Zircon Typological Investigations from the Seufzergründel Placer Near Hermsdorf in the Saxon Switzerland, Eastern Germany

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ABSTRACT: A set of 5871 zircon megacrysts was studied from the Seufzergründel placer in the Saxon Switzerland. Two subpopulations can be distinguished based on zircon typology from only 311 euhedral crystals and other features. The first subpopulation, representing 95 % crystals, is the common zircon type with predominant combination of {100} and {101} forms. These zircons are furthermore transparent to translucent, honey-coloured, and have a gem quality. 97 % of them are anhedral, mostly drop-like rounded. The second subpopulation forms only 5 % of the zircon crystals. 52 % are euhedral with a simple combination of {110} prism and {101} dipyramid. Somewhat smaller crystals are opaque, and red-brown- or grey-coloured. The crystals of both subpopulations are exceptionally large, 1.6 to 9 mm in length.

Parent rock of the placer minerals is the poorly exposed and strongly altered Hohwiese lapilli basalt breccia, near the placer locality. The first subpopulation, according to the zircon typology and other features, probably originated from alkaline basalt, thus the parent rock must be the lapilli in the Hohwiese basalt. Zircons of the second subpopulation are typical granitic zircons, which originated most likely from rare granitic xenoliths in the Hohwiese basalt.

KEY WORDS: zircon typology, gem placer, Tertiary volcanism, Saxon Switzerland (Sächsische Schweiz).

Introduction

Heavy minerals from the gem placer of the Seufzergründel Stream have been well known for a long time. The very interesting history of mining since the 16th century was described by Stelzner (1871), Wiedemann (1961a, 1962 b), Mädler (1991) and Tietz (1999).

The placer is situated in the eastern part of the Saxon Switzerland region (Sächsische Schweiz), south of the village of Hinterhermsdorf and near the border with the Czech Republic. The Seufzergründel is a small left-hand-side valley of the Kirnitzsch River (Fig. 1).

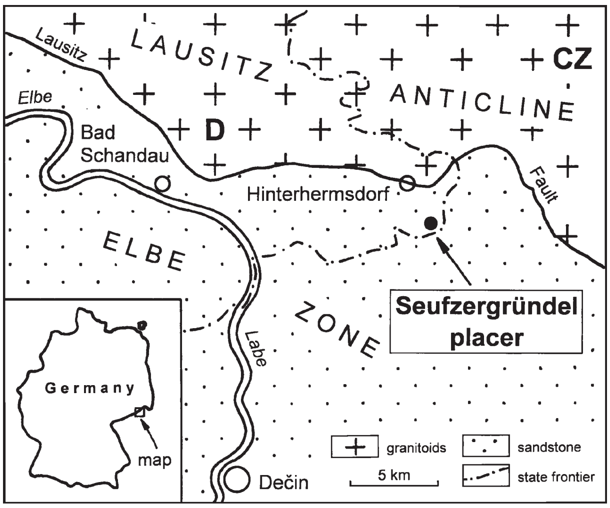

Fig. 1. Geological sketch-map of the Saxon and Bohemian Switzerland with the location of the investigated zircon placer.

The following study is based on four sample sets from private collectors. The largest collection contains over 4700 crystals and was created in the 1970s by F. Wagenknecht near Dresden, today in possession of the Staatliches Museum für Naturkunde Görlitz (Tietz 1999). A set of 5871 zircon crystals was investigated within this study (Table 1).

Geological and mineralogical situation

The source for the heavy minerals of the Seufzergründel placer was unknown for a long time. Herrmann and Beck (1897) first described the near locality of very poorly exposed glassy basaltic tuff breccia from the Hohwiese meadow as the true parent rock. The investigations of Tröger and Seifert (1963), Wiedemann (1961b and 1962a) and Bautsch et al. (1985) supported this

	Crystal forms			
Collection	euhedral	subhedral	anhedral	Total
Giesler	77	22	855	954
Mädler	19	0	63	82
Melchior	10	15	106	131
Wagenknecht	205	109	4390	4704
Total	311	146	5414	5871

Tab. 1. Investigated zircon crystals from the Seufzergründel placer, grouped according to different collections and crystal forms (collections: Giesler and Mädler – private, Wagenknecht and Melchior – Staatliches Museum für Naturkunde Görlitz).

	Heavy min. (in wt. %) 1)	Placer (in wt. %) 2)	Genesis
	(after TRÖGER and SEIFERT 1963)		(after BAUTSCH et al. 1985)
magnetite	70.4 3)	6.8–17 3)	high crystallization temperature, criteria insufficient for a genetic classification
alkaline Ti-augite	13.3 4)	1.3–2.1 4)	from basalts (or cumulative)
amphiboles	6.2	0.65–0.94	hornblende = from basalts (probably cumulative), kaersutite = accidental origin (xenocryst)
orthopyroxene (bronzite variety)	7.7	0.74–0.61	origin agnate to accidental, corresponds to high p-T conditions without deformation effects (after Tröger and Seifert 1963: Mg-rich bronzite)
spinel (ceylonite)	2.2	0.21–0.65	spinel to hercynite (non-uniform genesis)
zircon	0.2	0.01–0.03	certainly of different origin (was not studied or analysed in detail)
maghemite	(see above)	(see above)	origin obscure
diopside	(see above)	(see above)	similar to pyroxene xenocrysts of the Upper Lusatian Tertiary basalts
diopside (Cr-rich)	(see above)	(see above)	similar to olivine nodules in Ostritz basalt (spinel peridotite of the mantle)
ilmenite			?cumulative (iserine var.), external origin (picroilmenite var.), ?basaltic derivation (ilmenite s.s.)
apatite			insignificant
almandine			probably of metamorphic origin
corundum	together	together	no relevant data (Wagenknecht 1993 only – without genetic remarks)
rutile (nigrine var.)	0.2	0.02–0.04	genetic classification problematic
pyrope			high-pressure paragenesis (?kimberlitic, garnet peridodite or crystalline basement)
olivine			no significant criteria (after Tröger and Seifert 1963: chrysolite)
Sum	100%	9.7–21. 3 %	

1) for all heavy minerals (excl. limonite und hematite)
2) for washed and dried raw placer (first value: fossil placer, second value: recent placer)
3) with maghemite
4) with diopside and Cr-rich diopside

Tab. 2. Heavy minerals of the Seufzergründel placer, their distribution pattern and mineral genesis (compiled after literary data – see table heading and text).

genetic interpretation. According to these authors, the Seufzergründel placer is of eluvial genesis with the maximum transport distance of some 10 or 100 metres.

Today, 16 different heavy minerals are known from the Seufzergründel placer (Table 2). The crystal sizes commonly range between 0.2 and 20 mm, up to 45 mm in some specimens (for a colour microphoto of a small collection see Tietz 1999, Fig. 1). The petrogenetic origin of the heavy minerals is, according to the investigations of Bautsch et al. (1985), very different (see Table 2). A part of them are of basaltic origin (e.g., augite), but the other part shows a genesis under high pressure and must have originated from the lower crust or upper mantle (e.g., pyrope).

Data on the petrology of parent rock of the placer, the so-called "Hohwiese rock" (Wiedemann 1961b) are not of good quality because natural outcrops are only rare and the rocks are strongly altered. In addition, a small number of samples is known from some shallow boreholes with more or less altered rock material. According to the petrographic thin-section studies from this material, the Hohwiese rock is a basaltic lapilli-tuff (Wiedemann 1962a) or a basaltoid breccia (Bautsch et al. 1985) with about 60 % basaltic fragments (lapilli size), glass or cryptocrystalline matrix (15 %) and about 25 % xenoliths (proportions after Bautsch et al. 1985). Most of the xenoliths are formed by the country rock (i.e., Cretaceous sandstones and marlstones), but about 1 % of the xenoliths and xenocrysts are of exotic character. These are mostly formed by mafic rocks (more or less serpentinized pyroxene or mica peridodites, gabbroids), rarely granitoids and several xenocrysts, as in the Seufzergründel placer. Zircon crystals have never been observed in thin or polished sections (Bautsch, oral communication).

A range of indications argue for a kimberlite-like nature of the Hohwiese rock: (1) the pipe-like shape of the Hohwiese chimney, (2) the pyroclastic breccias fabric (diatreme), (3) rare kimberlitic xenoliths and (4) some high-pressure, high-temperature minerals in the Hohwiese rock and the derived placer.

The outcrop of the Hohwiese basalt is surrounded by Upper Cretaceous sandstones of the Bohemian Cretaceous Basin. The locality is situated on the northern margin of the Elbe Lineament Zone near the Lusatian Fault and in the middle of the Saxo-Thuringian Zone of the Variscan basement (Fig. 1). In the neighbourhood, the Lusatian Fault is intersected by the northeastern continuation of the Erzgebirge Fault. This fact is presumably important for the unusual occurrence of minerals in the Hohwiese rock and the derived Seufzergründel placer (see also Bautsch et al. 1985 and Ulrych and Uher 1999, Ulrych et al. 2000).

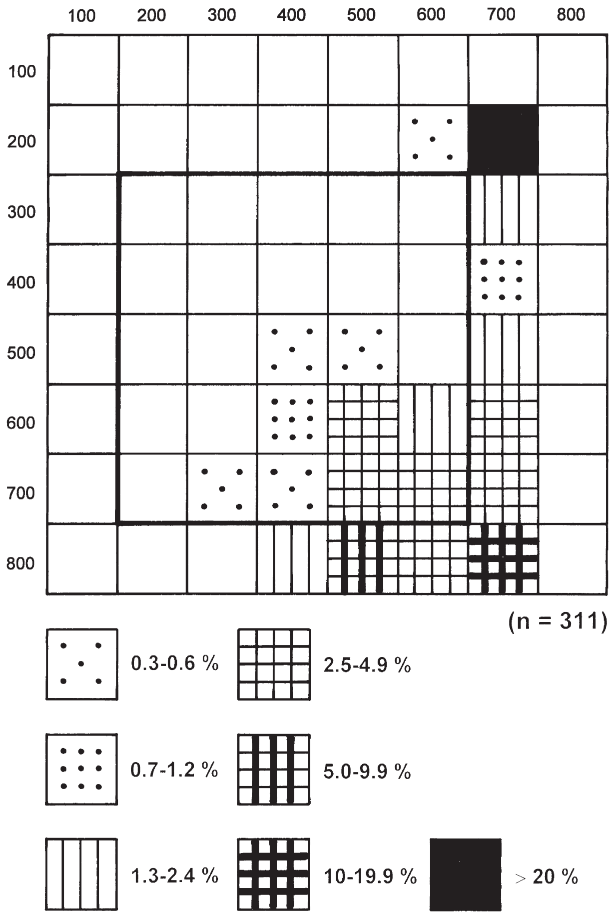

Fig. 2. Typological distribution of the euhedral Seufzergründel zircons according to the classification of Pupin (1980).

Study of zircon crystals

History

Stelzner (1871) described two crystal types of zircon already, but he gave no details about their colour. On the other hand, Tröger and Seifert (1963) distinguished two colour types with one crystal shape. Wagenknecht (1993) only differentiated between three zircon types according to colour, transparency and crystal morphology: rounded, more or less transparent normal type and two euhedral and rare types with generally opaque character and yellow-red or brown-grey colour. The last classification from Wagenknecht (1993) does not differ much from these investigations.

Zircon typology

Among the 5871 zircon crystals investigated, it was possible to determine 311 crystals according to the zircon typological classification after Pupin (1980; Fig. 2). All other crystals are more or less rounded without clear crystal faces. Among euhedral, mostly subangular crystals, two main subpopulations with two subordinate types (see below) are observed. The first subpopulation (n = 153) contains 17 different types in the lower right corner of the Pupin's diagram, the mean being the S_{25} subtype (mean point for the first subpopulation: 606 – horizontal I.A.-axis and 719 – vertical I.T.-axis). The most frequent type is type D (48 crystals), with {100} prism and {101} bipyramid. All other crystals have additional but subordinate {110} prism and/or {211} bipyramid.

It must be stated that the determination of the generally weakly subangular zircon crystals is difficult for those with very slim crystal faces (Fig. 3). It is possible for these crystals that the registration recorded a higher number of zircon types with simple combinations of crystal faces and prefers a small number of "main" types. That is probably the reason why the mean subtype (S_{25}) is not the same as the median type (D).

The second subpopulation (n = 158) contains only three subtypes in the upper right corner of the Pupin's diagram, with dominance of G_1 subtype and very rarely P_1 and L_5 subtypes (Fig. 2). The most developed is the combination of {110} prism with {101} bipyramid (Fig. 4). The mean point is situated inside the P_1-field with mean typological point I.A. = 699 and I.T. = 204. Weakly subangular zircon crystals predominate also here; it is, therefore, possible that the rare P_1 and L_5 subtypes and some other neighbouring types appear more often.

The two subpopulations plot directly next to each other in the Pupin's diagram (Fig. 2). However, is it possible to distinguish the two subpopulations by other typical features, such as the colour and transparency.

Further zircon features

All characteristics of the zircon crystals are summarized in Tab 3. Furthermore, both subpopulation can be distinguished into two subordinate types "a" and "b".

Crystals of subpopulation 1a are transparent and colourless to yellow brown, whereas subpopulation 1b is translucent-spotted and light to dark yellow-brown (Fig. 4). All zircon crystals from the first subpopulation have a typical honey-like colour and are of gem quality (for a colour microphoto of zircons from both subpopulations see Tietz 1999, Fig. 2). Unbroken crystals have an average length of 4.1 mm (±1.35 mm, n = 120). Macroscopically visible zoning is very rare and only weakly developed, without a core or rim structures. Cathodoluminescence images from nine cut and polished crystals show a well-developed and continuous zoning, but no older crystal cores (Finger, writing communication). All these features indicate an early and uniform magma crystallisation.

Crystals of subpopulation 2a are non-transparent or partly weakly translucent and are red-brown in colour; subpopulation 2b is yellowish (reddish) grey in colour. Unbroken crystals are not very large, having a mean length of 3 mm (±1.2 mm, n = 90). A special feature of the second subpopulation are intergrowths of twins and compound twins parallel or subparallel to the c-axis (35 to 45 % of all crystals, Fig. 4). Locally, they show artichoke-like intergrowths.

According to the significant features of colour and transparency, it was possible to sort all zircon crystals into the main and subordinate subpopulations. As the number of euhedral crystals changed in 1 : 1 ratio, the distribution of all crystals shows a very different pattern. About 95 % of all zircons belong to the first subpopulation (5540 crystals) and only approximately

Fig. 3. A selection of euhedral zircons (Subpopulation 1) illustrating the clear gem quality and the partly rounded, partly sharp fracture planes. Upper row: D-type and lower row: different S-types after Pupin (1980). Photomicrograph in reflected light (field height ca. 9 mm).

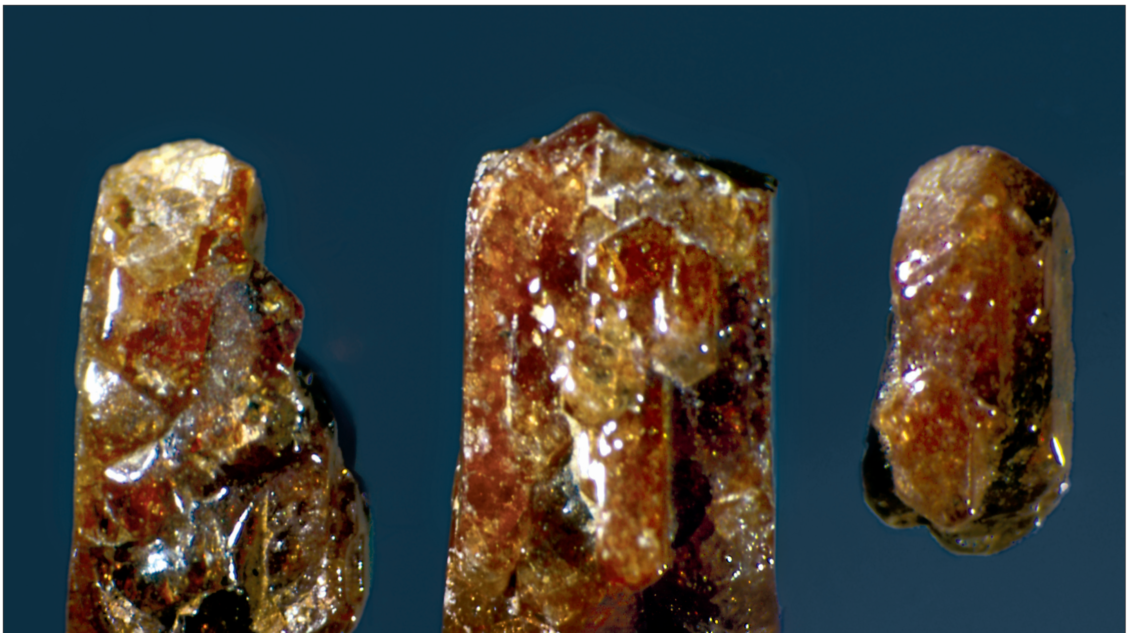

Fig. 4. Three euhedral zircons (subpopulation 2) with characteristic twinning. G_1-subtype after Pupin (1980). Photomicrograph in reflected light (field height ca. 9 mm).

Subpopulation	1a	1b	2a	2b
Number	1809 (30.8 %)	3731 (63.5 %)	230 (3.9 %)	101 (1.7 %)
Types (Pupin 1980)	D, J, S, P		G_1 (very rarely P_1 and L_5)	
transparency	transparent	translucent (spotted)	non-transparent to weakly translucent „spotty-dirty“	non-transparent (crystal edges partly translucent)
colour	colourless to yellow brown (honey-coloured)	light to dark yellow brown (honey-coloured)	mostly red brown	grey (dark grey and greyish brown), yellowish (reddish)
colour distribution	mostly homogeneous, rarely spotted	dark cristals often spotted	partly light grey stains (e. g. pyramids)	blurred spotted
crystal form: euhedr. **subhedral** **anhedral**	126 (7 %) 111 (6 %) 1572 (87 %)	27 (1 %) 13 (0,5 %) 3691 (98.5 %)	116 (50 %) 15 (7 %) 99 (43 %)	42 (42 %) 7 (7 %) 52 (51 %)
crystal face	smooth as glass	smooth as glass rarely finely pitted	smooth, partly local finely pitted	smooth
cracks	(very) rare and only few large-sized		many, reticular	
lustre	adamantine lustre		adamantine lustre	
break (euhedral crystals) **not broken into pieces** **sharp-edged** **fracture plane rounded**	 25 % 50 % 25 %	 25 % 50 % 25 %	 65 % 35 % 0 %	 35 % 65 % 0 %
fracture planes	stair-like, uneven or conchoidal, rarely even and smooth		mostly uneven-rough	
lustre of the cleavage planes	greasy or dry adamantine lustre	mostly dry adamantine lustre	greasy adamantine lustre	greasy adamantine lustre
cleavage	distinct to indistinct	distinct to indistinct	distinct (indistinct)	indistinct
intergrowths	only one intergrowth parallel to c-axis	only two intergrowths parallel to c-axis	45 % twins and compound twins	35 % twins and compound twins
inclusions	rare: small, rounded to shapeless opaque minerals (0.1–1 mm) very rare: (?rutile) needles, cracks extreme rare: (columnar) cavities		partly visible: small and large non-transparent aggregates	not visible
zoning	very rare and only weakly developed (without core and rim structures)		?	only by one crystal at cleavage plane
habit (only complete xx) **length (mean)** **length (min.–max.)** **width (mean)** **length: width**	of 120 crystals 4.13 mm ±1.35 mm 2.0–8.5 mm 1.94 mm ± 0.73 mm 2.21 ± 0.47		of 90 crystals 3.01 mm ± 1.19 mm 1.6–9.0 mm 1.28 mm ±0.46 mm 2.39 ± 0.56	
other features	gem quality anhedral crystals rounded euhedral crystals subangular		negative casts of other crystals	horn-like crystals
			euhedral crystals subangular	

Tab. 3. The most distinctive macroscopic features of zircon crystals from the Seufzergründel placer. Crystals are subdivided into two subpopulations 1 and 2 and subordinate types a and b (see text).

5 % represent the second subpopulation (331 crystals; Table 3). For this reason, the first subpopulation constitutes only 3 % of the euhedral crystals and the second subpopulation 48 % of all investigated zircon crystals.

Many anhedral zircons of the first subpopulation are rounded and drop-like with a smooth surface (48 % from the anhedral crystals). The most anhedral zircons of the second subpopulation consist again of crystals rounded on edges (57 %), drop-like crystals being less frequent (23 %). Both subpopulations furthermore contain about 20 % sharp-edged broken crystals, partly with rounded plane cleavage within the first subpopulation (two generations of cleavage planes here, Fig. 3).

Petrogenetic interpretation and discussion

According to the petrogenetic classification of Pupin (1980), zircons of the dominant first subpopulation fall into the field of alkaline basalts with gem-quality zircons for non-granitic rocks (Fig. 5). Crystallization temperature is very high: 800 to 900 °C according to Pupin (1980). Based on the large number of crystals, the parent rock for this subpopulation are the basaltic fragments (lapilli) of the Hohwiese basalt.

It has to be noted that the genesis of gem-quality zircons from alkaline basalts is not well explained, since only 5 samples have been studied so far by Pupin (1980) from Madagascar, Cambodia, Tasmania and the Massif Central (France). Nevertheless, he favours a mantle origin for the parent rock. Many new studies from eastern Australia including Tasmania, Thailand and Scotland show that the source of zircon and other gem minerals in alkaline basaltic rocks is very complex and not yet known in all details (e.g., Irving 1986, Hinton and Upton 1991, Coenraads et al. 1995 or Sutherland at al. 2002). These authors favour an involvement of evolved sialic or (nepheline) syenitic melts in the development of gem-quality zircons instead of direct growth in the alkaline basaltic magma.

Similarly, Hollies and Sutherland (1985) gave a detailed description of gem-quality zircons from 32 eastern Australian placer localities. The host rocks of the zircons are mostly alkali basalts and some trachytes. The zircons are typically accompanied by corundum, black spinel, ilmenite and partly by pyroxenes, olivine, amphiboles, and garnets – likely the Seufzergründel placer. In addition, the size, colour and development of the crystal shape is the same as in the Seufzergründel zircons. From the nine morphological groups, four are almost identical to the first subpopulation of the Seufzergründel zircons based on physical crystal features (size, colour, transparency and crystal typology). Hollies and Sutherland (1985) showed that the large zircons from eastern Australia are of diverse origin. They identified (1) a cognate origin in a fractionated basaltic magma, particularly in their salic end members, and (2) accidental sources from syenitic intrusives, plutonic cumulates and pegmatites.

Sutherland et al. (2002) investigated gem-quality zircons from a small gem field in eastern Australia without complex volcanic evolution through time and source magma of the provider eruptive rocks. They showed that the zircons crystallized in deeply evolved salic melts before transport in basalt.

Similarly large zircon crystals also occur in pegmatites from alkaline granites and nepheline syenites. Such origin is known from xenoliths or composite megacrysts in alkali basalts in Scotland, where zircon megacrysts intergrow other pegmatitic crystals or polycrystalline syenite xenoliths (Aspen et al. 1990, Upton et al. 1999). In contrast, Ulrych and Uher (1999) stated that an early magmatic stage of the alkali basalt magma is probably the primary source for the placer zircons of N Bohemia. The zircons from three investigated placer localities are low-hafnium types; only zircons from nepheline syenite xenoliths in an alkaline basalt pipe breccia of Košťálov Hill represents Hf-rich type (Ulrych and Uher 1999). One of the two types of the low-hafnium placer zircons is similar to the zircons from

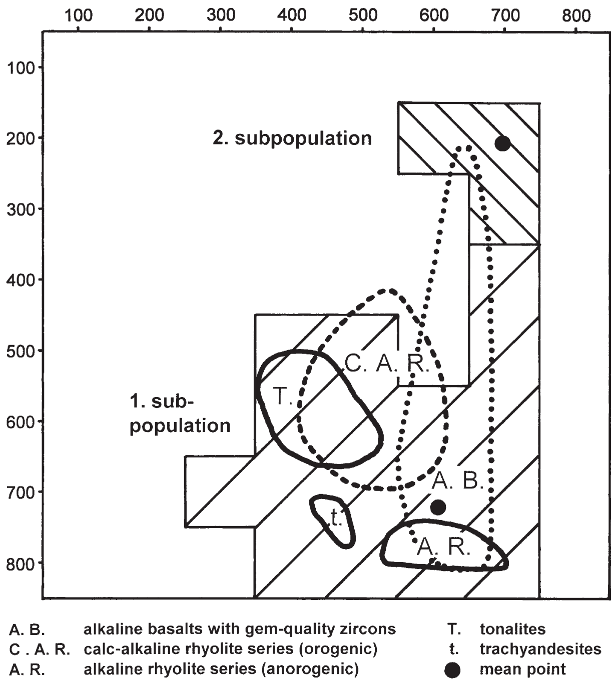

Fig. 5. The Seufzergründel zircon morphology pattern compared to some non-granitic groups of endogenous rocks after Pupin (1980).

the first subpopulation from the Seufzergründel placer according to colour, transparency, size and crystal morphology. This fact favours alkaline basalt as the primary source for the first subpopulation of the Seufzergründel zircons in the same sense as Pupin (1980), see above.

Zircon megacrysts up to 1 cm in size are also well known from kimberlites (Kresten et al. 1975). These zircons form rounded to subrounded grains, euhedral crystals being very rare. However, their typical surfaces have a frosted and pitted appearance (Mitchel 1986), which is lacking in the Seufzergründel zircons. Furthermore, zircon is a rare accessory phase in most kimberlites. Another doubtful explanation is a genesis in metamorphic rocks, e.g., in granulites or eclogites. Metamorphic zircon crystals are mostly rounded and clear but distinctly smaller, with a maximum length of 0.3 mm (Heede 1996).

Summing up all data, the Seufzergründel zircons of the first subpopulation must have originated from an alkaline basaltic source rock. Presently, there are no indications for a salic rock source for these zircons.

Zircons of the second subpopulation are typical granitic zircons (cf. Tietz 1996), and according to the Pupin's classification especially typical for hybrid or mantle granites (Pupin 1980). The crystallization temperature of about 600 °C is very low. The G_1 zircons are typical also for granitic pegmatites or occur as late magmatic generation in granitic rocks (mainly S-type), locally also in subsolvus A-type granites (Uher, writing communication). The primary rock for these zircons could be the granitic xenoliths in the Hohwiese basalt. These rare xenoliths correspond well with the very low number of zircons of the second subpopulation.

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