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WALL-ROCK-DERIVED ZIRCON XENOCRYSTS AS IMPORTANT INDICATOR MINERALS OF MAGMA CONTAMINATION IN THE FREISTADT GRANODIORITE PLUTON, NORTHERN AUSTRIA

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Abstract: By means of morphological criterions, two genetic groups of zircons could be recognized in the Freistadt Granodiorite Pluton, a felsic high-level I-type pluton in northern Austria: newly formed (N-type) zircons that nucleated in the granodiorite melt, and zircon xenocrysts (X-type zircons) that were incorporated by wall rock assimilation during magma emplacement. The N-types are small and have high elongation ratios and large (110) and (101) faces. These morphological properties refer to the physical and chemical conditions of the granodiorite melt and are exactly those which are to be expected in rapidly cooled felsic I-type granitoids. The xenocrysts are strikingly different and form two subgroups, which can be clearly correlated to the zircon populations of two distinctly older granitic wall rocks of the granodiorite pluton. The number of xenocrysts suggests that the granodiorite body contains on average ca. 10 %, locally at its margins up to ca. 20 % assimilated country rock material. This inherited material must have undergone a generally high degree of dissolution, for there are hardly any macroscopic indications of contamination in the granodiorite pluton. The zircon xenocrysts, however, show no signs of resorption and are euhedral, similarly to the N-types. The identification of zircon xenocrysts is therefore suggested to be one of the most potentially successful methods of recognizing and estimating the nature and extent of wall rock contamination in granitic intrusions.

Key words: zircon typology, granitoid rocks, zircon xenocrysts, Southern Bohemian Massif-Northern Austria.

Introduction

Zircons have received great interest as petrogenetic indicator minerals in granite petrology, mainly because zircon morphology may reflect physical and chemical conditions of granitic magmas. A series of observations on French granites led Pupin (1980), for example, to postulate that the relative growth rate of the two common zircon prisms (110) and (100) is a function of (and therefore indicative of) temperature (T-index = I. T in Fig. 4), while the relative growth rate of the two common zircon pyramids (211) and (101) is controlled by the aluminium/alkalies ratio of the parent melt (A-index = I. A in Fig. 4). Another important study is that of Kostov (1973), who proposed that the elongation (= length/breadth) of magmatic zircons is mainly a function of their speed of crystallization and thus reflects the cooling rate of a magma. Speer (1980) presents a detailed review of published work concerning relations between zircon morphology and the physical and chemical conditions of growth.

Based on these various concepts, geoscientists all over the world have successfully utilized statistical studies of zircon morphology as a method for the genetic interpretation and correlation of granitic rocks, often in combination with other specific zircon features such as colour, zoning, inclusions etc. (see e. g., Larson and Poldervaart, 1957; Frasl, 1963; Pupin, 1985; Broska and Uher, 1988). Nevertheless, we believe that reliable correlations and interpretations of granitic rocks by means of simple zircon statistics are basically handicapped by one serious problem: because of the refractory character of zircon, one obviously cannot simply proceed on the assumption that all zircons which occur in granitic rocks are true "magmatic" and thus true indicators of the physical and chemical conditions of the magmatic granite crystallization process. U-Pb isotopic studien in particular (e. g., Pidgeon and Aftalion, 1978; Williams et al., 1982; Liew and Mc Culloch, 1985; Bossart et al., 1986) repeatedly provided evidence that zircon populations of granites very often contain also older inherited zircons or zircon "cores".

It is the objective of this paper to demonstrate that such inherited zircons are often incorporated relatively "late" into uprising granite melts, i. e. during the emplacement stage, by wall or roof rock assimilation. Clearly, these xenocrystic zircons are purely coincidentally in their host granites and can, consequently, not be used for magmagenetic correlations, e. g., to decide whether two granite samples are derived from the same magma. Others than those zircons which nucleate in a granitic magma, they can not be expected to indicate physical and chemical conditions of the granite by their morphology. However, the zircon xenocrysts have another important petrological significance: They are particularly suitable as indicators of the nature and extent of contamination experienced by a granitic magma during ascent and emplacement.

Our concept is that zircon populations of granites should always be examined to determine if they contain wall-rock--derived zircons. Furthermore, magmatic zircons and xenocrystic zircons should be systematically distinguished by microscopy, if possible, before a comprehensive genetic interpretation is attempted. This will now be demonstrated, using the Freistadt granodiorite pluton in northern Austria as an example.

Geological and petrographical background

The study area containing the Freistadt granodiorite is located in northern Austria (Fig. 1). It belongs geologically to the Bohemian Massif, which is one of the major exposures of the Hercynian orogen in Central Europe. Most of the Bohemian Massif consists of high-grade metamorphic rocks including metasedimentary rocks, orthogneisses, amphibolites and granulites. These metamorphic rocks are intruded by large volumes of Late Paleozoic granitoids, which form several plutonic complexes throughout the Bohemian Massif.

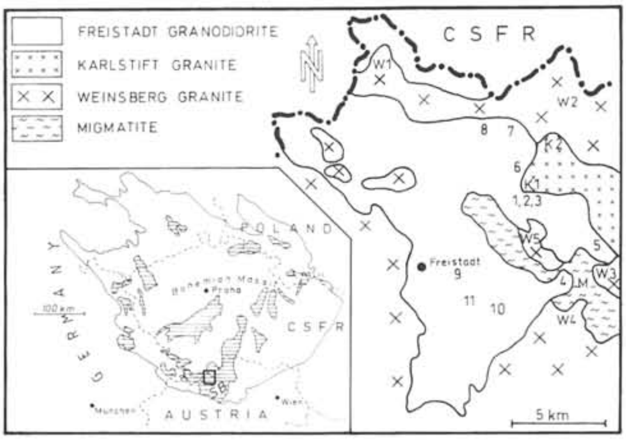


Fig. 1. Geological sketch map of the Freistadt granodiorite body and its country rocks.
Numbers mark sample localities of this study. Inset shows the position of the study area in Austria and in the Bohemian Massif, respectively. The Upper Paleozoic granitoid complexes of the Bohemian Massif are hatched (SB = Southern Bohemian Granitoid complex).

The Freistadt granodiorite body is a relatively small, late stage pluton within the Southern Bohemian Granitoid Complex, which occupies the western half of the Austrian section of the Bohemian Massif and extends into Bavaria in the west and into Czecho-Slovakia to the north (see Fig. 1). The Southern Bohemian Granitoid Complex consists of a group of older S-and high-K_2O I-type granitoids of Early Carboniferous age and a second group of younger S- and I-type granitoids of Late Carboniferous age (Liew et al., 1989). The older granitoids predominate and may be traced to crustal-derived anatectic melts which formed during the thermal climax of the Hercynian orogeny and solidified at lower crustal levels (Frasl and Finger, 1988). The younger granitoids, including the Freistadt granodiorite, intruded the Southern Bohemian Granitoid Complex during a phase of uplift and erosion, penetrating the earlier series either as discrete stocks or along major regional faults.

The Freistadt granodiorite pluton has I-type characteristics (Chappell and White, 1974) with respect to a high Na_2O/K_2O ratio and a low mol $Al_2O_3/CaO + Na_2O + K_2O$ characteristics but is rather felsic throughout (65–72 % SiO_2) and yields only a relatively small compositional variance from K--feldspar-poor biotite-granodiorite to K-feldspar-rich biotite-granodiorite (Friedl, 1990; Klob, 1971). Grain size is medium to fine. Locally the granodiorite grades into very fine-grained porphyritic variants which indicate a high level of emplacement. Three main types of older country rocks adjoin the Freistadt granodiorite body (Fig. 1), all of which are related to the Early Carboniferous anatectic events in the Southern Bohemian Massif (see above).

1) The Weinsberg granite (Kurat, 1965; Haunschmid, 1989) almost completely surrounds the granodiorite pluton. It is a coarse-grained biotite-granite with abundant K-feldspar megacrysts up to 10 cm.

2) The Karlstift granite (Klob, 1970), a medium- to coarse-grained biotite-granite, intruded the Weinsberg granite and extends along the eastern boundary of the granodiorite pluton for several kilometers.

3) Some migmatites, mainly anatectic paragneisses, occur to the east of the granodiorite stock (Frasl et al., 1965).

Results of zircon investigations

General view

The investigations were carried out mainly in the eastern sector of the Freistadt granodiorite pluton, which outcrops in several quarries and on roadsides. Eleven samples were collected from the granodiorite body and eight from the country rocks for the preparation of zircon concentrates. Sample localities are shown in Fig. 1.

In the granodiorite samples three distinct types of zircons are recognized. These types all contain euhedral zircons but each type is morphologically different and each has distinctive internal features (see Tab. 1).

Only one type of zircon was found in all samples of Freistadt granodiorite and it can thus be regarded as truly characteristic of the granodiorite pluton. The morphological properties of these zircons are exactly those which are to be expected in rapidly cooled high-level I-type plutons such as the Freistadt granodiorite, according to the findings of Pupin (1980) and Kostov (1973), and it is therefore likely that their growth was governed by the physical and chemical conditions in the granodiorite melt. We refer to these zircons as N-type (N = newly formed).

In contrast, the other two types of zircons which were found in the Freistadt granodiorite are interpreted as xenocrysts (X-type zircons), which were incorporated into the magma by processes of country rock assimilation. This interpretation is suggested because one type (X1) looks exactly like those zircons found in the adjoining Weinsberg granite, whereas the other type (X2) appears identical with the zircons in the Karlstift granite in the east of the granodiorite pluton (Fig. 1). On the other hand, no pendantes of N-type zircons were detected in the Weinsberg or Karlstift granite. The relative

Table 1. Average electron microprobe analysis data for the investigated zircon.

	N-type zircons	X1-type zircons	X2-type zircons
Dimensions	volumetrically small, often long prismatic (l/b > 4)	big, stubby (l/b < 2) to normal prismatic (l/b = 2-4)	big, stubby to normal prismatic
Development of crystal faces	(110) prism and (101) pyramid usually dominant, (100) prism absent or very small, (211) pyramid varies in size from (211) = (101) to (211) ≪ (101), but is often also absent	(110) prism and (211) pyramid usually dominant, (100) and (101) usually small but rarely absent	(100) prism and (101) pyramid dominant, (110) and (211) usually small, sometimes absent
Striking internal features	sometimes fine growth zoning	unzoned, big inclusions	growth zoning phenomena, cracks, small needle-shaped inclusions abundant, sometimes dark inherited cores

amounts of N-, X1- and X2-type zircons extracted from the samples of Freistadt granodiorite are shown in Tab. 2 (separation techniques are described in the appendix). A few grains which could not be clearly assigned to one of these three groups are summarized as "others" in Tab. 2. Maybe some of these grains are derived from the migmatite which occurs east of the Freistadt pluton (Fig. 1). This migmatite contains, however, only a few very heterogeneous, often rounded, ill-defined zircon grains.

Comparing the results of Tab. 2 with the particular sample localities marked on the geological sketch map in Fig. 1, it becomes clear that X2-type zircons were only found near the Karlstift granite (samples 1–6). This fact also supports the previous assumption that the X2-type zircons are derived exactly from this granite and it suggests, moreover, a rather late-stage country rock assimilation mechanism with respect to the magmatic evolution of the granodiorite stock, i. e. either during or even after magma emplacement. The inherited zircons were obviously not carried over larger distances and homogenously distributed within the plutonic body. Samples 1 and 2, which were collected most close to the contact (1 :1 m, 2 : 20 m) contain the highest amounts of X2-type zircons.

Table 2. Percentages of N-type, X1-type and X2-type zircons in single samples of Freistadt granodiorite.

Sample	N-type	X1-type	X2-type	Others
1	61	—	36 (24)	3
2	60	4 (2)	33 (22)	3
3	76	14 (7)	20 (14)	—
4	79	12 (6)	9 (6)	—
5	78	14 (7)	6 (4)	2
6	81	14 (7)	3 (2)	2
7	69	29 (15)	—	2
8	73	26 (13)	—	1
9	75	25 (13)	—	—
10	78	20 (10)	—	2
11	78	19 (10)	—	3

Numbers are based on the investigation and typological subdivision of 200 single zircons per sample. Numbers in brackets: calculated amounts (Vol. %) of assimilated country rock material (column II: Weinsberg granite, column III: Karlstift granite). For further explanations see section 4.

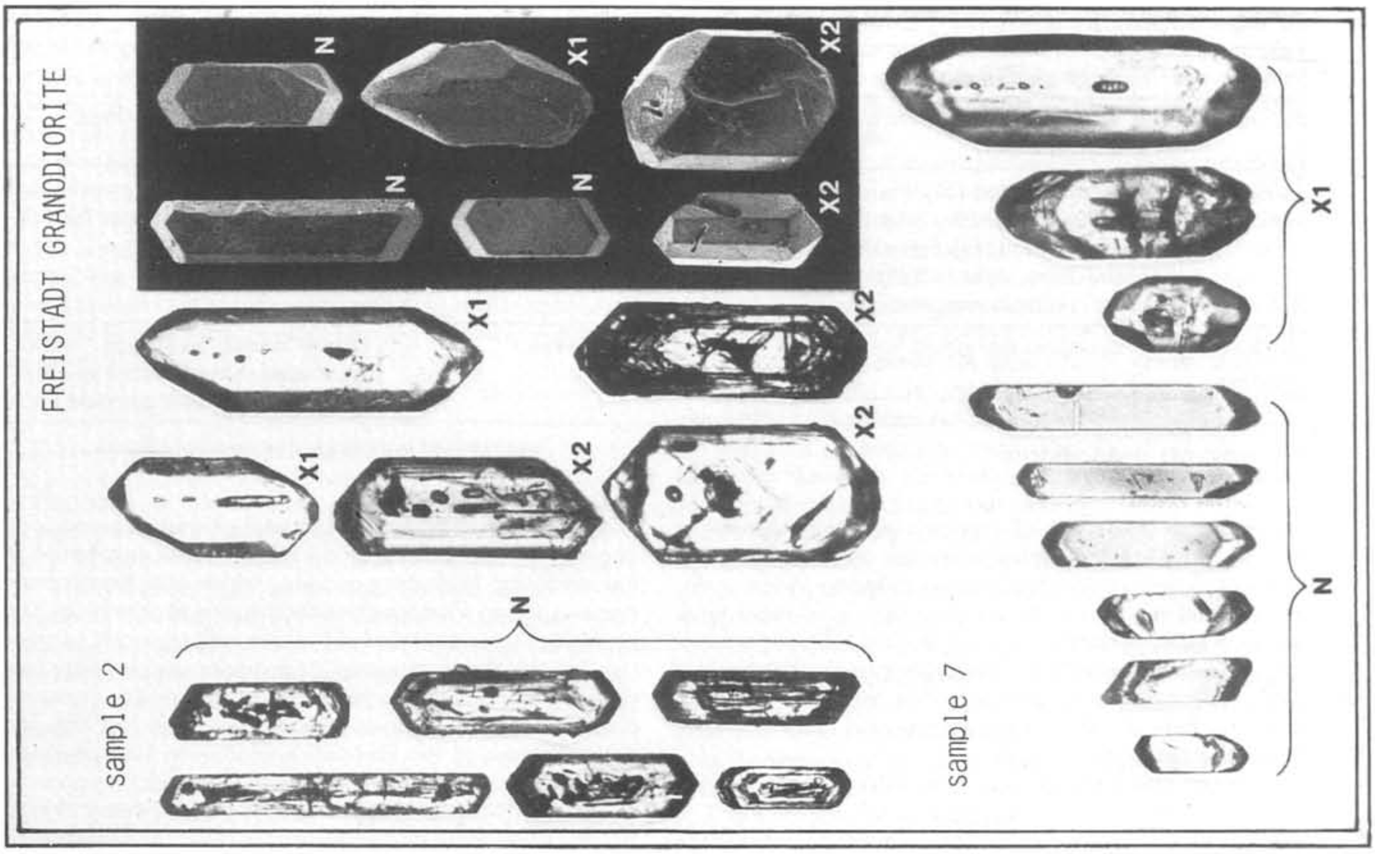
X1-type zircons occur throughout the Freistadt granodiorite pluton in accordance with the nearly overall distribution of the enclosing Weinsberg granite, which also forms many enclaves (up to 5 km long) within the granodiorite body. The generally high amounts of the zircon xenocrysts are surprising. None of the investigated granodiorite samples were free of X-type zircons, although all samples appeared macroscopically to be homogeneous granodiorites. The fact that the X-type zircons of the Freistadt granodiorite have generally little or no outgrowth and overgrowth, although they occur in association with variable amounts of newly formed N-type zircons, could mean that the incorporation of the country rock material occurred predominantly after the main phase of magmatic N-type zircon growth. On the other hand, many of the X-type zircons may not have formed new overgrowth because they were incorporated as "armoured" inclusions in country-rock mineral fragments of biotite, feldspars and quartz, which were not dissolved in the granodiorite melt.

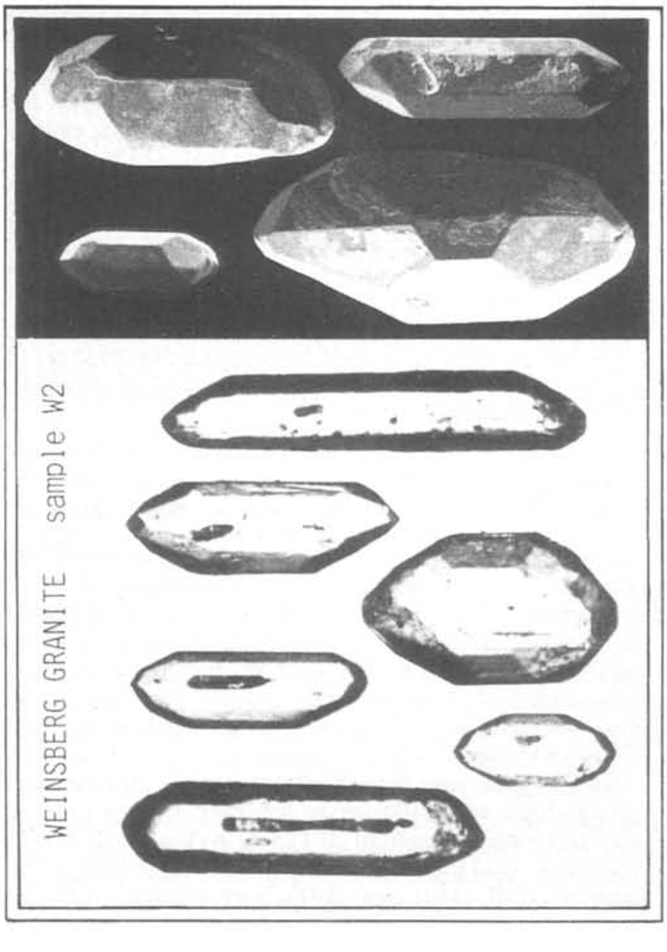
In contrast to most previous studies, which describe inherited zircons in granites either as anhedral grains or as inner "cores" overgrown by new zircon substance (e. g. Poldervaart and Eckelmann, 1955; Hoppe, 1963; Van Breemen et al., 1987), it is demonstrated in this paper that inherited zircons can be also absolutely euhedral and free of new overgrowth. They can appear in this respect just like newly formed zircon crystals. We suspect that the rate of zircon xenocrysts in granites is often ignored or underestimated for that reason.

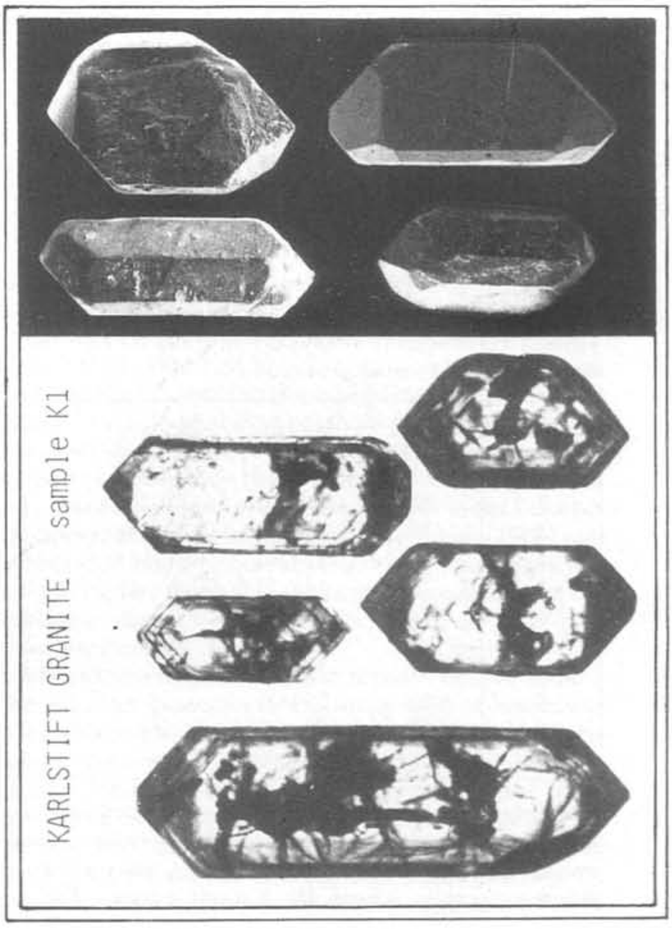
The features of the N-type zircons

Typical N-type zircons of the Freistadt granodiorite are shown in Fig. 2. The crystals are volumetrically small, but have, nevertheless, high elongation ratios (Fig. 3). According to Kostov (1973), these high elongations are likely to indicate rapid growth of zircon. The assumption of rapid growth is consistent with field evidence, according to which the Freistadt granodiorite is a rapidly cooled high level intrusion (Frasl and Finger, 1988).

The N-type zircons of the Freistadt granodiorite have large prisms (110), while (100) prisms are small or absent (see Fig. 4). Terminations vary from (101) only to (101) + (211) with (101) >> (211), (101) > (211) or (101) = (211). The dominance of (110) and (101) faces complies with the observation of Pupin according to which zircon populations in


FREISTADT GRANODIORITE
N
X1
X2
N
N
X2
X1
X2
X1
X2
X2
N
sample 2
X1
N
sample 7


WEINSBERG GRANITE sample W2


KARLSTIFT GRANITE sample K1

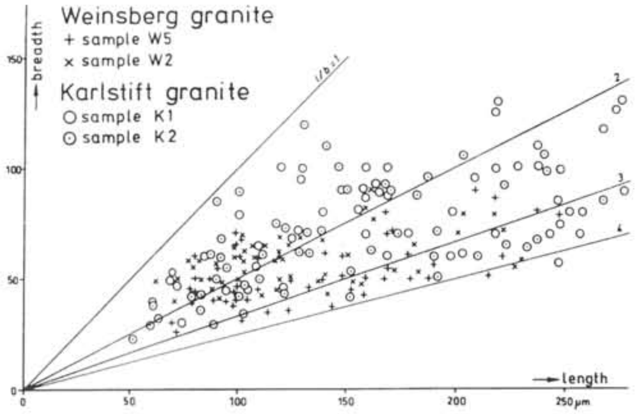


Fig. 3a. Dimensions of zircons in Weinsberg granite (2 samples) and Karlstift granite (2 samples). 50 crystals per sample have been plotted in each case.

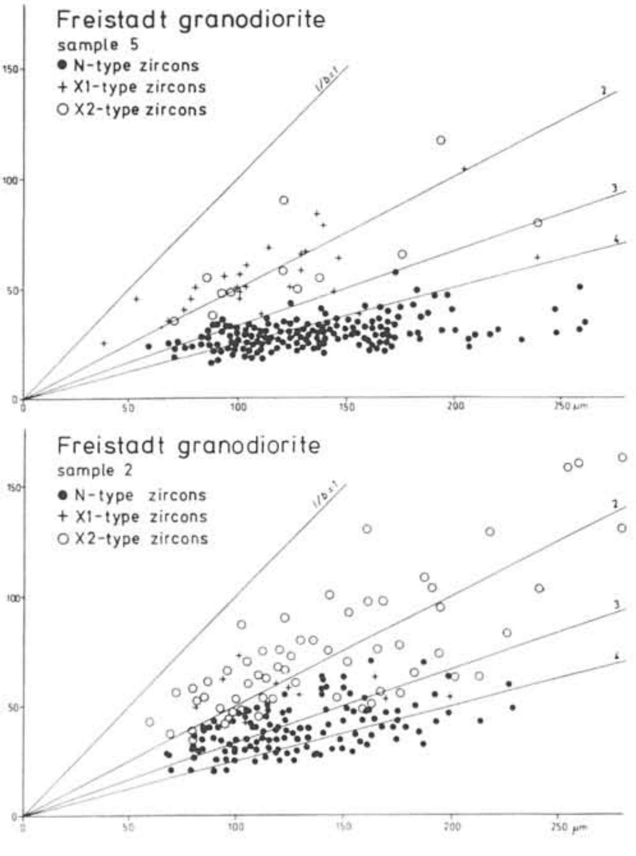


Fig. 3b, c. Dimensions and proportions of N-type zircons and X-type zircons in Freistadt granodiorite samples 2 and 5 (200 zircons per sample are plotted). The N-types have generally high elongations, whereas the X-types are usually stubby to normal prismatic.

highly evolved felsic I-type melts should have high I.A and low I.T values (Fig. 4).

Some of the N-type zircons of the Freistadt granodiorite are absolutely transparent, while some exhibit euhedral growth zoning comprising up to ten individual zones which may affect the transparency of the crystals considerably. The growth zones hardly change their habit from the centres of the crystals to the rims, which further supports the concept of nucleation and complete growth of the N-type zircons in the granodiorite melt. Inherited cores have never been observed microscopically. Inclusions are relatively rare, as are overgrowth and outgrowth phenomena in the sense of Speer (1980).

The features of the X-type zircons

The zircons of the Weinsberg granite and the X1-type zircons of the Freistadt granodiorite, respectively, are much coarser than the N-type zircons of the Freistadt granodiorite and stubby to normal prismatic (Figs. 2, 3). They are, therefore, likely to have crystallized in a slowly cooling, deep-seated magma (Kostov, 1973), consistent with the interpretation of the geologic setting of the Weinsberg granite. When compared with the N-type zircons, they exhibit a significantly different development of crystal faces. In terms of the nomenclature of Pupin (1980), the pyramidal development varies from (211) > (101) to (211) = (101). Typically, both prisms (110) and (100) are developed with (110) >> (100), (110) > (100) or (110) = (100) (see Fig. 4). As can be seen in Fig. 2, the zircons of the Weinsberg granite are often perfectly transparent and usually contain relatively large inclusions.

The zircons of the Karlstift granite and the X2-type xenocrysts in the Freistadt granodiorite, respectively, are also much coarser on average than the N-types and even somewhat coarser than the Weinsberg granite zircons (Figs. 2, 3). Like the latter, they are stubby to normal prismatic, indicating a similar cooling history of the Karlstift and the Weinsberg granite, as suggested also by geological data (Frasl and Finger, 1988). However, the zircons of the Karlstift granite can be distinguished from those of the adjoining Weinsberg granite by a relatively different development of crystal faces (see Fig. 4): prism development varies from (100) only through (110) << (100), (110) < (100) to (110) = (100), terminations vary from (101) only through (211) << (101), (211) < (101) to (211) = (101).

The zircons of the Karlstift granite usually have many striking features in their interior, e. g. euhedral growth zones, needle-shaped inclusions (apatite?) or dark anhedral cores with shapes varying from globular to more elongated. Striking radial cracks often extend from the centres of the crystals towards the rims. Due to their multiple inner phenomena these zircons are rarely perfectly transparent (Fig. 2).

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Fig. 2. Typical zircons of a) Weinsberg granite (sample W2), b) Karlstift granite (sample K1) and c, d) Freistadt granodiorite (sample 2 and 7).

The Freistadt granodiorite comprises N-type zircons as well as X-type (X1- and X2-type) zircons. Note the similarity between type X1 and the zircons in the Weinsberg granite and between type X2 and the zircons in the Karlstift granite. White background: transmitting light; black background: REM photographs. Magnification is for all crystals × 220.

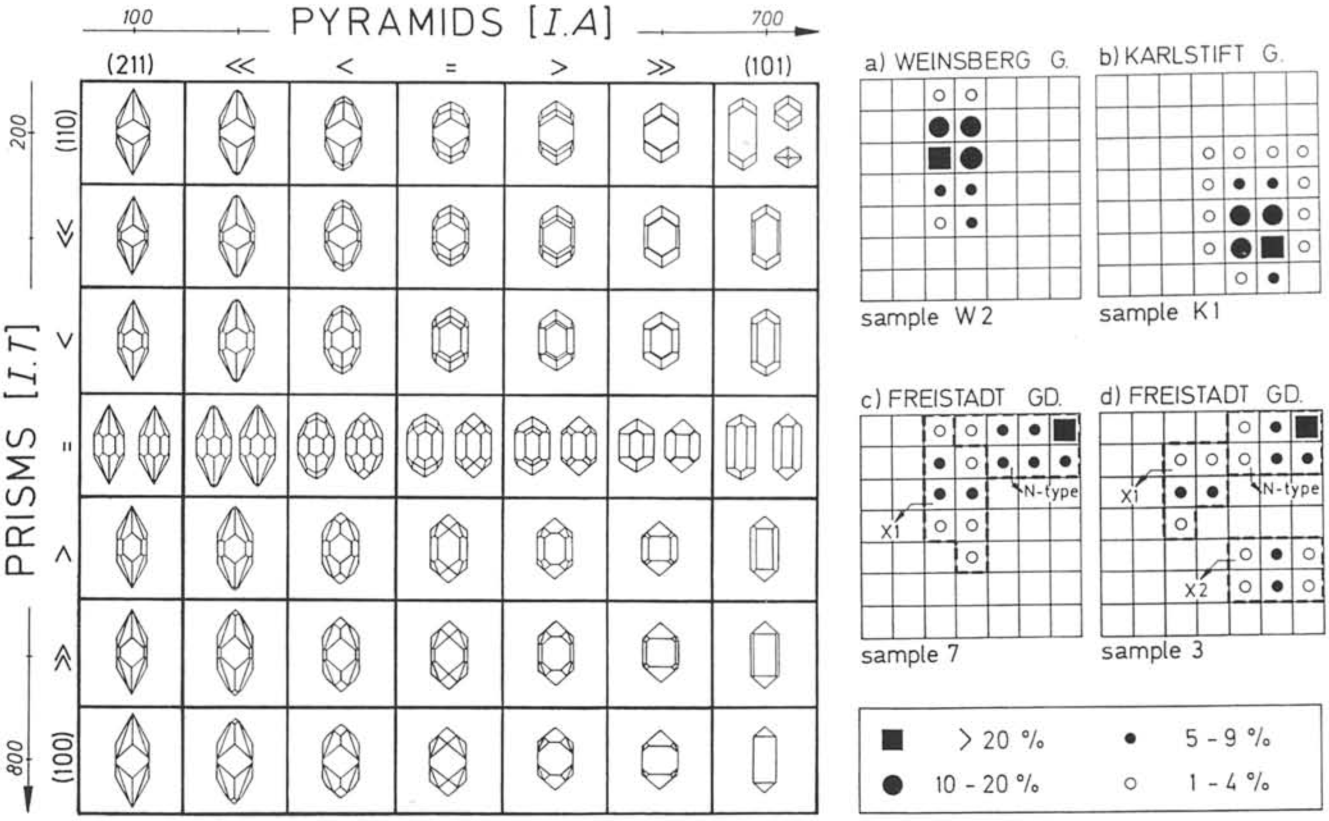

Fig. 4. Pupin-diagrams showing the frequency of distinct zircon habits (as depicted schematically on the lefthand side with I. A and I. T scale; see Pupin, 1980) in a) Weinsberg granite, b) Karlstift granite and c, d) Freistadt granodiorite (samples 3 and 7).
Each of the diagrams a-d is based on the investigation of 100 single zircons. Note the striking submaxima in c) and d) which are due to the xenocrysts, and the correspondence of these xenocryst-submaxima with the maxima found for the zircon populations of the Weinsberg and Karlstift granite in a) and b).

Discussion and conclusions

One objective of this study was to point out that a correlation and interpretation of granitic rocks by means of common zircon-statistical parameters (e. g. I.$\bar{A}$/I.$\bar{T}$ of Pupin, 1980; average length/breadth ratio and RMA values of Larson and Poldervaart, 1957) becomes much more effective, if only igneous zircons, excluding xenocrysts, are considered. The positive effect of this concept can be qualitatively estimated, when the morphological parameters of the two Freistadt granodiorite samples in Figs. 3 and 4 are compared. Tab. 3 shows the effect quantitatively for I.$\bar{A}$ and I.$\bar{T}$ values of Pupin (1980).

However, if zircon xenocrysts can be clearly identified and correlated with one or more distinct types of country rocks (e. g., by methods as described in section 3), the crystals can be effectively used as additional petrogenetic indicators: Identified X-type zircons can, for example, help to *solve the order of intrusion in granitoid complexes*, as younger intrusions might incorporate zircons from older adjacent ones, but never the other way around. The fact that zircons of the Weinsberg and the Karlstift granite could be recognized as xenocrysts in the Freistadt granodiorite pluton, means that both granites must be older then the granodiorite.

Such "relative age determinations" among neighbouring granite bodies by zircon xenocrysts can be successfully applied in badly exposed polyphase granitoid complexes, where age relations of single intrusions can not be determined by field observation (Finger and Haunschmid, 1988). The fact that zircons remain morphologically stable during metamorphism up to amphibolite facies grade (see e. g. Dölzlmüller et al., 1989) means that the same method may also be effectively used in granitic orthogneiss-complexes, where primary contacts of single intrusive bodies are covered or not clearly interpretable because of tectonic overprinting.

Table 3. I.$\bar{A}$ and I.$\bar{T}$ values calculated according to Pupin (1980) for Freistadt granodiorite samples 1, 7 and 10. I.$\bar{A}$/I.$\bar{T}$ (1): bulk zircon population; (2): X-types excluded.

Sample	I. $\bar{A}$ / I. $\bar{T}$ (1)	I. $\bar{A}$ / I. $\bar{T}$ (2)
1	621 / 383	626 / 224
7	536 / 280	617 / 226
10	563 / 251	619 / 223

Note that the values in (1) are relatively dissimilar and would falsely imply a derivance of the samples from at least two different magma series (see Pupin, 1980), although all three samples are clearly derived from one and the same plutonic body. In (2) the values are much more similar and account here, correctly, for a derivance of all samples from one magma series.

A second important point is that X-type zircons can be used for a *rough estimation of the nature and extent of wall or roof rock contamination* of a granitic intrusion. This is shown in Tab. 2 for the Freistadt granodiorite. Based on the particular numbers of Weinsberg-granite-derived X1-type zircons and Karlstift-granite-derived X2-type zircons as detected in the single samples, the appropriate amounts of rock material necessary to produce the observed percentages of inherited zircons have been estimated. The calculations are based on:

* the assumption of simple homogeneous admixing of country rock material.

* the observations in several thin sections that zircons are normally twice as abundant in the Weinsberg granite and 1.5 as abundant in the Karlstift granite as in the Freistadt granodiorite.

According to these crude estimates, most samples of Freistadt granodiorite are likely to contain ca. 10 % country rock and some seem to have assimilated up to ca. 20 % country rock material. Of course, it seems strange that such a high degree of contamination is hardly visible macroscopically, in particular as both relevant contaminating rocks, the Weinsberg and the Karlstift granites, are coarse-grained and contain K-feldspar megacrysts, which should occur as striking xenocrysts in the granodiorite. In fact, xenocrysts of K-feldspars are sometimes observed in the granodiorite, but only in small amounts which would suggest a much lesser degree of contamination in comparison to the extent indicated by the amounts of zircon xenocrysts. This discrepancy could be, however, easily explained if we assume a high degree of dissolution of the K-feldspars and other major components of the incorporated country rock in the granodiorite by partial melting. Furthermore, we can assume that local cataclasis potentially helped the granodiorite magma to dissolve and assimilate parts of its wall rocks. This interpretation appears likely in view of the fact that most of the younger I-type plutons of the Southern Bohemian Massif clearly used fault zones for emplacement.

In order to check the above assimilation concept and the reliability of the contamination ratios as calculated by means of the inherited zircons (Tab. 2), a simple chemical test involving the trace elements Rb and Sr was carried out: Analyses of samples of Freistadt granodiorite, as well as the average compositions of the Weinsberg and Karlstift granites (both are compositionally rather uniform in the study area – see Klob, 1970; Finger et al., 1987; Scharbert, 1989) were plotted in a Rb vs Sr diagram (Fig. 5). Some of the data were available from an isotopic study (Scharbert, 1989), further Rb-Sr analyses were carried out by standard XRF techniques on some of those samples which were used for the zircon investigations (samples 2–5, 8, 10). The diagram shows that most samples of Freistadt granodiorite plot along a common plutonic Rb-Sr evolution trend, characterized by a continual increase of Rb with decreasing Sr. Those samples which were classified as "low contaminated" by means of zircon studies (samples 4, 5, 8, 10) also plot along this trend. The contamination vectors of these samples, drawn according to the numbers in Tab. 2, are short. Contamination was obviously too little in these cases (and apparently also in case of most other plots used in Fig. 5) to blur the typical "magmatic" trend of the curve. On the other hand, those of the analysed samples which were recognized as "high contaminated" (ca. 20 %) by means of zircon studies earlier (samples 2 and 3) do not fit this magmatic trend at all. If we try to deduct the "contamination vector" of these two samples graphically, using the estimates in Tab. 2 once more, both approach the magma evolution trend as defined by the other less contaminated samples. This behaviour suggests that wall rock contamination is mainly responsible for the "displacement" of both samples 2 and 3, and that contamination values of Tab. 2 are really reliable, in spite of the scarcity of any macroscopic signs of contamination*. Apparently we have to reckon, indeed, with a far reaching penetrative destruction of the texture of the inherited country rock material and also with a considerable degree of dissolution of its major components by partial melting. Although the detailed mechanisms of the assimilation process must be presently considered as poorly understood and remain to be worked out, we find it important to know, that the inherited zircons

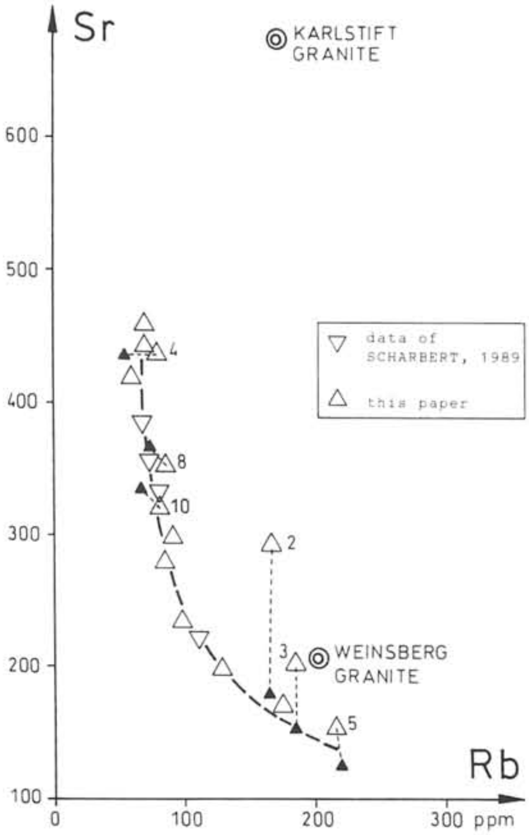

Fig. 5. Rb vs. Sr diagram with 18 analyses of Freistadt granodiorite (big open triangles) and the average composition of Weinsberg and Karlstift granite.

The heavy dashed line marks the presumed magmatic Rb-Sr evolution path of the granodiorite pluton. Thin dashed lines are the "contamination vectors", i. e. the assumed effects of country rock contamination as estimated by means of the zircon xenocrysts in the case of the samples 2–5, 8, 10.

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* The major elements and other trace element analyses (Zr, Y, Ba) recently available for the samples are consistent with the proposed mixing model. However, the contents of these elements are too similar in the three granites to show the mixing behavior as clear as the Rb vs. Sr plot.

were obviously able to survive nearly intact. The results of the present investigation encourage us to suggest that microscopic studies of zircon populations (in order to identify X-type zircons) are one of the most potentially successful possibilities currently available to recognize wall rock contamination effects in granites. Consequently, zircon studies can be recommended as a serious help for every granite petrologist who is required in practice to select sample material, which is as uncontaminated as possible, for analytical work.

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Appendix

Separation procedure and analytical techniques

Sufficently "representative" zircon concentrates must be prepared for the determination of the true amounts of inherited zircons in granitoid samples. For this purpose, approx. 1 dm^3 of each sample were ground in a disk grinder to less than 2 mm in diameter. The crushes were then subdivided to reduce the amount of material to be treated. Approx. 100 g were left for 24 hours in HCl (33 %) and then repeatedly ground until all the material passed a 250 μm sieve. The sieved material was further separated by settling in Tetrabromethane heavy liquid ($D = 2.96$). Magnetic minerals were then removed in a Frantz isodynamic separator. The non-magnetic residue was mounted on glass slides, embedded in Canadabalsam and studied by microscope under high magnifications, mostly with transmitting light. Determination of the indices of single zircon crystal faces (e. g. for grouping the crystals according to the scheme of Pupin, 1980) is often facilitated by use of light from the side. Three samples have been studied also by standard REM techniques (Fig. 2).

Additional investigations on the magnetic fraction and the light fraction left after the settling process reveals that approximately half of all the zircons in the starting material could be extracted by the above separation procedure. The second half of the zircons did not sink in the heavy liquid, mostly because the crystals were trapped as inclusions in quartz, feldspar or biotite. Comparative studies of the zircons scattered throughout the light fraction are, nevertheless, necessary to ensure that the heavy fraction is really representative of the whole rock and that the separation technique did not lead to an undesirable enrichment of distinct types of zircons (e. g., of heavy stubby inherited ones rather than small long prismatic magmatic crystals). Such an effect, if ignored, could of course lead to serious misinterpretations.

In the case of the investigated samples of Freistadt granodiorite, the zircon concentrates fortunately always proved to be sufficiently representative of the whole rock. It should, however, be noted that granites (especially fine-grained ones), sometimes contain large numbers of tiny needle-shaped zircons, which can not sufficiently be extracted by the separation technique described above. For example in a certain fine-grained granite in northern Austria (the Schrems granite – Finger, unpubl.), such small crystals made up more than 80 % of the N-type zircons. Heavy mineral separation led, however, to a more than hundredfold enrichment of X-type zircons, which were much bigger and heavier. This example clearly shows the necessity of checking the light fraction from the settling process.

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