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U–Pb zircon ages from igneous rocks of the Bernina nappe system (Grisons, Switzerland)

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Abstract

This study presents U–Pb ages for zircons from Carboniferous granodiorites, alkali-granites and rhyolites as well as of wallrock metasediments from the Bernina nappe, Lower Austroalpine Unit. The magmatic rock suites were emplaced in several stages within the Variscan belt into a pre-Variscan basement. Granodiorite-granitic series were dated at a mean value of 333 Ma, the alkali-granitic suite at 295 ± 12 Ma. The rhyolitic body, representing the latest acidic activity, was emplaced at 288 ± 7 Ma as an ignimbrite occurring discordantly above the alkali-granite suite. The majority of the zircon size fractions of the igneous rocks show no inherited lead components. Triassic events as well as Alpine-Tertiary metamorphism caused a lead loss resulting in discordancies of up to 39%. The time span for the evolution of the Bernina igneous complex is approximately 50 Ma. Magmatic activity began with granodiorites at a collisional stage resulting from a subduction of oceanic crust under the Variscan fold belt, the final stage being represented by late-orogenic/post-orogenic granites. The tectonic, geochemical as well as the geochronological evolution of the Bernina is comparable to that of other Variscan magmatic units within the intra Alpine fold belt, e.g., the Aar-, Gotthard-, Mont Blanc Massifs and the Tauern Window.

Data from two meta-sedimentary rock samples collected in the pre-Variscan Stretta basement point to primary crystallization zircon ages in Proterozoic times and comport therefore to data repeatedly found for basements within the Alps and the European Variscides. Their discordant distribution pattern is furthermore indicative for variable overprintings mainly due to late Variscan metamorphism.

Keywords: geochronology, U–Pb ages, Precambrian Variscan belt, Alpine metamorphism, Bernina nappe, Austroalpine, Switzerland.

Geological background

The pre-Alpine basement of the lower Austroalpine nappe system occurs in two major tectonic units: a) the Margna nappe and b) the Bernina nappe s.l. (SPILLMANN, 1993, Fig. 1). This basement contains several meta-igneous and meta-sedimentary rock units varying in degree of metamorphic overprinting. The Margna nappe is separated from the overlying Bernina nappe by a zone composed of Mesozoic sediments. Within the Bernina nappe igneous rocks, metamorphosed in low to middle greenschist facies, show still some undeformed intrusive contacts with the pre-Variscan basement whereas in the western part of the Bernina nappe, subdivided into two subnappes (Corvatsch, Sella), the contacts are in contrast strongly deformed by repeated metamorphic and tectonic overprintings (SPILLMANN and BÜCHI, 1993; TROMMSDORFF et al., 1993).

This study deals primarily with the evolution of Variscan magmatism of the Bernina nappe using U–Pb zircon data and reports in addition data for two gneiss samples from the Stretta-pre-Variscan basement (Fig. 1). Sample localities as well as rock connotation are given in table 1. A detailed geological description of the area is given by RAGETH (1984), SPILLMANN (1993) and SPILLMANN and BÜCHI (1994).

Both the intrusives as well as the adjacent rhyolite unit belong to an intra-Alpine suite with a pre-Alpine magmatic history similar to those in

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the massifs of the Aar and Gotthard as well as in the Tauern Window. Geochemical signatures (RAGETH, 1982, 1984; BÜCHI, 1987, 1994) favour different sources for the parental melts and show the existence of a calc-alkaline and of an alkaline differentiation trend (RAGETH, 1984).

Besides meta-igneous rocks, paragneisses and micaschists are widespread in the Bernina basement. Pre-Alpine tectonic structures can be observed in regions where Alpine overprintings are weak. Rocks in the Stretta basement are composed mainly of white mica schists and gneisses, partly with alkalifeldspar augentexture. Leucocratic augengneisses are interpreted as representing orthogneisses (SPILLMANN, 1993). For metasedimentary suites neither information on their sedimentation ages nor on ages of the parental sources of their detrital zircons exist.

Based on recent petrographical and geochemical studies (RAGETH, 1982, 1984; BÜCHI, 1987; HERMANN and MÜNTENER, 1992; SPILLMANN and BÜCHI, 1993), the Variscan igneous suites which were emplaced into a lower amphibolitic facies basement (SPILLMANN, 1993), are subdivided into for major groups:

group A: calc-alkaline gabbro-diorite-granodiorite-granite suite,

group B: alkaline syenite-alkaligranite-leucogranite suite,

group C: alkaline subvolcanic to volcanic rhyolitic bodies, and

group D: basic dykes, lamprophyres.

Field evidence, within the above sequences, shows group A to be the oldest unit whereas groups B and C represent the younger acidic magmatic event within the Variscan evolution in this area. Basic dykes (group D) crosscut granodiorites, granites and the rhyolites. Field observations suggest a Permian-Triassic age for these dykes. They could be linked to basic magmatic activity, recorded even in sediments of the Triassic cover (RAGETH, 1982; EIKENBERG, 1983).

U–Pb zircon analyses were performed in order to date: the intrusion age of granodiorites, of the alkali-granites and the extrusion age of the rhyolitic body, overlying unconformably the intrusives. Zircon suites out of five granodiorite samples of group A, one alkali-granite of group B, a rhyolite of group C, a granite sample of the Julier nappe further to the NW (Fig. 1), as well as two gneisses from the Stretta basement have been studied.

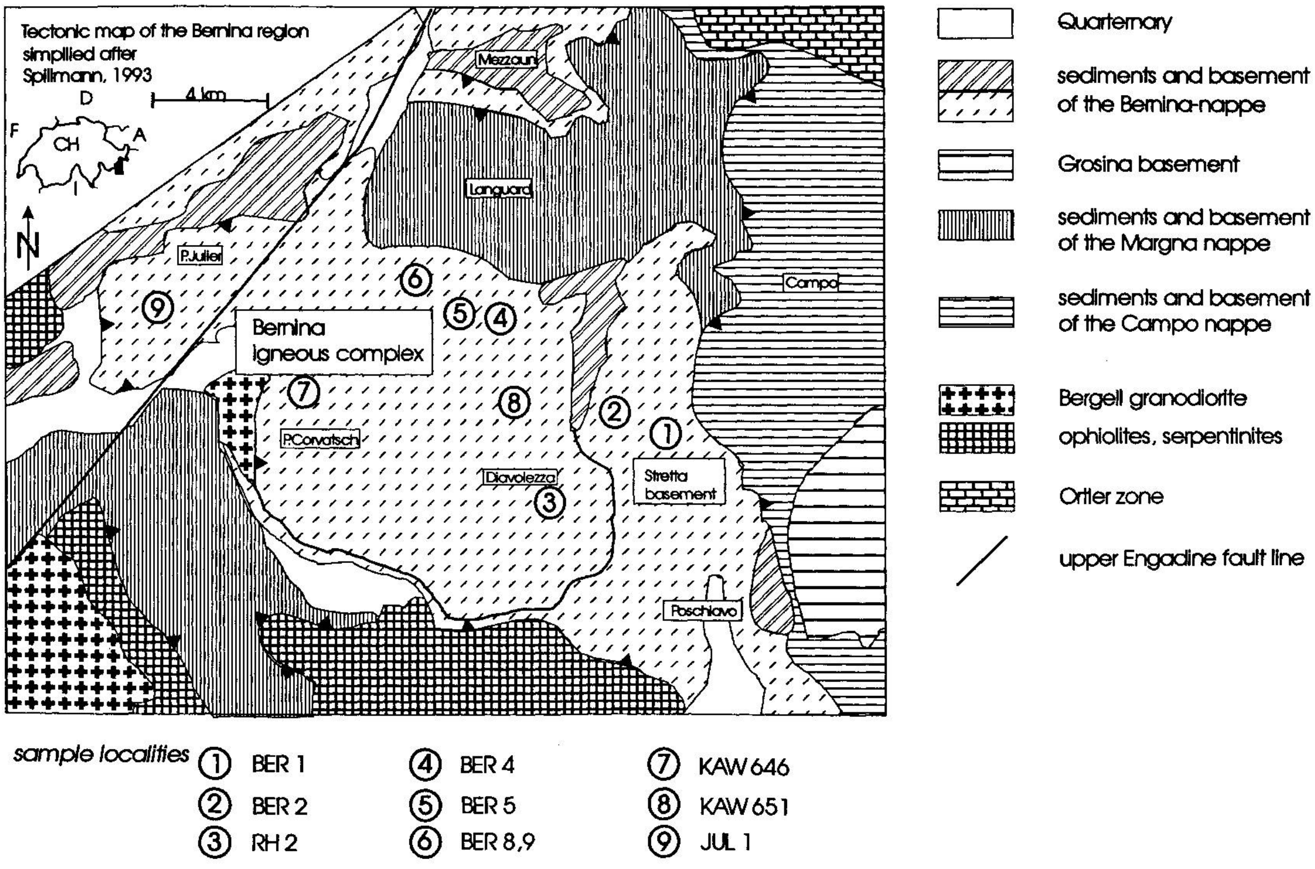

Fig. 1 Simplified geological map of the Bernina nappe s.l. after SPILLMANN (1993).

Tab. 1 Sample localization and rock connotation.

sample	Swiss coordinates	rock type	rock forming minerals
BER 4	792900–147750	granodiorite	quartz-plagioclase-alkalifeldspar-amphibole
BER 8	789230–151600	granodiorite	quartz-plagioclase-alkalifeldspar-amphibole
BER 9	789300–151500	granodiorite	quartz-plagioclase-alkalifeldspar-amphibole
KAW 646	782300–144200	granodiorite	quartz-plagioclase-alkalifeldspar-amphibole
KAW 651	794750–144600	granodiorite	quartz-plagioclase-alkalifeldspar-amphibole
BER 5	792300–148300	alkali-granite	quartz-alkalifeldspar-biotite
JUL 1	777550–149100	alkali-granite	quartz-alkalifeldspar-biotite
RH-2	794200–143100	rhyolite	quartz-alkalifeldspar
BER 1 BER 2	799600–143350 796700–145500	gneisses	quartz-phengitic mica-alkalifeldspar-plagioclase

Methods

Rock samples (10 to 30 kg fresh material) were crushed and a fraction < 300 μm was processed; heavy minerals were separated and concentrated using a Wilfley table, heavy liquids and magnetic separations. Handpicked size fractions were used for the analysis.

Parts of the U–Pb zircon analyses (BER, KAW, JUL) were performed in the Seventies (cf. methods: e.g., GEBAUER and GRÜNENFELDER, 1976) and are recalculated according to the decay constant values given by STEIGER and JÄGER (1977). Dissolution and chemical separation for RH-2 was performed according to the method described by VON QUADT, 1992. Total Pb blanks ranged between 30 and 70 pg. Pb was loaded on a single Re filament with H_3PO_4 and silica-gel, U on double Re filament with 2n HNO_3. Isotope ratios were measured using a Finnigan Mat 261 mass spectrometer with a fixed multicollector-system. U and Pb concentrations were determined using a $^{205}Pb/^{235}U$ mixed spike. Linear fractionation effects equivalent to 0.13% per mass unit were corrected, based on repeated measurements of the NBS SRM 981 standard. The reproducibility of the standard-measurements was 0.1% for $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ and 0.2% for the $^{208}Pb/^{204}Pb$ ratio (2 sigma). The errors on the U–Pb concordia diagrams were calculated using 2 sigma errors (RODDICK, 1987).

Results

U–Pb results (see Tab. 2, 3) are discussed in geochemical as well as geological contexts. Tera-Wasserburg diagrams were used for all plots (Figs 2–11). In cases with intercept ages separated by only tens of million years, the corresponding discordia lines separate much better than the classical Pb-evolution diagram.

Group A:

Calc-alkaline diorite-granodiorite rocks: BER 4, BER 8; BER 9, KAW 646, KAW 651.

Rocks of group A represent a genetically coherent group (SPILLMANN and BÜCHI, 1993). Four zircon fractions of BER 8 and five fractions of BER 4 show a variable spread in discordancy from 17% to 32%. The U content, varying from 1275 to 2769 ppm, comports to a typical range found in Variscan granites (e.g., SCHALTEGGER and VON QUADT, 1991; SCHALTEGGER and CORFU, 1992). Zircon fractions of the granodiorite BER 8 define a regression line with an upper intercept age of 332 ± 15 Ma (Fig. 2), fractions of sample BER 4 plot on a regression line with an upper intercept age of 338 ± 18 Ma (Fig. 3). The lower intercepts for these samples give ages of 80 ± 20 Ma and 60 ± 30 Ma respectively and indicate lead losses in late Cretaceous-Tertiary times. Zircon fractions of both rocks show a correlation between U-concentration and degree of discordancy depending on grain size and magnetic susceptibility (SILVER and DEUTSCH, 1963). Granodiorite BER 9 defines a discordia line with an upper intercept age of 324 ± 12 Ma (Fig. 4), if the fraction > 75 μm magnetic, whose high $^{207}Pb/^{206}Pb$ ratio suggests the existence of an older Pb component, is omitted.

The results of the KAW samples are plotted in figures 5 and 6. All fractions are discordant up to 29%. Three zircon fractions of the granodiorite sample KAW 646 define a regression line with an upper intercept of 338 ± 9 Ma (Fig. 5) and a lower

Tab. 2 U–Pb analytical data for zircons from granodiorites and alkali-granites.

sample	fraction	U	Pb rad	Pb com	^{206}Pb	^{238}U	^{206}Pb	^{207}Pb	^{207}Pb	^{206}Pb	^{207}Pb	^{207}Pb
		ppm	ppm	ppm	^{204}Pb	^{206}Pb	^{238}U	^{235}U	^{206}Pb	^{238}U	^{235}U	^{206}Pb
							atomic ratios			apparent ages		
Group A												
BER 4	< 42 m.	2767	85.64	3.54	1374	31.67	0.031574	0.227858	0.05234	200	208	296
BER 4	42–53 m.	2328	77.12	3.21	1519	29.53	0.033858	0.245561	0.052598	215	223	312
BER 4	53–75 n.m.	1409	56.28	1.39	2418	24.38	0.041012	0.299678	0.052993	259	266	329
BER 4	> 75 n.m.	1264	51.83	1.2	2670	23.70	0.042193	0.308368	0.053003	266	273	329
BER 4	> 75 n.m. rep.	1275	52.07	3.00	2422	23.79	0.042023	0.307402	0.053051	265	272	331
BER 8	< 42 n.m.	1677	67.87	1.25	1574	23.95	0.04175	0.302277	0.052510	264	268	308
BER 8	42–53 n.m.	1600	63.45	0.98	4161	24.37	0.041026	0.297139	0.052526	259	264	277
BER 8	42–53 m.	2769	88.72	3.24	1649	30.05	0.033273	0.239152	0.052126	211	218	291
BER 8	53–75 n.m.	1371	56.89	1.2	3004	23.29	0.042923	0.313052	0.052893	270	277	324
BER 8	53–75 n.m. rep.	1362	56.39	1.17	2948	23.33	0.042853	0.31165	0.052742	271	275	318
BER 8	> 75 m.	1809	65.08	2.31	1655	26.72	0.03742	0.271613	0.052639	237	244	313
KAW 646	< 53 m.	1620	60.68	0.0	9711	25.87	0.03866	0.279587	0.052451	244	250	305
KAW 646	53–75 m.	1448	55.65	0.4	8499	25.16	0.03973	0.287446	0.052473	251	256	306
KAW 646	75–100 n.m.	1196	48.89	0.13	19690	23.59	0.042381	0.307847	0.052682	268	272	315
KAW 651	< 53 n.m.	1792	69.42	1.78	1885	25.07	0.039893	0.288552	0.052456	252	257	305
KAW 651	< 75 m.	3079	97.76	3.68	1188	30.47	0.032817	0.236984	0.052372	208	215	302
KAW 651	< 75 m.rep.	3078	98.63	1.74	3498	30.34	0.032954	0.235377	0.0518	209	215	277
KAW 651	75–100 n.m.	1662	64.71	1.4	2033	24.77	0.040377	0.292528	0.052545	255	260	309
KAW 651	> 100 n.m.	1520	60.61	2.82	1526	24.17	0.041372	0.300924	0.052749	261	267	318
BER 9	< 42 m.	703	28.11	1.01	1699	25.03	0.03994	0.287875	0.052272	253	257	297
BER 9	42–53 n.m.	554	23.75	0.64	2256	23.29	0.042929	0.310483	0.052451	271	275	305
BER 9	> 75 n.m.	531	23.14	0.69	2005	22.91	0.043643	0.316711	0.052629	275	279	313
BER 9	> 75 m.	654	25.95	1.54	981	24.79	0.040339	0.296967	0.053389	255	264	345
Group B												
BER 5	< 42 m.	1687	60.46	2.21	1687	28.07	0.035628	0.255277	0.051963	226	231	284
BER 5	< 53 n.m.	1217	50.29	1.48	2145	24.32	0.041876	0.300382	0.052024	264	267	287
BER 5	42–53 n.m.	1217	50.63	1.14	2567	24.23	0.04126	0.297241	0.052249	261	263	296
BER 5	53–75 m.	1680	60.71	3.11	1202	27.82	0.035934	0.257975	0.052068	228	233	289
BER 5	> 100 n.m.	1184	50.14	2.93	1253	21.56	0.046393	0.338455	0.052911	292	296	325

Common lead correction: $^{208}Pb/^{204}Pb$ = 38.07, $^{207}Pb/^{204}Pb$ = 15.602, $^{206}Pb/^{204}Pb$ = 18.21 (STACEY and KRAMERS, T = 310 Ma); abbreviations: m. = magnetic; n.m. = non magnetic; rep. = repetition.

intercept of 85 ± 35 Ma. The smallest fraction (< 53 n.m.) has the highest U content as well as the lowest $^{207}Pb/^{235}U$ and $^{206}Pb/^{238}U$ ages (Tab 1). Inherited old crustal components are not discernible. Five zircon fractions of the KAW 651 granodiorite sample plot on a discordia line with an upper intercept age of 332 ± 18 Ma and with a lower intersection at 78 ± 30 Ma (Fig. 5). The high U content of fraction < 75 μm magnetic (3079 ppm) suggests a strong lead loss due to advanced metamictization. Magnetic fractions (Tab. 2) show a discordance of up to 20% while within the non-magnetic fractions, the largest one (> 100 μm) has a discordance of 5%. The U contents of the magnetic fractions vary in a small range between 2051 and 2236 ppm, whereas in the non-magnetic fraction the U content is significantly lower (1565 ppm).

Tab. 3 U–Pb analytical data for zircons from alkali-granites, rhyolite and meta-sediments.

sample	fraction	U	Pb rad	Pb com	^{206}Pb	^{238}U	^{206}Pb	^{207}Pb	^{207}Pb	^{206}Pb	^{207}Pb	^{207}Pb
		ppm	ppm	ppm	^{204}Pb	^{206}Pb	^{238}U	^{235}U	^{206}Pb	^{238}U	^{235}U	^{206}Pb
							atomic ratios			apparent ages		
Group C												
RH-2	> 65 n.m.	1518	67.09	2.59	1624	22.82	0.043814	0.315356	0.052202	276	278	294
RH-2	< 65 m.	2105	94.55	3.28	1809	22.49	0.044462	0.318191	0.051904	280	281	281
RH-2	53–65 n.m.	2946	137.60	2.45	3506	21.59	0.046318	0.332388	0.052046	292	292	288
RH-2	< 53 n.m.	1953	95.26	2.13	2797	20.68	0.048352	0.347940	0.052190	304	303	293
RH-2	< 53 m.	2039	96.46	1.97	3027	21.29	0.046973	0.335668	0.051828	295	293	278
JUL 1	< 42 n.m.	1678	66.99	2.25	1550	24.84	0.040252	0.289802	0.052217	257	262	305
JUL 1	> 75 n.m.	1528	58.22	1.89	1661	25.86	0.038666	0.278015	0.052148	247	252	302
JUL 1	42–53 m.	3785	103.64	3.2	1153	35.83	0.027910	0.200689	0.052151	179	188	302
JUL 1	> 75 m.	3965	109.23	3.56	853	35.40	0.028246	0.202525	0.052002	181	1902	295
meta-sediments												
BER 1	< 42 m.	711	40.59	25.25	117	17.26	0.057945	0.481115	0.060215	363	399	611
BER 1	< 65 n.m.	504	34.97	7.89	290	14.21	0.070355	0.6174	0.063642	438	488	730
BER 1	> 65 m.	584	39.19	15.94	167	14.94	0.066942	0.610127	0.066099	418	484	810
BER 1	> 65 m. rep.	565	38.43	15.19	1708	14.75	0.067783	0.621015	0.066443	423	491	820
BER 2	< 42 n.m.	690	46.04	1.08	2637	14.54	0.068793	0.573166	0.060424	429	460	619
BER 2	42–65 n.m.	638	43.84	1.00	2401	14.19	0.070465	0.605206	0.062288	439	480	684
BER 2	42–65 n.m. rep.	623	42.15	1.15	2341	14.22	0.070329	0.606031	0.062497	438	481	703
BER 2	> 65 n.m.	559	40.91	1.52	1726	14.16	0.070605	0.67387	0.065506	464	523	791

Common lead correction: $^{208}Pb/^{204}Pb$ = 38.07, $^{207}Pb/^{204}Pb$ = 15.602, $^{206}Pb/^{204}Pb$ = 18.21 (STACEY and KRAMERS, T = 310 Ma); abbreviations: m. = magnetic; n.m. = non magnetic; rep. = repetition.

K–Ar biotite data of sample KAW 646 granodiorite yield ages of 237 and 223 Ma (E. JÄGER pers. comm.), whereby K–Ar biotite data of the granitic rock suite show ages varying from 236 Ma to 258 Ma (HUNZIKER et al., 1992).

Group B:

Alkaline syenite-alkaligranite-leucogranite suite: sample BER 5.

Five zircon fractions of an alkaligranite, BER 5, define a discordia line which intersects the concordia curve at 317 ± 17 Ma and at 80 ± 30 Ma respectively (Fig. 7). Fraction > 100 μm clearly shows the presence of an older zircon component. Neglecting this biggest zircon size fraction the upper intercept at 295 ± 12 Ma is interpreted as the intrusion age. As in group A the U distribution (1687 to 1184 ppm) decreases from the smallest to the biggest grain size.

Group C:

Rhyolitic body: sample RH 2.

Data for five fractions are given in table 2. Large variations show up in the U concentration; however in this case no U correlation to grain size and magnetic susceptibility is observed. These zircons represent a much smaller variation in grain size than found in the intrusive rock suites. Such a narrow size distribution as compared to, e.g., those out of the granodiorites is suggestive for a faster cooling rate. The discordia line defines an upper intercept age of 288 ± 7 Ma (Fig. 8). Leach experiments on fractions of sample RH-2 show U loss increasing up to 1.5% of the total content, whereas the Pb loss remained negligible.

Microprobe analyses of U and Th of a number of sub-euhedral zircons yield profiles showing an enrichment of both U and Th up to 100% from the core to the rim (Fig. 9). This pattern may indicate that processes related probably to Permo-Triassic and even Alpine events may have leached U; this can be an explanation of the observed U–Pb ratios plotting above the concordia (Fig. 8).

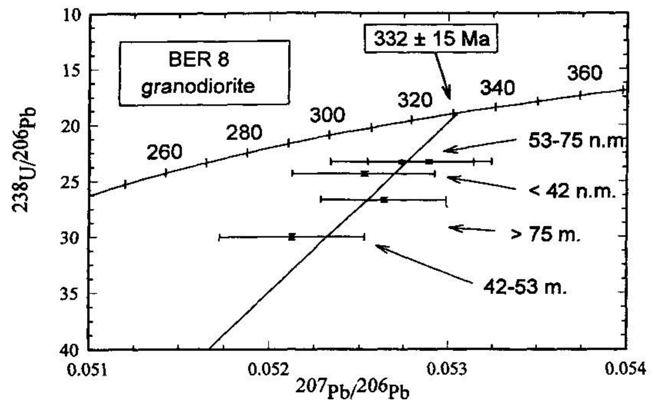

Fig. 2 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the granodiorite BER 8.

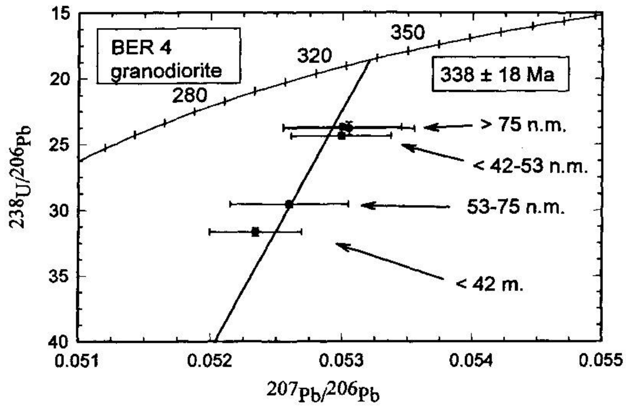

Fig. 3 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the granodiorite BER 4.

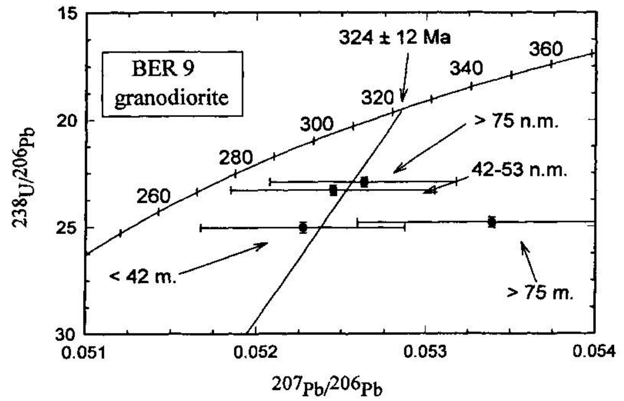

Fig. 4 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the granodiorite BER 9.

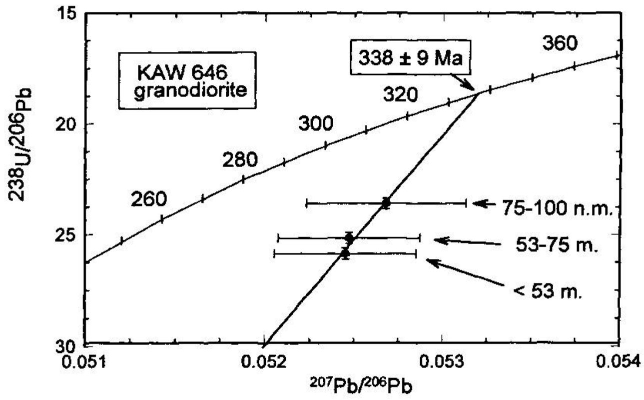

Fig. 5 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the granodiorite KAW 646.

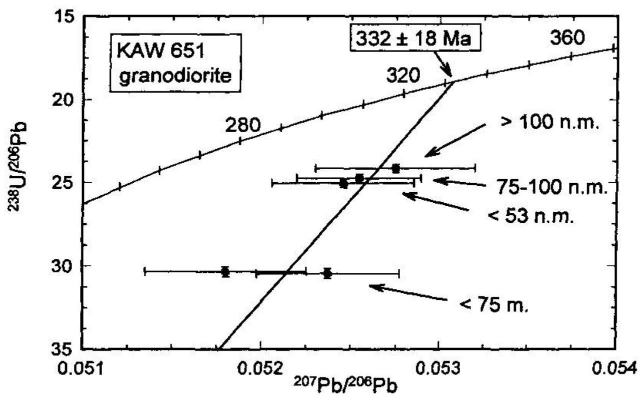

Fig. 6 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the granodiorite KAW 651.

Alkali-granite JUL 1, Julier nappe:

Sample JUL 1 was collected in the Julier-pass region (Fig. 1); the unit belongs to the Bernina igneous complex. This rock is part of the alkaline evolution series as reported by MERCOLLI and OBERHÄNSLI (1988). Both non magnetic and magnetic fractions define a discordia line intersecting the concordia at 292 ± 6 Ma (Fig. 10) and with a lower intercept at 10 ± 12 Ma, having undergone a recent lead loss.

Meta-sedimentary rocks (Stretta-basement), BER 1 and BER 2:

Zircon data of these rocks (Fig. 11), into which the Variscan granitoids have intruded, show a scatter as expected for inherited zircon-multi-components with differing geological histories. The observed patterns are consistent with those encountered in other pre-Variscan basements of the Alps as well as of the European Variscides and demonstrate the appearance of primary crystallizations Proterozoic, possibly even Archean in age (e.g., GRAUERT and ARNOLD, 1968; PIDGEON et al. 1974; GEBAUER and GRÜNENFELDER, 1977; TEUFEL, 1988).

In contrast to the igneous zircons (group A to C), the majority of crystals are characterized, with minor exceptions, by a xenomorphic, rounded habitus. Moreover the U contents between 500 to 690 ppm are throughout much lower than in

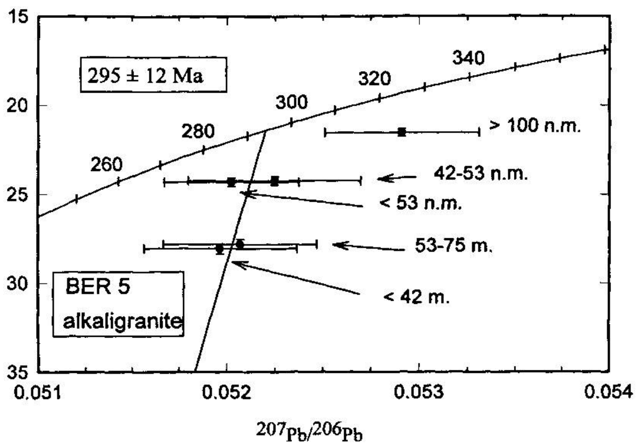

Fig. 7 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the alkaligranite BER 5.

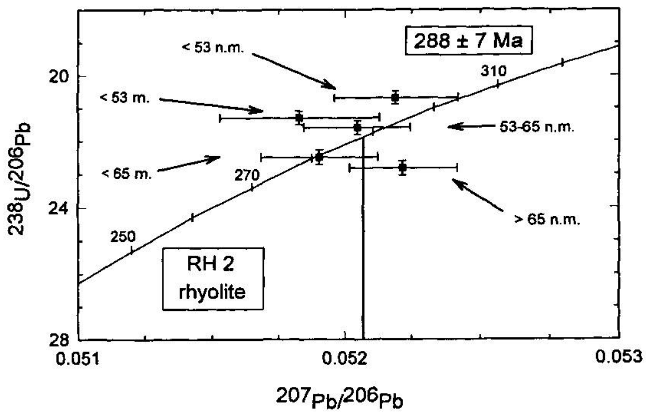

Fig. 8 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the rhyolite RH-2.

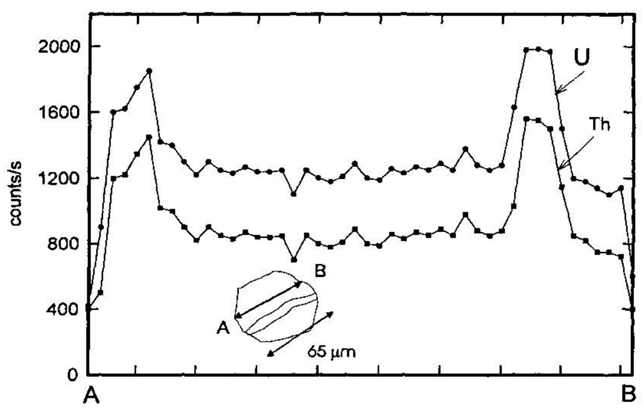

Fig. 9 Microprobe profile (U, Th) of a zircon crystal of the rhyolite sample RH-2.

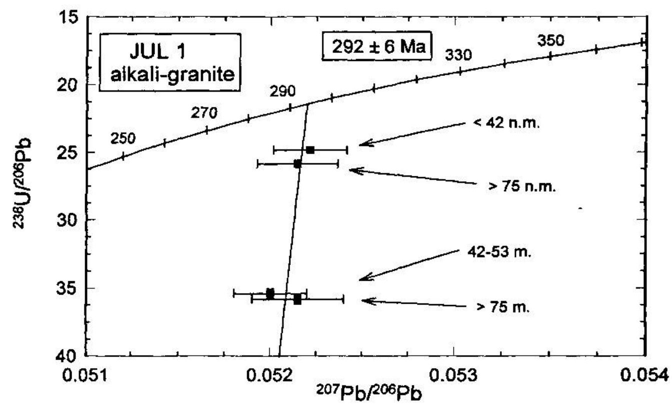

Fig. 10 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the alkaligranite JUL 1.

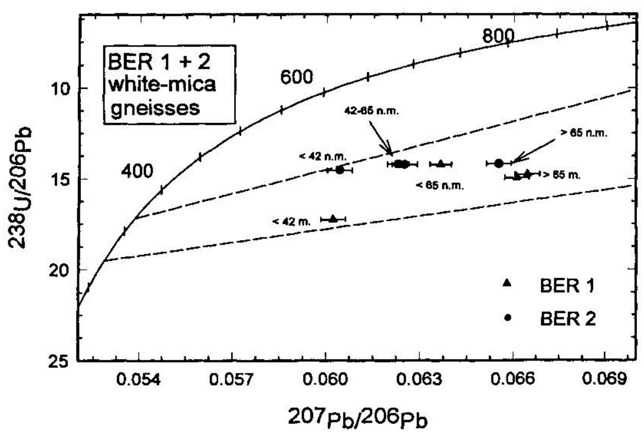

Fig. 11 $^{207}Pb/^{206}Pb$ vs $^{238}U/^{206}Pb$ plot for zircons from the paragneiss samples BER 1 and BER 2.

zircons of the igneous rock suites (Tab. 3). Both above observations are indicative for natural mechanical abrasive processes occurring prior to the final sedimentation of the original rock.

Figure 11 points out a fan-like field of data which are concentrated above all near to the concordia curve for Variscan ages. Thus, these data-settings infer overprintings of the U-Pb-system due to Variscan metamorphic events, possibly related also to the intrusions starting at 338 Ma (Fig. 5). However since no single crystal data are presently available, effects of later U–Pb disturbances cannot be excluded.

Discussion

For the case of the analyzed meta-sedimentary zircon suites (Fig. 11), their U–Pb data do retain information about their primary crystallization ages in the Precambrian. Variscan overprintings of these data are quite conspicuous.

Zircon fractions out of the igneous rock suite record variable lead losses induced by repeated overprintings: in Triassic times, due to extension tectonics and upwelling of the subcontinental

Tab. 4 Summary of U–Pb zircon ages in Bernina nappe units.

region (Fig.1)	sample	rock type	age in Ma	age interpretation
Group A				
	BER 4 BER 8 BER 9 KAW 651 KAW 646	granodiorite granodiorite granodiorite granodiorite granodiorite	338 ± 18 332 + 15 324 ± 12 332 ± 18 338 ± 9	intrusion
Group B				
	BER 5	alkali-granite	295 ± 12	intrusion
Julier	JUL 1	alkali-granite	292 ± 4	intrusion
Group C				
	RH-2	rhyolite	288 ± 2	extrusion
Stretta basement Stretta	BER 1 BER 2	gneiss gneiss		the data sets provide indications for differing primary crystallization ages in the Precambrian as well as metamorphic overprintings in Variscan times

mantle as reported by TROMMSDORFF et al., 1993, as well as in subsequent Cretaceous to Tertiary times. Therefore multiple, i.e., anewed U–Pb derangements may best explain the observed scatter of the extrapolated lower intercepts varying between 126 to 10 Ma for the groups A to C suites. Most zircon fractions plot on discordia lines without indicating a major influence of older lead components, except those, cf. figure 4: fraction > 100 μm n.m. and figure 7: > 75 (μm m., containing crystals with rounded zircon cores, epitactically overgrown with zoned zircon substance.

The analyzed calc-alkaline granodiorite-granite-alkaligranite rock suites represent the main intrusive mass of the Bernina nappe. This intrusion process to commence in Visean time is suggested as a result of a convergent ocean-continent collision at a southern flank of the Variscan fold belt. Generally, the age progression from a calc-alkaline to a alkaline suite conforms well with motions of an evolving arc system. Such a cordillera model has been recently proposed by MERCOLLI and OBERHÄNSLI (1988) for the N-W neighbouring region. In the Austrian Alps (FINGER and STEYRER, 1990), the Variscan fold belt comports to collision states in its early part to be followed by a plate configuration with subductions of oceanic crust under the fold belt and then to an anorogenic state related to granitic alkalic regimes (BONIN et al., 1993). The occurrence of alkali-granites as well as of late rhyolitic extrusives appears therefore to express the latest anorogenic process in time. The latest acidic intrusive activity is dated at 295 ± 12 Ma; a postintrusive subaerial event (RAGETH, 1982, 1984; BÜCHI, 1987) at 288 ± 8 Ma. Geochemical data (RAGETH, 1984, BÜCHI, 1994) are in favour of a cogenetic evolution of the plutonic alkali cycle and the alkali-rhyolites. A comparison of U–Pb zircon ages (Tab. 4, 5) display a time span for the Bernina igneous evolution of around 50 Ma.

In contrast to Variscan granitoids of the Moldanubian zone and the Bohemian massif which are strongly dominated by S-type units (LIEW and HOFMANN, 1988; LIEW et al., 1989), Variscan granitic suites within the intra Alpine fold belt appear for the most part as I-types, as reflected by Sr, Nd and Hf data of whole rocks, e.g., in the Tauern window (VON QUADT and FINGER, 1990 and 1992) as well as in the Aar massif (SCHALTEGGER and CORFU, 1992).

Conclusions

1) Early Variscan granitoids of the calc-alkaline suite of the Bernina suites intruded in Visean time, at approximately 333 Ma; the alkali-granite of the alkaline syenite-granite suite has been dated at 295 ± 12 Ma; rhyolites overlying alkali-granites are 288 ± 7 Ma in age.

Tab. 5 Comparison with some Variscan intrusion ages (U–Pb zircon system) in the central and eastern Alpine fold belt.

region	unit and rock types	intrusion age in Ma	reference
eastern Alps Tauern Window	Granatspitz, granodiorite Hochalm, granite Sonnblick, granite	335 ± 15 314 ± 7 313 ± 10	CLIFF, 1981 CLIFF, 1981 CLIFF, 1981
eastern Alps Tauern Window	Granatspitz, granodiorite Knorrkogel, granite Venediger, tonalite	333 ± 12 335 ± 8 290	VON QUADT, unpubl. VON QUADT, unpubl. VON QUADT, unpubl.
central Alps: Aar Massif	shoshonitic-ultrapotassic suite diorite Central Aar granite	334 ± 2.5 308–310 296.5–299	SCHALTEGGER and CORFU, 1992 CORFU, 1992
central Alps: Gotthard Massif	porphyric granite leucocratic granite	300.6 ± 1.4 295 ± 2	SERGEEV and STEIGER, 1993
Mont Blanc Massif	granite granite Mg-rich granite Fe-rich	304 ± 3 306 +5/–3 305 ± 2	BUSSY, 1992 BUSSY, 1992 BUSSY, 1992
Lower Austroalpine Bernina nappe	granodiorite (group A) alkali-granite (group B) rhyolite (group C)	see table 4	this study this study this study

2) U–Pb zircon data as well as geochemical data (RAGETH, 1982, 1984; BÜCHI, 1987) of the Bernina igneous suites probably relate to magmatic processes resulting from an early collisional to a late subduction stage which is also reported from other localities in the central and the eastern Alps.

3) Some zircon populations show a classical correlation of grain size, magnetic susceptibility, discordancy and U content (SILVER and DEUTSCH, 1962).

4) U–Pb zircon analyses of meta-sediments in the pre-Variscan Stretta basement (BER 1 + 2) point to multi-component systems with different Precambrian primary ages. Furthermore these data are in part consistent with Nd crustal residence ages of 2.0–2.3 Ga reported for the Tauern Window (VON QUADT and FINGER, 1992).

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References

BÜCHI, HJ. (1987): Geologie und Petrographie der Bernina IX. Das Gebiet zwischen Pontresina und dem Morteratschgletscher. unpubl. diploma thesis, University of Zurich.

BÜCHI, HJ. (1993): Der variskische Magmatismus in der östlichen Bernina (Graubünden), Schweiz. Mineral. Petrogr. Mitt., 74, 361–364.

BUSSY, F. (1992): U–Pb zircon dating of the Mont-Blanc granite and its microgranular enclaves. Schweiz. Mineral. Petrogr. Mitt., 73, 1, 144–145.

CLIFF, R.A. (1981): Pre-Alpine History of the Pennine Zone in the Tauern Window, Austria: U–Pb and Rb–Sr Geochronology. Contrib. Mineral. Petrol., 77, 262-266.

DEUTSCH, A. (1983): Datierungen an Alkaliamphibolen und Stilpnomelan aus der südlichen Platta-Decke (Graubünden). Eclogae geol. Helv., 76/2, 295–308.

FINGER, F. and STEYRER, H.-P. (1988): Granite types in the Hohe Tauern (eastern Alps, Austria). Some aspects on their correlation to Variscan plate tectonic processes. Geodinamica Acta (Paris), 2, 75–87.

FINGER, F. and STEYRER, H.-P. (1990): I-type granotoids as indicators of a late Paleozoic convergent ocean-continent margin along the southern flank of the central European Variscan orogen. Geology, 18, 1207–1210.

GEBAUER, D. and GRÜNENFELDER, M. (1976): U–Pb zircon and Rb–Sr whole-rock dating of low-grade metasediments. Example: Montagne Noire (Southern France). Contrib. Mineral. Petrol. 59, 13–32.

GEBAUER, D. and GRÜNENFELDER, M. (1977): U–Pb systematic of detrital zircons from some unmetamorphosed to slightly metamorphosed sediments of Central Europe. Contrib. Mineral. Petrol. 65, 29–37.

GRAUERT, B. and ARNOLD, A. (1968): Deutung diskordanter Zirkonalter der Silvrettadecke und des Gotthardmassivs (Schweizer Alpen). Contrib. Mineral. Petrol. 20, 34–56.

GRAUERT, B., HÄNNY, R. and SOPTRAJYNOVA, G. (1974): Geochronology of a Polymetamorphic and Anatectic Gneiss Region: The Moldanubicum of the Area Lam-Deggendorf, Eastern Bavaria, Germany. Contrib. Mineral. Petrol. 45, 37–63.

HERMANN, J. and MÜNTENER, O. (1992): Strukturelle Entwicklung im Grenzbereich zwischen dem penninischen Malenco-Ultramafitit und dem Unterostalpin (Margna- und Sella-Decke). Schweiz. Mineral. Petrogr. Mitt. 72, 225–240.

HUNZIKER, J.C., DESMONS, J. and HURFORD, A.J. (1992): Thirty-two years of geochronological work in the Central and Western Alps: a review on seven maps. Mémoires de Géologie (Lausanne), No. 13, 59 pp.

JÄGER, E. (1973): Die alpine Orogenese im Lichte der radiometrischen Altersbestimmung. Eclogae geol. Helv., 66/1, 11–21.

KÖPPEL, V. and GRÜNENFELDER, M. (1973): A study of inherited and newly formed zircon from paragneisses and granitized sediments of the Strona-Ceneri-Zone (Southern Alps). Schweiz. Mineral. Petrogr. Mitt. 51, 385–409.

LIEW, T.C. and HOFMANN, A. (1988): Precambrian crustal components, plutonic associations, plate environment of the Variscan fold belt of central Europe: Indications from a Nd and Sr isotopic study: Contrib. Mineral. Petrol., 98, 129–138.

LIEW, T.C., FINGER, F. and HÖCK, V. (1989): The Moldanubian granitoid plutons of Austria: Chemical and isotopic studies bearing on their environmental setting: Chemical Geology, 76, 41–55.

MANHES, G., ALLÈGRE, C.J. and PROVOST, A. (1984): U–Th–Pb systematics of the eucrite "Juvinas": Precise age determination and evidence for exotic lead. Geochim. Cosmochim. Acta, 48, 2247–2264.

PIDGEON, R.T., KÖPPEL, V. and GRÜNENFELDER, M. (1974): U–Pb isotopic relatioship in zircon suites from a para- and orthogneiss from the Ceneri zone, Southern Switzerland. Contrib. Mineral. Petrol. 26, 1–11.

RAGETH, R. (1982): Geologie und Petrographie der Bernina III: Diavolezza. Unpubl. diploma thesis, ETH Zurich.

RAGETH, R. (1984): Intrusion und Extrusion der Bernina-Decke zwischen Morteratsch und Berninapass (Graubünden). Schweiz. Mineral. Petrogr. Mitt. 64, 83–103.

RODDICK, J.C. (1987): Generalized numerical error analysis with applications to geochronology and thermodynamics. Geochim. Cosmochim. Acta 51, 2129–2135.

SCHALTEGGER, U. and VON QUADT, A. (1990): U–Pb zircon dating on the Central Aar Granite (Aar Massif, Switzerland). Schweiz. Mineral. Petrogr. Mitt. 71, 391–403.

SCHALTEGGER, U. and KRÄHENBÜHL, U. (1990): Heavy Rare Earth Element enrichment in Granites of the Aar Massif (Central Alps, Switzerland). Chemical Geology; 89; 49–63.

SCHALTEGGER, U. and CORFU, F. (1992): The age and source of late Variscan magmatism in the central Alps: evidence from precise U–Pb ages and initial Hf isotopes. Contrib. Mineral. Petrol., 111, 329–344.

SILVER, L.T. and DEUTSCH, S. (1963): Uranium lead variations in zircons: a case study. J. Geology, 71, 747–758.

SPILLMANN, P. and BÜCHI, HJ. (1993): The pre-Alpine Basement of the Lower Austroalpine Nappes in the Bernina Massif (Grisons, Switzerland; Valtellina, Italy). In: VON RAUMER, J.F. and NEUBAUER. F. (eds): The Pre-Mesozoic Geology in the Alps. Springer Verlag, Berlin.

SPILLMANN, P. (1993): Die Geologie des penninisch-ostalpinen Grenzbereichs im südlichen Berninagebirge. Doctorate thesis. ETH-Zurich, No. 10175.

STAUB, R. (1916): Tektonische Studien im östlichen Bernina-Gebirge. Vjschr. natf. Ges. Zürich, 61.

STEIGER, R.H. and JÄGER, E. (1977): Subcommission on Geochronology: Convention on the use of decay constants in Geo- and Cosmochronology. Earth Planet. Sci. Lett. 36, 359–362.

TERA, F. and WASSERBURG, G.J. (1972): U, Th, Pb systematics in three Apollo 14 basalts and the problem of intial Pb in lunar rocks. Earth Planet. Sci. Letters, 14, 281.

TEUFEL, ST. (1988): Vergleichende U-Pb- und Rb-Sr-Altersbestimmungen an Gesteinen des Übergangsbereiches Saxothuringikum/Moldanubikum, NE-Bayern. Göttinger Arb. zur Geol. und Paläont. Nr. 38.

TROMMSDORFF, V., PICCARDO, G. and MONTRASIO, A. (1993): From magmatism through metamorphism to sea floor emplacement of subcontinental Adria lithosphere during pre-Alpine rifting (Malenco, Italy). Schweiz. Mineral. Petrogr. Mitt. 73, 243–255.

VON QUADT, A. and FINGER, F. (1990): Entwicklung der prä-alpidischen kontinentalen Kruste im Tauernfenster aufgrund von Sm/Nd-, Rb/Sr-Isotopenuntersuchungen und U-Pb-Zirkonanalysen. Beiheft Eur. J. Mineral. 2, 1, 215.

VON QUADT, A. (1992): U–Pb zircon and Sm–Nd geochronology of mafic and ultramafic rocks from the central part of the Tauern Window (eastern Alps). Contrib. Mineral. Petrol., 110, 57–67.

VON QUADT, A. and FINGER, F. (1992): Isotopengeochemische Hinweise auf mittelproterozoische Krustenkomponenten in altpaläozoischen Metavulkaniten und jungpaläozoischen Granitoiden des Tauernfensters. Eur. J. Mineral. 4, 1, 223.

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