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GeoBerlin 2015

DYNAMISCHE ERDE – von Alfred Wegener bis heute und in die Zukunft. Exkursionsführer

DYNAMIC EARTH – from Alfred Wegener to today and beyond. Excursion guide

GeoBerlin 2015. Dynamische Erde. Exkursionsführer/Dynamic Earth. Excursion guide

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Titelbild:

Friedrichsgracht - Die nach Friedrich Wilhelm von Brandenburg (1620–1688) benannte Straße liegt am westlichen der beiden Flußarme, die die Spreeinsel (Alt-Cölln) umfassen. Im Haus No 57 kam am 1. November 1880 Alfred Wegener (kleines Foto) zur Welt. Der zweigeschossige Barockbau war seit 1812 Sitz einer seit 1734 bestehenden privaten Stiftung, die verwaisten Söhnen von preußischen Beamten eine angemessene Erziehung und Schulbildung zuteilwerden ließ. Alfred Wegener‘s Vater Richard stand der als Schindlersches Waisenhaus stadtbekannten Einrichtung vor. Im Zuge der Umgestaltung der südlichen Spreeinsel (Fischerinsel) bis hin zum Schloßplatz (Staatsratsgebäude) wurde die gesamte historische Bebauung, darunter mehrere denkmalgeschützte Häuser, in den 1960er Jahren abgerissen, einzig das 1885/86 vollendete Pfarrhaus der St. Petrigemeinde Friedrichsgracht 53–55 mit seiner schönen Ziegelfassade blieb verschont und erlaubt es heute, die Position des Geburtshauses von Alfred Wegener zu bestimmen (aus Wutzke 2015, dieser Band).

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Inhaltsverzeichnis

Bussert, R. & Juschus, O. (2015): Classical sites of the Quaternary northeast of Berlin. – In: Röhling, H.-G. (Hrsg.): Geo Berlin 2015. DYNAMISCHE ERDE – von Alfred Wegener bis heute und in die Zukunft. Exkursionsführer / DYNAMIC EARTH – from Alfred Wegener to today and beyond. Excursion guide. – Exkurs.f. u. Veröfftl. DGG, 255: S. 9-16; Hannover.

GeoBerlin 2015 Exkursion 02

Classical sites of the Quaternary northeast of Berlin

Robert Bussert[2], Olaf Juschus[1]

[1] University of Sustainable Development Eberswalde, Faculty of Land Use Management and Nature Conservation, Schicklerstr. 5, D-16225 Eberswalde, Germany

[2] Technische Universität Berlin, Institute of Applied Geosciences, Ackerstraße 76 ACK 1-1, D-13355 Berlin, Germany

Introduction: Geological and geomorphological settings of the excursion area

The field trip area is located roughly 50 km northeast of Berlin's city center (Fig. 1, 2). It represents a classical region of Quaternary geology that shows the archetypical Weichselian glacial landscape and near-surface geology of northeastern Germany. Key morphological units are the morainic upland area of the Barnim, the ice marginal valley ('Urstromtal') of Toruń-Eberswalde, comprising the Oderbruch depression, and the end moraine ridges of the Pomeranian stage that are located few kilometers to the north of the Urstromtal. Due to the wealth of well-developed landforms and its proximity to Berlin the area was recognized as key region of Quaternary research in the late 19th century (Lüthgens and Böse 2012), at a time during which the glacial theory had become widely accepted.

Morphology and geology of the excursion area are the result of south-directed advances of the Scandinavian Ice Sheet in the Pleistocene. Glaciogenic and glaciofluvial sediments are regularly 50 to 100 m thick, but reach up to 200 m in Elsterian subglacial tunnel valleys (Stackebrandt & Manhenke 2010). In contrast, outcrops of Pre-Quaternary sediments are rare. Such outcrops normally consist of Oligocene or Miocene sediments that were transported to the surface by glaciotectonics, for example by thrusting and folding in push moraine complexes.

The Late Weichselian Pomeranian end moraine ridge forms a distinct morphological and geological boundary in the area. During the Weichselian, areas south of

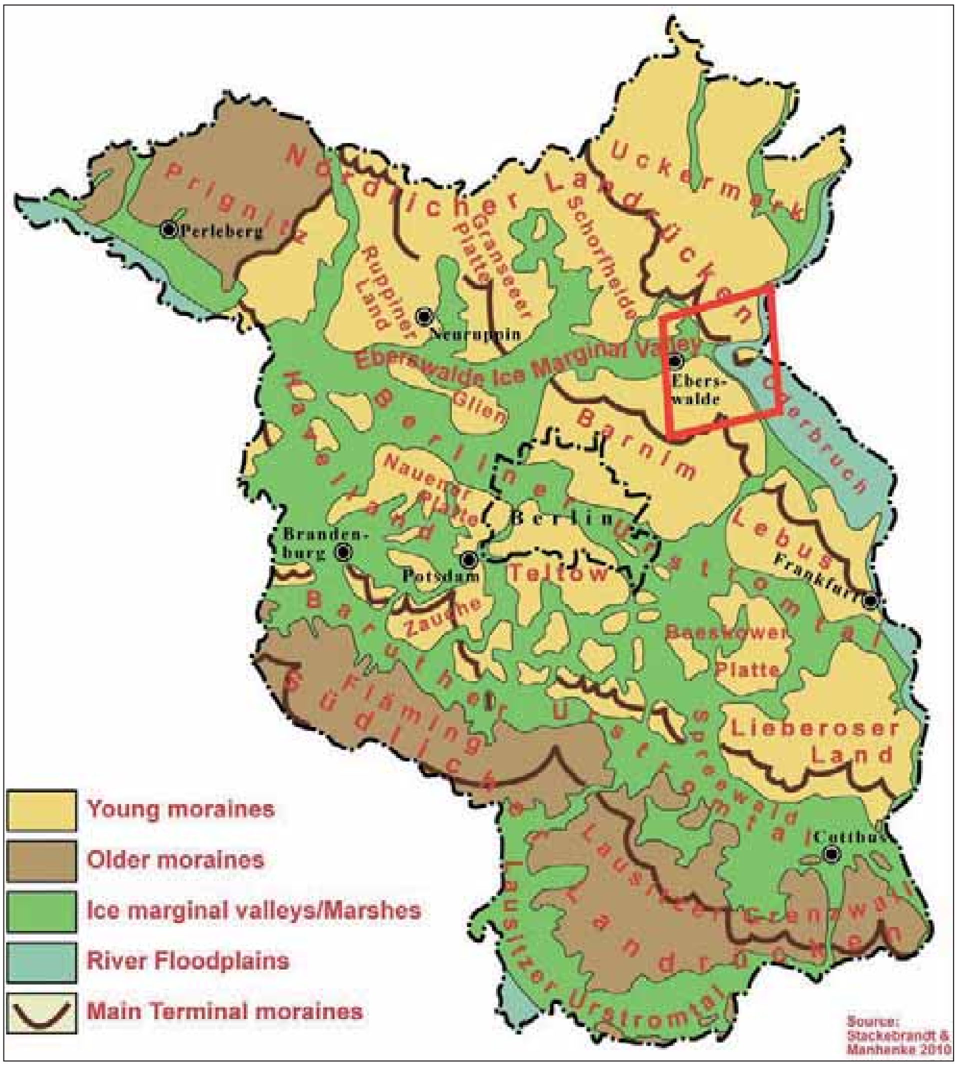

Fig. 1: Geomorphological sketch map of Brandenburg showing major Quaternary landform units. The excursion area is marked as a red rhombus (base map: Stackebrandt & Manhenke eds. 2010).

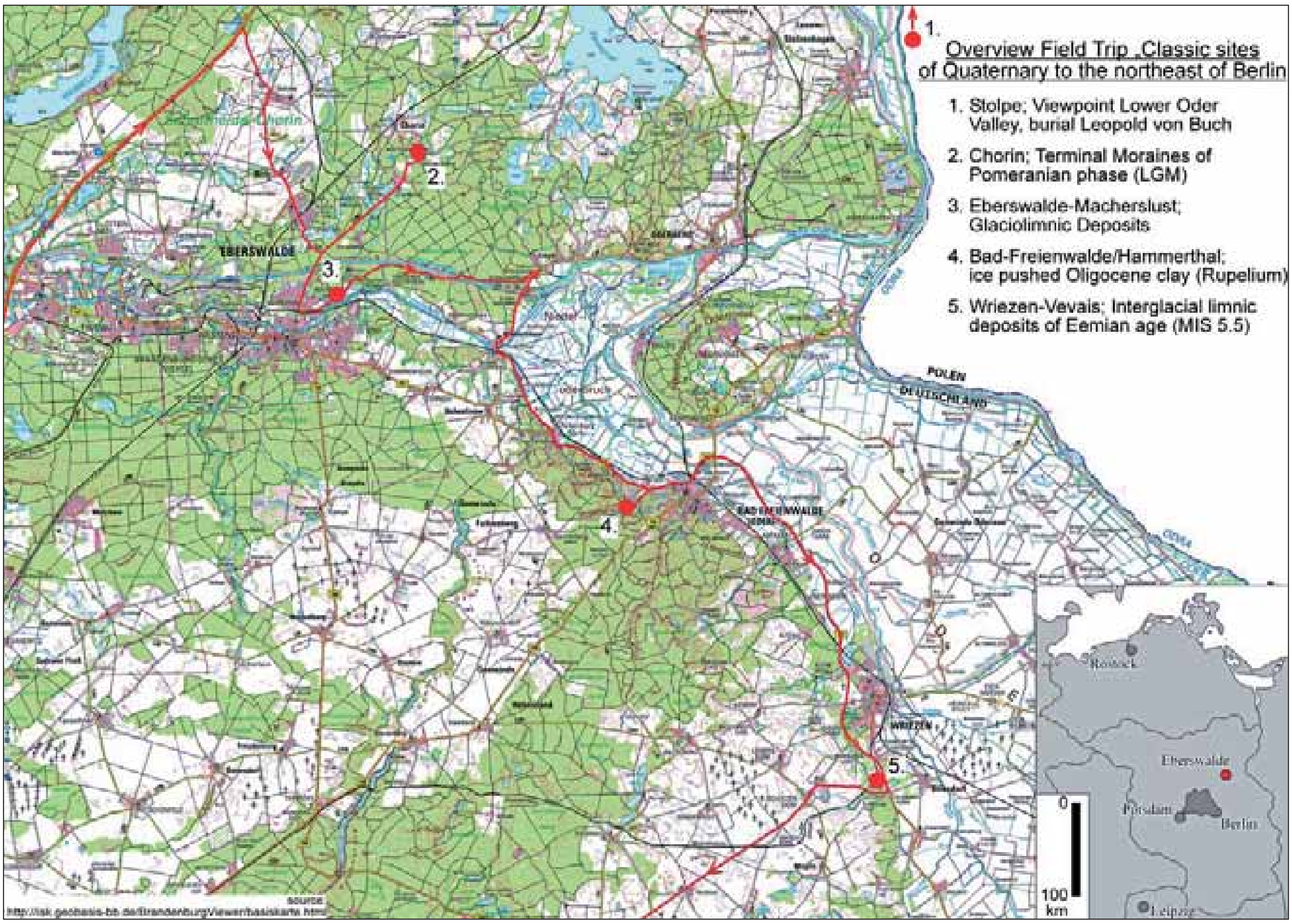

Fig. 2: Excursion stops (base map: Brandenburg Viewer, http://bb-viewer.geobasis-bb.de/).

the end moraines were only affected by the ice advance of the Brandenburg stage, which had very restricted influence on the morphology and geology. Sediments of the Brandenburg stage are rather thin, with tills and pre-ice advance glaciofluvial sediments (‘Vorschüttsande’) that rarely reach a thickness of more than 5 m. Ice-marginal outwash fan sediments (‘Sander’) are patchily distributed and also quite limited in thickness. Thus, the bulk of the Barnim upland consists of deposits of the Saalian ice advance that locally exceed 100 m in thickness. Nevertheless, north of the Pomeranian end moraines, Weichselian sediments are significantly thicker than in the south, up to around 40 m. But even there, they do not reach the thickness of Saalian deposits.

The classical sequence of landforms that formed at a stationary terrestrial ice margin called the ‘Glaziale Serie’ – originally introduced for the Alpine glaciations by Penck (1879) – is ideally developed in the excursion area. The upland areas of the Barnim represent a till plain that was deposited during the Brandenburg ice advance, but the ice-marginal valley of Toruń-Eberswalde as well as the outwash plains and terminal moraines to the north formed during the Pomeranian ice advance.

Stop 1
Stolpe, the Lower Oder valley and the burial place of Leopold von Buch

Stolpe is located in the hinterland of the main ice marginal position of the Pomeranian Ice stage, a region that is characterized by landforms and sediments that relate to minor recessional ice marginal positions. Wealth and variable positions of these sediments and landforms likely reflect a highly mobile ice margin (Stackebrandt et al. 2013). Taken together, the various recessional terminal moraines form the Pomeranian end moraine zone (Lippstreu 2010). However, many of the landforms in the vicinity of the Oderbruch are primarily inherited from Saalian glaciotectonic deformation (Brose 1995).

Before the Oder flows into the Dammenschen Lake close to Szczecin/Stettin, it passes through the Lower Oder Valley, north of the Oderbruch. This river stretch is characterised by an extremely low elevation of the river floodplain, only a few decimetres above sea level while the Oder river almost flows at sea level.

The formation of the Lower Oder Valley as an elongated low lying area most likely is the result of glaciogenic respectively glaciofluvial processes, similar to other large river valleys in Brandenburg (e.g. the valley of the Ücker River) and Mecklenburg-Western Pomerania (e.g. the valleys of the rivers Tollense and Warnow). Different to most other river valleys, which are limited in the south by the Pomeranian ice margin, the Lower Oder Valley breaches the ice margin and continuous southward in form of the Oderbruch depression. Additionally, the Lower Oder Valley forms basins and narrows. The cause of this morphological structuring of the river valley is still disputed.

In the Lower Oder Valley, it seems that the river stretch between Hohenwutzen in the south to the north of Schwedt was established as a morphological depression already in the Elsterian, in form of a subglacial tunnel valley that reaches -150 m b.s.l. But since north and south of this river stretch the base of the Quaternary does not clearly correlates to the surface morphology, the supposed connection could be purely coincidental.

In the narrows of the valley, the modern floodplain occupies the full valley floor, while in the basins High and Late Weichselian terraces are present that correlate to the Randow-Welse ice marginal valley and the ice-dammed lake of Szczecin. The morphology of the terraces is peculiar because it does not show a terrace flight but gradually borders surrounding upland areas. The ultimate cause might be a gradual incision of the main Oder River and the development of a typical point bar and cut bank river morphology. With the shift from glaciogenic to purely fluviatile processes in the Oder Valley during the Bölling period, Brose (1994) suggests a short-term incision of the Oder River down to a level of -40 m b.s.l., while Börner (2007) proposes a maximum incision of just -10 m b.s.l. At the transition from the Late Weichselian to the Holocene, the Oderbruch was located at about -5 m b.s.l. During the relatively arid period of the Pre-Boreal and Boreal, eolian dunes began to form in the Oderbruch. Subsequently, the Oder valley was filled up with fluviatile sands, peat and mud. In the course of anthropogenic deforestation that started at latest in the mediaeval period, organic-rich floodplain clays were deposited that now dominate the modern flood plain.

Stolpe is located in one of the basin-like widenings of the Oder Valley. While at the western side of the Oder, in a cut bank situation the floodplain directly borders the upland areas, high lying terraces are present on the eastern side that are today quarried in the gravel pit of Bielinek.

One of the founders of the Deutsche Geologische Gesellschaft, Christian Leopold Freiherr von Buch, was born in Stolpe on the 26th of April 1776. Von Buch is the son of a traditional aristocratic family of the Uckermarck region. In the first half of the 19th century, during his scientific career, von Buch became one of the founders of modern geology. While he was studying at the Bergakademie in Freiberg/Saxony together with renowned scientists such as Alexander von Humboldt, he was taught by Abraham Gottlob Werner, one of the founders of "geognosy" in Germany. Due to this influence, von Buch started as a Neptunist, but later changed his view and became a Plutonist. As an enthusiastic traveller, he established geological field work as one of the cornerstones of geosciences.

At the start of his scientific career, von Buch was mainly interested in volcanism and in the study of volcanic rocks, but later shifted his interests to palaeontology. As a major step forward, he coined the term "Leitfossil". Many of his influential publications therefore deal with stratigraphy.

Possibly his most important scientific achievement is the publication of a monography that defined the Jurassic as a System. He also coined the stratigraphic term of the Keuper as being part of the German Triassic. Aged 78, von Buch died on the 4th of March 1853 in Berlin.

Stop 2
Terminal moraines around Chorin

In the surrounding of the small village of Chorin close to Eberswalde, research in the Quaternary started soon after the glacial theory became widely accepted by German geoscientists in 1875 (Torrel 1875) and in the following years (e.g. Berendt 1879, Credner 1879, Penck 1879). As early as in 1879, Berendt published the first geomorphological interpretation of the end moraines, and in 1888, he produced a geomorphological map of the area. An example for the progress in the understanding of the geomorphological and geological consequences of the Pleistocene glaciations is the case of the Chorin gap, located in the Pomeranian end moraine ridge. The gap was first mentioned by Berendt et al. (1899) as a valley-like breach ('thalartiger Durchbruch') and explained by the author as having formed by a spillover of an ice-dammed lake that was located directly south of the Pomeranian ice margin. In contrast, Louis (1934) interpreted the gap as a major glacier outlet that remained active for a long period of time during which it caused the terracing of frontal outwash plains. In this concept, the main level of the ice-marginal valley of Toruń-Eberswalde, about 36 m a.s.l., is interpreted to correlate in principle with the Pomeranian stage. However, the presence of terraces at a significantly higher level at the southern edge of the Eberswalde Valley (Lembke 1939) challenged this concept. It became evident that the valley had developed not in one but in multiple phases and was not the result of the activity of only one major meltwater stream. Following pioneering work of Ost (1935), Liedtke (1956/57) convincingly demonstrated in a landmark publication such a multi-phase development of glacial spillways not only for the Toruń-Eberswalde ice-marginal valley but also for other meltwater courses in the region. The author explained that both the ice-marginal valley of Toruń-Eberswalde and associated outwash plains are distinctly terraced, and that only the highest terrace level (around 47 m asl) correlates to the Pomeranian ice margin. The main terrace is younger in age and resulted from meltwater streams coming from the Angermünde Ice Stage, a recessional moraine located north of the end moraines of the Pomeranian ice margin. Meltwaters of the Angermünde Ice Stage breached the main Pomeranian end moraines close to the village of Chorin and created the gap at the monastery of Chorin. This shows, that in the surrounding of Chorin at least two "Glaziale Serien" are present and are intimately interfingering. Following the research of Liedtke (1957/57), the presence of a third "Glaziale Serie" in the region was postulated by Brose (1978).

The Cistercian monastery of Chorin is one of the most noteworthy historic buildings of the red brick Gothic in Brandenburg. The monastery was founded in 1258 at the shore of neighboring Lake Parenstein by the Margraves of Brandenburg Johann I and Otto III. In 1273, the monastery was shifted to Chorin, mainly due to hydrological and hygienic problems at its original site, and because of much better transport connections at its new site in a gap through the end moraine ridge. During the Reformation the monastery was secularized. In the following, it was used as a storage place, and later as a quarry for building stones. In the 19th century, it increasingly gained historic and cultural importance. The buildings were first protected from further damage, later renovated and finally partially re-built.

Stop 3
Glaciolacustrine sediments of Eberswalde-Macherslust

In Macherslust annually bedded ('varved') glaciogenic lake sediments are outcropping within the ice-marginal valley of Toruń-Eberswalde. The valley fill comprises, besides ubiquitous fluvial sands, deposits of ice-dammed lakes. However, the lake sediments were not deposited in a single phase but in several temporally and spatially separated lake basins that existed during both the Saalian and the Weichselian. This shows that large parts of the region of Eberswalde formed a morphological low for an extended period of time that at least spanned two glacial periods.

OSL dating indicates a late Weichselian age of the varved lake sediments in Macherslust, generally less than 18,000 years B.P. Nevertheless, differing OSL datings by Krebetschek (17,000 years ± 4 kyr; in Schirrmeister 1998) and by Lüthgens (14,700 years, ± 1 kyr; in Lüthgens et al. 2011) imply divergent interpretations. Whereas Schirrmeister (1998) places the lake deposits in a stratigraphic position below the fluvial ice-marginal valley sediments, Pisarska-Jamrozy et al. (2013) hold the opinion that they were deposited after the meltwater-fed valley became inactive.

Overall, the varved lake sediments of Macherslust represent a period of about 87 years (Schirrmeister 1998), though the author acknowledges uncertainty in the annual character of the bedding and, thus, in the absolute number of years covered. According to his view, several beds could have formed within one year. Some varves might therefore represent event beds related to abnormal cold periods during summertime or deposited by exceptional meltwater floods during winter.

Fig. 3: Varved sediments in Eberswalde-Macherlust. Soft-sediment deformation of varved beds in the middle part of the outcrop was caused by sub-aquatic slumping. Tilting and faulting of the outcrop relates to post-depositional melt-out of dead ice.

Seasonal varves consist of coarse-grained silt layers deposited during summer and of medium- to fine-grained silt layers that represent wintertime. Winter beds additionally can contain internal laminae. True clay layers are lacking and the clay content reaches a maximum of 30% in winter layers. Single fine-grained sand layers are present, but they are rather thin. Summer layers are always ungraded and usually much thicker than the winter layers, up to 45 cm in thickness. However, the thickness typically varies considerable from bed to bed. Sedimentary structures such as ripple cross-lamination are missing. These characteristics were taken by Pisarska-Jamrozy (2013) as diagnostic for a transportation of the silt into the lake basin by hyperconcentrated flows. Regarding the winter layers, deposition by settling out of suspension is envisaged during periods when turbulence in the lake was completely hindered by a closed ice cover.

Of special interest is the presence of a soft-sediment deformed bed in the varve succession. The formation of such deformation structures in glacial lake sediments usually is linked to syn-sedimentary melt-out of underlying dead ice. In the case of Macherslust, melt-out of dead ice seems to have caused the overall

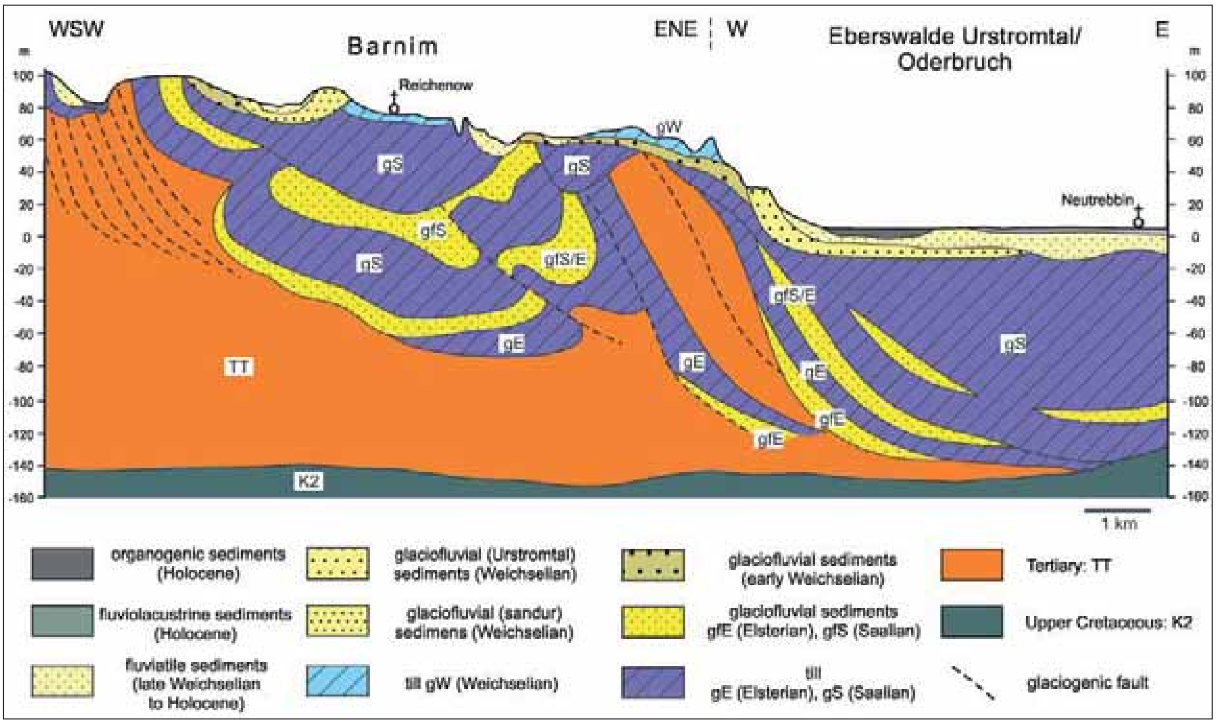

Fig. 4: Schematic cross-section from the upland area of the Barnim in the WSW to the Urstromtal of Eberswalde respectively the Oderbruch in the East Tertiary sediments are present as fault bounded thrust slices in highly deformed Pleistocene deposits (Based on Schroeder ed. 2004).

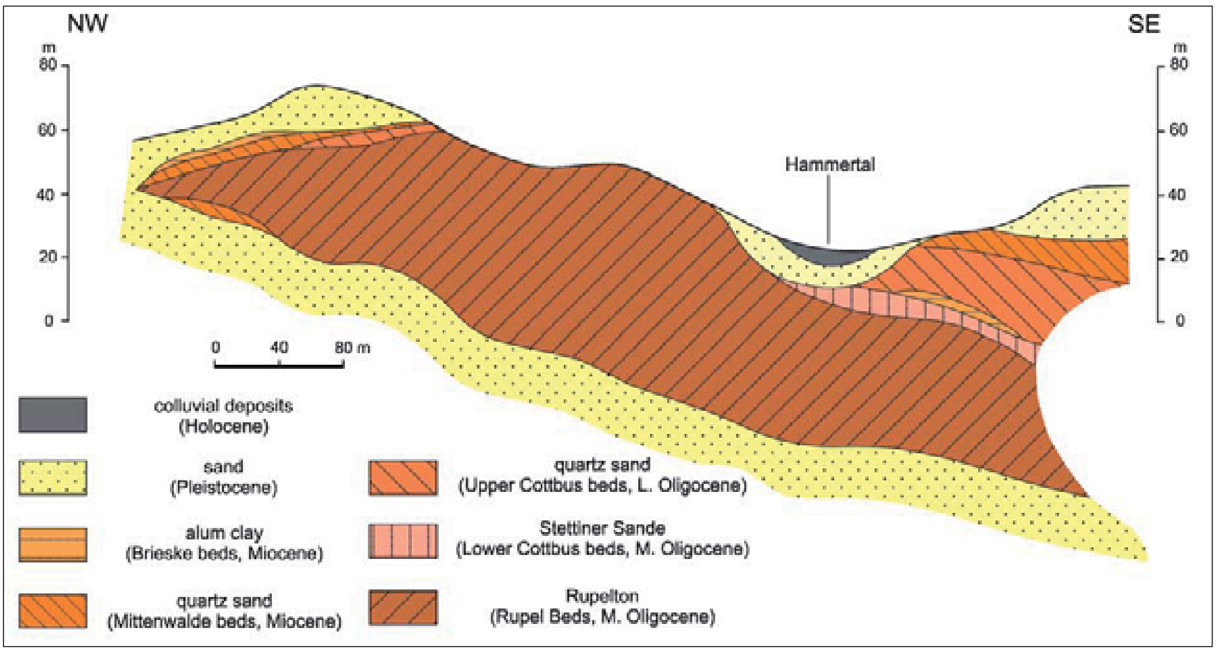

Fig. 5: Schematic cross-section of outcrops of Tertiary sediments in the Hammertal, close to Bad Freienwalde. The deposit represents a thrust complex within a push moraine (Based on Schroeder ed. 2004).

tilting of the varve succession, but was likely not the origin of syn-depositional deformation. Although the two soft-sediment deformed layers very likely formed by sub-aquatic slumping, the trigger mechanism remains disputable.

Since the outcrop in Macherslust represents one of the most important outcrops in the Quaternary of Brandenburg, it is protected by law as a natural monument.

Stop 4
The Tertiary of Bad Freienwalde

The Tertiaryof Freienwalde is located on the Barnim upland. It belongs to the push moraine complex that forms the hilly landscape nearby Bad Freienwalde. The region shows the highest amount of local relief all over Brandenburg, with the water level of the Alte Oder close to Bad Freienwalde below 1 m a.s.l., whereas the Hohe Barnim within only a few kilometers distance reaches elevations above 120 m. The Semmelberg is located just about 4 km away from the western edge of the Oderbruch, yet with its height of 156 m a.s.l. it forms the highest point of the Barnim upland. The positive relief of the Hohe Barnim is primarily the result of the glaciotectonic deformation of older sediments by the Saalian ice advance. Due to the deformation process, Tertiary sediments are today located more than 100 m higher than in places where undeformed deposits occur. In consequence, the highest landforms in the region are built up of Tertiarydeposits, and are overlain by just a thin layer of Weichselian sediments.

Different to most other outcrops of Tertiary deposits in central Brandenburg, which are mainly composed of Miocene deposits, primarily Oligocene sediments occur in Bad Freienwalde at the surface and in the shallow sub-surface. The deposits consist predominantly of whitish mica-rich sands of Late Oligocene age that are associated with Middle Oligocene "Stettiner Sand" that are rich in glauconite as well as in FeOx-concretions. Of major economic interest is the presence of Middle Oligocene Clay (Rupelton). In the past, the clay was quarried in numerous clay pits in the surrounding of Bad Freienwalde. Although mining operation is inactive now, reopening of mining works is always possible, at least according to mining law.

Intense deformation of the Rupelton has resulted in very complex hydrogeological conditions in the region, with multiple active springs located above local free groundwater level. The springs are used for the prosperous health resort and spa business in Bad Freienwalde.

Close to Bad Freienwalde, within the small valley cut of Hammertal (note that the nearby village is written Hammerthal), a thick succession of Tertiary sediments is outcropping in an abandoned clay pit. The outcrop is dominated by Middle Oligocene Rupelton, and is overlain by a residual bed of Stettiner Sande and by a thin cover of Quaternary deposits. The outcrop is widely known for the presence of well-developed gypsum crystals within the Rupelton. The crystals formed by the weathering and oxidation of original pyrite and by reaction with calcite and/or aragonite within the Rupelton. Well-developed swallow-tail and Christmas tree-like gypsum twins are common. Fossils such as bivalve shells also occur, yet they are more difficult to find than the ubiquitous gypsum crystals.

Stop 5
Eemian deposits at Wriezen-Vevais

At the end of the 19th century, while construction work at the railway line was well underway in order to connect Berlin via Wriezen with Bärwalde, geologists who visited the construction site discovered sediments of Eemian age close to Vevais, at the western rim of the Oderbruch depression. Since then the deposits have been intensely studied. Lately, Brose and Strahl (2003) and Brose et al. (2006) have published new results on the genesis and palaeoenvironmental significance of the deposits.

The outcrop is located at the transition of the Oderbruch to the Barnim plateau. In this region, the Oderbruch is not directly bordering the till plains of the Barnim that

Fig. 6: Ice pushed Oligocene clay (Rupelton) overlain by Miocene "Stettiner Sande".

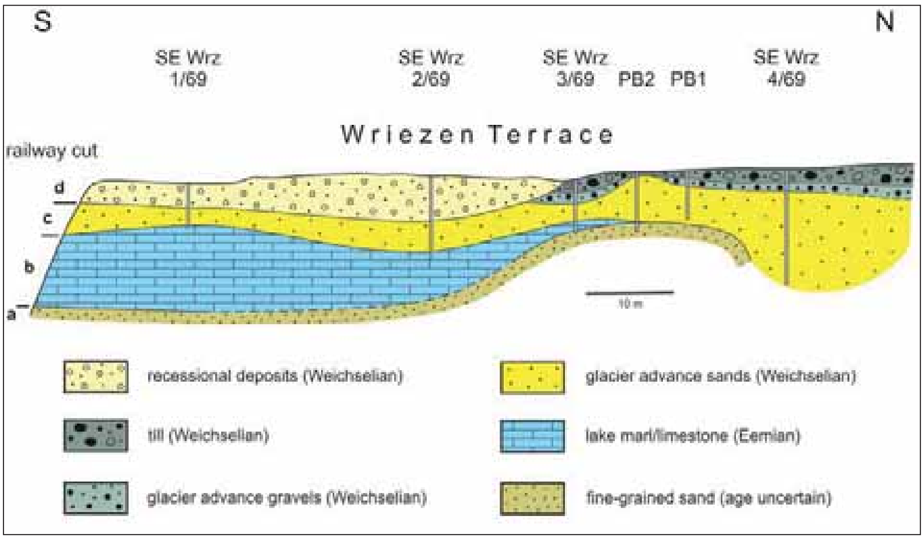

Fig. 7: Cross-section running from the Oderbruch in the south to the terrace of Wriezen in the north. It shows the position of Eemian lake marls in Vevais below Weichselian glaciofluviatile glacier advance deposits. The position of exploration wells is indicated. Based on Brose (2003).

formed north of the Frankfurter ice margin but adjoins to the terraces of Wriezen. Around Wriezen, terraces attain a height of around 32 m a.s.l. This elevation suggests that the meltwaters that deposited the terraces were not discharging into the Toruń-Eberswalde ice-marginal valley but instead towards the north, utilizing the meltwater spillway of Randow-Welse. The terrace deposits are relatively coarse-grained, usually gravelly to stony. This suggests that they consist essentially of eroded and reworked Weichselian till. More evidence to support this hypothesis has come from the nearly complete lack of till in morphologically higher lying beds in the near surrounding of the terraces. However, some relict till was found in wells drilled to the west.

The Eemian deposits are located at an altitude of roughly 25 m a.s.l., and are laterally traceable for several hundreds of meters. The altitude, significantly higher than the level of the then existing precursor of the Oderbruch, is not astonishing because an accentuated relief and an unbalanced hydrology are normal features of young morainal landscapes. Even at present, in close distance to the western rim of the Oderbruch, small lakes and mires exist on both the Barnim and the Lebus plateaus. It is however very likely that during deposition of the Eemian deposits the western rim of the Oderbruch was positioned further to the east than today. During the Holocene, the Eemian deposits were located clearly above groundwater level. In consequence, most organic matter present in the deposits has decayed due to oxidation. Thus, the pollen grains are somewhat corroded but still identifiable. Today, only calcareous sediments and pollen and spores are preserved. These deposits contrast strongly with other sediments of Eemian age in East Germany, e.g. in Neubrandenburg-Hinterste Mühle (Mecklenburg-Western Pomerania), which are very rich in organic matter.

In Vevais, the Eemian deposits consist primarily of shallow-water lake marl and are under- and overlain by calcareous muds. Palynological analyses show an almost continuous sedimentary record without major hiatuses during the Eemian (Brose et al. 2006). Nevertheless, late Saalian and early Weichselian sediments are missing. In principle, a typical Eemian vegetation succession is documented in the lake sediments, starting with light-demanding trees (PZ (Pollen Zone) 1 and 2), superseded by a succession of thermophilic deciduous forest trees (PZ 3-5), followed by shade-

Fig. 8: Eemian lake marls in Vevias overlain by Weichselian glaciofluvial glacier advance sands.

loving vegetation (PZ 6 and 7), and finally replaced by light-demanding trees (PZ 8 and 9).

Vevais represents one of the rare permanent surface outcrops of Eemian sediments in Brandenburg, and the only one at the western margin of the Oderbruch. Thus, the outcrop is protected by law as a 'Geotop'.

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GeoBerlin 2015 Exkursion 03

Field trip 3: Cenozoic Lausitz Volcanism and its Basement

Jörg Büchner[1], Olaf Tietz[1], Peter Suhr[2], Anselm Loges[3], Gerhard Franz[3]

[1] Senckenberg Museum für Naturkunde Görlitz, Germany

[2] Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Freiberg, Germany

[3] Technical University Berlin, Germany

1. Introduction

1.1 The Lausitz Volcanic Field – Boundary and geological setting

The Lausitz Volcanic Field (LVF, Tietz et al. 2011a, 2013, Büchner et al. 2015) is bounded to the south by the České Středohoří Mountains (CS) in the Czech Republic and to the East by the Fore-Sudetic Basin in Lower Silesia, Poland. Over long intervals, small-volume volcanoes like scoria cones, maars and domes have been strongly modified by erosion especially during the Quaternary when much of the volcanic field was glaciated and subject to repeated periglacial weathering (Tietz et al. 2011a, 2011b); therefore, the volcanic structures are scarcely preserved as intact, original landforms but are often easily recognized as prominent landmarks due to the higher resistance to weathering of some volcanic lithologies.

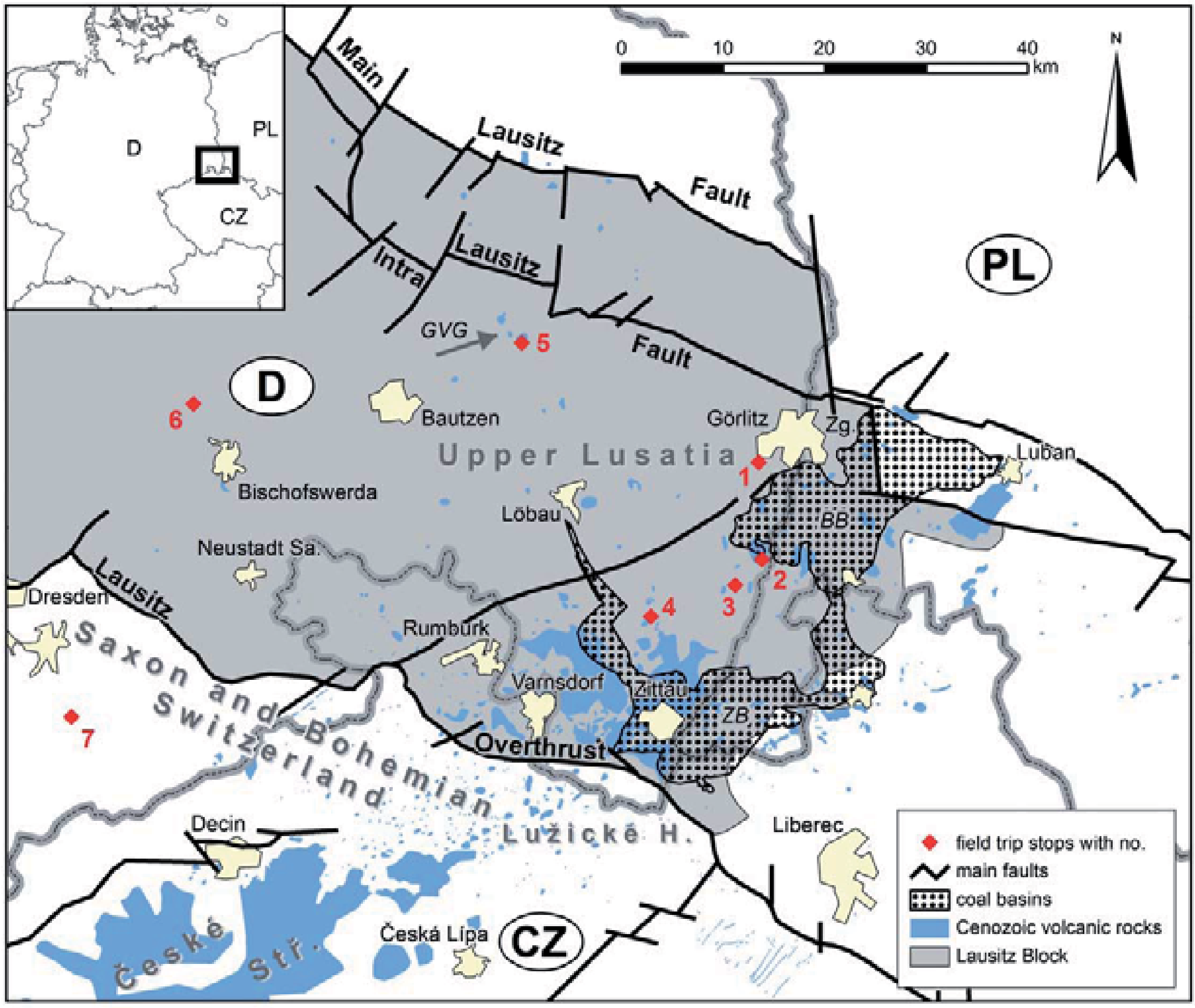

Fig. 1: Overview of the Lausitz Volcanic Field (LVF) with the main geological units and landforms. BB – Berzdorf Basin, ZB – Zittau Basin, GVG – Guttau Volcano Group, Zg. – Zgorzelec, Lužické h. - Lužické hory, Ceské str. –Ceské středohoří.

The LVF includes volcanic formations from Upper Lusatia (Oberlausitz, Germany; Łużyce Górne, Poland), Bohemian and Saxon Switzerland (České Švýcarsko, Czech Republic; Sächsische Schweiz, Germany), Lausitz Mountains (Lužické hory, Czech Republic) and the Zittau Mountains (Zittauer Gebirge, Germany) (Fig. 1).

The LVF is located on various geological units (compare e.g. the overview of Kozdrój et al. 2001). The northernmost and northeastern parts overlap Paleozoic anchimetamorphic sediments of the Kaczawa and Görlitz Synclinoria and more to the south Cadomian granitoides and greywackes. The latter two basement units together build up the Lausitz Block (see Stop 6). The southern part of the LVF is situated at the northernmost margin of the North Bohemian Cretaceous Basin and the Elbe Zone. In both units the volcanic rocks overlie Upper Cretaceous sediments, mostly sand-, silt- and marlstones. The Lausitz Overthrust cuts this basin and graben zone against the uplifted Lausitz Block. Only the Cretaceous sandstones of the Zittau Mountains are actually uplifted, the result of tectonic inversion since c. 35 Ma (Tietz & Büchner 2015. The basement of the southeastern margin of the LVF consists of metamorphic rocks of the Proterozoic-lower Paleozoic Karkonosze-Jizera Block.

The puzzle of different basement slices is the result of the Variscian tectonics and consolidation before 325 Ma. Since about 100 Ma the Lausitz Block and the Karkonosze-Jizera Block is uplifted as the western part of the West Sudetes block ("Lugicum" in older literature) – one of the low mountain range blocks of Central Europe. Great faults limited the block to the south (Lausitz Overthrust) and the north (Main Lausitz Fault, eastward in the Marginal Sudetic Fault continued). The vertical displacement of about 1000 – 3500 m took place after the Variscian orogeny in the Permo-Carboniferous (320-260 Ma, Kozdrój et al. 2001) and since the Upper Cretaceous with a climax at 85-50 Ma (Lange et al. 2008, see also chapter 1.3).

1.2 Volcanic rocks – distribution, ages, petrography and "basaltic" zircons

The volcanic rocks are mainly concentrated along tectonic faults and around the tectonic basins of Berzdorf and Zittau, which mark the eastward continuation of the Ohře/Eger Graben (Fig. 1). The largest concentration of volcanic successions is observed in the southern part of the LVF in the vicinity of Zittau. Outside of this area only isolated volcanics occur. In the LVF roughly 500 vents (volcanic centers) are exposed in more than a thousand volcanic outcrops (Büchner et al. 2015).

The age of the volcanic rocks is mostly Lower and Upper Oligocene. The published data show a maximum range between 20 Ma (Alibert et al. 1987) and 70 Ma (Pfeiffer 1994, pp. 190). The climax of K/Ar isotopic ages ranges between 30 and 25 Ma (Pfeiffer et al. 1984, Kaiser & Pilot 1986, Suhr & Goth 2002) and of Ar/Ar ages between 35 and 27 Ma (Büchner et al. 2015 and Fig. 2). One of the youngest ages was measured by K/Ar (whole rock age) with 22 ± 2 Ma at a basaltic lava flow, intercalated in the basal part of the lignite seem complex in the Berzdorf Basin (Tietz & Czaja 2004). The bio- and lithostratigraphic sequences of the sedimentary profile support a reliable age determination and therefore a continuation of the volcanic activity up to the lowest Miocene.

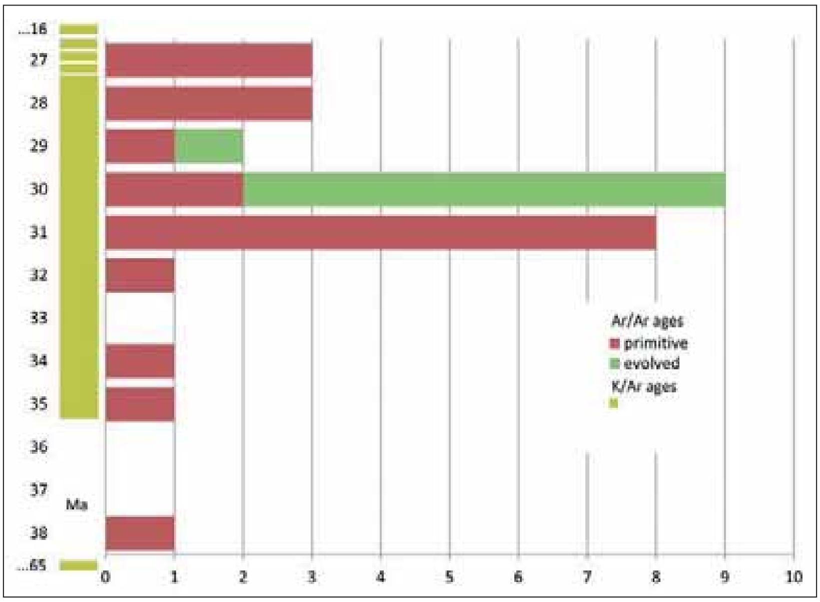

Fig. 2: Ar-Ar isotopic ages of alkaline volcanic rocks in the LVF (Büchner et al. 2015) K/Ar ages according to Pfeiffer et al. (1984), Kaiser & Pilot (1986) and Suhr & Goth (2002).

The volcanic rocks of the LVF show an alkaline fractionation trend (Fig. 3), which is typical for Cenozoic magmatism in Central Europe and generally for continental intraplate magmatism. Nephelinite, basanite, tephrite, intermediate lavas as well as phonolite and trachyte can be observed according to the TAS-classification. In contrast, alkali basalts are rare. The complete alkaline suite could be observed in the central part of the LVF around the Zittau Basin and the Zittau Mountains (Büchner et al. 2015). Outside this centre the volcanic rocks are mostly nephelinite, basanite and tephrite. Additionally, ultramafic melilite-bearing rocks occur at marginal areas of the LVF in

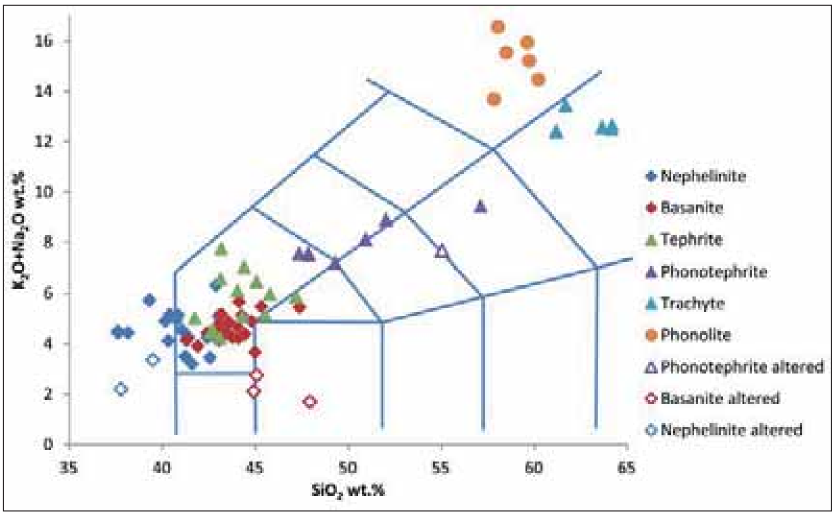

Fig. 3: TAS-diagram showing data of RFA analyses of volcanic rocks of the LVF (Büchner et al. 2015).

a magmatic corrosion in the basaltic host melt. In contrast, zircons from phonolithic rocks are smaller (0.2-0.8 mm) and mostly euhedral. The origin and the genesis of these zircon megacrysts derived from alkaline continental intraplate volcanic rocks are currently controversially discussed. Trace element characteristics of Bohemian and Saxonian zircons indicate an alkali-silicic parental melt, probably syenite, nepheline syenite or fenite (Seifert et al. 2008b, 2012) of *in situ* “basaltic” zircons and implicate an origin from the lithospheric mantle (Tietz et al. 2010).

Fig. 4: Zircon megacrysts in gem stone quality derived from alkaline basaltic rocks. Placer deposit in the Seufzergründel valley near Hinterhermsdorf, Saxon Switzerland. Crystal length 2–4 mm.

the Sächsische Schweiz (Zeughaus dike) and in Görlitz (“Pomologischer Garten”) (Seifert et al. 2008a).

A special feature of the LVF is the occurrence of zircon megacrysts derived from alkaline volcanic rocks (Tietz et al. 2010). Such occurrences have been known for a long time, e.g. in the Sächsische Schweiz (Tietz 2003), but only from alluvial placer or weathering residuals (Fig. 4). The first worldwide proof for an alkaline volcanic origin of zircon was found at a small quarry 10 km south of Görlitz in the LVF (Tietz & Büchner 2007). Other *in situ* evidences from zircon megacrysts in alkaline basaltic rocks were contemporaneously supplied by Italian geologists (Visonà et al. 2007) and by mineral collectors in the Upper Palatine, Germany (Meier & Weiß 2007). Recently, zircon megacrysts are known in the LVF from four alkaline basaltic localities and from three phonolitic localities (Tietz et al. 2013). The zircon megacrysts derived from alkaline basaltic rocks have a mean size of 2 to 4 mm (min. 1 to max. 9 mm) and are of gem stone quality. Many crystals are intensively rounded, the result of

1.3 Volcanology and postvolcanic landscape evolution

The extensive erosion of the Cenozoic eruption products causes difficulties in reconstruction of the former volcanic edifices. On the other hand the denudation processes give insights into the root zone of volcanoes, which is impossible by young or active volcanoes.

The volcanism at the LVF is dominated by the end members of the magmatic evolution trend; therefore nephelinite-basanite and phonolithe-trachyte prevail. This bimodal distribution is reflected by the volcanology and morphology of the volcanic remnants. The most frequent type at the LVF is the scoria cone type. These are relatively small basaltic volcanoes, of which only the hard "core" in preserved, represented by the lava lake fillings, feeder dykes, plugs or lava flows. The name-giving scoriae are mostly denudated. This was the reason for many and persistent misinterpretations in the past and the common reconstruction of the Lusatian volcanoes as cryptodomes or lava domes. Today, we know only some localities with occurring scoriae remnants (Tietz & Büchner 2007, Tietz et al. 2011a,b, Büchner & Tietz 2012, Tietz & Büchner 2015, p. 142). These are mostly small deposits with welded scoria or localities protected beneath massive lava flows. The lava flow remains of scoria cone volcanoes often occur isolated today without connection to a known eruption centre. A typical feature is the occurrence as morphological relief inversion; former valleys appear as ridges or hills today. In some cases relicts from top or basal breccias can beare observed.

Maars represent a rare volcanologic type in the LVF (Suhr & Goth 1996, see chapter 1.4). Mostly, these hidden volcanic structures are only known from geophysical investigations and bore holes (Lorenz et al. 2003) and these phreatomagmatic eruptions are common for the initial stage of scoria cone volcanoes in the LVF.

Because of the deep erosion level, often diatreme breccias in the root zone of the scoria cones are a common feature. In some cases only this initial stage of volcanism is preserved (Tietz et al. 2011b, Büchner et al. 2015, Wenger 2015). Initial phreatomagmatic structures are mostly developed in the sandstone areas in the Zittau Mountains and Saxon Switzerland. However, such volcanic diatreme breccia structures occur also in the granitic basement (Tietz et al. 2011a, Büchner & Tietz 2012 and unpublished data – see stop 4).

Lava domes or cryptodomes of phonolitic or trachytic rocks occur only in the southern and central part of the LVF and mostly superficial successions are assumed. This assumption is proved by observations of vesiculated rocks (solidified phonolitic lava foam) on the top of phonolitic hills, phonolitic pumice clasts in a tephritic diatreme structure as well as the low erosion level in the Zittau Mountains with many phonolitic-trachytic deposits and the close position side by side of phonolitic-trachytic and superficial basaltic volcano remnants in the same level (Tietz et al. 2011b). We can distinguish in some cases monogenetic from complex polygenetic types by the phonolitic-trachytic lava domes (Büchner et al. 2015).

Certain volcanic remains can be used as markers of the pre-eruptive land surface if detailed characteristics are known. Hence, the Cenozoic volcano remnants are a powerful tool for the reconstruction of the morphology of the landscape before about 30 Ma and give information about the post-volcanic landscape evolution. The study of numerous volcanic edifices and Quaternary deposits from three areas of the LVF give following results for the Lausitz Block (Tietz & Büchner 2015, see Fig. 5): (1) The uplift and denudation rate is very moderate at 2-3 mm/ka, only up to 90 m of the basement were eroded since the Upper Oligocene. In comparison, for the Lausitz Block apatite fission track ages show a pronounced cooling and uplift event for the time between 85 and 50 Ma with a total uplift of 3,000-3,500 m and a denudation rate of 100 mm/ka (Lange et al. 2008). Furthermore, the uplift of the Lausitz Block did not took place en block, but rather along different internal micro blocks (Büchner & Tietz 2012); (2) The uplift of up to 300 m of the Zittau Mountains increased since the Elsterian Glacial Period to (Tietz & Büchner 2015).

Moderate uplift was especially intensive in the Middle Pleistocene. Many findings from the investigation of the volcano remnants, the Pleistocene sediments and the geomorphology suggest an intensive neotectonic movement at the turn of the Elsterian to the Saalian Glacial Stage before about 320 ka before present (Tietz & Büchner 2015).

1.4. The Guttau Volcano Group – A multifarious volcanic unit at the northwestern margin of the LVF

The Guttau Volcano Group is, except of three small occurrences of volcanic rocks along the Lausitz Main Fault, the northernmost volcanic area associated with the Ohře/Eger rift (Fig. 1). It consists of five known structures: the volcanoes Schafberg und Eisenberg (former scoria cones with lava lakes) and the three maars Kleinsaubernitz, Baruth and Buchwalde (Fig. 6). While The basalt hills have been known for a long time, where as the maars were discovered only recently by geophysical surveys and drillings (Suhr & Goth 1996, 1999). The basement rocks of the volcanic structures are Cadomian granodiorites and Upper Protorozoic greywackes, in the northern part Paleozoic slates and conglomerates (Lower Carboniferous). Above these units lies a blanket of soft Cenozoic sediments with intercalated lignite seams. During the Pleistocene the area was covered three times by continental ice shields, which caused erosion of the vast bulk of the scoria and made the solid parts of the lava lakes visible.

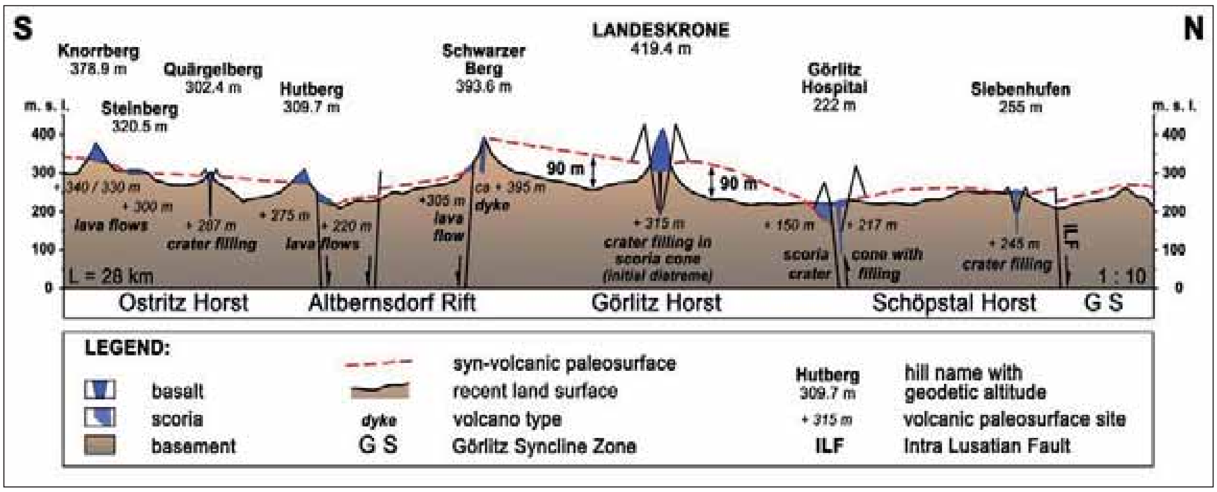

Fig. 5: N–S cross-section through the northeastern Lausitz Block surrounding the Landeskrone Volcano with the reconstructed paleosurface at the time of volcanism, approximately 35–27 Ma ago (according to Büchner & Tietz 2012).

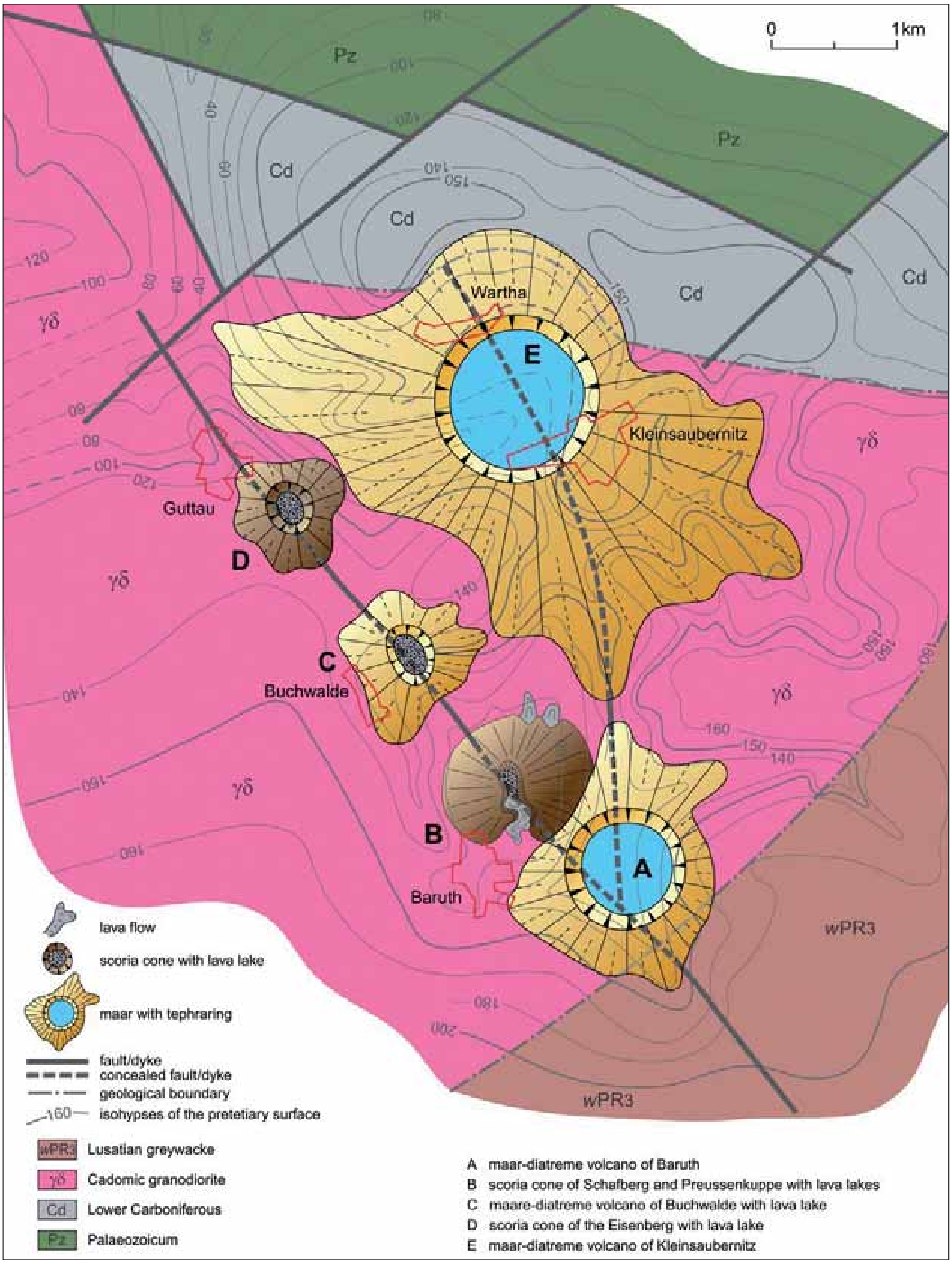

Fig. 6: Geological map of the Guttau Volcano Group.

The Schafberg Volcano

The Schafberg and its surroundings is a complex volcano with a long mining tradition. Together with the Preußenkuppe and the Dubrauker Horken there were eight active basalt quarries between 1884 and 1999. Today the large quarry on the southern side of the Schafberg is protected as a technical monument. Recent volcanological, petrographical and geochemical investigations (Tietz et al. 2011a, Büchner et al. 2015) suggest a multistage development of this complex volcano as follows (Fig. 7):

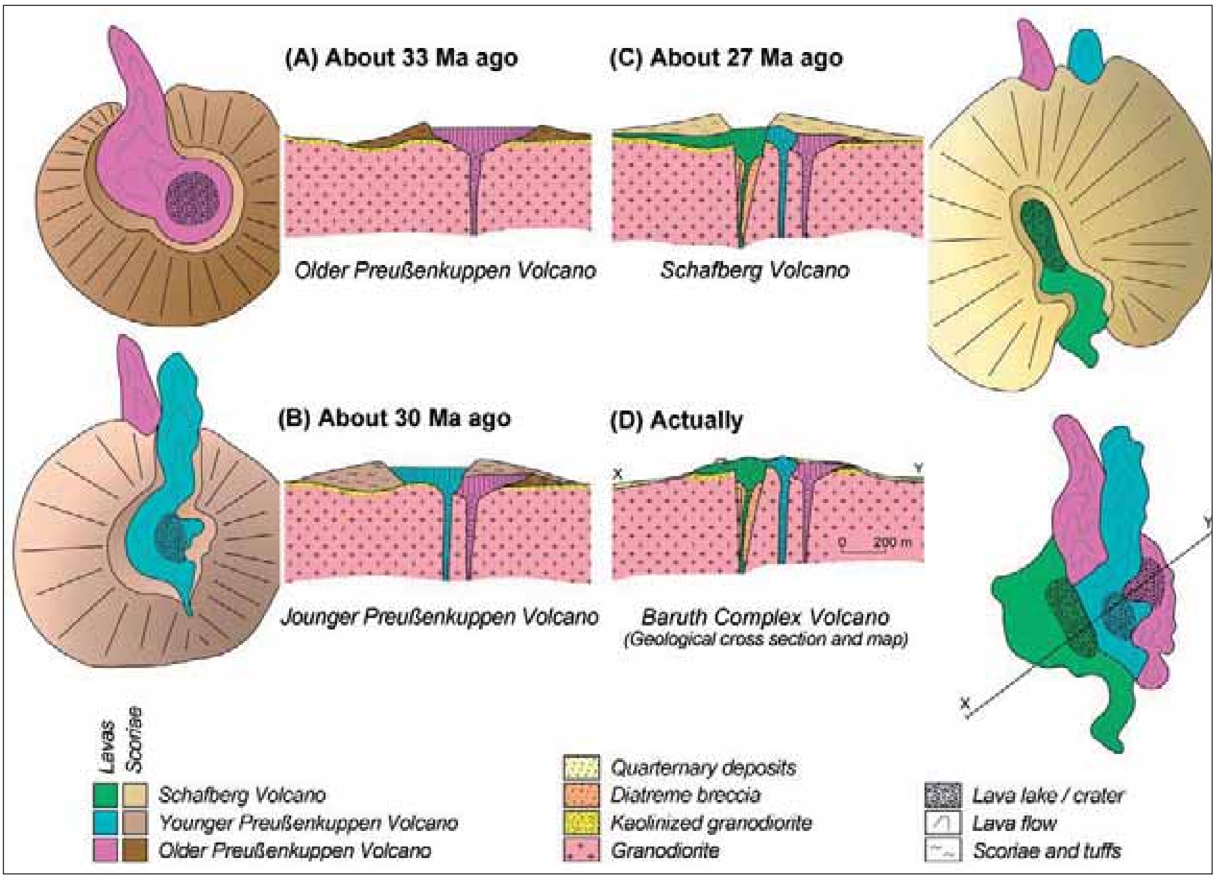

Fig. 7: Schematic sketch of the volcanic history of the Baruth complex volcano, adapted from Tietz et al. (2011a).

- ***Older Preußenkuppen Volcano***:
  Nephelinitic lava flow at the western part of the Dubrauker Horken (Ar/Ar plateau ages of ~ 33 Ma)
- ***Younger Preußenkuppen Volcano***:
  Basanitic lava lake and the lava flow at the eastern part of the Dubrauker Horken (Ar/Ar plateau ages of ~ 30 Ma)
- ***Schafberg Volcano***:
  Basanitic lava lake and a lava flow to the south and west of the Schafberg hill (Ar/Ar plateau ages of ~ 27 Ma)

The remnants of these three volcanos represent scoria cones mutually overgrowing each other. Time gaps of several My between the eruptions are reliable. There are a lot of age determinations, which support the same time span (K/Ar age determinations by the lab of ATOMKI, Debrecen and Ar/Ar age determinations by TU BAF Freiberg and the lab of GEOMAR Kiel). The most recent volcano (Schafberg Volcano) showed a phreatomagmatic initial phase with simultaneous strombolian eruptions. It evolved later into a scoria cone with increasing strombolian-style eruptions. The scoria cones are almost completely degraded except for a remnant within a small outcrop. The entire volcanic complex shows an evolution with increasing partial melting of the mantle. In the third volcanic phase (Schafberg Volcano) the fractionation of the melt intensified during the ascent (Tietz et al. 2011a).

Beside the multistage development the impressive contact features between the kaolinitic weathered granodiorite basement and the hot lava are of interest. The resulting rocks are peperites documenting a strong influence of water during their formation. These peperites are preserved in the big Schafberg quarry.

The Eisenberg Volcano

Like the Schafberg, the Eisenberg (Iron hill) is a remnant of a former scoria cone with a lava lake. The remains of the lava lake document just a single stage of the development. Some K/Ar ages scatter between 13.5 ±0.5 Ma (Puschkarev, St. Petersburg unpubl.) and 28.7 ±1.2 Ma (Pécskay, Debrecen pers. comm.). The higher age fits with the youngest eruption phase of the Schafberg volcano. Its associated magnetic anomaly has a value of < -1000 nT and indicates a strong inverse polarity of the basalt (Lindner et al. 2006). An old quarry shows thick steeply inclined basalt columns of the lava lake filling.

The Maar of Kleinsaubernitz

The irregular bedding structures and thick lignite seams, in the area around the village Kleinsaubernitz attracted attention duringin the last century. During a regional gravimetric survey (Lindner 1963) a noticeable anomaly of -10 mGal was recognized and interpreted as a small Variscan granite intrusion (Lindner & Brause 1967). A special survey was performed later (Böhnert 1986) with only 100 m distances between the measure points. After interpolation, a nearly circular form of the anomaly with a diameter of 2 km was observed. In addition this gravity anomaly coincides with a strong magnetic anomaly.

In 1970 a borehole was drilled in the center of the gravity anomaly. The upper 200 m consist of ± common Lusatian Miocene sediments with some lignite seams. Underneath a more than 300 m thick sedimentary sequence, unknown before, was found. Due to technical problems with the equipment the drilling was stopped at a depth of 528.5 m without reaching pre-Tertiary rocks.

A revision of this drill core by Suhr & Goth (1996) confirmed assumption expressed earlier that the structure Kleinsaubernitz is a fossil maar-diatreme volcano. The drill core starts with coarse breccias consisting mainly of the country rock (Lusatia granodiorite, Lower Carboniferous slates and lydite-chert-conglomerate (“Kieselschiefer-Hornstein-Konglomerat”). The matrix is composed of tuffite with scarce lapilli and bombs of an altered mafic volcanic rock. After the eruptions this material slid from the rampart and the steep crater walls into the initial maar lake. The limnic sedimentation starts with thin layers of fine-grained oil shale between thick debris flow deposits and turbidites. During the lacustrine development the allochthonous clastic contribution (turbidites) decreases. Oil shale was deposited under quite calm conditions and in many features resembles the oil shale from Messel, Odenwald (high content of organic components, thin lamination, accumulation of the coccal chlorophyte alga *Tetraedron minimum*, distinct siderite layers, content of diatoms, sponge needles, chrysophyte cysts etc.). After ca. 100 m of oil shale sedimentation, the content of diatom frustules increases until almost pure diatomite was deposited. With this thinly laminated diatomite, the maar lake of Kleinsaubernitz was filled completely. The lake sediments yield macrofossils like fishes, insects and especially lots of plant remains (Walther 1999). The spore and pollen flora confirms an Upper Oligocene age of the sediments (Goth et al. 2003), which fits well with the youngest eruption of the Schafberg volcano.

The thick overlaying sequence of normal Miocene sediments with well connectable lignite seams allows an estimation of the post eruptive subsidence of the maar-diatreme structure Kleinsaubernitz (Suhr et al. 2006) by thickness comparison of equal stratigraphic units above and outside the structure. The total post-eruptive subsidence above the maar-diatreme sums up to more than 280 m for the last 27 Ma.

The recent surface above the maar-diatreme volcano of Kleinsaubernitz is coined by the subsurface and open cast mining of lignite. The so called “Olba Lake” is not the result of the post eruptive subsidence but the relict of an open cast mine flooded in 1929.

The Maar of Baruth

A known gravity-magnetic anomaly east of the village of Baruth was the reason for extensive geophysical surveys by scientists from the former GGA Hannover (today LIAG) and the University of Leipzig (Prof. Jacobs). After the confirmation of these anomalies two research bore holes were drilled, one into the centre and one near the margin of the structure. The lowermost 11 m of the core of the central bore hole (FB Bth 1/98) consist of huge blocks of granodiorite interstitially filled by tuffitic material, the so called “collapse breccia”, which represents the uppermost part of the diatreme filling. Directly above lie the first subaquatic deposited sediments of the former maar lake. Genetically these sediments are turbidites and debris flows, which were generated from the pyroclastics of the ring wall. The next sequence consists of about 7 m lapilli tuff with granodiorite xenoliths. Probably both components came from outside, possibly from the simultaneously active Schafberg volcano. On top of this layer fine-grained lake sediments with partly pure diatomites follow. Very often, clastic material is deposited in between. During the lake sedimentation the debris flows progressively develop into turbidites. Distinct siderite layers are quite common in certain sections and indicate meromictic conditions in the Baruth maar lake. Towards the top of the sequence the amount of diatomites increases. At about 145 m depth, phonolitic ash is intercalated, originating from the phonolitic volcanoes in the southern part of Upper Lusatia. The uppermost 30 m of the diatomite are excellently laminated and include just a few clastic layers. After an erosional discordance at 50 m depth clastic sediments of Middle Miocene age were deposited. A lignite seam of 2.5 m thickness follows and correlates with the 2nd Miocene seam horizon in the regional context. Above the seam, light-colored Miocene clays and silts complete the pile. Quaternary sediments of only some decimeter thickness complete the profile.

The second core (FB Bth 2/98) in the marginal facies shows completely different lake sediments compared to the center. Coarse debris flows of blocks of granodiorite are mixed with organic rich sands. These granodiorite blocks are severely corroded because the water could easily circulate and altered the feldspars into clay minerals.

A detailed description of the two cores is given by Goth & Suhr (2005, 2007). Hottenrott (2003) gives an Upper Oligocene age of the laminated maar sediments by palynological investigations of three samples.

The Maar of Buchwalde

The maar of Buchwalde is still an enigmatic structure. The small but strong magnetic anomaly NE of the village of Buchwalde (NW of Baruth) can be explained by basic volcanites below a thin cover of Quaternary fluvial sediments. An initial maar explosion may have occurred, but there was not enough water for further phreatomagmatic eruptions and the maar crater was filled with lava. This lava lake of dense basalt counteracts the gravimetrical anomaly that is typical for maars. A shallow drill hole in the center of the magnetic anomaly hit a highly altered basic volcanic rock at 14 m depth, which explains the magnetic anomaly.

1.5 The Cottaer Spitzberg

The Cottaer Spitzberg south of Pirna is more interesting for the xenoliths the basanitic melt brought up than for its volcanological features. Alongside the mantle and upper crustal rock fragments that are common in volcanoes of mantle origin penetrating a thick continental crust, we also find large (up to 2.5 cm) green-core clinopyroxenes (gc-cpx). These pyroxenes are characterized by an exceptionally low Mg# around 0.5, which means they must have crystallized from a melt that was much more evolved than the basanite in which we find them today (Loges et al., submitted). The gc-cpx themselves contain different kinds of inclusions, most notably three immiscible melts in textural equilibrium: phonolitic, carbonatitic and sulfidic melt. This suggests that the gc-cpx formed during and most likely as a result of unmixing of carbonatitic and sulfidic from a parental phonolitic melt. The association of gc-cpx inclusions with xenoliths containing chrome spinel and the lack of plagioclase in the xenoliths suggest that the phonolitic chamber producing the gc-cpx was situated at lower crustal depths, possibly at the base of the crust, although reliable barometry is not possible due to the lack of barometer calibrations for phonolitic melts and Fe-rich cpx at high-pressure conditions. The findings at this location demonstrate that even under a single small and humble volcano of primitive composition we may discover surprisingly complex and highly developed magmatic plumbing systems by simple means of detailed petrography of inclusions. Expanding such studies to more localities will help to learn more about the hidden parts of the LVF and the Eger Graben Volcanics in general and hopefully contribute to our understanding of what drives melt generation in intraplate settings in the absence of mantle plumes.

2. Excursion stops (positions see Fig. 1)

Stop 1: The Landeskrone Volcano – A large monogenetic scoria cone

<u>Locality</u>: hill on the southwest margin of the town of Görlitz (summit 419.4 m a.s.l., foot of the hill about 275 m a.s.l.), visited outcrop: abandoned basalt quarry Ratssteinbruch on the northern slope of the Landeskrone Hill by 315 m a.s.l., 51.13108 N, 14.93190 E.

<u>Geology</u>: The Landeskrone Hill is a remnant of a monogenetic scoria cone with an age of 31.81 ± 0.27 Ma (Büchner et al. 2015). Today we find mainly the lava lake filling as dense nephelinite with weakly developed columnar jointing. This massive nephelinitic rock forms the steep slope of the Landeskrone Hill above a gentle inclined slope of the granodioritic hill foot (Cadomian basement). The columnar joints of nephelinite in the numerous exposed cliffs at the hill show a dip direction almost inclined outward the present hill. The inclination on the base of the nephelinite hill cone is with 40° flattest and increases up to 90° at the summit. Simultaneously the diameter of the columns rises from 0.4 to 1.0 m. These features indicate a cooling process as it can be observed in a lave lake. This assumption is supported by vesicle lava at the summit of the Landeskrone Hill interpreted as an upper part of the former lava lake and basaltic scoriae on the foot of the nephelinitic hill; the scoriae are actually exposed in the visited outcrop (Ratsteinbruch, Fig. 8). The in-situ scoriae are weakly weath-

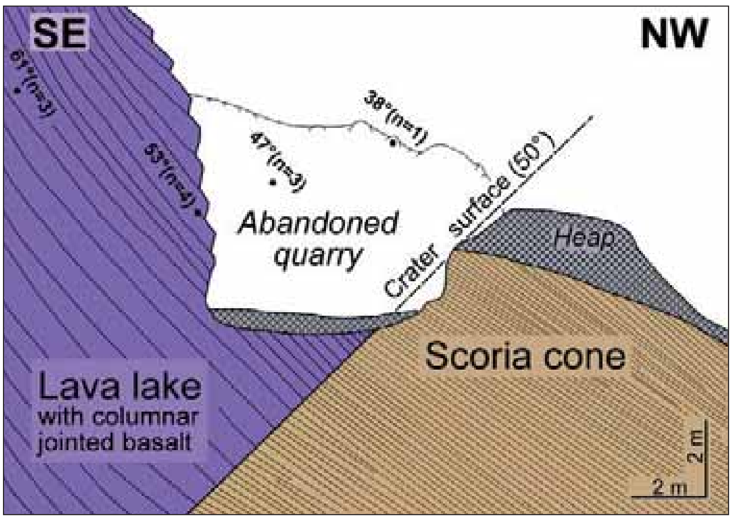

Fig. 8: Schematic cross-section of the abandoned quarry Ratssteinbruch on the northern slope of the Landeskrone Hill. Note the inclined basaltic columnar jointing in relation to the reconstructed crater surface (according to Büchner & Tietz 2012).