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The sediments of the Bautzen Elbe River: distribution, composition and reconstruction of the river course

Die Sedimente der Bautzener Elbe: Verbreitung, Zusammensetzung und Rekonstruktion des Flusslaufes

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Abstract

Between Dresden and the Neiße River different gravel deposits with pebbles of predominantly Bohemian and eastern Erzgebirge provenance are observed. Genieser (1955) firstly combined these deposits in the so-called Bautzen Elbe River stratigraphically belonging to the Tegelen Complex of Early Pleistocene age. Due to the distribution of these sediments, three arms (Rietschen, Weißwasser and Kamenz arms) of the Bautzen Elbe River have been differentiated (Wolf & Schubert 1992). Since the investigations done by Fliegner (1955) and Buchwald (1966), no detailed analyses were made of these fluvial sediments. Modified outcrop conditions and new sediment-petrographic interpretations give reason for further analyses of the deposits. Based on various studies by Genieser (1955, 1957, 1962) and the different relating map sheets from Koch & Alexowsky (1999a, b) and Standke (1994, 1999), 15 deposits were explored and documented. In eight outcrops sampling was successful. In total, 27 samples have been analysed for composition, granulometry and morphometry (Reichelt 1961, Zingg 1935). The deposits of the Cunnersdorf outcrop were identified as probably not representing sediments of the Bautzen Elbe River.

Kurzfassung

Verschiedene Schottervorkommen mit Geröllen vorwiegend böhmischer und osterzgebirgischer Herkunft zwischen Dresden und dem Grenzfluss Neiße wurden erstmals von Genieser (1955) als Ablagerungen der sogenannten Bautzener Elbe zusammengefasst. Stratigraphisch wird die Bautzener Elbe dem frühpleistozänen Tegelen-Komplex zugeordnet. Aufgrund der Verbreitung der Sedimente werden drei Verläufe der Bautzener Elbe unterschieden: ein Rietschener, ein Weißwasserer und ein Kamenzer Arm (Wolf & Schubert 1992). Seit den Bearbeitungen von Fliegner (1955) und Buchwald (1966) wurden keine detaillierten Untersuchungen mehr an diesen fluvialen Sedimenten vorgenommen. Veränderte Aufschlussbedingungen und neue sedimentpetrographische Interpretationen geben Anlass für eine erneute Analyse dieser Ablagerungen. Auf der Basis verschiedener Studien von Genieser (1955, 1957, 1962) und mehrerer Kartenblätter von Koch & Alexowsky (1999a, b) sowie Standke (1994, 1999) wurden 15 Aufschlüsse aufgesucht und dokumentiert. In acht Aufschlüssen war eine Beprobung erfolgreich. Insgesamt wurden 27 Proben bezüglich Zusammensetzung, Granulometrie und Morphometrie analysiert (Reichelt 1961, Zingg 1935). Die bei Cunnersdorf aufgeschlossenen Schottervorkommen sind voraussichtlich nicht der Bautzener Elbe zuzuordnen.

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Fig. 1. Typical outcrop situation of the Bautzen Elbe River deposits exemplified at Roter Berg near Strohschütz. The quartz-rich fluvial sediments cause a relief inversion due to their weathering resistance.

1. Introduction and geological setting

At the beginning of the Pleistocene (Quaternary) strong climate changes with decreasing temperatures effected several ice ages of different intensities and extensions and influenced the distribution of the different fluvial deposits in Saxony, also concerning the Bautzen Elbe River. The largest expansion of the ice mass was reached during the Elster glacial period and it is marked by the so-called Feuersteinlinie (Grahmann 1934, Wagenbreth & Steiner 1990). South of this line deposits contain no Nordic components. At the pass of Jítrava the ice crossed the watershed of Bohemia and Nordic sands and gravels were transported into the Bohemian Basin (Eißmann 1997). In the following, these materials were partly fed into the Elbe River by smaller streams and returned to Saxon territory this way (Pietzsch 1956). During the cold periods the ice cover reduced or stopped the water flow of many rivers, so banded clay layers could develop in glacial lakes and later were covered by the basal moraine. Thereafter, rising temperatures led to a warmer and maybe more humid climate causing a stronger weathering and thus a loamification and a reddish colouration of the sediments (Pietzsch 1962). Reviving rivers effected stronger erosion, formed the relief and changed the flow regime (Präger 1976). At some places, due to their weathering resitance the overlaying quartz-rich sediments saved the underlying kaolinitic layers and form single hills in the present landscape (Buchwald 1966; Fig. 1). The study area has not been reached by the ice during the following Weichsel glacial period. Nevertheless, it was periglacially influenced and covered with loess, sand loess and quicksand (Pietzsch 1962). Before 10,000 years, during the Pleistocene–Holocene boundary interval, the northern regions of Germany became iceless and therefore the influence of the ice on climate, vegetation and sedimentation decreased.

First findings of terraces of the Elbe River are reported from Engelmann (1911) and Grahmann (1934) showing very different classifications. Genieser (1955) continued Grahmann's work but followed the former course of Elbe River further to the north. He tried to correlate the terraces of northern Bohemia with the gravel deposits of the Elbe River and gave them their names still used today, like the Bautzen Elbe River. Heavy mineral analyses and searching for climate notes followed and additionally, he tried to interpret and determine the ages of palaeocourses of the Elbe River (Genieser & Diener 1958). Later terrace classifications were made by Präger (1976, 1984) and Wolf (1980).

According to Genieser (1955, 1957, 1962) gravel deposits of the Bautzen Elbe River have been preserved in Kleingießhübel, Struppen, Coblenz, Kamenz, Bautzen, Rietschen, Gozdnica (Freiwaldau, Poland), Weißwasser, Großwig, Roitzsch and Neiden. Additionally, there are also some outcrops with redepostited gravel material of the Bautzen Elbe River. The distribution of these gravels makes it necessary to distinguish between three arms of the Bautzen Elbe River: a Rietschen, a Weißwasser and a Kamenz arm (Wolf & Schubert 1992; Fig. 2).

Eißmann (1997: 21) described the composition of the Bautzen Elbe River deposits as a "varying, typical Quaternary pebble association" with quartz-lydite content of

Abb. 1. Typische Aufschlusssituation der Bautzener Elbeschotter am Beispiel Roter Berg bei Strohschütz. Die quarzreichen fluvialen Sedimente bedingen durch ihre Verwitterungsresistenz eine Reliefumkehr.

usually less than 75%. Heavy minerals such as sillimanite, staurolite, andalusite and augite dominate and allow inferences for the determination of corresponding drainage areas of the Elbe River. On the one hand, a high percentage of feldspar components in crystalline rocks is transformed into kaolinite. On the other hand, fresh components exist, thus showing that the sources for the material must have been very different. Within the river deposits all typical, classifying index components from Bohemia and the eastern Erzgebirge are included, especially quartz-lydite conglomerate, tephrite, microgranite or granite porphyry and Tharandter Wald rhyolite pebbles (Genieser & Diener 1958). Furthermore, remarkable are cryoturbations and ice-wedge pseudomorphosis as observed at several localities (Schubert 1980). Palaeomagnetic measurements done by Wiegank (1982) on clay layers at Kleingießhübel indicate a normal magnetisation (probably Olduvai Event). Therefore, the deposits of the Bautzen Elbe River fit into the Tegelen Complex of Early Pleistocene age.

2. Samples

2.1. Cunnersdorf (33U, 435438 N, 5684676 E; 185 m)

The outcrop at Roter Berg, situated between Biehla and Cunnersdorf, 5 km northwest of Kamenz, is an open kaolin pit with an up to 14 m thick gravel package on top. The pit is operated by the Stephan Schmidt Meißen GmbH. The underlying yellowish-beige to brown-black kaolin emerged from the greywackes of the Radeburg-Kamenzer Grauwackenzug and was formed *in situ* during the Late Cretaceous and Early Tertiary. It is capped by some sediments of Late Tertiary to Early Pleistocene age probably belonging to the Senftenberg Elbe River. These ca. 3 m thick fluvial deposits mainly consist of coarse-grained gravels and gravelly sands, partially bigger boulders are observed. As the upper 2 m thick part of this unit obviously differs in composition from the lower portion, three samples were taken from distinct levels to separate a possible Bautzen Elbe River from the older Senftenberg Elbe River (CUN 2–4). At the western and northern edge of the pit an erosional edge is formed causing a local sediment thickness of up to 14 m. During the Elster glacial period, the kaolinitic units and the river deposits were partly eroded and redeposited (Schellenberg & Kleeberg 1997).

2.2. Wiesa (33U, 439320 E, 5679162 N; 200 m)

This open kaolin pit is located ca. 1 km south of Kamenz (no. 1 in Fig. 2; Pl. I, Fig. A). It also belongs to the Stephan Schmidt Meißen GmbH. The granodiorite at the base of this pit is part of the Lausitz Granitoid Suite (Linnemann & Romer 2002). During the Late Tertiary, the upper portions of this complex weathered to a varicoloured kaolinitic succession of a total thick-

Table 1. List of unsampled localities.

Tabelle 1. Liste der unbeprobten Aufschlüsse.

Locality	UTM-coordinates (WGS 84)	Altitude	Map	Current situation
Guhra (no. 5 in Fig. 2)	33U, 450410 E, 5676874 N	203 m	Koch & Alexowsky (1999) map sheet 2569 Kamenz	Refilled with construction waste, entry to the pit is not allowed, the whole area is overgrown
Storcha (no. 6 in Fig. 2)	33U, 451143 E, 5674730 N	200 m	Koch & Alexowsky (1999) map sheet 2569 Kamenz	Placed in the middle of the village on a little hill, which is built-up
Großwelka (no. 8 in Fig. 2)	33U, 456614 E, 5673734 N	207 m	Koch & Alexowsky (1999) map sheet 2569 Kamenz	Ca. 500 m northwest of the village, used for agriculture
Cölln (no. 9 in Fig. 2)	33U, 457319 E, 5675029 N	200 m	Koch & Alexowsky (1999) map sheet 2569 Kamenz	Overbuilt
Teichnitz (no. 10 in Fig. 2)	33U, 458590 E, 5672334 N	210 m	Koch & Alexowsky (1999) map sheet 2569 Kamenz	Situated on a little hill below the abandoned factory buildings of the former VEB Plattenwerk Bautzen
Weißwasser (no. 12 in Fig. 2)	33U, 473685 E, 5704184 N	140–145 m	Koch & Alexowsky (1999) map sheet 2470 Weißwasser	Apparently refilled and completely covered by wood; perhaps sediments of the Bautzen Elbe River are still available in the neighbouring opencast lignite mine Nochten adjoining directly to the forest in the south
Niesky (no. 13 in Fig. 2)	33U, 488380 E, 5684387 N	185 m	Standke (1994, 1999)	The whole area is covered by wood, sampling was not possible

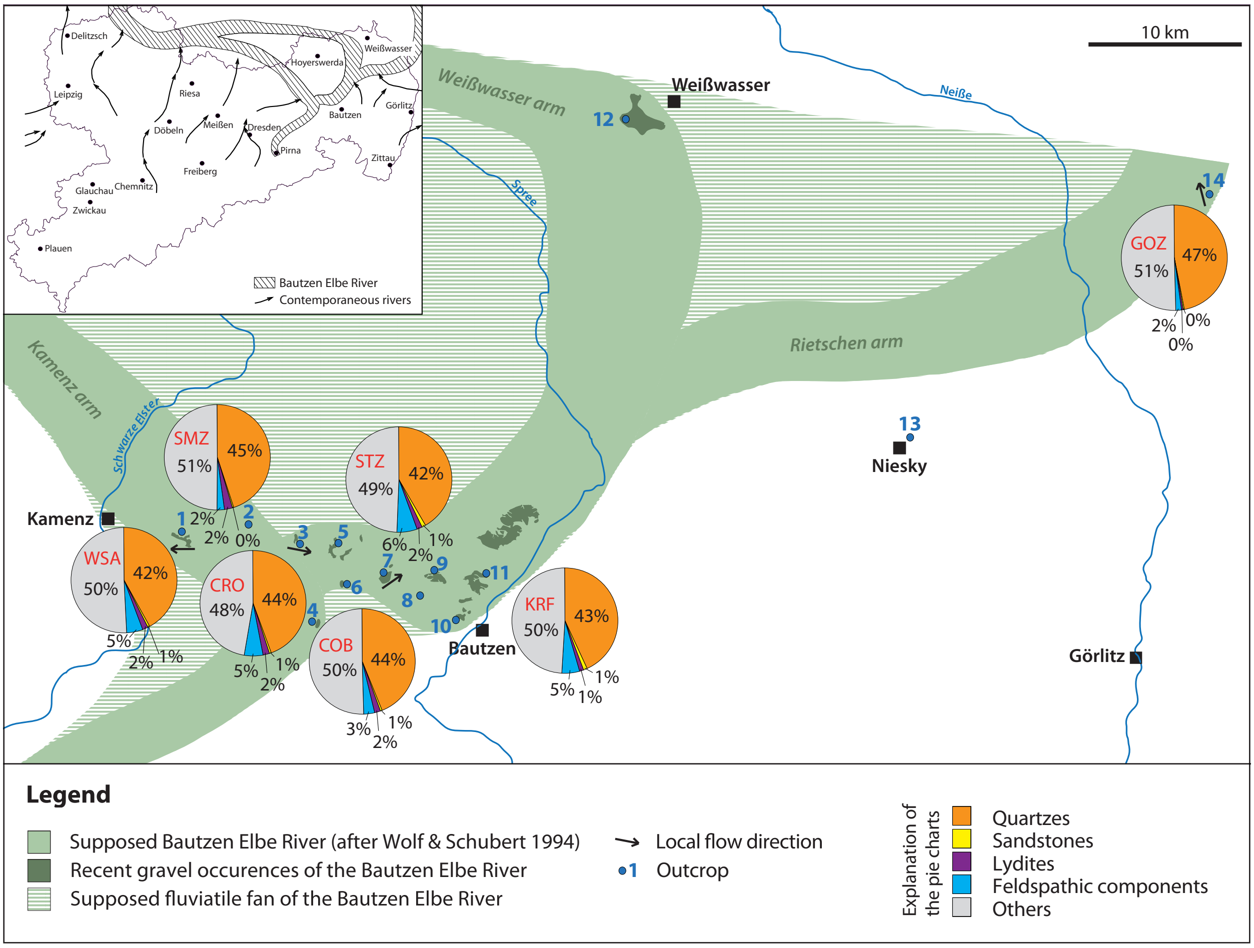

Fig. 2. General map showing the three arms of the Bautzen Elbe River in the area of the eastern Lausitz (modified after Wolf & Alexowsky 2008). The sample locations are indicated by dots and numbers: **1** – Wiesa (WSA), **2** – Schmeckwitz (SMZ), **3** – Crostwitz (CRO), **4** – Coblenz (COB), **5** – Guhra (unsampled), **6** – Storcha (unsampled), **7** – Strohschütz (STZ), **8** – Großwelka (unsampled), **9** – Cölln (unsampled), **10** – Teichnitz (unsampled), **11** – Kronförstchen (KRF), **12** – Weißwasser (unsampled), **13** – Niesky (unsampled), **14** – Gozdnica (GOZ, Freiwaldau, Poland).

Abb. 2. Übersichtskarte des Gebietes der östlichen Lausitz mit den drei Armen der Bautzener Elbe (verändert nach Wolf & Alexowsky 2008). Die Probenlokalitäten sind durch Punkte und Nummern markiert: **1** – Wiesa (WSA), **2** – Schmeckwitz (SMZ), **3** – Crostwitz (CRO), **4** – Coblenz (COB), **5** – Guhra (unbeprobt), **6** – Storcha (unbeprobt), **7** – Strohschütz (STZ), **8** – Großwelka (unbeprobt), **9** – Cölln (unbeprobt), **10** – Teichnitz (unbeprobt), **11** – Kronförstchen (KRF), **12** – Weißwasser (unbeprobt), **13** – Niesky (unbeprobt), **14** – Gozdnica (GOZ, Freiwaldau, Polen).

ness of 20 – 60 m. Thus, the kaolin is regarded as an autochthonous unit. The transition between the granodiorite and the kaolin is gradual. Although this transitional zone mostly is ca. 3 m thick, its thickness can increase enormously. Up-section, following a sharp transition, the kaolin is covered by a package of Tertiary sediments. These are represented by light to dark grey clays with some intercalations of Lower Tertiary coal layers. This unit strikes from north-northwest to south-southeast. According to Rascher & Plüschke (1999) the 4.5 m thick topmost portion of the succession is formed by Quaternary clays, sands and gravels. Within these sediments some single drift blocks as well as cryoturbatic formations document the influence of alternating icing and melting processes (Pl. I, Fig. B). Five samples from the Quaternary sandy and gravely intervals were taken at the south eastern edge of the pit (WSA 1 – 5; dipping: 15° – 35°).

2.3. Schmeckwitz
(33U, 444485 E, 5679090 N; 185 – 190 m)

Neumann & Schmidt (1990) mentioned melt water deposits from the Elster glacial period and scattered gravel deposits of a former Elbe River with an Early Pleistocene age for the area northeast of Schmeckwitz (no. 2 in Fig. 2). The location is situated between Wendischbaselitz and Räckelwitz in the outer rim of the Lugewald. The glacial and fluvial sediments are underlain by Tertiary units also including thin bedded, but workable coal layers. These certainly gave the main reason for the mining of the gravel deposits some decades ago. The entire succession of the Lower Pleistocene sediments has a thickness of ca. 6 – 7 m. Currently, slope failure is proceeding. Nevertheless, it was possible to take a sample in the periphery from ca. 0.5 m below ground level (SMZ).

2.4. Crostwitz
(33U, 448131 E, 5677375 N; 205 m)

In this open kaolin pit, situated between Kamenz and Bautzen, sedimentary deposits of the Bautzen Elbe River show a thickness of ca. 4 m (Pl. I, Fig. C). The pit is located ca. 500 m northeast of Crostwitz in the area of the Galgenberg (no. 3 in Fig. 2). The operating company is the Umwelt- und Baustoffaufbereitung Neschwitz GmbH. Up-section, the kaolin is covered by some sedimentary units, which contain no flints and were deposited before the Elster glacial period. Genieser (1955) classified them as deposits of the Bautzen Elbe River. Later they were described by Schubert (1978: 6) as "genetically and stratigraphically differentiated fluvial and glaciofluvial gravelly sands, which are separated by a distinct erosional unconformity". The composition of the gravel deposits is characterised by a mixture of fine- to medium-grained and partially coarse-grained gravelly sands containing scattered basaltic and phonolitic pebbles of diameters of up to 50 cm (CRO 1 – 3; Pl. I, Fig. D). These bigger components are mostly weathered intensely and thus, they crumble during the washing and sieving processes. Up-section, an interval of cryoturbatic, fine-grained sandy to silty layers occurs. This is separated by an unconformity from the overlying 5 m thick package of melt water sediments. Moreover, Schubert (1978) mentioned involutions, syn- and epigenetic ice wedges. As reported, a ground moraine and a hillside loam have been exposed during a previous outcrop situation.

2.5. Coblenz
(33U, 449329 E, 5671927 N; 230 m)

Ca. 300 m west of Coblenz (no. 4 in Fig. 2), on the road to Pannewitz, remains of a small forest occur on the left hand side. Gravel deposits of the Bautzen Elbe River are supposed at this locality. The investigated sedimentary unit is ca. 0.5 – 1 m thick. Two samples were taken from this locality. The first sample comes from within the small forest, the second one is from ca. 50 m further to the street (COB 1 and 2).

2.6. Strohschütz
(33U, 454059 E, 5675176 N; 199 – 203 m)

Gravel deposits of the Bautzen Elbe River are reported from the Roter Berg close to the village of Strohschütz (Fig. 1; no. 7 in Fig. 2). Bastian et al. (2005) described a widespread sand mining from that locality in 1933. The resulting former outcrop exposing a 5 m thick sediment succession of Bautzen Elbe River deposits is still clearly identifiable, although the area is overgrown since many decades. The sampling conditions were good because the pit was not refilled and the rib sides were freely accessible. At the northwestern edge of the pit, sampling was successful (STZ 1 and 2; dipping: 10° – 17°).

2.7. Kronförstchen
(33U, 459606 E, 5674066 N; 203 m)

The Helaswald is located close to the village of Kronförstchen, on the road from Quatitz to Lubachau (no. 11 in Fig. 2). In the middle of this small forest ca. 1 m thick gravel deposits from the Bautzen Elbe River are assumed, due to the information from Koch & Alexowsky (1999a). Primarily, sampling (KRF) was successful for investigations using compositional and sedimentary approaches. However, further selective excavations demonstrated that this occurrence probably represents just a small rest of a gravel deposit showing an incomplete succession. Additionally, the area in general is strongly overgrown or used for agriculture.

2.8. Gozdnica (33U, 504672 E, 5699084 N; 171 m)

Another outcrop sediments were analysed from is located ca. 1 km west of Gozdnica (Freiwaldau, Poland) and ca. 25 km northeast of Niesky (Germany; no. 14 in Fig. 2; Pl. I, Fig. E). It is an open kaolin pit and since 2000 operated by CRH Klinkier Gozdnica. There, a dark grey kaolinitic unit at the base is up-section followed by an interval of fine- and medium-grained sandy alternations and a clay layer with some coal-bearing horizons. This succession is capped by a 6 m thick package of gravels on top, which Genieser (1955) defined as deposits of the Bautzen Elbe River (Pl. I, Fig. F). Samples for further analyses (GOZ 1: 2 m below ground level, GOZ 2: 4 m below ground level, GOZ 3: 6 m below ground level) were taken at the northwestern slope of the new pit.

All unsampled localities are listed in Tab. 1.

3. Methods

Altogether, 15 outcrops were visited but only in eight of them sampling was successful. 20 samples were investigated by granulometric, morphometric and pebble analytical methods at the Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Sektion Petrographie. In addition, pebbles with sizes > 20 mm were collected and integrated as reference material into the collection of the Sektion Petrographie. In some outcrops it was possible to measure the stratification (see discussion below). After washing and drying, pebbles were separated in individual grain sizes by 10 minutes of mechanical sieving and a following hand sieving. All pebbles were sorted according to their petrographic determination to get an overview about the composition. For several components, it was necessary to break them up, to remove their weathering crusts or to prepare thin-sections of them. The subsequent investigation and petrographic classification was achieved with a polarising microscope. The group of "granitoids" contains all granitoids, regional as well as Nordic ones. Volcanic rocks are distinguished by their composition ("feldspar-volcanic rocks" and "alkaline volcanic rocks"). The group of "quartzites" only consists of metaquartzites. "Gneisses" form an own group and are separated from the group of "schistose quartzites, quartz-mica and mica schists". Roundness analyses of all pebbles were made sensu Reichelt (1961). Four classes or categories are distinguished herein: angular, subangular, rounded and (very) well rounded (Fig. 3). We only used monocrystalline and polycrystalline quartzes of grain sizes from 6.3 – 10 mm and 10 – 20 mm for these investigations because of their weathering resistance and the possibility of long way transport. Shape analyses of all pebbles were made *sensu* Zingg (1935). Also depending on the axes' lengths, he divides the pebbles into four different categories: oblate (disk), equiaxial (sphere), triaxial (bladed) and prolate (roller). The corresponding axial ratio defines the shape of the pebble. The values of the individual ratios lie between 0 and 1.The limiting value for the ratios of b/a and c/b is 2/3 (Fig. 3). These latter data provide no evidence for the grade of roundness.

4. Results and discussion

The results of the investigations for composition, roundness and morphometry conducted on 17 samples from seven localities (WSA 1 – 5; SMZ; CRO 1 – 3; COB 1, 2; STZ 1, 2; KRF; GOZ 1 – 3) are given in the following (Figs. 4, 5; Tab. 2, 3). The samples from Cunnersdorf (CUN 2 – 4) are not considered in this article as further investigation and analysis showed that they do not represent gravel deposits of the Bautzen Elbe River.

Monocrystalline and polycrystalline quartzes are the dominant components in all analysed samples. Index pebbles from all possible source areas occur: lydites from Bohemia, sandstones from the Elbsandsteingebirge as well as granitoides, gneisses and mica schists together with agates and amethysts from the eastern Erzgebirge. Tertiary quartzites as a distinctive feature are also present in almost all samples.

Flints or characteristically red Scandinavian granites as Nordic pebbles are absent (Figs. 4, 5; Tab. 2). The observed typical and conspicuous siliceous crusts were already described by Schubert (1978) for the Crostwitz locality. In several samples "dove-blue pebbles" are recognised (see Genieser 1955). Microscopic investigations show that these special pebbles contain smallest amounts of mica, quartz and fragments of other rocks as well as remains of radiolaria. Particularly striking are the isolated, sponge spiculae as biogenic components. Currently, the rock material these pebbles originate from is not identified and thus, also their provenance is not yet clarified. During the cooperation with the Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie (LfULG) in Freiberg, it has been suggested that the "dove-blue pebbles" derived from a source area with silicified sedimen-

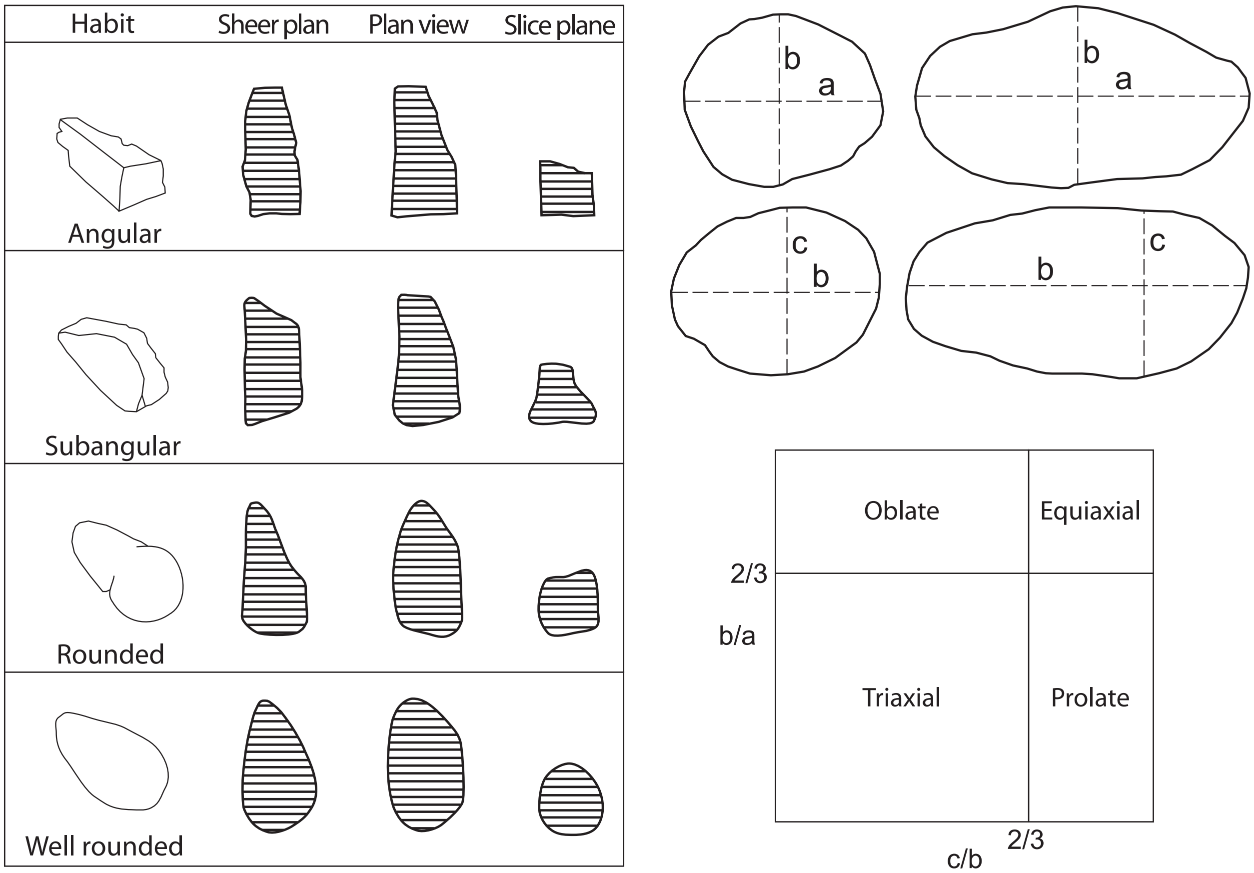

Fig. 3. Classification of grain roundness (after Reichelt 1961) and shape (after Zingg 1935).

Abb. 3. Klassifizierung der Kornrundheit (nach Reichelt 1961) und Kornform (nach Zingg 1935).

tary rocks in the Czech Republic (e.g., Předni Kopanina, northwest of Prague).

All analyses of roundness were made only on monocrystalline quartzes. The fractions of rounded and angular pebbles are highly variable in content. Well rounded pebbles are rare or absent. In nearly all samples more than 50% of all grains are classified as subangular. An exception makes sample COB 2 (10 – 20 mm) that lies faintly below this value with its 49% of subangular grains (Fig. 6; Tab. 3). Simultaneously, in this sample the portions of angular and rounded pebbles reach the highest percentage of about 25% for each of them. The advantage of the method of Reichelt (1961) is doubtlessly the rough and rapid determination of roundness, but the implied subjectivity possibly leads to incorrect conclusions and interpretations.

The shape analyses *sensu* Zingg (1935) revealed no clear results (Fig. 7; Tab. 3). For a precise arrangement, the mean values of every shape analysis were separated into size clusters. Even though their plots in the larger scale equiaxial field are situated too close together as single tendencies would be identifiable. Along the whole course of the Bautzen Elbe River the morphometry of the pebbles changes only slightly or not at all. There is no significant increase of roundness downstream. That means that either the shaping was completed in the headwaters, or some tributaries brought fresh material.

Measurements relating to flow velocity and flow direction display controversial results (Fig. 2). The deposits in Wiesa show a direction of strike of 204 – 300° (dipping: 15 – 35°), thus implying a south- to northwestern flow direction and sedimentation trend. According to Wolf & Schubert (1992) Wiesa maybe marks the place of the third deflection of the Bautzen Elbe River (Kamenz arm). In Crostwitz the striking shifts to a northeastern to southwestern direction (077 – 150°) with decreasing dip angles of 10 – 15°. Strohschütz shows northeastern striking trends (010 – 045°) with a dipping similar to Crostwitz (10 – 17°). In Gozdnica the direction of striking changes again to northwest (298 – 328°) and very low-angle dipping (3 – 10°) implicates a strong decrease of flow velocity.

Probably a first deflection of the Bautzen Elbe River to a northwestern direction is indicated here, represented by the Rietschen arm. In conclusion, a continuous river system with eastwards decreasing transport and water energy is obvious. As the majority of the quartzes from Gozdnica shows rough and bumpy surfaces, problems in their classification of roundness were caused, predominantly in the clusters "rounded" and "subangular". Additionally, some single, light bluish monocrystalline quartzes occur, especially in the small grain size fractions. Possibly, these pebbles were brought by a former Neiße River from the south.

Table 2. Numerical results of composition analyses from all samples: **a**, grain size 6.3 – 10 mm; **b**, grain size 10 – 20 mm.

Tabelle 2. Numerische Ergebnisse der Zusammensetzungsanalysen aller Proben: **a**, Korngrößenbereich 6,3 – 10 mm; **b**, Korngrößenbereich 10 – 20 mm.

Sample	**WSA 1**		**WSA 2**		**WSA 3**		**WSA 4**		**WSA 5**		**SMZ**		**CRO 1**		**CRO 2**	
Grain size	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Quartzes (monocr.)	303	287	95	6	347	127	328	104	266	36	786	346	554	234	259	300
Quartzes (polycr.)	33	38	12		58	27	64	19	28	6	132	50	106	18	36	37
Cell quartzes													1		1	
Vein quartzes			2				1		2		1		2			1
Amethysts														1		
Agates/jaspers																
Feldspars	15	2	6		26	1	15	3	30	3	25	1	30	1	15	1
Sandstones	3	2	2	1	7	2	3	1	3		8	7	5	1	5	3
Conglomerates	1				2						1		1		1	
Cherts		2			4				1		5				2	1
Greywackes	1												3	1	6	
Rhyolites	1	1	1		5	1	6			1	1	1	4	1	10	1
Feldspar-volcanic rocks															1	
Alkaline volcanic rocks				3												
Granulites																
Granitoids	20	5	8	1	12	1	6	2	32	3	21	1	31	9	30	9
Gneisses			1	1	1									1	1	1
Lydites	18	29	6	1	16	8	11	10	13	2	48	11	32	19	20	18
Quartzites	15	14	3	1	35	2	12	5	8	5	57	28	6	8	9	2
Tertiary quartzites			1		1	2	1		2		3	2	2	1	5	2
Schistose quartzites, quartz-mica and mica schists	3		3	1			4		2		1	1	7		10	5
"Dove-blue pebbles"		4			2	2	4	2	4		5	1	3		5	
Climate witnesses															1	
Undefined	77	17	36		20	9	23	11	50		30	7	5	1	6	3
TOTAL	**490**	**401**	**176**	**15**	**536**	**182**	**478**	**157**	**441**	**75**	**1123**	**457**	**792**	**296**	**423**	**384**

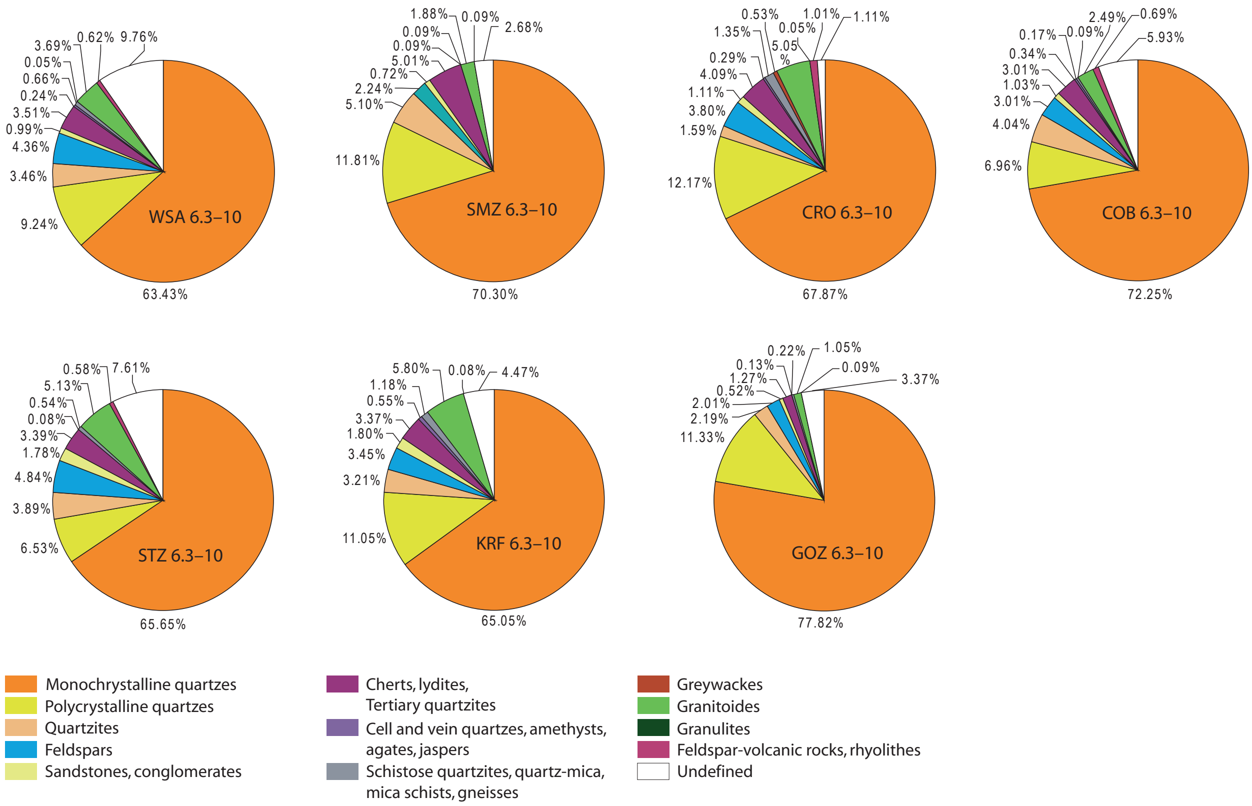

Fig. 4. Graphical illustration of the results of composition analyses of grain sizes 6.3 – 10 mm.

Abb. 4. Graphische Darstellung der Ergebnisse der Zusammensetzungsanalysen im Korngrößenbereich 6,3 – 10 mm (Legende siehe Abb. 5).

Table 2 – continued.

CRO 3		COB 1		COB 2		STZ 1		STZ 2		KRF		GOZ 1		GOZ 2		GOZ 3		**Sample**
a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	B	Grain size
598	187	409	156	432	210	683	159	905	211	830	313	642	131	693	154	444	34	Quartzes (monocr.)
111	38	26	14	55	28	37	12	121	28	141	46	74	12	151	37	34	6	Quartzes (polycr.)
																		Cell quartzes
	2	2			1					3	1	1			1	2	1	Vein quartzes
2		1																Amethysts
		1				2			1	4								Agates/jaspers
34	4	25	2	10		71	5	46	1	44	5	46	2					Feldspars
11	6	1	2	10	4	20	1	23	8	23	3	5	1	5		2		Sandstones
		1									1							Conglomerates
		1			2	5	3	9	2	5	7							Cherts
2	6			1														Greywackes
6	3	4		4		6	2	8		1		2	2					Rhyolites
																		Feldspar-volcanic rocks
		2																Alkaline volcanic rocks
1																		Granulites
44	6	4	5	25	3	87	8	37	8	74	6	11	2	12	1	1		Granitoids
1	1			1		3		2		2								Gneisses
21	25	16	11	17	16	28	6	37	18	33	10	15	6	3	5			Lydites
18	18	15	14	32	9	34	18	60	17	41	12	34	5	13		3		Quartzites
3	1			1		2	1	1	1	5	2	4	1					Tertiary quartzites
9	2			1		4	5	4	3	13	4	4				1		Schistose quartzites, quartz-mica and mica schists
		1	3		1		5	4		4		3	1					"Dove-blue pebbles"
																		Climate witnesses
11	4	50	19	19	27	134	26	50	18	57	29	49	20	16	14	12	6	Undefined
872	**303**	**559**	**226**	**608**	**307**	**1116**	**251**	**1307**	**316**	**1280**	**432**	**897**	**183**	**893**	**212**	**499**	**47**	**TOTAL**

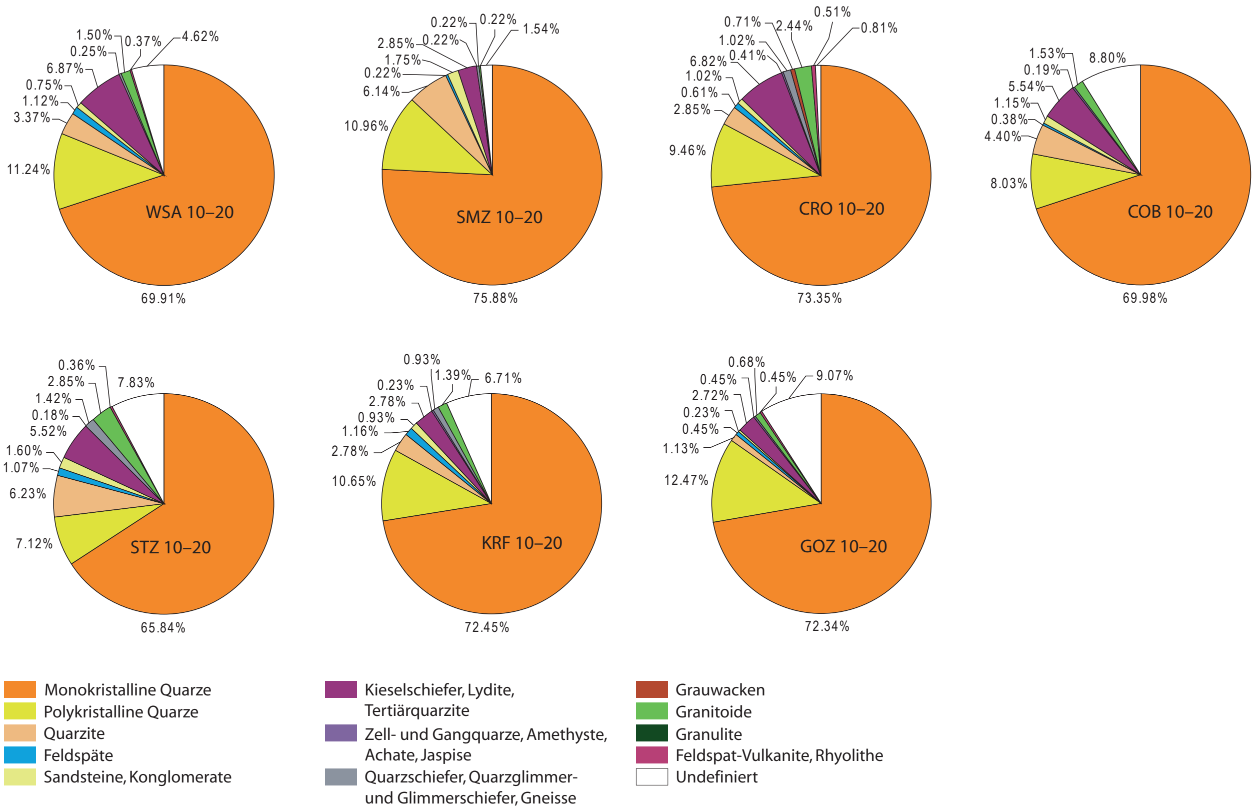

Fig. 5. Graphical illustration of the results of composition analyses of grain sizes 10–20 mm (for legend, see Fig. 4).

Abb. 5. Graphische Darstellung der Ergebnisse der Zusammensetzungsanalysen im Korngrößenbereich 10–20 mm.

Fig. 6. Results of roundness analyses of grain sizes 6.3 – 10 mm and 10 – 20 mm after Reichelt (1961).

Abb. 6. Ergebnisse der Rundheitsanalysen im Korngrößenbereich 6,3 – 10 mm und 10 – 20 mm nach Reichelt (1961).

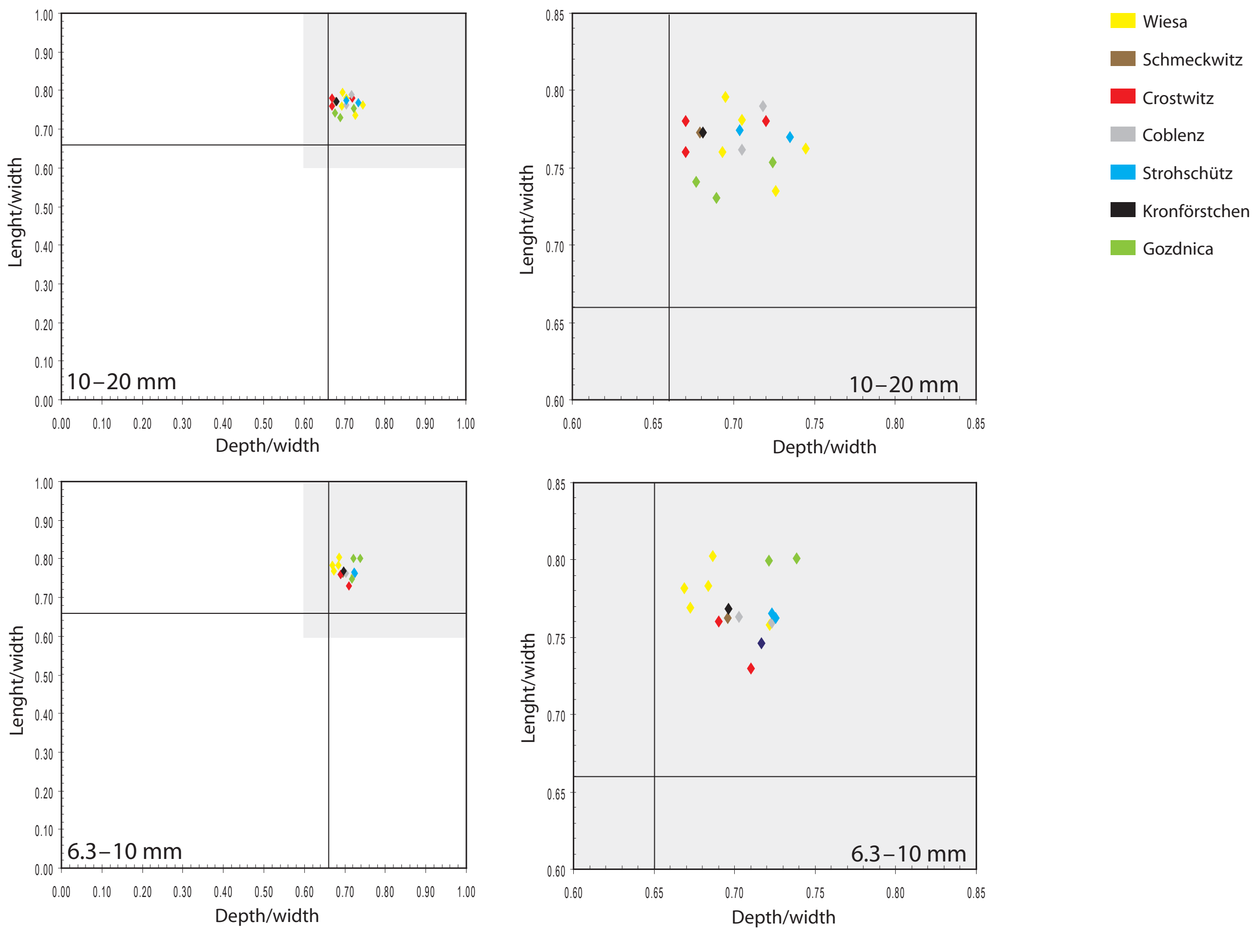

Fig. 7. Graphical illustration of the results of shape analyses of grain sizes 6.3 – 10 mm and 10 – 20 mm after Zingg (1935).

Abb. 7. Graphische Darstellung der Ergebnisse der Formanalysen im Korngrößenbereich 6,3 – 10 mm und 10 – 20 mm nach Zingg (1935).

Table 3. Numerical results of roundness and shape analyses from all samples: **a**, grain size 6.3–10 mm; **b**, grain size 10–20 mm; **n**, number of investigated pebbles.

Tabelle 3. Numerische Ergebnisse der Rundheits- und Formanalysen aller Proben: **a**, Korngrößenbereich 6,3–10 mm; **b**, Korngrößenbereich 10–20 mm; **n**, Anzahl der untersuchten Gerölle.

Sample		Angular [%]	Subangular [%]	Rounded [%]	Well rounded [%]	Width/ length	Depth/ width
WSA 1	a; n = 303	3.6	84.2	12.2	0	0.78	0.67
	b; n = 287	1.4	77.0	21.3	0.3	0.76	0.69
WSA 2	a; n = 95	2.1	90.5	7.4	0	0.77	0.67
	b; n = 6	0	100.0	0	0	0.73	0.73
WSA 3	a; n = 347	3.5	85.6	10.9	0	0.80	0.69
	b; n = 127	0	79.5	20.5	0	0.78	0.71
WSA 4	a; n = 328	3.7	79.2	17.1	0	0.78	0.68
	b; n = 104	1.9	87.5	10.6	0	0.76	0.74
WSA 5	a; n = 266	1.1	83.8	14.7	0.4	0.76	0.72
	b; n = 36	0	83.3	16.7	0	0.80	0.69
SMZ	a; n = 786	5.0	82.8	12.0	0.2	0.76	0.70
	b; n = 346	2.0	76.0	21.7	0.3	0.77	0.68
CRO 1	a; n = 661	2.7	93.2	4.1	0	0.76	0.69
	b; n = 252	2.4	91.2	6.0	0.4	0.76	0.67
CRO 2	a; n = 295	8.5	86.5	4.7	0.3	0.73	0.71
	b; n = 337	3.9	88.1	7.1	0.9	0.78	0.72
CRO 3	a; n = 709	3.1	89.3	7.5	0.1	0.76	0.69
	b; n = 225	4.5	92.0	3.1	0.4	0.78	0.67
COB 1	a; n = 409	11.5	75.5	13.0	0	0.76	0.70
	b; n = 156	5.1	87.2	7.7	0	0.76	0.71
COB 2	a; n = 432	29.9	59.2	10.9	0	0.76	0.72
	b; n = 210	24.8	49.0	25.2	1.0	0.79	0.72
STZ 1	a; n = 683	8.8	85.9	5.3	0	0.76	0.73
	b; n = 159	4.4	88.7	6.9	0	0.77	0.73
STZ 2	a; n = 905	3.7	84.0	12.3	0	0.77	0.72
	b; n = 211	1.0	90.5	8.5	0	0.77	0.70
KRF	a; n = 830	1.9	86.2	11.8	0.1	0.77	0.70
	b; n = 313	0.6	80.5	18.9	0	0.77	0.68
GOZ 1	a; n = 642	1.2	87.9	10.7	0.2	0.75	0.72
	b; n = 131	1.5	87.0	10.7	0.8	0.75	0.72
GOZ 2	a; n = 693	3.7	89.2	7.1	0	0.80	0.72
	b; n = 154	7.1	92.9	0	0	0.74	0.68
GOZ 5	a; n = 444	3.6	91.9	4.5	0	0.80	0.74
	b; n = 34	8.8	91.2	0	0	0.73	0.69

5. Summary

The results of the analyses of 17 samples from the Bautzen Elbe River are in general agreement with those of Wolf & Schubert (1992). Nevertheless, our new data provoke a more detailed discussion and led to the interpretation of potentially representing a huge gravel fan. The different values of flow velocity and flow direction can be explained as local variances within a single river system. Based on the equality of all samples concerning the roundness and composition, a simultaneous sedimentation within the coexisting three arms of the Bautzen Elbe River is assumed.

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Plate I

Photographic documentation of three selected outcrops exposing gravel deposits of the Bautzen Elbe River.

A Deposits of the Bautzen Elbe River overlying granodiorite, kaolin and kaolinitic clay in the active open kaolin pit at Wiesa near Kamenz.

B Cryoturbations have been observed within the deposits of the Bautzen Elbe River e.g., in the open kaolin pit at Wiesa.

C In the active open kaolin pit at the Galgenberg near Crostwitz the sediments of the Bautzen Elbe River cover the kaolin.

D The drift boulder of a two-mica granodiorite occurs within the deposits of the Bautzen Elbe River in Crostwitz.

E In the topmost part of the active open kaolin pit at Gozdnica (Freiwaldau, Poland) also gravel deposits of the Bautzen Elbe River are exposed.

F Erosional structures prove the incising of the sediments of the Bautzen Elbe River into the underlying Tertiary units e.g., clay layers.

Tafel I

Fotografische Dokumentation von drei ausgewählten Aufschlüssen mit Schotterablagerungen der Bautzener Elbe.

A Sedimente der Bautzener Elbe überlagern Granodiorit, Kaolin und kaolinitischen Ton im aktiven Kaolintagebau in Wiesa bei Kamenz.

B In den Ablagerungen der Bautzener Elbe treten Kryoturbationen auf, wie hier im Kaolintagebau Wiesa.

C Im aktiven Kaolintagebau am Galgenberg bei Crostwitz wird der Kaolin von Sedimenten der Bautzener Elbe überdeckt.

D Der Driftblock eines Zweiglimmergranodiorits befindet sich in den Ablagerungen der Bautzener Elbe bei Crostwitz.

E Im Topbereich des aktiven Kaolintagebaus in Gozdnica (Freiwaldau, Polen) sind ebenfalls Schotter der Bautzener Elbe aufgeschlossen.

F Erosionsstrukturen belegen das Einschneiden der Sedimente der Bautzener Elbe in die unterlagernden tertiären Einheiten, beispielsweise Tonhorizonte.

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