Introduction

Lower Silesia is a region situated in southwestern Poland and for thousands of years it provided a variety of rock materials for different local populations (from Palaeolithic until now), due to its proximity to the Sudety mountains. This mountain range, with peaks of up to 1602 m.a.s.l. borders Lower Silesia to the south. Only the area of slightly undulating hills located between 200–500 m.a.s.l. was exploited by inhabitants during prehistoric times and the early Middle Ages.

The older quarry, dating back to the Neolithic, was exploited to supply populations with serpentine rocks, used in production of adzes (Wojciechowski 1982, 1983). Until the first centuries AD, only surface bedrocks were exploited by the local people. The emergence and development of the Przeworsk culture in the Central European Barbaricum brought about intensification of stone quarrying, which was strongly tied to the need for quernstone and whetstone production. People of the Przeworsk culture in the 2nd–3rd century AD initiated a new stage in the rock exploitation of the Sudeten Mountains with granite quarrying in the Ślęża Massif and used to produce quernstones and quarzites quarrying in Strzelińskie Foothills for making whetstones (Pazda & Sachaniński 1991, Domański 2002:93–99). Quernstones and whetstones made from these local rocks were rapidly spread throughout the entire area of Silesia. After the Migration Period (Volkswanderung), when Silesia was
abandoned by the German tribes of the Przeworsk culture, the first Slavic settlers from the eastern lands appeared at the turn of the 6th and 7th century AD and they probably found mostly uninhabited land (see the discussion about ethnogeny of the Slavs in: Dworaczyk et al. 2006). In the 7th century AD, the Slavs started exploitation of the same outcrops as their predecessors in the Roman Period 150 years earlier (Domański 1980).

This paper is focused on quarrying and quernstone production and their distribution in the early Middle Ages in southwestern Poland, as it relates to the economy of the Slavic tribes (6th/7th–10th century AD) and the subsequent emergence and development of feudalism (10th–half 13th century AD). All data presented are based on excavated material, as there are no written records describing quarrying activities or quernstone production and usage in the area under study. Three quarries are discussed below: Ślęża Massif, Kamieniec Ząbkowicki and Gilów (Fig. 1–2).

History of archaeological research

By 2008, investigation concerning the archaeological and petrographic description of quernstones was limited only to the identification of several units, summarised by K. Jaworski (2008). Thus the overall research, which had taken place in 2008–2011, included the identification of the type of rock material used to make millstones and a short description of examined artefacts. Almost 100 quernstones from 30 different archaeological sites were examined and it is preliminary the results of this work that are presented below.

Quernstone quarries and workshops from the early Middle Ages are dealt with through archaeological observation. The largest density of quarries was observed on the northern slopes of the Ślęża Massif. In 1736, H. Burghardt gave a short presentation of the quernstone industry in the Ślęża region, illustrated by a drawing of a view of the Ślęża Massif and discus lapidus (Fig. 3), which is regarded by historians and archaeologists as an example of a quernstone from the Middle Ages (Burghardt 1736:Fig. 2). Regular excavation of these quernstone quarries started towards the end of the 19th and continued into the beginning of the 20th century (Sadebeck 1855, Lustig 1904). Many unfinished products, which have never been published, were uncovered close to quarries. According to facts revealed by F. Geschwendt and M. Jahn, quernstone quarries located on the northern slopes of Mt. Ślęża are still considered to have been used during the late Roman Period and the Middle Ages (Geschwendt 1922, 1926, 1928, Jahn 1929). The 1925 discovery of a Middle Age settlement with a quernstone workshop in Chwałków was a breakthrough in the archaeological knowledge of quernstone production (Jahn 1929). It was demonstrated that some of these stones were finished in the workshop located no more than 5 km from the nearest quernstone quarries. It was the first archaeologically recorded millstone workshop in the region of Silesia. Further investigations in the region of Mt. Ślęża uncovered more Early Middle Age settlements with quernstone workshops.

Pioneer excavation of the quernstone quarries carried out by Polish archaeologists in the early 1960s made it possible to clarify the chronology of particular quarries (Wojciechowski 1962, Domański 1963, 1965a, 1965b). It was also discovered that some pits (quarry relicts) were used in the late Middle Ages, as well as in the Roman Period and the early Middle Ages. Most likely, unworked stone material, and possibly unfinished quernstones, might have been exploited for use as building material. In the 1990s, archaeologists from Wrocław made a detailed mapping of all quarries (Kamiński & Kaźmierczyk 1994). Furthermore, A. Wójcik examined these outcrops from a geological perspective and made a comprehensive petrographic analysis of granite from Mt. Ślęża, in addition to referring to some particular quernstones and specific architecture from the Middle Ages (Wójcik 2002).

Knowledge of millstone quarrying in other parts of Silesia is scarce. Some evidence of production of quernstones was recorded in the Gilów stronghold situated in the Niemczańskie Foothills and dated back to the
end of the 9th and the beginning of the 10th century (Jaworski 2005:77–78). There, quernstones were made using low quality local gneiss cataclasites (Jaworski & Wójcik 1997:136–137). Finally, a quarry was supposed to be located in Kamieniec Ząbkowicki, as K. Jaworski recently suggested (2008). Based on unpublished materials from the excavation carried out in the 1980s, K. Jaworski assumed that it would be possible to find the quernstone quarries from the Early Middle Ages. Considering the fact that more than 10 mica schist millstones and unfinished pieces were recorded in the settlement at Kamieniec Ząbkowicki, there should be exploitation sites of mica schist outcrops within close proximity. Recently, the quarry in Kamieniec Ząbkowicki was also excavated (Lisowska 2011).
Granite rotary quernstones of the Ślęża Massif

Petrography
The main source of stone material for quernstone production was the quarry area located on the northern slopes of the Ślęża Massif. From a geological point of view, it represents the granitoids from the eastern part of the Strzegom-Sobótka granite intrusion (dating from ca. 292–309 Ma). The most widespread granitic stone materials in this region are biotite granodiorites and biotite-muscovite granodiorites, locally hydrothermally altered. Both are known by the local name “Chwalkow granite” (Fig. 4).

Biotite-bearing granodiorites are light grey in colour, with unoriented and massive structure. The main mineral constituents are irregular quartz, oligoclase (often with oscillatory zoning), microcline and biotite. Spheroidal and oval enclaves of tonalites are most widespread, while occurrences of pegmatite and aplite veins are rare.

The most common variety of quernstone source material from this area is grey two-mica granodiorite with porphyritic structure. It consists of large individuals of alkali feldspar (microcline) surrounded by a fine-grained mass composed of quartz, plagioclase (with zoning), biotite (often with parallel oriented platelets), muscovite and accessory zircon, apatite and garnet (Fig. 5). Most typical for this type of granodiorite is the occurrence of small, round, dark-coloured enclaves of diorites (Majerowicz 1963, Puziewicz 1990).

The millstone quarries and manufacturing technology
More than 150 quernstone quarries were exploited from the 3rd–4th century until the 15th century on the northern slopes of Mt. Ślęża; almost all of them represent pit quarries (Fig. 6). Nowadays, common quarries in this area are no more than 6 m deep with a diameter ranging between 10 to 20 m. Pit quernstone quarries were often located in places where the humus was relatively thin and it was easy to reach the rock. There is a higher density of quarries on the lower parts of the mountain, where conditions are favourable for communication between a settlement and a quarry.

Granite was exploited in several ways. Fireplaces recorded from archaeological excavations of quarries indicate that heating rocks to cause exfoliation of granite was probably one of the most popular methods of extraction (Domański 2002:41). Traces of fire were discovered inside more than five quarry pits. The second method, by contrast, was hypothetically controlled freezing of water inside the cracks during the winter using wooden pegs. There is no obvious archaeological evidence that may confirm the use of this technique, but some ethnographic observations suggest the possibility of the use of such techniques (Kaźmierczyk 1990:26–50). It is beyond doubt that 12th century quarry-workers used iron wedges to extract blocks of granite (Wojciechowski 1962:47), as is confirmed by the archaeological finds of 8 iron wedges (Fig. 7) discovered in one of the quarries and dated back to the 12th century (based on pottery findings). Wedges were probably also used for quarrying in previous centuries, but no similar findings of this type were found during excavation to prove this assumption.

Huge plates of granite (with a diameter up to 60 cm) were extracted by using the methods mentioned above. Quernstones were given their initial circular shape within a quarry (Fig. 8), but there are no circular outlines in the bedrock. Sometimes both the hole and circular shape were formed simultaneously with chisels. Many quernstones were discarded in different
stages of production nearby the quarries, due to damage to the rock while forming the discoid shape (Domański 2002:Fig. 37–38, 47). Granite from Mt. Ślęza represents an ordinary material for grinding stones, which often cracks into pieces. However, natural conditions and availability of rock material in the Early Middle Ages, especially in its older phases (until 10th century), make this granite a good alternative for making querns because better material was inaccessible. Still, it is hard to count the amount of unfinished quernstones lying on the slopes of Mt. Ślęza; some of them were reused as building material, many units were probably taken by villagers.

Quernstone production during the Early Middle Ages in Lower Silesia was strongly associated with the existence of local workshops at settlements nearby the quarries, for the simple reason that finishing the surface treatment of a quernstone took time and it was more convenient to work with the assemblage of
iron tools supported by a settlement. The results from archaeological excavations at three sites in the Śleża region represent Early Middle Age settlements (dated to the 8th–13th century) with quernstone workshops located nearby the villages of Chwałków, Będkowice and Strzegomiany (Jahn 1929, Śledzik-Kamińska 1996, Domański 2002:64, 70, 80, Jaworski 2008:76–80). Unfinished discoid quernstones were transported the few kilometres from the quarries to the villages, where the final stage of the production process took place, i.e. forming the shape and the surface of querns and drilling the eye. These activities are confirmed by archaeological finds of unfinished quernstones at the sites mentioned above (Fig. 9).

The dimensions of quernstones made of granite differ; the smallest specimen measures just 35 cm, the largest 50 cm. No connection or dependence was observed between quernstone dimensions and their relative chronology. Most of the quernstones made from granite have an average diameter of 41 cm, they are generally around 8 cm thick and the diameter of the eye is an average of 5 cm. Accurate measurement of all dimensions was possible for 49 quernstones from 20 different archaeological sites.

Mica schist rotary quernstones of Kamieniec Ząbkowicki

Petrography

The Niemcza-Kamieniec Metamorphic Complex is a large, meridionally elongated unit, situated to the east of the Góry Sowie Massif and of the Niemcza Shear Zone in the Fore-Sudetic Block. The tectonic evolution of this area is the subject of multiple, conflicting interpretations (Mazur & Józefiak 1999:2–5, Obers-Dziedzic et al. 2005:365, 368). The metamorphic belt is composed mainly of medium-grade mica schists, with
minor amounts of quartzo-feldspatic schists, marbles, quartzo-graphitic schists, amphibolitic schists and eclogites (Mazur & Józefiak 1999). According to Mazur and Puziewicz (1995:786–787), the Niemcza-Kamieniec Metamorphic Complex can be divided into two parts. The northern part is aligned along the eastern border of the Niemcza Shear Zone, whereas the southern part forms an isolated outcrop in the vicinity of Kamieniec Ząbkowicki. The metapelites in the latter fragment of the unit comprise two main structural varieties, namely coarse- and fine-grained schists. The rock type from which investigated quernstones were produced is petrographically very similar to garnet-bearing coarse-grained schists from the southern part of the complex described by Mazur and Józefiak (1999:5–6).

The raw material used for the quernstones is coarse-grained, and exhibits a grano-lepidoblastic structure and has well-developed foliation (Fig. 10), which is locally disturbed by crenulation folds (Fig. 11.1). The mica schist is composed of quartz, muscovite, biotite, garnet, plagioclase and chlorite; common accessory minerals are tourmaline, apatite, zircon, rutile and ilmenite, while staurolite and andalusite represent less frequent components. The rock consists of alternating muscovite-biotite and quartz or quartz-mica layers (Fig. 10). Muscovite plates are usually aligned subparallel to the foliation planes. In many places, elongated, fine-grained aggregates composed of randomly oriented sericite, plagioclase and quartz can also be observed (Fig. 11.2).

Garnet porphyroblasts (spanning 5 mm across or more) are very often partly decomposed and replaced by pseudomorphs of biotite, chlorite and iron hydroxides (Fig. 11.3–5). In less altered grains, inclusion trails of rutile, ilmenite and quartz are often visible.

Post-kinematic porphyroblasts of andalusite up to 6 mm across (Fig. 11.6) were ascertained only in one sample (quernstone from Bardo). They often enclose...
numerous inclusions of muscovite, biotite, quartz and ilmenite.

**The question of millstone quarries and manufacturing technology**

In the region of Kamieniec Ząbkowicki, there are many rocks where past quarrying activities are clearly visible (Fig. 15–16), represented by traces of the use of wedges and drills, or simple rock cutting, which are represented by artificial gaps in the bedrock. Only one settlement dating back to 9th–10th century AD corroborates a possible quernstone workshop (Jaworski 2008:81). More than 10 quernstones made from mica schists were found at this location (Fig. 12–14); some of them are complete, with visible traces of usage, while a few unfinished units represent different stages of quernstone production. Until 2009, excavations focusing on possible Middle Age quarry sites in this region had not revealed any quarries. The excavation carried out in 2009 at a small quarry, the nearest possible place to exploit mica schists, has shed more light on the problem.
of past quarrying activities in this area (Lisowska 2011). We noted that one unfinished disc for a quernstone still was attached to the bedrock (Fig. 15). This is the only specimen under production known from the region of Lower Silesia. Results of the excavation carried out at this site suggest that probably the Early Middle Age quarry was destroyed by the later mica schist exploitation, which took place in the 15th–18th century. The connection between the Early Middle Age settlement in Kamieniec Ząbkowicki and the excavated quarry site is confirmed through geochemical analysis (electron microprobe analysis – energy dispersive spectroscopy, wavelength dispersive spectroscopy) of garnets in mica schists sampled from the outcrops in the region of Kamieniec Ząbkowicki. The best geochemical similarity to the mica schist quernstones found in the settlement occurs in the samples that had been taken from the excavated quarry. The excavation of the quarries in the Kamieniec Ząbkowicki region will continue.

Quernstones made from mica schist were formed in two ways. The first method was very similar to that noted in the abovementioned workshops situated in the Ślęza Massif. Huge blocks of polygonal plates of a specified thickness (no more than 10 cm) were transported from the quarry to the workshop in the settlement. Both the circular shape and the eye were formed in the stone, which is confirmed by the finds of unfinished quernstones from the site. The second method used in Kamieniec Ząbkowicki was to shape a circle directly into the stone in the bedrock. Unfortunately, no archaeological evidence of the kind of tools used in this work was found, and no traces of the use of specific tools to separate the stone from the bedrock were noted. Characteristic traces after removing quernstones from quarries in other parts of Europe, represented by circular outlines in the bedrock (for example Heldal & Meyer 2011:Fig. 2, 8, 12, Jaccottey 2011:Fig. 14, 19, 20), are absent in southwestern Poland. It is also difficult to tell exactly what method of rock extraction was used in Early Middle Age quarrying in Kamieniec Ząbkowicki, because of the fact that Middle Age quarrying activities were almost totally destroyed by modern exploitation of mica schist (Lisowska 2011:147). Traces of using wedges and drills preserved in studied quarry sites are definitely from the modern era.

The case of quernstones from Gilów

A very special case of a quernstone workshop was discovered in the stronghold in Gilów, situated in the Niemczańskie foothills. Recent research carried out within the last two decades shows that the stronghold was built at the end of the 9th century by the people of Great Moravian origin (Jaworski 2005:272–286). By the beginning of 10th century, the inhabitants of the stronghold had left their settlement for unknown reasons. The residents of Gilów had no insight into the natural resources of Lower Silesia. They used only local rock from outcrops in the vicinity of the stronghold to produce whetstones and quernstones. To make millstones for their own needs, they exploited gneiss cataclasites (Jaworski & Wójcik 1997:136), which is a very brittle rock and unsuitable for this purpose. Quernstones made from gneiss cataclasites are known only from Gilów, and such finds have not been discovered at any other archaeological sites (Fig. 17–18). Since
the stronghold was quickly abandoned, there was probably no possibility of procuring a better quality of raw material from other parts of Sudeten. Contact between other inhabitants of the region was strongly needed to obtain granite from Ślęża or mica schists with garnets from Kamieniec Ząbkowicki. The local millstone workshop in Gilów existed for only a few decades. The stone material was probably derived from the quarry situated in the central part of the stronghold (Jaworski & Pankiewicz 2008:184–188) or from the nearby outcrops.

**Distribution of quernstones during early Middle Ages (6\(^{th}/7^{th}\)–13\(^{th}\) century) in southwestern Poland**

Millstones made of granite and mica schist were further distributed within Lower Silesia. Good quality quernstones were willingly purchased by the people settled in the northern part of the region. Quernstones were transported to, and floated up, the nearest navigable rivers. This hypothesis is confirmed by the distribution of mica schist quernstones, with the greatest concentration of finds recorded in the Nysa Klodzka basin (Fig. 19), a left tributary to the Oder River. The Nysa Klodzka river is easily navigable in its middle and lower sections and it runs very close to the outcrops of mica schists near Kamieniec Ząbkowicki, making it the most convenient way to transport the material. We find a different situation in the area of Mt. Ślęża, where there are no major rivers in the vicinity that can be used to transport quernstones. Thus, the highest density of granite quernstones noted at the Early Middle Age sites was observed nearby, within a distance of 10 km from Mt. Ślęża (Fig. 20). Granite quernstones have also been recorded at sites situated further north, approximately 100 km from the outcrops on Mt. Ślęża. In our opinion, such distribution probably depended on the range of the Slavic tribe Sleenzanie in the oldest phases of the Early Middle Ages (7\(^{th}/10^{th}\) century AD). The Sleenzanie tribe inhabited exactly the same area as the boundaries of distribution of granite quernstones mentioned above.

In later centuries, the distribution of granite quernstones was connected with the existence of trade routes. The main track from the south to the north ran very close to the area of Mt. Ślęża (Możdzioch 1990). The route crossed the Odra River in Wrocław, which was the most important trade and political centre during the Middle Ages in southwestern Poland. It is beyond doubt that Wrocław acted as transit place in the trade of granite quernstones during the Middle Ages (11\(^{th}/13^{th}\) century). This is confirmed by numerous findings of granite quernstones imported from Mt. Ślęża discovered at Early Middle Age sites in Wrocław (Kaźmierczyk 1990:152–159). For example, at the Ostrów Tumski stronghold site at Wrocław, more than 50 quernstones were made from granite of the Ślęża type (Fig. 21). Wrocław should be regarded as the most important trade centre, a hub for the transport and
distribution of Sudeten rocks in the 10th–13th century. This is confirmed by the dispersion and distribution of other stone items, which were quarried and then manufactured in the Sudetenland, including the very popular whetstones made from quartzite schists.

The current state of research enabled us to undertake petrographic identification and typological classification of only 50 per cent of all quernstones known from the excavated archaeological sites. Many previously discovered quernstone finds were lost or totally...
damaged during World War II or lost during flooding in 1997.

In the petrographic comparative analysis of the quernstones from different archaeological sites in Lower Silesia, we used several complementary methods. Both for samples taken from the outcrops and from millstones, apart from studying thin sections, we used electron microprobe analysis (using a Cameca Electron Microprobe analyser) and rare earth element analysis (using inductively coupled plasma atomic emission spectroscopy at Acme Analytical Laboratories in Vancouver, Canada). Detailed discussion of the results of the geochemical research will be published soon in two separate articles. On the basis of the mentioned petrographic research, we created the distribution map showed in Fig. 19–20.

Final remarks

The quarrying and manufacturing of quernstones by Silesian Slavic tribes was fairly simple and straight-
forward from a technological point of view. This early simple technology was developed over time. The development of monumental architecture in the 11th–13th century led to increasing interest in rock materials, as well as a significant enrichment of the range of tools used for rock exploitation. It is surprising that although the Slavs were a culturally alien ethnic group, they exploited exactly the same outcrops as their predecessors in the Roman Period. It seems that the distribution of the quernstones made from Sudetic rocks had a rather local character and would not have gone beyond the area of southwestern Poland. This thesis is confirmed indirectly through a quernstone made from mica schist found in Wolin, Pomerania, which was made from schist of Norwegian origin, probably from the area of Hyllestad in western Norway (judging from a macroscopic analysis), and not from Sudetic rocks which were much closer, no more than 500 km away. In the light of the presented data, the region of Lower Silesia seems to have been totally self-sufficient for millstone production in the Early Middle Ages. The quality of the raw material was rather good, but not considered suitable for export other regions. Also, the absence of any imported quernstones from other parts of Poland and Europe clearly indicates economic independence with regard to the quarry and the distribution of quernstones.

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