Recrystallization of quartz, biotite and feldspars from Erstfeld to the Leventina nappe, Swiss Alps, and its geological significance

Autor(en): **Voll, Gerhard**

Objekttyp: **Article**

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

Band (Jahr): **56 (1976)**

Heft 3

PDF erstellt am: **21.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-43709

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

Schweiz. mineral. petrogr. Mitt. 56, 641–647, 1976

Recrystallization of Quartz, Biotite and Feldspars from Erstfeld to the Leventina Nappe, Swiss Alps, and its Geological Significance

By *Gerhard Voll**)

Abstract

This paper contains results of a study concerning recrystallization, polygonisation and strain induced boundary migration in response to deformation of quartz, biotite and feldspars. Details, including diagrams and pictures are published elsewhere.

Alpine rocks from this cross section are mainly variscan granites and gneisses, worked into the Alps. They all contain quartz, biotite and feldspars formed at variscan times. Cover sediments, pinched between Aar- and Gotthard-massif as Urseren-syncline contained clastic quartz and feldspars. All these crystals were deformed during the alpine orogeny and heated at the same time or afterwards to maximum temperatures reaching 250°C in the N, c. 580°C at Airolo (S-margin of Gotthard massif) and more than 600°C in the Leventina nappe.

DEFORMATION

Basement rocks, rising to the S below the cover of helvetic nappes and parautochthonous sediments nr. Erstfeld are – at the N-end of the profile – very little deformed. Microscopic study is necessary to display plastic deformation of quartz, bending and kinking of micas (together with strong alternation of biotite to chlorite, K-feldspar, prehnite), bending and fracturing of feldspars. From N of Amsteg increasing alpine deformation and penetrative movement may be seen even megascopically. Alpine cleavage planes are covered by silky surfaces, produced by fine newly formed micas, carrying the alpine stretching fibre str_1. Across Aar- and Gotthard-massifs these s_1-planes form a fan, dipping S with average angles in the N, steeply N at the S-margin

*) Mineralogisch-Petrologisches Institut, Universität Bonn, Poppelsdorfer Schloss, D-5300 Bonn.

of the Gotthard massif. Especially within the granites this deformation is often homogeneous, but inhomogeneous as a whole. Near Amsteg the s_1-planes resemble fractures extended by friction, with less deformed lenses and slabs inbetween. There tension joints are found. Towards the S these shearplanes quickly become broader and more penetrative, deformation in slabs inbetween becomes stronger. Deformation becomes more and more homogeneous towards the S, but to the S end of the Gotthard massif narrow zones persist in which deformation is either much stronger or less than in surrounding rocks. Str_1 – fanning along Aar- and Gotthard massifs along the strike towards SW-plunge in the E and NE plunge in the W is steep everywhere in this cross section, indicating upward extension corresponding to narrowing to c. $1/3$ of the original width in the basement profile. This deformation seems to be achieved within 1 act. In gneisses at the S-margin of the Aar-, at N- and S-margin of the Gotthard-massif and within cover sediments of the Urseren syncline and S of the Gotthard massif, however, refolding is found, first round str_1 and then round axes subnormal to str_1. These zones are more deformed, narrowed to c. $1/15$ of original width, again under corresponding extension upwards.

The Leventina nappe – deformation is determined by s_1 over most of its length, rising steeply from the root, lying flat N of it and being refoldet near the front by friction at the lower side and increased rotational deformation above. Str_1 (and str_2 on s_2-planes near the front) are normal to the strike and usually flat.

QUARTZ

Variscan quartz from granites entered alpine deformation usually unrecrystallized, that of gneisses variably recrystallized, polygonized and sutured. In the N such prealpine features may easily be distinguished from alpine ones.

At Erstfeld alpine deformation develops: deformation lamellae (mostly subparallel to basal planes), bending, kinkbands and healed fractures (now including gas-liquid inclusions: pore-planes).

Going S the first effect of heating during alpine metamorphism is felt at c. 275°C between Erstfeld and Amsteg. Tiny liquid inclusions seed at dislocations of deformation lamellae, changing these into Böhm-Lamellae. Immediately S of the N-margin of this feature – still N of Amsteg – first subgrains become visible microscopically, close to the margin of microscope-resolution. They form by migration of dislocations at most deformed grain parts, i.e. at kinkbands and deformation lamellae. At the same time quartz/quartz-boundaries acquire a first still very fine suturing – much finer than the one acquired during variscan strain induced boundary migration, superimposed upon it. Here, accordingly, all processes have started, which develop in consequence to heating after deformation and become more effective towards the S (VOLL, 1960):

1. *Polygonisation:* Within deformed grains dislocations migrate by diffusion into subboundaries, leaving strain free subgrains behind. Subboundaries are mainly tilt boundaries normal to the glide vector, i.a. parallel to c.
2. *Strain induced boundary migration:* Where two adjoining quartz grains are deformed the interface separates regions of stronger deformation being on one from others with weaker deformation at the other side. Going along a boundary the stronger deformation may change from one to the other side. If annealing T is low or deformation small the less deformed part of one neighbour seeds outgrowths growing at the expense of the more deformed neighbour. The quartz/quartz interface is sutured with reentrant angles towards both sides.
3. *Recrystallization:* New seeds form (usually from strongly disoriented subgrains) and grow undeformed at the expense of deformed parents.

   Processes 1–3 are driven by deformation free energy. They are joint by a 4th process immediately, driven by grain boundary free energy:
4. *Collective crystallization (Sammelkristallisation):* Larger concave quartz grains grow at the expense of smaller convex ones reducing thus the quartz/quartz interface. Common interfaces and interedges are drawn into equilibrium angles producing polygonal grain shapes.

Polygonisation and subgrain formation together with straininduced boundary migration start at c. 275°C. Immediately to the S, still N of Amsteg, recrystallization starts. At Amsteg first effects of collective crystallization make themselves felt amongst recrystallized grains. These are still very fine and often subparallel to parent grains.

Towards the S and rising T the following changes are observed:

1. Grain size of recrystallized grains increases.
2. At equal deformation: Vol. new grains/Vol. parent grains increases.
3. Size of subgrains and tilt angles between them increase. Parent relics are stabilized increasingly.
4. Straight parts of sutured boundaries between reentrant angles grow.
5. The effect of collective crystallization becomes more distinct.

These changes are extremely smooth from N of Amsteg to Airolo. Across this distance volumes of recrystallized grains grow steadily from 7×10^{-6} – 5×10^{-1} mm³. Within the uniform granits of the Aar massiv samples lying ca. 300 m apart along the N-S profile may often be distinguished by comparing median grain sizes gained from 300 recrystallized quartz grains/sample. A vertical zonation using this parameter should be possible. The effects of recrystallization and collective crystallization cannot be separated – the grain size being determined by introduction of heat energy at each point between the time at which 290° (starting of recrystallization) was surpassed and the time at which cooling went below 290° C. The effect of stronger (or weaker) deformation, however, can be excluded (stronger deformation effecting smaller grain size and increased recrystallization) as different degrees of deformation are found at each point. A slightly fibrous growth of recrystallized grains parallel str_1 is common, indicating that recrystallization is at least partly syntectonic. This does not, however, interfere with the smooth increase in grain size. Polygonal grain shapes often indicate that annealing outlasted deformation in most parts of the profile. Late deformation is weak everywhere, causes straininduced boundary migration between recrystallized grains, but no net change in grain size.

The amount of recrystallization again increases steadily – quickly at first, more slowly further S. At the N-margin of the Aar massiv granites 50% of the parent grains are replaced, at the N-end of the Gotthard tunnel 70%. Small differences in the amount of deformation have hardly an effect.

The increase of grainsize can reliably be observed only from pure quartz grain aggregates. From the very start intercalation of other minerals – especially sheet silicates – fixes quartz/quartz boundaries resulting in smaller grain size and indicating that collective growth is effective. During recrystallization a large amount of liquid inclusions is eliminated from parent grains. As most of these recrystallize close to the N margin of the Aar massiv more water is set free there (a fact which may be related to the recrystallization isograd of biotite). Surplus water, however, does not have any apparent effect on the features mentioned: sizes of the recrystallized grains fit into the curve whether they are obtained from much or little hydrated granites, from granites or from clastic grains or quartz veins of sediments.

Subgrains, tilt angles between them, straight parts of sutured boundaries all grow along smooth curves towards the S, i.e. towards higher annealing T, all correlated. Parts of parent grains are stabilized and built into the grain aggregates. Towards the S they are less and less distinguishable from new grains.

Within the Leventina nappe this development is lost. There the new grains recrystallize again, are strongly deformed, sutured, polygonized.

BIOTITE

Here I shall mention only an effect, known from the work of Jäger et al. (f. I. 1967). At c. 300°C variscan biotites are changed under adaptation to alpine conditions and at the same time recrystallize. Recrystallization favours new seeds with basal planes under high angles to parent micas, forming high angle and – energy interfaces which can be moved more easily. Rising T towards the S again leads to increase of recrystallized grains (or newly formed ones of other kinds of formation) and growing replacement of parent-matrix.

Geological consequences of quartz- and biotite-recrystallization

At c. 300°C quartz and biotite of variscan granitic basement rocks recrystallize, i.e. $\frac{1}{3}$ or more of the volume of these rocks. This coincides with a strong increase of penetrative, plastic component of deformation. This is explained by a sudden increase of grain boundary gliding. At this boundary a gasphase rich in water must be mobilized discontinuously. This is a consequence of and at the same time an aid to the recrystallization processes. This increases deformability: by processes of solution and redistribution under stress – and strain gradients; by sudden increase of feldspar hydration and easy rotation of feldspar fragments in the new micaceous matrix. The stretching fibre becomes an important fabric element, produced by solution under pressure and redeposition within pressure shadows.

I conclude: The N-margin of the outer basement massivs – i.e. Aar-, Mont Blanc-massifs etc. – is determined by starting recrystallization of quartz and biotite within basement granitic rocks and correlated processes. N of this boundary the basement is but little deformed. S of it and up to 500°C where feldspars start recrystallizing there is a zone with medium deformation but distinct penetrative deformation, narrowing of the alpine cross section and upward extension made possible by $\frac{1}{3}$ or more of the volume becoming mobile by quartz- and biotite recrystallization, increased hydration as partly a consequence. This zone extends to the N margin of the Tessin gneiss nappes and feldspars are still rigid crystals within this zone.

FELDSPARS

Below 450–500°C are rigid with respect to alpine deformation. They are bent, kinked or broken, fragments drift apart parallel to str_1, cracks are filled with fibrous quartz, micas or calcite, by outgrowths consisting of adularia (in less hydrated) and/or albite (in more hydrated rocks). This crackfilling is a penetrative equivalent to formation of tension gashes and does not occur at falling T only. An-contents from variscan times and zoning may persist in little hydrated parts. There plagioclase may be "twinned" mechanically, though this is made difficult by ordering. Lattice mobility is indicated by many features and certainly aided by hydrolizing activity of water. Composition planes of variscan pericline twins become mobile after change into low albite which is common in more hydrated parts and demands bond breakage itself. From ca. 300°C to the S-margin of the Aar massif K-feldspars are increasingly ordered (even the adularias formed in tension gashes are affected by this process). Unmixing is carried beyond that from variscan time of cooling. Twin domains in microcline grow. All this internal mobility has little effect on the deformation behaviour as outlined above.

Not far from the N-end of the Gotthard massif the oligoclase isograd of granitic rocks (containing epidote/clinozoisite) is reached. Oligoclase forms – very little at first – as disordered phase, growing round albite (usually albitized variscan plagioclase or K-feldspar) or at the expense of albite by ion diffusion. At the same time K-feldspars ordered at lower T are monoclinized and disordered (and only little reordered on cooling). C. 3 km N of Gotthard pass a spontaneous recrystallization of both feldspars becomes more and more important and affects the largest part of parent grain volume nr. Airolo. Recrystallized plagioclases are grown as disordered oligoclase, frequently zoned; recrystallized K-feldspars formed as monoclinic phase and became slightly reordered, as presserved parent crystals on cooling. Recrystallized grains of both kinds are seeded by subgrains of parent feldspars.

Within the Leventina nappe (and in the Simano- and Adula-nappes above it) the largest part of parent feldspars is recrystallized though relics of these may be preserved S to the root zones. The recrystallized grains grow to the S, form aggregates flattened in s_1, strongly elongate in str_1 and folded by $B_{2,3}$.

Geological consequences of feldspar-recrystallization

Granitic rocks of the basement acquire high mobility within the total volume with onset of feldspar recrystallization. I conclude that the N-margin of tongue-shaped nappes of the Tessin culmination is largely determined by this fact. With respect to feldspar recrystallization 4 types of basement nappes may be distinguished:

1. Nappes as the Leventina which are entirely within the area of feldspar recrystallization. They show strong plastic deformation through-out, largely acquired at the high T necessary for this recrystallization. Antigorio- and Simano-nappes belong to this type. These nappes left their root area simply deformed and remained simple on travelling over the major part of their extent. s_1, str_1 dominate. Frontal parts may be wrapped in and complicated by refolding, caused by friction.
2. Very high basement nappes (Silvretta-Ötztal-, Schladming-basement nappes) have never been heated to feldspar recrystallization, have moved as much more rigid blocks with little penetrative deformation.
3. The Monte Rosa nappe crosses the feldspar recrystallization "isograd". Its part N of it shows no feldspar recrystallization and behaved more

rigid. The part S of it is highly deformed, feldspars are recrystallized. This nappe has reached its position largely rigid, the strong deformation in the S being superimposed. The internal structure is simple, largely determined by str_1 and s_1.

4. The Adula-nappe again reaches across the feldspar recrystallization "isograd" but its northerly parts are highly deformed, tongue-shaped and refolded. There are 2 possibilities to explain this: a) the frontal parts have heated in the S and feldspar recrystallization was transported into cool northerly areas. b) the nappe has suffered a high pressure low T – metamorphism close to its root, moved N under reconstitution of feldspars from break down products which developed during the first stage. Preservation of glaucophane schists in the frontal parts and the unique position with respects to the relation between style and feldspar recrystallization isograd favour the second explanation.

It seems that nappes closely adjacent today have rather different histories at their home country and on travelling N. This is not astonishing if we consider that what is called the root zone and condensed to c. 5 km today had a width of near 100 km to start with (Vogler and Voll, 1976).

Finally it may be pointed out that the sudden increase of grain boundary area caused by biotite-quartz recrystallization and increased formation of finely divided micas; and again the sudden start of feldspar-recrystallization may well have an effect on wave velocities observed by geophysicists.

References

Jäger, E., Niggli, E. und Wenk, E. (1967): Rb-Sr-Altersbestimmungen an Glimmern der Zentralalpen. Beitr. Geol. Karte Schweiz, N.F. *134*, Liefrg. 1–67.

Vogler, S. W. and Voll, G.: Fabrics and metamorphism from tonalite, granitic augen gneiss and Tonale series at the S-margin of the Swiss Alps, E of Bellinzona. 1976, this volume.

Voll, G. (1960): New work on petrofabrics. Liverpool and Manchester Geol. Journal *2/3*, centenery issue, 503–567.