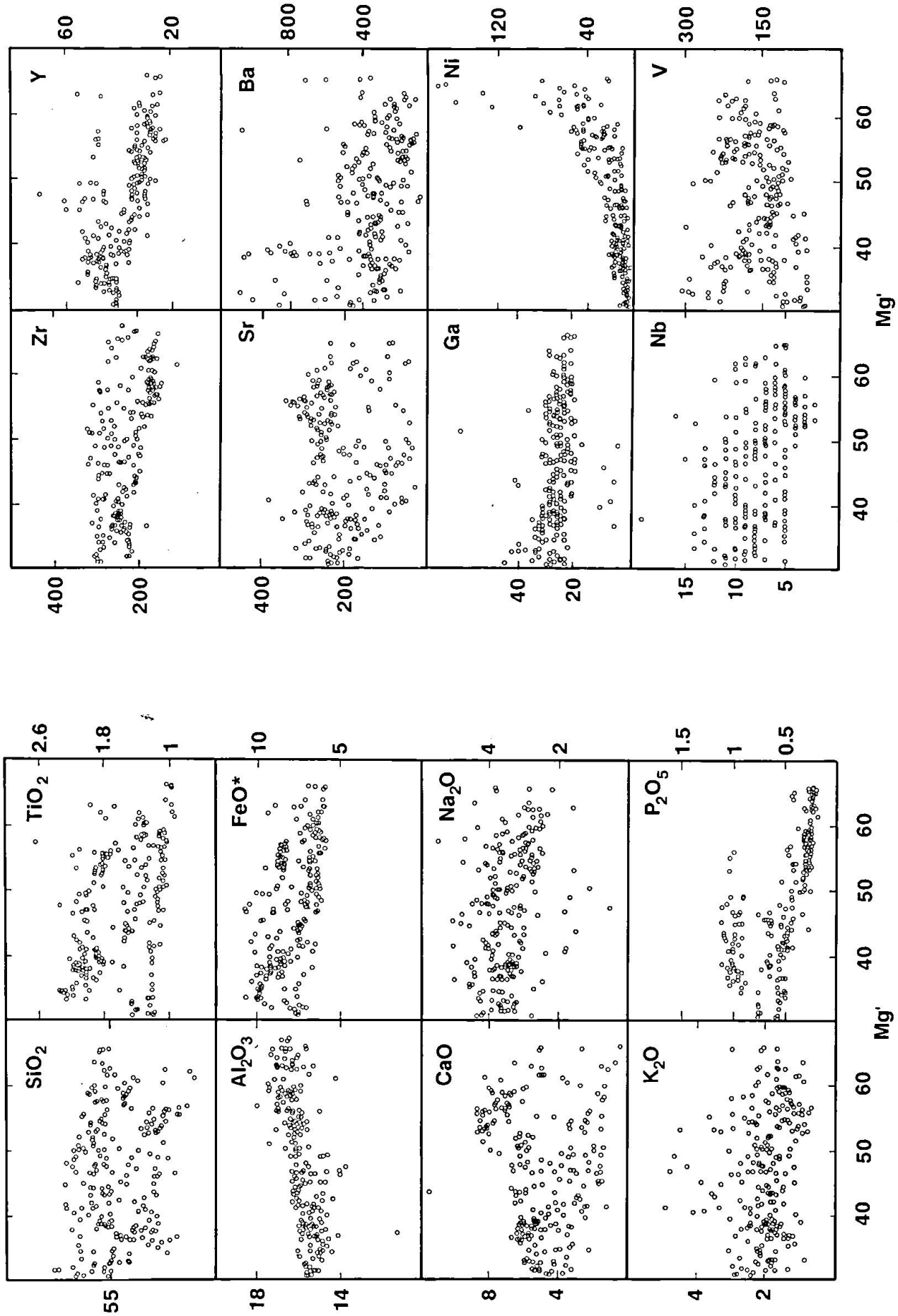


Fig. 2 Variation diagrams for selected major (wt%) and trace elements (ppm) for 235 diabases from the Silvretta. FeO\* = total Fe as FeO.

Tab. 1 XRF and INNA analyses of ten representative samples.

Sample No.	BH318	BH329	BH332	BH337	BH343	BH364	BH374	BH376	BH422	BH432
SiO <sub>2</sub> (wt%)	51.54	55.53	47.90	48.67	56.09	52.08	56.34	52.65	57.15	54.96
TiO <sub>2</sub>	2.16	1.06	1.66	1.67	1.08	2.10	0.96	0.93	1.42	2.20
Al <sub>2</sub> O <sub>3</sub>	14.85	16.95	16.75	17.01	15.91	15.21	16.48	14.30	15.93	14.86
Fe <sub>2</sub> O <sub>3</sub>	3.45	0.61	2.01	1.94	0.91	2.26	1.71	1.26	1.98	3.28
FeO	9.15	5.99	8.21	7.74	7.23	8.14	4.90	6.38	6.33	8.37
MnO	0.20	0.11	0.14	0.19	0.13	0.16	0.08	0.13	0.10	0.20
MgO	3.29	4.44	6.39	6.44	4.69	2.94	6.44	5.69	5.98	2.94
CaO	6.30	7.16	7.74	6.93	4.37	5.87	2.75	3.89	1.45	4.10
Na <sub>2</sub> O	4.49	3.72	3.69	4.08	3.64	4.41	3.77	3.59	4.32	3.87
K <sub>2</sub> O	1.11	1.31	0.96	1.45	2.58	1.17	2.08	1.62	1.42	2.13
P <sub>2</sub> O <sub>5</sub>	1.04	0.28	0.30	0.32	0.32	1.06	0.96	0.28	0.39	0.49
LOI*	1.96	2.34	3.60	3.17	3.00	4.57	3.71	8.28	3.20	2.17
Total	99.54	99.50	99.35	99.61	99.95	99.97	100.06	99.00	99.67	99.57
Mg	35.50	56.20	56.90	56.70	54.80	36.70	65.20	60.80	59.50	34.60
Ba (ppm)	249	175	57	145	348	238	694	172	222	273
Cr	17	102	125	122	153	35	306	283	55	30
Cu	30	33	35	47	40	10	34	34	4	5
Ga	26	21	22	22	20	26	20	20	20	27
Nb	14	6	8	7	9	7	4	4	10	7
Ni	17	48	46	48	51	8	176	66	16	5
Rb	49	49	58	74	132	80	63	58	56	70
Sc	31	23	32	32	25	n.d.	23	25	n.d.	n.d.
Sr	270	324	295	306	137	183	178	86	133	174
Th	7	6	<5	<5	6	<1	5	7	6	1
V	138	133	189	182	128	137	113	124	215	228
Y	56	26	48	30	30	46	27	26	33	42
Zn	106	89	76	119	93	116	56	18	71	111
Zr	290	154	159	162	237	252	237	195	214	229
La	28.74	12.80	21.11	10.62	17.75	n.d.	14.17	12.52	n.d.	n.d.
Ce	73.25	32.43	46.37	32.25	44.41	n.d.	32.44	36.35	n.d.	n.d.
Nd	39.05	15.44	18.47	17.00	20.46	n.d.	16.96	15.27	n.d.	n.d.
Sm	10.29	4.08	5.72	4.95	5.21	n.d.	4.26	4.29	n.d.	n.d.
Eu	3.63	1.58	2.13	1.64	1.76	n.d.	1.52	1.33	n.d.	n.d.
Gd	9.52	3.76	6.50	4.58	5.23	n.d.	4.64	4.11	n.d.	n.d.
Dy	8.32	3.62	5.58	5.24	4.82	n.d.	3.84	4.20	n.d.	n.d.
Er	4.17	1.96	3.06	2.85	2.64	n.d.	2.12	2.45	n.d.	n.d.
Yb	3.77	1.98	3.20	2.65	2.51	n.d.	2.00	2.34	n.d.	n.d.
Lu	0.64	0.31	1.21	0.42	0.48	n.d.	0.17	0.38	n.d.	n.d.
(La/Lu) <sub>cn</sub>	5.20	4.78	2.02	2.93	4.28	n.d.	9.66	3.82	n.d.	n.d.

LOI\* = Loss on ignition  
 cn = chondrite normalized  
 n.d. = not determined

They therefore may be connected to the diabase dikes of the Ötztal massif being geologically related (time of emplacement) to the dikes of the Silvretta. The Ötztal dikes are classified as alkali basalts (PURTSCHELLER and RAMMELMAIR, 1982).

In the Silvretta case, a classification according to this diagram has been abandoned, because zirconium and phosphorus are not well enough correlated with Mg' and an alkali chemistry has not been proved. All diabase dikes of the Silvretta can be classified with the JENSEN (1982) triangle

diagram  $\text{Al}_2\text{O}_3\text{-MgO-FeO}_{\text{tot}}$  as tholeiitic basalts. Element variations are moderately controlled by fractional crystallization processes of olivine, plagioclase and pyroxene, as shown by the positive correlations of Ni, Cr (not shown) and Al. Nickel and chrom contents are low for most samples, but increase steeply for primitive, high  $\text{Mg}'$  dikes. The high Mg, Cr and Ni-contents as typical for crystallization from primitive mantle derived magmas are however not attained.

Porphyritic varieties correlate frequently with the more acid compositions and correspondantly with lower  $\text{Mg}'$  values. No other relationship between texture and chemistry has been found.

Major element variations within a single dike are most obvious in higher  $\text{Na}_2\text{O}$  and  $\text{K}_2\text{O}$  contents at the center of the dike. Fe, Mg, Ca and Mn migrate into the more acid wall rocks. Where diabase dikes intruded basic series, these small scale differences in chemical compositions are neglectable. Flow-differentiation by plagioclase and pyroxene alignment at the center of a dike can cover the chemical differences mentioned above.

#### 4. Rare earth element (REE) geochemistry

The chondrite-normalized REE pattern of 100 samples show typical trends of continental tholeiites (see Fig. 3). A characteristic feature of all dikes is the marked enrichment of light REE in respect to heavy REE with  $(\text{La}/\text{Lu})_{\text{cn}}$  varying from 0.8 up to 25. For the samples with an increased  $(\text{La}/\text{Lu})_{\text{cn}}$  ratio ( $> 4$ ), a generation of the magma within the stability field of garnet is assumed. Dikes with lower REE abundances and flat pattern resemble p-type MORB (Fig. 3b, BH 337). In normalized spidergrams samples with high REE contents show peaks typical of continental crust (e.g. Lewisian gneiss, WEAVER and TARNEY, 1980) represented by negative anomalies for Th, Rb, Nb, Sr and Ti. It is therefore not ruled out that the non-linear behaviour of these elements in the variation diagrams could be the result of the influence of sialic material prior to dike emplacement.

Only few samples show a marked negative Eu-anomaly as would be expected from the late-stage plagioclase-rich differentiates. Dikes with a negative Eu-anomaly reinforce the conclusion of an olivine-, clinopyroxene and plagioclase dominated fractionation of these melts.

From the similarity of all REE patterns a common mantle source, i.e. a common parental magma is assumed. The tholeiitic diabase dikes

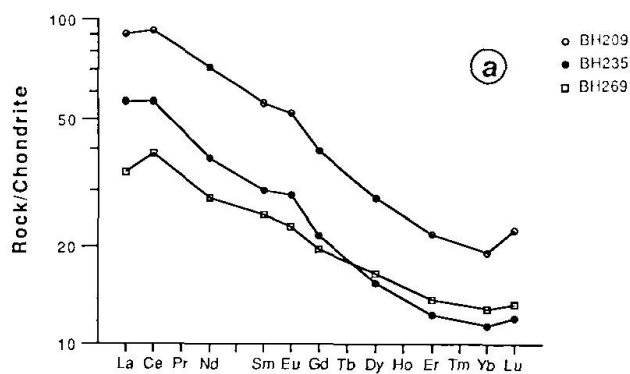


Fig. 3a Chondrite-normalized REE abundances for three selected samples. Normalization factors by NAKAMURA (1974).

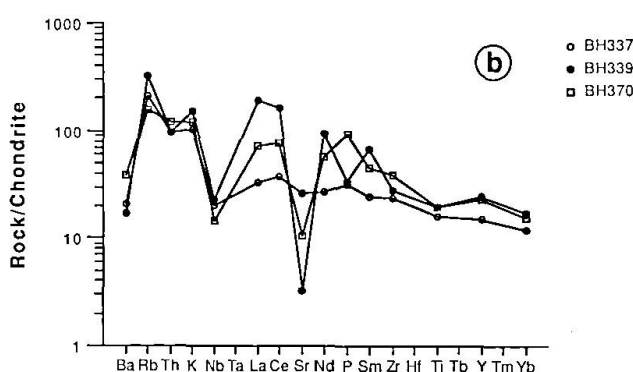


Fig. 3b Reduced trace element diagram for three selected samples. Normalizing factors as in Fig. 3a. Sample BH 337 resembles p-type MORB.

of the Silvretta are chemically similar to other continental, tholeiitic dikes, e.g. the quartz-dolerite from Mull (MORRISON et al., 1980), a dolerite from Marocco (BERTRAND et al., 1982) and the Great Cleveland dike in Great Britain (MACDONALD et al., 1988).

#### 5. Conclusions

The diabase dikes of the Swiss part of the Silvretta can be described as continental, tholeiitic basalts. In chemical variation diagrams fresh and altered samples reflect influences of post-magmatic metamorphic overprints, as well as primary crustal contamination effects and/or mantle heterogeneities.

The dikes represent a magmatic suite, which evolved by fractional crystallization of olivine, clinopyroxene and plagioclase from a mantle derived magma.

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