Origin and variation of the microcline triclinicity in granitic bodies of the Central Alps

Autor(en): **Hafner, Stefan S. / Loida, Andreas**

Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **73 (1980)**

Heft 2: **Symposium alpine geotraverses with special emphasis on the Basel-Chiasso profile : Lausanne, 4-5 October 1979**

PDF erstellt am: **21.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-164975

Nutzungsbedingungen

Die ETH-Bibliothek ist Anbieterin der digitalisierten Zeitschriften. Sie besitzt keine Urheberrechte an den Inhalten der Zeitschriften. Die Rechte liegen in der Regel bei den Herausgebern.
Die auf der Plattform e-periodica veröffentlichten Dokumente stehen für nicht-kommerzielle Zwecke in Lehre und Forschung sowie für die private Nutzung frei zur Verfügung. Einzelne Dateien oder Ausdrucke aus diesem Angebot können zusammen mit diesen Nutzungsbedingungen und den korrekten Herkunftsbezeichnungen weitergegeben werden.
Das Veröffentlichen von Bildern in Print- und Online-Publikationen ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Die systematische Speicherung von Teilen des elektronischen Angebots auf anderen Servern bedarf ebenfalls des schriftlichen Einverständnisses der Rechteinhaber.

Haftungsausschluss

Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.

Ein Dienst der *ETH-Bibliothek*
ETH Zürich, Rämistrasse 101, 8092 Zürich, Schweiz, www.library.ethz.ch

http://www.e-periodica.ch

Eclogae geol. Helv.	Vol. 73/2	Pages 563-570	4 figures in the text	Basle, July 1980

Origin and variation of the microcline triclinicity in granitic bodies of the Central Alps

By STEFAN S. HAFNER¹) and ANDREAS LOIDA²)

ABSTRACT

Microclines from the Rotondo granite often have an "adularia" type of structure with lattice varying between apparently monoclinic and maximum triclinic. Crystal fragments of 0.1-0.3 mm size usually have homogeneous, well-defined lattices. The twinning relationships of Rotondo microcline are generally not strain-free, but semiquantitative determination of the degree of Al, Si ordering can be made from lattice relationships without inconsistency; sodium exsolution always corresponds to lowest temperatures, independent of the degree of ordering.

No systematic small-scale trend could be detected in profiles through the granite. The "adularia" type of structure is probably due to kinetic factors. It represents a transformation without nucleation in a highly specific cooling process.

ZUSAMMENFASSUNG

Mikrokline aus dem Rotondogranit haben oft eine adularartige Struktur, mit einem Gitter, das zwischen scheinbar monoklin und maximal triklin schwanken kann. 0,1-0,3 mm grosse Kristall-Bruchstücke haben aber in der Regel einheitliche, gut definierte Gitter. Die Verzwillingungsbeziehungen in Rotondo-Mikroklinen sind im allgemeinen nicht deformationsfrei. Immerhin ist es möglich, den mittleren Al/Si-Ordnungsgrad ohne Widerspruch aus den Gitterkonstanten zu bestimmen. Die Albit-Entmischung entspricht immer dem Gleichgewicht bei tiefster Temperatur, und zwar unabhängig vom beobachteten Ordnungsgrad.

In den Profilen durch den Granit konnte kein systematischer Trend der Triklinität im Kleinbereich festgestellt werden. Die adularartige Struktur des Mikroklins ist vermutlich die Folge von kinetischen Faktoren. Sie ergibt sich aus einer Umwandlung ohne Nukleation im Verlauf des alpidischen Abkühlungsprozesses unter bestimmten Bedingungen.

Introduction

Microcline is an important rock-forming mineral in granitic gneisses of the central massifs of Aare and Gotthard. Particularly the originally granitic bodies of hercynic age, i.e. Rotondo granite, Tremola-Prosa granite (a variety of Rotondo granite), Fibbia gneiss, Gamsboden gneiss, Central Aare granite, etc. include large

---

¹) University of Marburg, Department of Geosciences, Lahnberge, 3550 Marburg, Federal Republic of Germany.

²) Present address: Institute of Mineralogy, Ruhr-Universität, Universitätsstrasse 150, 4630 Bochum, Federal Republic of Germany.

microcline crystals. It is well-known that microcline may occur in these bodies in highly metastable states. The mineral may be either apparently monoclinic, or maximum triclinic, or in intermediate states between monoclinic and maximum triclinic. In thin sections, microcline generally appears as perthite with more or less substantial exsolution of albite.

In the past decade, two tunnel constructions have permitted collection of unweathered specimens along geographically continuous, fairly straight profiles. The direction of the Gotthard highway tunnel (total length 16.3 km) from Airolo (south end) to Göschenen (north end) is fairly perpendicular to the general axis of the two massifs. The profile cuts from south to north Tremola-Prosa granite (1.0 km), Gamsboden gneiss (4.2 km) and Central Aare granite (3.2 km). The new Furka-Oberalp-Bahn railway tunnel (total length 15.4 km) from Oberwald (southwest end) to Realp (northeast end) is approximately parallel to the axis of the massifs. Its auxiliary tunnel in the southeast direction towards Ronco, Bedretto, the "Bedretto window" (total length 5.2 km), however, is nearly perpendicular to that axis. It is located over 4.1 km in the Rotondo granite. The general location of these profiles is shown in Figure 1.

The profiles of the Gotthard highway tunnel and of the "Bedretto window" provide an opportunity to study possible variations in the intensity of alpidic metamorphosis by continual scanning from extensive high-temperature recrystal-

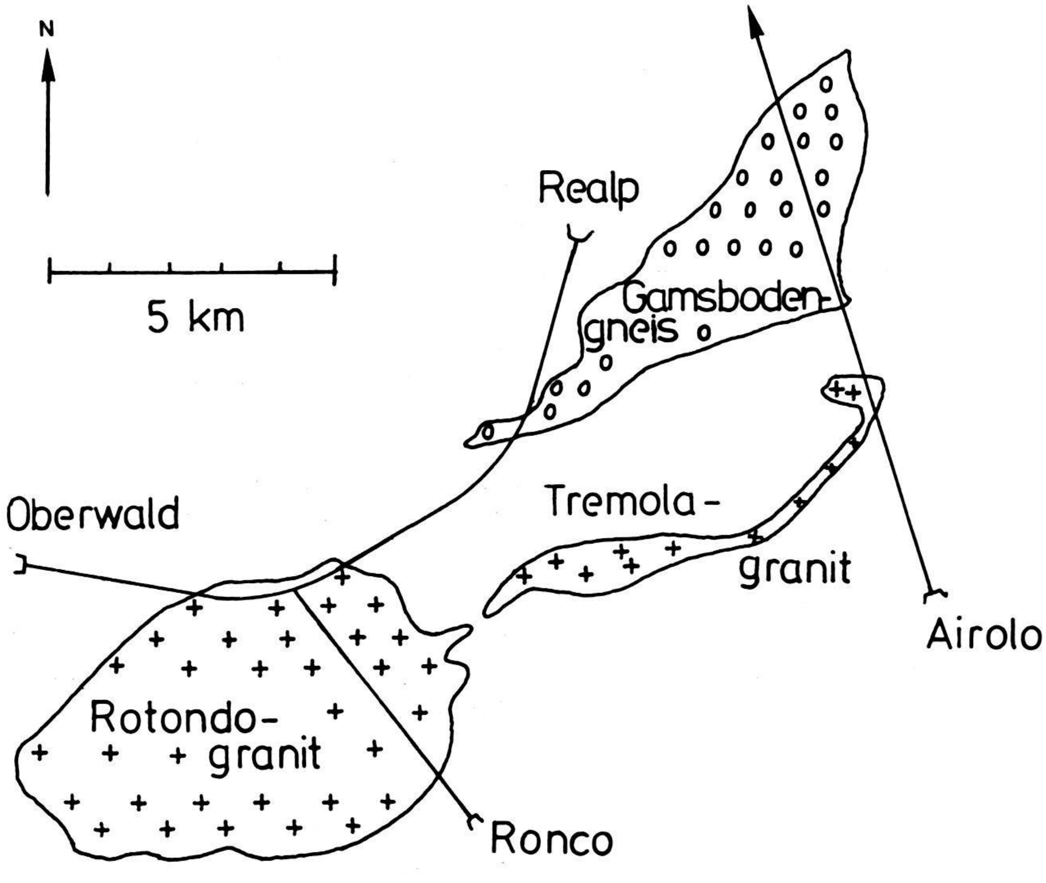

Fig. 1. New highway and railway tunnels through granitic bodies in the Gotthard massif.

lization in the south to partial recrystallization and/or predominantly mechanic destruction of the fabric at lower temperatures in the north. The aim of this study was to investigate possible trends in the triclinicity of microcline from south to north. Moreover, it was intended to study the nature of the "diffused" triclinicity with smeared intensities between the $130-1\bar{3}0$ and $131-1\bar{3}1$ reflections in Guinier powder patterns.

Experimental

Microcline crystals were studied with an X-ray diffraction camera of the precession type using Mo *Ka* radiation and a Zr filter. For this, some crystals of 0.3 mm size were cut from thin sections. Powdered crystals were also studied with a Guinier-Hägg-type camera using Cr$K\alpha_1$ radiation. Refined lattice parameters were determined on the basis of the least-squares principle from 20 to 34 reflections which were carefully indexed. Sodium contents of coexisting albite crystals as well as albite exsolution lamellae in microcline were determined with the electron microprobe of the Max-Planck-Institut für Kernphysik, Heidelberg.

Holger Ried from the Universität Frankfurt (Main) kindly studied microcline crystals from two samples of Rotondo granite using transmission electron microscopy and electron diffraction.

Results

One of the surprizing observations was the fact that the lattice constants of microclines from the granitic bodies, as determined by the X-ray precession technique, may vary significantly on a very small scale. Crystals from a 10 cm size rock fragment may exhibit lattice parameters between apparently monoclinic and nearly maximum triclinic. Small fragments from one phenocryst may have different parameters. Thus, different microcline crystals e.g. from 10 cm size rock fragments, or even phenocrysts, generally do not possess a homogeneous, well-defined "triclinicity" of the lattice. Nevertheless, small crystal fragments with diameters of 0.1-0.3 mm as commonly used for precession photographs usually showed sharp, well-defined reflections which permitted a precise determination of the reciprocal lattice constants.

Rotondo granite: Lattice constants of crystal fragments from the Bedretto window profile exhibited variations from nearly monoclinic to nearly maximum triclinic. In the α^*, γ^* plot according to MACKENZIE & SMITH (1955), Rotondo granite data cover the entire range between maximum microcline and sanidine. While 0.1-0.3 size crystal fragments show precise α^* and γ^* values there may be large scattering among crystals from one rock fragment. No systematic small-scale trend could be detected along the profile. Phenocrysts from the Oberwald-Realp tunnel, i.e. from the northern part of the granite body appear to be *more* triclinic at the *rim* and *less* triclinic in the *core.*

Under the polarization microscope, the crystals showed highly inhomogeneous extinction optics. Some parts of a crystal may display crosshatched twinning with rather small single crystal domains, which corresponds to *M*-type twinning in precession photographs (cf. SMITH 1974). Other parts may appear to be quasi-homogeneous or show undulatory extinction. Fairly sharp triclinic cross-hatching seems to be more frequent in the southern part of the granitic body. A typical pattern of cross-hatching is shown in Figure 2.

Tremola and Gamsboden granite: Microclines are between nearly or apparently monoclinic and intermediate (cf. also BAMBAUER & BERNOTAT 1980). They show much less variation in the lattice constants than crystals from the Rotondo granite. Typical values for the angles α^* and γ^* are $90.00 < \alpha^* < 90.20$ and $90.00 < \gamma^* < 90.67$ degrees, respectively. Optically, the crystals often appear quite homogeneous. Cross-hatching is rather rare (cf. Fig. 3).

Central Aare granite (northern part): Microclines were found to be maximum triclinic over the entire profile (cf. also BAMBAUER & BERNOTAT 1980). Under the polarization microscope, they exhibit typically crosshatched twinning with rather large sized single crystal domains.

Correlated single crystal precession photographs and Guinier powder patterns: Diffraction patterns from powdered crystals which were studied first with the precession technique permitted an unambiguous interpretation of the smeared $130-1\bar{3}0$ and $131-1\bar{3}1$ splittings. The diffused region results from microcline phenocrysts with inhomogeneous "triclinicity", i.e. from powdered crystal fragments with different lattice parameters. Guinier patterns from crystal fragments with sharp,

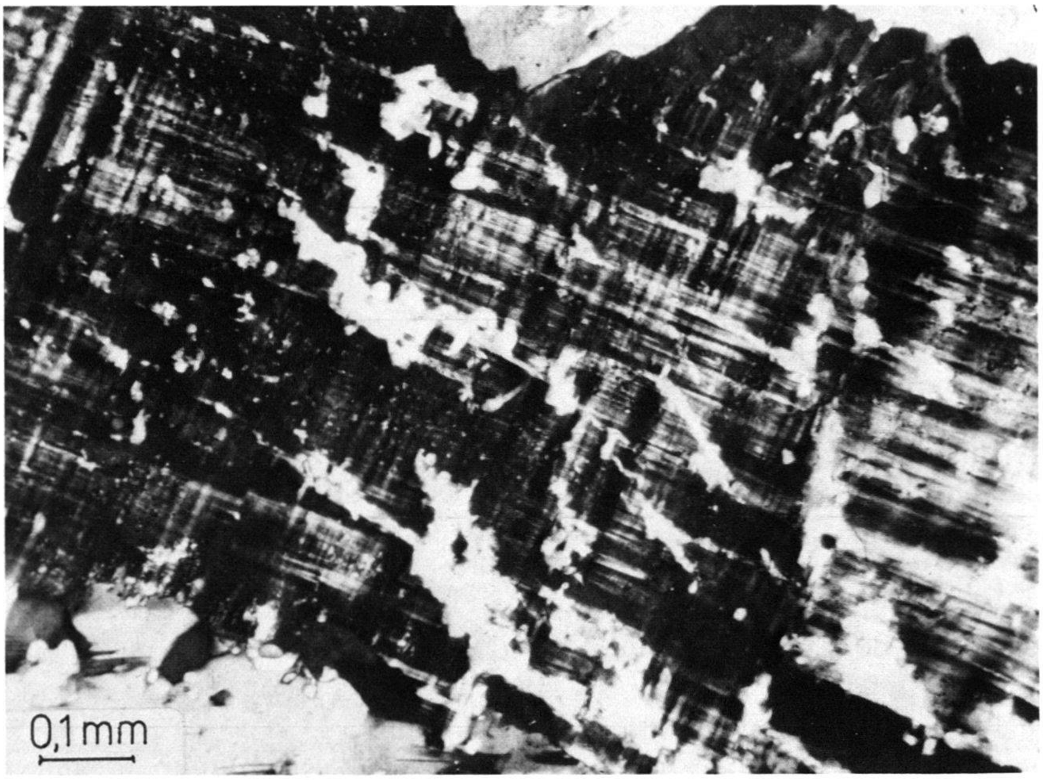

Fig. 2. Fairly sharp crosshatched twinning of microcline in Rotondo granite, Bedretto window, 1200 m from the Ronco tunnel entrance (sample R-1200).

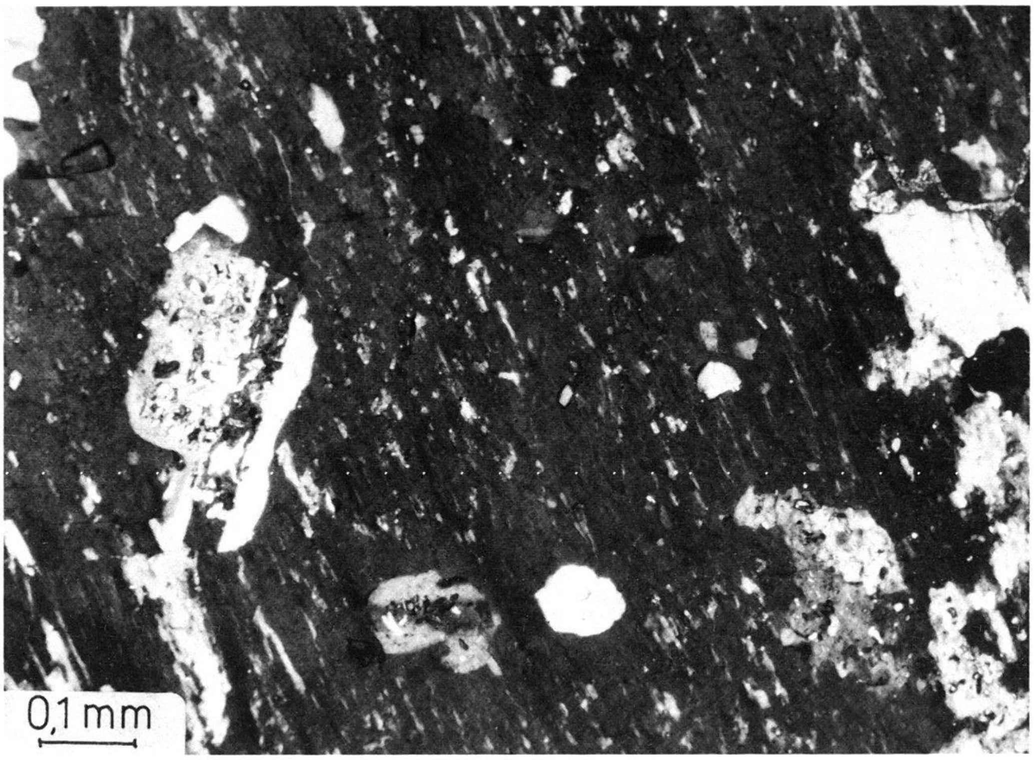

Fig. 3. Apparently monoclinic potassium feldspar from Gamsboden gneiss, 6292 m from the Airolo entrance (sample S-6292). No crosshatched twinning and fairly small albite exsolution lamellae (cf. also Fig. 4).

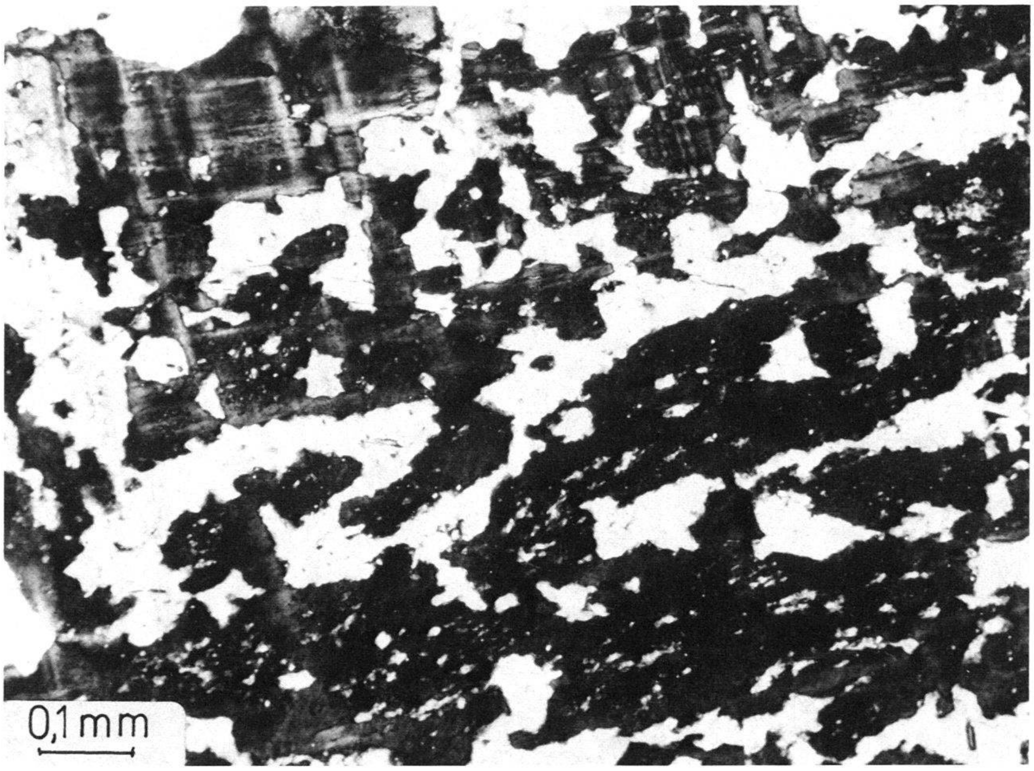

Fig. 4. Perthitic exsolution in a microcline crystal from Rotondo granite, 5031 m from the Oberwald entrance (sample O-5031). Exsolved albite occurs in large, clearly incoherent domains. A small part of the crystal (upper left) shows crosshatched twinning.

uniform reflections in *hk0* and *0kl* precession photographs yield sharp 130-$1\bar{3}0$ and 131-$1\bar{3}1$ reflection pairs.

Coherency relationships: It is well-known that cryptoperthites e.g. from volcanic rocks may possess coherent exsolution lamellae which cannot be resolved optically. In such cases the lattices of host and exsolved phase show substantial distortion due to strain (YUND 1975; YUND & DAVIDSON 1978). Moreover, the microcline host lattice may be distorted by coherency effects connected with small-domain *M*-type twinning. Maximum microclines from the Central Aare granite with optically coarse cross-hatching are expected to be strain-free with no coherency effects. In the potassium feldspars from the granitic bodies of the Gotthard massif, the problem is more involved. Here, parts of crystals often show apparently homogeneous optics, and the presence of some coherency effects which may distort the lattice are not unlikely.

Holger Ried from the University Frankfurt (Main) carried out a transmission electron microscope and electron diffraction study of microclines from two samples, R-2887 and O-5031, of Rotondo granite. Sample R-2887 was from the Bedretto window 2887 m from the Ronco entrance. Sample O-5031 was from the Furka railway tunnel 5031 m from the Oberwald entrance. No coherency was found between microcline host and exsolved albite. Diffuse, modulated planes were generally observed, however, due to pericline or albite twinning.

Discussion

In principle, the observed steady states of varying triclinicities of microcline may result from five interrelated phenomena: a) partial coherency between host and perthitic exsolution lamellae, b) partial coherency among twinned microcline domains, c) degree of Al, Si order-disorder among the four nonequivalent tetrahedral positions in the crystal structure of microcline, d) amount of Na substituted for K in the crystal structure of microcline, and e) varying kinetic parameters responsible for the intracrystalline Al, Si exchange reaction which may depend on chemical impurities, e.g. OH, in the crystal structure; they may also be related to external mechanical strain. Each of the five phenomena may be partially responsible for the observed small-scale variation in the lattice constants of microcline. They are, of course, *not* independent of each other.

The first factor, varying coherency between host and exsolved albite lamellae, seems to be completely absent. There are no optically unresolved, cryptoperthitic areas of albite exsolution in microcline crystals.

About the second factor, coherency due to twinning, some conclusions can be drawn from lattice relationships as described by STEWART & WRIGHT (1974) and KROLL (1980). Evaluation of Guinier patterns using the diagrams of KROLL (1980) showed that the lattice constants a are *undistorted* within an experimental error of <0.006 Å. The amount of Na substituted for K in the microcline host may be determined either from the lattice volume or from *a*. Both determinations yielded the same result which corresponds to equilibrium conditions of complete exsolution at low temperatures: 2-6 atomic percent Na. Thus, the intrinsic distribution of Al, Si over the tetrahedral positions in the crystal structure of microcline can indeed be determined from the repeat distances in the $[1\bar{1}0]$ and $[110]$ directions by use of the diagrams of KROLL (1980). These distances are *insensitive* to small amounts of coherency. No significant inconsistency in the lattice relationships of microclines from the Rotondo granite could be detected.

Thus, the lattice constants of microclines from the Gotthard massif determined from Guinier powder patterns seem to permit, at least in principle, a direct derivation of the intrinsic degree of Al, Si ordering in the crystal structures (factor *c*), as well as the amount of Na substitution (factor *d*). Microclines from *Rotondo granite* exhibit varying degrees of partial Al, Si disorder between almost completely ordered and almost completely disordered states. The observed variation of Al, Si order-disorder in phenocrysts represents an "adularia type" of crystal structure. However, albite exsolution is always complete, corresponding to the low albite-maximum microcline solvus at lowest temperatures. This is also observed in crystals with a high degree of Al, Si disorder. Complete exsolution coexisting with a high degree of Al, Si disorder probably presents a highly metastable system. It hints at a particular alpidic cooling history as a secondary process subsequent to reheating after the original, granitic cooling.

The small-scale scatter of Al, Si order-disorder and the absence of systematic trends along profiles show that there is no direct relationship to temperature. *Kinetic factors (e)* during cooling in the subsolidus range of temperatures, below the equilibrium monoclinic to triclinic lattice transition, seem to play a deciding role. Details about these factors are not yet known.

Microclines from *Gamsboden* gneiss are apparently more disordered. Crystal fragments with a high triclinicity were not found. Microclines from *Tremola* granite are, on average, more ordered than from Gamsboden but less than from Rotondo. Albitic exsolution is complete in both granitic bodies; 3-7 atomic percent Na in microcline is substituted for K.

In summary, it is concluded that for this geological area, a combined study of precession photographs (determination of α^*, γ^*) and Guinier patterns (refined avarage lattice constants) permits a semiquantitative estimate of the Na component in the microcline lattice as well as the degree of Al, Si order-disorder. However, the latter is *not* related to the temperature-time relationship alone. It is apparently connected to a transformation without nucleation in a secondary cooling process. Originally, the Rotondo microclines were probably completely ordered. A subsequent, alpidic reheating process may just about have reached temperatures of the triclinic to monoclinic phase transition. The highly metastable steady states now observed reflect the kinetics of the cooling process after reheating. Factors which govern the Al, Si ordering kinetics in the cooling process are not yet known in detail.

It will be interesting to compare the detailed lattice characteristics of the Rotondo Microclines with samples from a geographically wider area (cf. BAMBAUER & BERNOTAT 1980). A description and interpretation of average triclinities of potassium feldspar (powder data) from the Lepontin were presented by WENK (1967). However, in order to derive significant differences in comparison with microclines from the Gotthard massif detailed small-scale crystal data would be needed.

Acknowledgment

We thank Professor M. Korekawa and H. Ried, Frankfurt (Main), for transmission electron microscopy. Professor A. El Goresy, Heidelberg, for electron microprobe analyses. Drs. J.D.C. McConnell, Cambridge, and H. Kroll, Münster, for valuable discussions.

REFERENCES

BAMBAUER, H.U., & BERNOTAT, W.H. (1980): *Microcline-sanidine transformation isograde in metamorphic regions.* - Schweiz. mineral. petrogr. Mitt. (in preparation).

KROLL, H. (1980): *Estimation of the Al, Si distribution of alkali feldspars from lattice translations tr [1$\bar{1}$0] and tr [110], revised.* - N. Jb. Mineral. [Mh.] *1*, 31-36.

LOIDA, A. (1979): *Die Kristallchemie von Granat und die Triklinität der Alkalifeldspäte als petrogenetische Indikatoren in Verbindung mit der Kristallisationsgeschichte granitischer Gesteine des Gotthardmassivs/Schweiz.* - Diss. Univ. Marburg.

MACKENZIE, W.S., & SMITH, J.Y. (1955): *The Alkali Feldspars: I Orthoclase-microperthites.* - Amer. Mineralogist *40*, 707-732.

SMITH, J.V. (1974): *Feldspar minerals* (Vol. 1). - Springer Berlin, Heidelberg, New York.

STEWART, D.B., & WRIGHT, T.L. (1974): *Al/Si order and symmetry of natural alkali feldspars, and the relationship of strained cell parameters to bulk composition.* - Bull. Soc. franç. Minéral. (Cristallogr.) *97*, 356-377.

WENK, H.R. (1967): *Triklinität der Alkalifeldspäte in lepontischen Gneissen.* - Schweiz. mineral. petrogr. Mitt. *47*/1, 129-146.

YUND, R.A. (1975): *Subsolidus phase relations in the alkali feldspars with emphasis on coherent phases. Microstructure, kinetics, and mechanisms of alkali feldspar exsolution.* In: RIBBE, P.H. (Ed.): *Feldspar Mineralogy.* - Mineral. Soc. Amer. Short Course Notes *2*.

YUND, R.A., & DAVIDSON, P. (1978): *Kinetics of lamellar coarsening in cryptoperthites.* - Amer. Mineralogist *63*, 470-477.