Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 62 (1982)

Heft: 2

Artikel: The microcline/sanidine transformation isograd in metamorphic regions, II. The region of Lepontine metamorphism, Central Swiss Alps

Autor: Bernotat, W.H. / Bambauer, H.U.

DOI: https://doi.org/10.5169/seals-47970

Schweiz. mineral. petrogr. Mitt. 62, 231-244, 1982

The Microcline/Sanidine Transformation Isograd in Metamorphic Regions

II. The region of Lepontine metamorphism, Central Swiss Alps*

By *W. H. Bernotat* and *H. U. Bambauer* **

Abstract

In eleven selected traverses across the Central Swiss Alps, the K-feldspar discontinuities, as described and discussed in paper I, were discovered by x-ray and partly optical and infrared methods. These discontinuities are fairly sharp changes from low microcline to variable high microclines. The latter are interpreted as being pseudomorphs after Alpine sanidine. One can use the discontinuity to define a microcline/sanidine transformation isograd, over a distance of more than 140 km. This isograd fits well into the known pattern of metamorphic zonation of the Central Alps. The microcline/sanidine isograd corresponds to an isotherm of approx. 450°C during the climax of the late Alpine (Lepontine) metamorphism.

Zusammenfassung

In 11 ausgewählten Profilen durch die Zentralen Schweizer Alpen wurden mit röntgenographischen und zum Teil optischen und IR-spektroskopischen Methoden die in Teil I dieser Arbeit beschriebene und diskutierte K-Feldspat-Diskontinuität ermittelt. Die gefundenen Diskontinuitäten sind im Profil erkennbar an einem deutlichen Wechsel von Tief-Mikroklin zu variablen Hoch-Mikroklinen, wobei letztere als Pseudomorphosen nach alpidischem Sanidin interpretiert werden. Die Diskontinuitäten lassen sich zu einer mehr als 140 km ausgedehnten Mikroklin/Sanidin-Isograde verbinden. Diese fügt sich in guter Näherung in das bekannte Bild metamorpher Zonierung der Zentralalpen. Die Mikroklin/Sanidin-Isograde entspricht einer ~450°C-Isotherme während des Höhepunktes der spätalpidischen (lepontinischen) Metamorphose.

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* Dedicated to Professor Eduard Wenk on the occasion of his 75th birthday.

** Institut für Mineralogie, Universität Münster, Corrensstrasse 24, D-4400 Münster, Fed. Rep. Germany.

Introduction

As a result of the Lepontine phase[1] of Alpine metamorphism which reached its climax during mid-Tertiary, a marked concentric metamorphic zonation developed in the Swiss Alps. Its central part, in the amphibolite facies, is situated in the Lepontine Alps (Plate I). A sketch map of this area and the corresponding literature are given in paper I of this series (BAMBAUER & BERNOTAT 1982). The *K-feldspar discontinuity,* discovered by BAMBAUER & BERNOTAT (1976) in the St. Gotthard traverse, was treated in detail in above mentioned paper I, which is a general study of perthitic alkali feldspars from the Aar and Gotthard Massifs. This discontinuity is characterized by a fairly sharp change from *low microcline*[2] in the north to *high microcline* (with variable amounts of low microcline) in the south. The high microcline displays variable degrees of Al,Si order, and is interpreted as transition pseudomorph after sanidine which formed during the Alpine retrograde metamorphism. The discontinuity indicates the approximate northernmost point within the traverse, at which the temperature of the diffusive transformation microcline/sanidine was reached. This temperature was estimated to be $T_{diff} \sim 450^0C$ at ~ 3 Kbar for a composition $Or_{95-90}Ab_{05-10}$. Hence the K-feldspar discontinuity defines a *microcline/sanidine transformation isograd.*

In the present paper II, the K-feldspar discontinuity is described in additional traverses in order to establish the microcline/sanidine isograd for the Central Alps. Preliminary results were reported by BERNOTAT & BAMBAUER (1980). Details of methods and criteria to be taken into account when interpreting the results were treated in paper I.

Sampling and survey of data

Samples were taken along eleven traverses across a curved zone which extends from the Centovalli-Simplon fault in the west to the Adula nappe in the east (Plate I). The traverses were placed so that they would include the K-feldspar discontinuity which was expected approximately at uniform distances from the staurolite-in boundary. Lattice parameters, optic axial angle, and infra-red spectra of the K-feldspar were determined for each rock sample in the St. Gotthard and Val Medel traverses. This use of several methods, advisable for a still unknown region, could be reduced for most traverses to a microscopical inspection of the rocks and the identification of high and low microcline (as

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[1] The geographical term Lepontine Alps and the temporal term Lepontine phase are to be clearly distinguished (compare E. Wenk 1975).

[2] It occasionally may contain minor traces of high microcline (compare paper I, p. 217, 220).

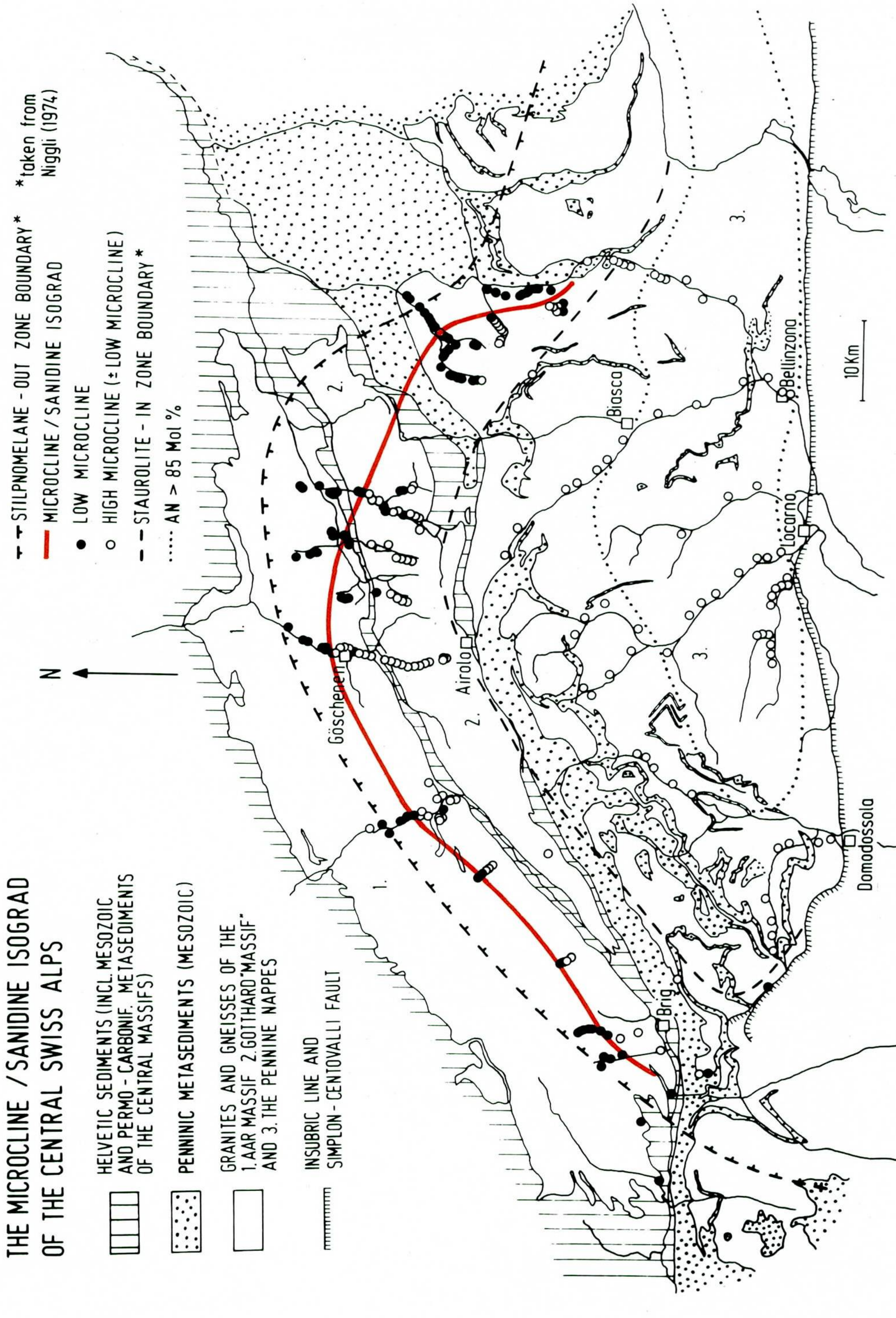
THE MICROCLINE / SANIDINE ISOGRAD OF THE CENTRAL SWISS ALPS
HELVETIC SEDIMENTS (INCL. MESOZOIC AND PERMO - CARBONIF. METASEDIMENTS OF THE CENTRAL MASSIFS)
PENNINIC METASEDIMENTS (MESOZOIC)
GRANITES AND GNEISSES OF THE 1. AAR MASSIF 2. GOTTHARD "MASSIF" AND 3. THE PENNINE NAPPES
INSUBRIC LINE AND SIMPLON - CENTOVALLI FAULT
N
STILPNOMELANE - OUT ZONE BOUNDARY*
MICROCLINE / SANIDINE ISOGRAD
LOW MICROCLINE
HIGH MICROCLINE (± LOW MICROCLINE)
STAUROLITE - IN ZONE BOUNDARY*
AN > 85 Mol %
*taken from Niggli (1974)
10 Km
1.
2.
3.
Brig
Göschenen
Airolo
Biasca
Bellinzona
Locarno
Domodossola

Table 1 Sample localities (topographic coordinates) and rock type of alkali feldspar samples as listed in Table 2 from various traverses through the Central Swiss Alps as shown in Plate 1.

sample No.	coordinates		rock type
Traverses of the Western Aar Massif (1)			
SZA - 1	642.750	139.550	central Aare granite
SZA - 15	637.175	136.850	
SZA - 17	637.750	136.075	
SZA - 22	638.200	134.575	gneiss (Altkristallin)
SZA - 31	632.950	128.300	
Aare Valley and Grimsel Pass, Aar Massif (2)			
SZA - 136/1	666.125	165.975	central Aare granite
SZA - 136/2	666.125	165.975	
SZA - 44	669.650	157.125	
SZA - 36(1)	670.650	157.175	gneiss (Altkristallin)
SZA - 36(2)	670.650	157.175	
SZA - 45(1)	670.400	156.825	
SZA - 45(2)	670.400	156.825	
SZA - 47	670.450	156.125	granite (Altkristallin)
SZA - 97	672.775	158.925	central Aare granite
St. Gotthard, Aar Massif and Gotthard			
compare Table 2 and 4, paper I			
Val Val and Val Maighels, Aar Massif and Gotthard (3)			
SZA - 109	696.200	166.575	schist (Urseren Zone)
SZA - 104	695.925	164.050	orthogneiss (Gotthard)
SZA - 101B	695.425	162.575	
SZA - 101A	695.425	162.575	
SZA - 98	694.950	161.200	

Table 1 continued

Val Nalps (3), Gotthard "Massif"

SZA - 118(2)	701.675	164.800	orthogneiss
SZA - 115	700.825	163.475	
SZA - 1884	700.800	163.225	
SZA - 114(1)	700.550	163.025	
SZA - 113	700.550	162.525	
SZA - 111	700.450	161.700	
SZA - 110	700.450	161.450	

Val Medel (4), Aar Massif, Tavetsch Massif, Gotthard

compare also Table 3 and 5, paper I

Val Cristallina (5), Gotthard

SZA - 130	708.425	162.800	Cristallina Granodiorite
SZA - 129	708.450	162.425	
SZA - 128	708.775	162.175	
SZA - 127	708.775	162.100	
SZA - 125	708.825	161.550	
SZA - 124	708.950	161.325	
SZA - 123(1)	709.100	161.225	

Lake Zervreila (6), Adula Nappe

SZA - 1572	725.400	158.825	gneiss
SZA - 1573	725.950	158.550	
SZA - 1574	726.175	158.375	

San Bernardino Pass (7), Adula Nappe

SZA - 4592	734.375	145.225	gneiss

(1) Landeskarten der Schweiz (State maps of Switzerland): Blatt (sheet) 1269 (Aletschgletscher), 1231 (Urseren), 264(Jungfrau), 274 (Visp)
(2) " " " : Blatt 1230 (Guttannen), 1250 (Ulrichen)
(3) " " " : Blatt 1232 (Oberalppass)
(4) " " " : Blatt 1213 (Trun)
(5) " " " : Blatt 1233 (Greina)
(6) " " " : Blatt 1234 (Vals)
(7) " " " : Blatt 1274 (Mesocco)

defined in paper I) by x-ray powder methods and occasionally by additional measurement of $2V_x$. Approximately 250 Guinier diagrams were made and from 132 diagrams lattice parameters were refined to obtain data in order to best define the feldspars (Table 2 of the present paper II and Tables 4, 5 of paper I). For comparison with the results of H. R. WENK (1967) and HISS (1978) (see part I, p. 225) and in order to obtain further information on the history of the alkali feldspars which were heated to the highest metamorphic temperature in this area, additional samples were taken in traverses through the Lepontine Alps (Plate I). These samples were always found to contain high microcline. Minor amounts of low microcline may occur. Their lattice parameters will be published in a following paper of this investigation.

Presumably, the more rapid $\bar{2}04/060$ method of WRIGHT (1968) would be sufficient to determine the K-feldspar discontinuity. As can be seen from Fig. 1 high and low microclines are well separated (compare Fig. 8 of paper I). If only the distinction of high and low microcline is needed even the 060 reflection will

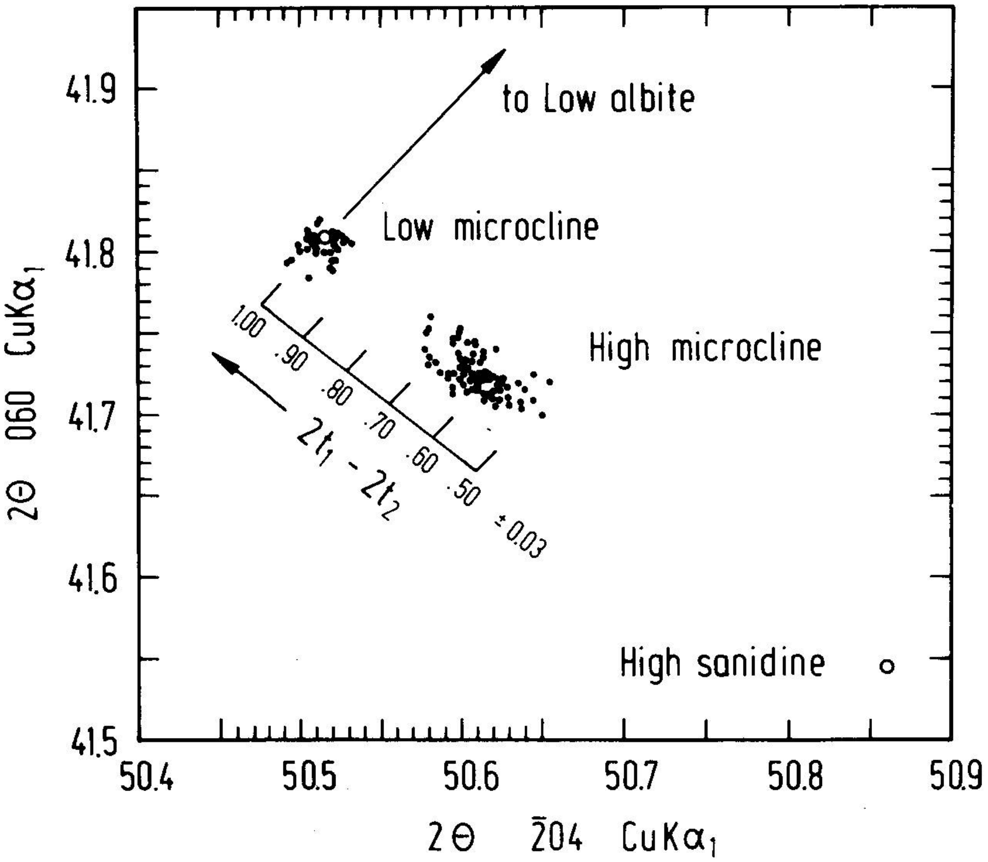

Fig. 1 Plot of 2θ 060 versus 2θ $\bar{2}04$ according to Wright (1968). The circles show reference points for the end-members low microcline and high sanidine. The filled circles are calculated from refined lattice parameters of natural K-feldspars from the Aar Massif and the Gotthard (Table 2, and in paper I: Table 4 and 5). The scaling of the Al,Si distribution ($2t_1$-$2t_2$) is based on values calculated from the same refined lattice parameters by the tr[110] method (Kroll, 1980a).

suffice, since high microclines have 2θ values (Cu $K\alpha_1$) of about 41.7 and low microclines of about 41.8. But the diagram also shows that the 2θ values of crystals with identical Al,Si order (as determined by any other method) may vary considerably - even if measured from sharp lines. This is indicated in Fig. 1 by an error of ± 0.03 for the $(2t_1\text{-}2t_2)$ scale. Here the estimation of Al,Si order is based on only two reflections, while experience shows that at least 30 powder reflections are necessary for a reliable value.

The very sensitive separation of the line pair $131/1\bar{3}1$ often does not allow more than a qualitative characterisation of the structural state, because several diffuse «131» lines may occur or the $1\bar{3}1$ line of oligoclase may fall within the range of the «131» pair of high microcline. The Al,Si distributions given in Table 2 fall within the scatter of Figures 8-10 and 13 of paper I without any exception. The frequency distribution, with a minimum at intermediate degrees of order and the clearly shown transition from sanidine having $2t_1\text{-}2t_2 < \sim 0.5$ to low microcline displaying $t_1o\text{-}t_1m \sim 1$, apparently is characteristic for the whole metamorphic region shown in Plate I. Both findings were discussed in paper I.

The microcline/sanidine isograd

The *K-feldspar discontinuity* is defined by the first occurrence of high microcline. It may show the simple pattern of a discontinuous transition from low microcline to a structurally variable high microcline; however, it may also show a more irregular pattern. For example, the St. Gotthard (Fig. 7 of paper I) and Val Medel traverses (Fig. 2) both show a section of about 2 km width in which high microcline is absent (except minor traces) close to the northern end of the high microcline region. Just two high microcline samples were found at a distance of 8 km in the Zervreila lake traverse, farther to the east. Of course, the details of an irregular pattern depend on sampling statistics (i.e. on the distance between localities and the number of K-feldspars studied within a rock sample) and the availability of K-feldspar. Unfortunately, K-feldspar was replaced by albite in many of the samples of traverses in the western Aar Massif; especially close to the Urseren Zone (Rhône Valley). Also, the rocks common to the Urseren Zone, the Tavetsch Massif, and the southern Aar Massif cropping out along the Val Medel traverse (Fig. 2) barely contain K-feldspar. In these cases, local occurrence of pegmatites was very helpful. In addition, widely differing elevations between adjacent localities may influence the resulting pattern. Thus we cannot definitely exclude the possibility, in all cases, that the irregularities mentioned above, are due to insufficient sampling.

In Plate I the K-feldspar discontinuity points are connected to define the *microcline/sanidine isograd*. The tracing of this transformation isograd turned out to be neither better nor worse than the tracing of mineral zones or reaction

Table 2 Lattice parameters, chemical composition, and Al, Si distribution of K-feldspar from perthites as listed in Table 1. Though the refinement of lattice parameters resulted in calculated errors of 0.001 Å or 0.01° (often less), it is more realistic to assume errors of ± 0.002 Å and ± 0.02°.

sample No.	a	b	c	α	β	γ	Volume	Ab	Al occupancy			Lines
	[Å]	[Å]	[Å]	[°]	[°]	[°]	[Å^3]	[mol%]	t_1o	t_1m	$2t_2$	No.
Traverses of the Western Aar Massif												
SZA - 1	8.5741	12.9624	7.2215	90.636	115.932	87.623	721.15	5.2	1.00	0.00	0.00	40
SZA - 15	8.5838	12.9678	7.2256	90.675	115.961	87.665	722.53	1.2	0.99	0.00	0.00	43
SZA - 17	8.5792	12.9605	7.2229	90.626	115.951	87.699	721.54	4.1	0.99	0.01	0.00	41
SZA - 22	8.5722	12.9631	7.2222	90.634	115.942	87.707	721.08	5.4	0.98	0.01	0.01	44
SZA - 31	8.5742	12.9677	7.2218	90.634	115.945	87.722	721.46	4.3	0.97	0.00	0.03	44
Aare Valley and Grimsel Pass, Aar Massif												
SZA - 136/1	8.5805	12.9633	7.2233	90.637	115.957	87.646	721.78	3.4	1.00	0.00	0.00	50
SZA - 136/2	8.5631	12.9732	7.2079	90.225	116.009	89.302	719.58	9.6	0.57	0.27	0.17	43
SZA - 44	8.5802	12.9637	7.2236	90.646	115.942	87.657	721.90	3.0	1.00	0.00	0.00	36
SZA - 36 (1)	8.5810	12.9787	7.2062	90.071	116.020	89.837	721.21	5.1	0.43	0.36	0.20	25
SZA - 36 (2)	8.5829	12.9647	7.2201	90.660	115.946	87.637	721.80	3.3	0.99	0.00	0.01	23
SZA - 45 (1)	8.5820	12.9805	7.2077	90.020	116.002	89.894	721.65	3.8	0.43	0.38	0.19	32
SZA - 45 (2)	8.5769	12.9677	7.2215	90.656	115.955	87.671	721.57	4.0	0.98	0.00	0.02	31
SZA - 47	8.5794	12.9694	7.2218	90.681	115.962	87.652	721.85	3.2	0.98	0.00	0.02	30
SZA - 97	8.5821	12.9821	7.2052	90.000	116.029	90.000	721.34	4.7	0.30	0.39	0.22	28
St. Gotthard compare Table 2 and 4, paper I												
Val Maighels and Val Val												
SZA - 109	8.5770	12.9662	7.2219	90.658	115.933	87.639	721.65	3.3	0.99	0.00	0.01	61
SZA - 104	8.5798	12.9769	7.2087	90.000	116.032	90.000	721.19	5.1	0.40	0.40	0.19	26
SZA - 101B	8.5764	12.9763	7.2109	90.101	116.019	89.604	721.15	5.2	0.50	0.33	0.17	35
SZA - 101A	8.5816	12.9774	7.2049	90.064	116.010	89.772	721.11	5.3	0.45	0.35	0.20	34
SZA - 98	8.5736	12.9820	7.2076	90.002	116.013	89.815	720.95	5.8	0.44	0.36	0.20	40

Table 2 continued

Val Nalps, Gotthard												
SZA - 118 (2)	8.5812	12.9817	7.2071	90.028	116.025	89.864	721.45	4.4	0.43	0.37	0.21	34
SZA - 115	8.5782	12.9802	7.2057	90.000	116.018	90.000	721.02	5.6	0.39	0.39	0.21	35
SZA - 1884	8.5797	12.9818	7.2050	90.000	116.024	90.000	721.13	5.3	0.39	0.39	0.22	34
SZA - 114 (1)	8.5777	12.9661	7.2218	90.655	115.952	87.638	721.58	4.0	0.99	0.00	0.01	45
SZA - 113	8.5729	12.9781	7.2074	90.000	116.026	90.000	720.58	6.9	0.40	0.40	0.20	32
SZA - 111	8.5802	12.9787	7.2036	90.033	116.004	89.887	720.98	5.7	0.42	0.37	0.21	36
SZA - 110	8.5826	12.9789	7.2075	90.000	116.021	90.000	721.48	4.3	0.40	0.40	0.20	26
Val Medel, Tavetsch Massif												
SZA - 1225	8.5772	12.9639	7.2215	90.669	115.931	67.641	721.51	4.2	1.00	0.00	0.00	71
compare also Table 3 and 5, paper I.												
Val Cristallina, Gotthard												
SZA - 130	8.5808	12.9664	7.2226	90.636	115.957	87.653	721.91	3.0	0.99	0.00	0.01	46
SZA - 129	8.5802	12.9658	7.2237	90.655	115.940	87.634	722.03	2.7	1.00	0.00	0.00	40
SZA - 128	8.5774	12.9643	7.2232	90.674	115.949	87.634	721.61	3.9	1.00	0.00	0.00	53
SZA - 127	8.5790	12.9630	7.2213	90.650	115.940	87.634	721.53	4.1	1.00	0.00	0.00	53
SZA - 125	8.5811	12.9856	7.2069	90.000	116.089	90.000	721.25	5.0	0.38	0.38	0.24	16
SZA - 124	8.5785	12.9631	7.2208	90.635	115.933	87.640	721.49	4.2	1.00	0.00	0.00	38
SZA - 123 (1)	8.5789	12.9653	7.2230	90.658	115.946	87.649	721.80	3.4	0.99	0.00	0.01	44
Lake Zervreila, Adula Nappe												
SZA - 1572	8.5718	12.9638	7.2218	90.658	115.932	87.643	721.08	5.4	1.00	0.00	0.00	74
SZA - 1573	8.5702	12.9633	7.2223	90.662	115.927	87.630	720.99	5.7	1.00	0.00	0.00	104
SZA - 1574	8.5711	12.9647	7.2227	90.674	115.934	87.629	721.14	5.3	1.00	0.00	0.00	105
San Bernardino Pass, Adula Nappe												
SZA - 4592	8.5668	12.9642	7.2206	90.675	115.932	87.657	720.57	6.9	0.99	0.00	0.01	67

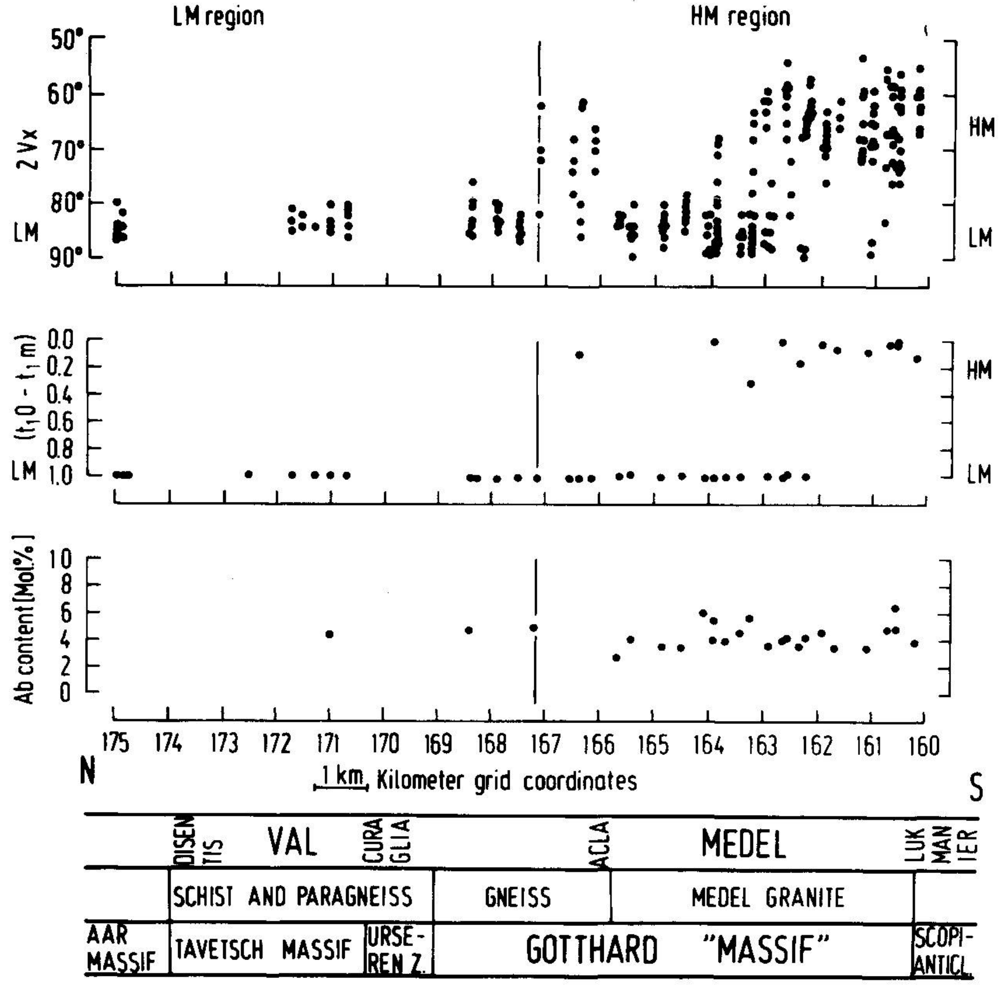

Fig. 2 Plot of optic axial angle $2V_x$, degree of Al,Si order (t_1o-t_1m), and composition as mol% Ab of the K-feldspar of perthites along the Val Medel traverse (data from Table 3 and 5 in paper I). HM = high microcline, LM = low microcline.

isograds in the Central Alps. As compared to the previous description by Bernotat & Bambauer (1980), the isograd shown in Plate I is slightly shifted to the north, and, in addition, its extension farther to the east was determined. The shifts are a result of denser sampling. But even now, some uncertainty in the exact location of the isograd remains, because of local incompleteness of data. Smooth tracing of the isograd is difficult in the area between the St. Gotthard and Val Medel traverses, because the discontinuity appears to be located too far to the south in the Val Maighels/Val Val traverse. Generally, we observe that the discontinuity is less well developed east of the Gotthard pass than west of it. This observation has to be confirmed by further sampling. It seems to us that the more frequent the sampling - the more boundary irregularities were found.

Besides statistical questions, the exact trace of a microcline/sanidine isograd depends on the distinctness of the K-feldspar discontinuity in a given traverse. This again depends essentially on the metamorphic conditions and especially on the dip of the isothermal surface T_{diff} during the climax of metamorphism and the following retrograde phase. Also, the structural state of the pre-metamorphic K-feldspar may contribute to the distinctness of the discontinuity. Probably, the local conditions of metamorphism, modified by the local composition, fabric permeability, and heat conductions of rocks (H. R. WENK & E. WENK, 1969) resulted in boundary irregularities in the isothermals surface T_{diff}. Also, it seems unlikely that only *one* of the «catalytic» factors, which are thought to activate the transformation to low microcline, may serve as the *common* explanation of irregularities in the local discontiuuities and the isograd. A hypothetical explanation, not mentioned before, might be the superposition of perhaps two metamorphic phases in close succession. More detailed information is needed to investigate this suggestion, and up to now there is no support by other investigations. The planned extension of this regional study and the further sampling might yield more detailed information; thereby slight local shifts of the isograd to the north may be expected.

Plate I shows that the microcline/sanidine isograd fits well into the general pattern of metamorphic zonation. It is found at a nearly constant distance between the stilpnomelane-out and staurolite-in boundaries, and also nearly parallel to the tremolite-dolomite-calcite isograd (EVANS & TROMMSDORFF, 1970). Also, the microcline/sanidine isograd is always found north of the oligoclase boundary (E. WENK, 1962, E. WENK & KELLER, 1969), corresponding to somewhat lower metamorphic temperatures.

The question as to whether the structural state and the domain texture of the K-feldspar in the high microcline region, especially in the southern Lepontine area, may yield additional information on the metamorphism, cannot definitely be answered. As expected, the lattice parameters show a structural variable high microcline. This agrees with the studies of H. R. WENK (1967) and HISS (1978) on the regional distribution of the triclinicity $\triangle$ (GOLDSMITH & LAVES, 1954) of K-feldspars mainly from gneisses. HISS found $\triangle$-values between zero and nearly 1 with a frequency minimum at intermediate values. The reader should compare the corresponding histograms (Figures 11, 13, and 14) of paper I. VISWANATHAN (1968) obtained similar results on K-feldspars from pegmatites found in the southern Lepontine area: $\triangle = 0.16$–0.92 and $2V_x =$ 59–84.5°. Using the methods described in paper I, VISWANATHAN was the first one to show that the broad scatter of the resulting data may occur in different samples as well as within the same K-feldspar pseudomorph. This was confirmed by HAFNER & LOIDA (1980) in a study of the K-feldspars from the Rotondo granite. HISS (1978), who obtained corresponding results, cannot see any indication for a characteristic regional arrangement of structural states in the Lepontine Alps. This does not quite agree with her attempt to derive temperatures of formation from Al,Si distributions (see comments in paper I). However, the maps given by WENK and HISS show conspicuous local abundances of

K-feldspars which were found to be monoclinic by x-ray powder methods, especially in the Maggia and Verzasca region and in the Bergell. The resulting property of being «x-ray monoclinic» is ambiguous. It only means that the domain size of the orthoclase[3] studied is beyond the resolution limit, and it is known that the structural state of such K-feldspars may vary considerably. Therefore, as pointed out in paper I, the distinction between x-ray monoclinic/triclinic is in no way a suitable criterion for determining the microcline/sanidine isograd. In this case, we agree with the doubts on the petrogenetic significance of this distinction, as expressed by SMITH (1974, I, p. 436). On the other hand, it is obvious that x-ray monoclinic K-feldspars are rather abundant in the high microcline region, as was shown earlier by WENK et al. (1966) and VISWANATHAN (1968).

For a long time, the occurrence of orthoclases instead of distinctly cross hatched microclines has been considered as an indicator of a relatively high metamorphic grade, especially for the «dry» conditions of granulite facies. For instance, x-ray monoclinic orthoclases frequently occur in the regional metamorphic Moine series of the Scottish Highlands. During the Caledonian metamorphism the K-feldspars were cooled from conditions of amphibolite facies, i.e. from far above T_{diff}, several times slower than in the Lepontine area during Alpine metamorphism. As KROLL (1980b) has shown, x-ray monoclinic orthoclase was found in the whole area, and in addition, the amount of low microcline increased with decreasing metamorphic grade along a regional gradient ranging between 680–530 °C. Intermediate states were not found. It seems to be plausible that those K-feldspars which were heated to the highest temperatures above T_{diff} tend to form most easily those particular fine-scaled mimetic domain textures which usually cannot be resolved by powder methods. A reason for this may be the memory effect mentioned in paper I (p. 221). Apparently, the cooling rate alone is not the most important retaining factor. It must be assumed that «catalytic» factors, i.e. local stress and partial H_2O pressure, have often modified the local appearance of orthoclase by activating domain growth. However, it might be interesting to follow this question by improved sampling statistics in the Lepontine Alps.

There is one exception in the general pattern of structural states shown in Plate I. High microcline was found again north of the stilpnomelane-out boundary in the Grimsel pass traverse. It is assumed to be a pre-Alpine relic, the structural state of which possibly remained unchanged since Hercynian times. The occurrence of pre-Alpine structural states in the lower greenschist facies was discussed in paper I and will be studied in a following investigation.

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[3] Definition in Table 1 of part I.

Summary: The microcline/sanidine transformation isograd indicates a ~450 °C isotherm at the climax of the Lepontine metamorphism in the Central Swiss Alps. This statement is valid only for the narrow zone of the isograd. It may be difficult to determine the grade of metamorphic overprinting and to determine a metamorphic zonation in granite and gneiss complexes. The microcline/sanidine isograd offers a new way to recognize the greenschist facies in such rocks and to subdivide the greenschist facies in its higher grade range.

Acknowledgement

We thank PD Dr. A. B. Binder and Prof. M. Frey (Basel) for helpful comments. The technical assistance of Mrs. I. Schmiemann and Ms. G. v. Cölln in data collecting and preparation of tables and drawings is gratefully acknowledged. We are indebted to S. Löw, Basel, for providing samples from the Piz d'Arbeola area. Financial support by the Deutsche Forschungsgemeinschaft is gratefully appreciated.

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Manuscript received 16 June 1982.