



## DENDROCHRONOLOGICAL STUDIES OF WOOD FROM MEDIAEVAL MINES OF POLYMETALLIC ORES IN LOWER SILESIA (SW POLAND)

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Received 9 November 2006

Accepted 8 January 2006

**Abstract:** The paper presents results of dendrochronological dating of wood encountered in abandoned mines in the eastern part of Lower Silesia. The research was carried out in gold mines in Złoty Stok, Gluchołazy, and Zlate Hory, a polymetallic-ore mine in Marcinków as well as old mines in the Sowie Mts: the Silberloch adit, an adit on the hillside of Mała Sowa, a graphite mine, and the silver and lead mine Augusta. Altogether 69 samples were taken from timbers of coniferous tree species: *Pinus sylvestris*, *Abies alba*, *Picea abies* and *Larix decidua*. The oldest wood, from the turn of the fifteenth and sixteenth centuries was encountered in the gold mines in Zlate Hory and Gluchołazy. In the gold mine in Złoty Stok, graphite mine in Sowie Mts and in Marcinków there was identified wood from the seventeenth and eighteenth centuries. Generally, timbers from the nineteenth century were prevailing, and in three cases there was even encountered relatively young twentieth-century wood in the gold mine in Złoty Stok and in the Silberloch adit. The analyses carried out were only preliminary. Broader, interdisciplinary investigations, including dendrochronology, archaeology, geology, mining, and palaeobotany, would substantially contribute for learning the history of the mining in the whole region.

**Keywords:** dendrochronological dating, tree-ring analysis, mines, SW Poland

### 1. INTRODUCTION

Dendrochronological studies of wood occurring in old mines in Poland have a short, only several-year history. The first pioneering studies from this scope were carried out in the Wieliczka salt mine at the end of 1980s. Ten years later, at the end of 1990s detailed dendrochronological sampling was made in this historic mine, in particular on the first, oldest level of the mine, where almost 300 samples were taken from wooden casings of the oldest, but still accessible mining chambers (Szychowska-Krapiec, 2003a). Dendrochronological studies were also performed in the Bochnia salt mine, where over 300 wood samples were taken from timbering of chambers situated on seven mining levels (Szychowska-Krapiec, 2003b). These studies resulted in a number of absolute datings, ranging from the fifteenth to the twentieth century. Both salt mines belong to the oldest mining

factories in Poland, their beginnings reaching back in time to the thirteenth century.

They are, however, not the only such old mines in Poland. Even older is apparently mining history in Lower Silesia, connected with exploitation of gold and polymetallic ore deposits. Without doubt the beginnings of mining should be bound with search for gold, of which deposits occur in the vicinities of Złoty Stok, Złotoryja, Bolesławiec, Lwówek Śląski, in Karkonosze, and in the Opawskie Mts. Cretans were most probably the first searchers of this precious metal about 2000 BC, and later Celts washed gold-bearing sands in the stream and river valleys. Purely mining activity started in the Middle Ages, in the twelfth and thirteenth centuries, when Złoty Stok, Gluchołazy, Zlate Hory became important centres of exploitation of this precious metal (Dziekoński, 1972). In later centuries most of the old mines were abandoned and/or closed, so presently in many cases their remains are vestigial; filled, and collapsed galleries and chambers, often requiring laborious efforts to reach to them. In the last years works were undertaken in order to make access

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to at least some of these old mines and uncover still legible traces of historic mining in the region.

Since 1970s the ore mining in the Lower Silesia region is a subject of archaeological works, consisting in searching for, inventory, and recognition of the old mining areas, unveiling the extent of the old mining works, as well as reconstruction of conditions of the exploitation of deposits (Firszt, 2006). In numerous uncovered galleries old timbers are preserved; either as old wooden casings or as elements of old mining machines and devices. Dendrochronological dating of these elements, combined with archaeological, mining, geological, and palaeobotanical studies, would substantially broaden our knowledge about the mining history in the region. Such was the idea of preliminary dendrochronological analyses of wood sampled in selected mines from the eastern part of the Sudety Mts (the Sowie Mts, Kłodzko region, and the Opawskie Mts) in the years 2004-2005.

## 2. RESEARCH MATERIALS AND METHODS

The materials for analyses came from eight old mines: the gold mine in Złoty Stok, the polymetallic-ore mine in Marcinków, the gold mines in Głucholazy and Złate Hory (Czech Republic) as well as old mines in the Sowie Mts (the Silberloch adit, an adit on the hillside of Mała Sowa, a graphite mine, and the silver and lead mine Augusta (Fig. 1). The amount and state of preservation of wood in these objects was highly diversified.

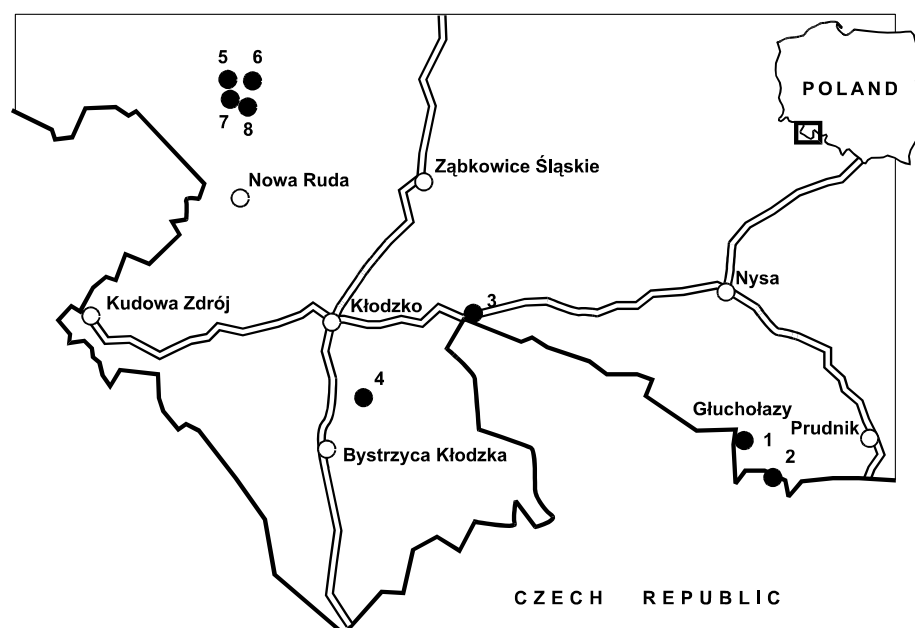
### The gold mine in Złoty Stok

The Złoty Stok gold mine belongs to the oldest and most important gold mines in Lower Silesia. The mining works apparently started there in the tenth century, and the first documents concerning mining there date back to 1273. Until the eighteenth century the principal exploited material was gold, which later became only a by-product at the industrial production of the arsenic. The mine con-

tinuously functioned until 1961, when it was closed down (Łuszczkiewicz and Muszer, 1997). It was re-opened in 1996, but as the Museum of the Gold Mining and Metallurgy. In many galleries and chambers there are preserved relics of wooden casings of walls and ceilings, as well as fragments of shaft timberings. From these wooden remains 33 samples for analyses (mostly in form of slices, in some cases corings) were taken from timberings of mining chambers and shafts in the following parts of the mine: the Prince's Adit, the Black Higher Inclined Drift, the Black Lower Inclined Drift, the Masters' Adit, and the Round Adit (Fig. 2). Generally the timbers were preserved in the mine in a rather bad state; very often wood was cracked, saturated with water and rotten.

### The mine in Marcinków

Another evidence of old mining works in the region is provided by the vestiges of an old mine of polymetallic ores in the village Marcinków, at the foot of the Śnieżnik Massif, near Bystrzyca Kłodzka. The first notes about this mine date back to the sixteenth century (1575). The mine operated, with some interruptions, for more than three centuries and, finally, was definitively closed at the beginning of the twentieth century (Madziarz and Sztuk, 2004). Later, after the Second World War, some attempts of exploitation of uranium ores were undertaken, however, the contents of this element turned out to be insufficient, and the mine in Marcinków was categorised as unprofitable. In the last years two adits, the upper and the lower, were dug out, in which wooden elements of casings of mining galleries as well as an inclined, timbered shaft with a windlass were discovered (Szychowska-Krapiec and Stysz, 2006). These wooden elements were subjected to dendrochronological sampling, carried out with a Pressler increment borer and handsaw for cutting wood (Fig. 3). Altogether 27 slices and cores were taken from both adits.



**Fig. 1.** Locality of the mine objects in which samples were taken for dendrochronological analyses:

- 1) the gold mine in Głucholazy,
- 2) the gold mine in Złate Hory,
- 3) the gold mine in Złoty Stok,
- 4) the mine in Marcinków,
- 5) the Silberloch adit,
- 6) the graphite mine in the Sowie Mountains,
- 7) the mine on the hillside of Mt. Mała Sowa,
- 8) the Augusta mine.



Fig. 2. Wooden casings in the gold mine in Złoty Stok



Fig. 3. Taking samples with the Pressler increment borer from the shaft timbering in the Marcinków mine.

### Gold mines in Głucholazy and Zlate Hory

In two neighbouring towns in the Opawskie Mountains, Głucholazy and Zlate Hory, gold mining has a long tradition, closely connected with discovering deposits of this precious metal near Zlate Hory at the beginning of the thirteenth century, which contributed to the development of both towns. Gold was being extracted there in two ways: in open pits and, more often, with a shaft system. In Głucholazy, up till today about 80 mining shafts are preserved, the biggest of them is about ten metres in diameter and is four metres deep. Gold had been exploited, with some breaks, until the nineteenth century. After the Second World War the mining in this area was reactivated, with exploitation of copper, zinc, and lead ores, as well as up to 30 kg of the annual production of gold. At present, all the mines have already been closed, but strange events still remind of the mining past. In places of old mines the terrain sometimes collapses, uncovering parts of ancient adits and galleries as well as elements of old wooden casings. From an old timbering this way uncovered, one sample, in form of a slice, was taken for dendrochronological analyses.

The mining past of Zlate Hory, where rich deposits of gold were discovered in the beginning of the thirteenth century, is inseparable from the history of mining in neighbouring Głucholazy. Shallow deposits were exploited, with some interruptions, till the middle of the nineteenth century. After the Second World War the ore exploitation has been once more undertaken, that time mostly directed at copper, zinc and lead. Gold, as in Głucholazy, was only a by-product, and the mine in Zlate Hory was definitively closed in 1993. At present fragments of ancient casings can be seen in accessible parts of the mine, where two slices were picked up for analyses.

### Mines of polymetallic ores in the Sowie Mountains

In Lower Silesia not only gold deposits were being exploited but also, among others, ores of arsenic, copper, tin, iron, silver, lead or cobalt. Polymetallic deposits occurred, among others, in the Sowie Mountains, where today over hundred old mines are known. In this region there were exploited e.g. ores of lead and silver, what is

still evidenced by common relics after ancient mining; numerous shafts and drifts, mining chambers, galleries, sometimes with fragments of wooden casings and elements of mining machines, some of them reaching back to the fourteenth century (Mączka and Stysz, 2006). To that time dates back the Silberloch adit, at present the best-preserved old-mining object in this massif. The Silberloch was being exploited to the eighteenth century, then, for some time, it functioned as a tourist attraction, showing former mining techniques, ways of accessing deposits for exploitation, as well as draining, ventilation, lighting, and finally transport and further treatment of the ores (Madziarz and Sztuk, 2004). Although few wooden elements, which could be dendrochronologically sampled, are preserved in the adit, two samples, in form of slices, were taken.

In the same massif of the Sowie Mountains one can find an entrance to the ancient graphite mine, with fragments of old wooden casings. From these casings two slices of wood were picked up.

The third dendrochronologically analysed object is a little mine situated between the villages Rzecznka and Walim, on the north-western hillside of Mt. Mała Sowa. This mine is a single gallery, not longer than 30 metres, and in its prevailing part it is flooded with water up to the height of about 40 cm (Stysz and Mączka, 2005). In the bottom of this gallery a fragment of wood was encountered and sampled (in form of a slice) for dendrochronological analyses.

Also in the Sowie Mountains is situated one of the most beautiful mines – the lead and silver mine Augusta, relatively young, established at the end of the nineteenth century. Its mining area stretches over the commons Kamionki, Pieszyce, and Rościszów. The mine consisted of four levels, some divided with wooden platforms made from beams and boards. On the third level of the mine, close to the gallery heading, traces of an old railtrack were found, with only one retained sleeper, from which a dendrochronological sample was taken (Stysz, 2005).

From all the above-presented mines altogether 69 samples were taken. The investigations were carried out in the dendrochronological laboratory of WGGiOŚ AGH-UST in Cracow, the standard methodology (Krapiec,

1995; Schweingruber, 1988) having been applied. Measurements were made to the nearest 0.01 mm. The obtained sequences of annual growth rings were processed the packages of programs TREE-RINGS (Krawczyk and Krapiec, 1995) and COFECHA (Holmes, 1994). Absolute dating of the sequences produced was carried on the basis of accessible regional standards from Poland, Germany and the Czech Republic for the coniferous tree species. Fir wood was dated against the fir standard for S Poland, embracing the period 1106-1998 AD (Szychowska-Krapiec, 2000), and the Czech chronology (1131-1997 AD) (Kyncl and Kyncl, 1998). In the case of the pine wood, age determinations were based on the regional standard for N Poland, embracing the period 1106-1991 AD (Zielski, 1997), the Małopolska regional standard (1622-1996) (Szychowska-Krapiec, 1997), the East German regional standard (924-1995 AD) (Heußner, 1996), the local chronologies for Wrocław (1080-1333 AD and 1655-1831 AD) and Lubsko (1254-1376 AD and 1721-1848 AD; Szychowska-Krapiec and Krapiec, 2001), as well as contemporary local patterns for Bystrzyca Kłodzka (1840-1996), Śnieżka (1837-1996 AD) and Oborniki Śląskie (1872-1989 AD; Zielski *et al.*, 2001). Spruce was dated on the basis of the Czech regional chronology (1279-1997AD; Kyncl pers. comm.), and in the case of the larch wood, hetero-connection with the fir and pine chronologies was applied.

### 3. RESULTS

On the basis of the investigations carried out, the species of wood were determined as well as absolute age determinations were produced. Amongst the examined timbers, exclusively wood of coniferous tree species was determined: *Pinus sylvestris*, *Abies alba*, *Picea abies* and *Larix decidua*.

#### The gold mine in Złoty Stok

The wood sampled for analyses represented three tree species: pine (24 samples), spruce (two samples) and fir (seven samples). Generally, the growth sequences were rather short, consisting of 26-76 rings, most often of 30-50 rings. Such short sequences caused serious problems at the absolute dating, especially in the case of spruce samples, dating of which failed.

However, absolute dating of fifteen samples representing pine and fir wood was successful (**Table 1**). Among them there were six samples of fir. The oldest dates were obtained for wood from the shaft timbering in the Masters' Adit (1667 AD) and for wood coming from the old gun-powder store, also in the Masters' Adit (1751 AD). These timbers were dated against the Czech fir standard, with which they displayed the highest convergence. The younger, nineteenth-century wood was encountered in the Prince's Adit, in the Black Upper In-

**Table 1.** Results of dendrochronological analysis of wood samples from the gold mine in Złoty Stok

No	Lab. code	Locality	Species	No of tree rings	Sequence dating	Date of felling the tree	Correlation with the standard t and r values
1	2ZST1	Prince's Adit	<i>Pinus sylvestris</i>	59	1883-1941	after 1941	5.23 0.58
2	3ZST2	Prince's Adit	<i>Abies alba</i>	35	1770-1804	after 1804	4.77 0.65
3	3ZST4	Black Upper Inclined Drift	<i>Abies alba</i>	27	1859-1885	after 1885	4.81 0.72
4	2ZST10	Black Lower Old Inclined Drift, behind the fall	<i>Pinus sylvestris</i>	76	1809-1884	after 1884	5.67 0.61
5	2ZST14	Round Adit, western field	<i>Pinus sylvestris</i>	40p	1794-1833	1833	4.33 0.49
6	2ZST16	Masters' Adit	<i>Pinus sylvestris</i>	53p	1841-1893	1893	4.47 0.54
7	2ZST19	Masters' Adit, shaft timbering	<i>Pinus sylvestris</i>	43	1838-1880	after 1880	4.23 0.51
8	3ZST21	Masters' Adit, shaft timbering	<i>Abies alba</i>	45	1623-1667	after 1667	4.92 0.59
9	3ZST22	Masters' Adit, old gun-powder store	<i>Abies alba</i>	41p	1833-1873	1873	4.75 0.62
10	3ZST24	Masters' Adit, old gun-powder store	<i>Abies alba</i>	55	1697-1751	after 1751	5.17 0.76
11	2ZST25	Masters' Adit, shaft timbering	<i>Pinus sylvestris</i>	37	1848-1884	after 1884	4.12 0.51
12	2ZST26	Masters' Adit, shaft timbering	<i>Pinus sylvestris</i>	45	1849-1893	after 1893	4.33 0.49
13	3ZST29	Small shaft, sample no 3	<i>Abies alba</i>	72p	1830-1901	1901	5.21 0.54
14	2ZST31	Gallery under small shaft, sample no 5	<i>Pinus sylvestris</i>	43	1759-1801	after 1801	4.34 0.47
15	2ZST32	Gallery under small shaft, sample no 5A	<i>Pinus sylvestris</i>	40	1748-1787	after 1787	4.69 0.48

p = underbark ring

clined Drift, and in the Masters' Adit – in the gun-powder store. The youngest date was obtained for wood from a small shaft – 1901 AD. This dating is precise, because the examined timber retained its last, underbark ring. The younger sequences displayed the highest similarity to the S Poland standard.

In the case of the pine wood, nine samples were absolutely dated, seven of them to the nineteenth century. The oldest date was produced for wood from a gallery below the small shaft, at the fall of the rock debris – 1787 AD. Another piece of wood from that site was dated to the beginning of the nineteenth century. Since both sequences of annual rings were only fragmentary, devoid of a certain number of the last rings, it may be supposed, that these samples represented pine trees cut down in the same time, i.e. at the beginning of the nineteenth century. A little bit younger, though also from the first half of the nineteenth century, wood was encountered in the Round Adit (1833 AD). The next, still younger dates fell in the second half of the nineteenth century; wood from the Black Lower Old Drift, from the site behind the fall was dated to 1884 AD, whereas wood from timbering of the flooded shaft in the Masters' Adit came from 1890s. The youngest date was produced for wood from the Prince's Adit – 1941 AD (Table 1).

#### The mine in Marcinków

The analysed wood represented four coniferous tree species: spruce, fir, pine and larch. The pine samples (18 pieces) substantially outnumbered the other species; seven samples of larch, and only one sample each in cases of fir and spruce. The length of individual sequences varied from about 70 growths at the longest patterns to about 30 at the shortest ones. Most of them

exhibited 40-50 growth rings. The dendrochronological analysis carried out enabled dating of eight samples from the upper adit and two from the lower, including seven pine samples and three of larch (Table 2). In the upper adit the oldest date was obtained for pine wood from the timbering (1614 AD). The other dates fell in the nineteenth century, the casings of the upper adit being somewhat older (1808-1815 AD) than the timber from the shaft. The latter pointed at two phases: the older – 1826 AD, and the younger – 1863 AD. From the lower adit two pine samples were dated; one represented the tree cut down in 1833 AD, and the second tree was felled after 1869 AD. These dates fell in the same time intervals as the dates produced for wood from the upper adit (Table 2).

#### Gold mines in Glucholazy and Zlate Hory

The wood from the mines represented the silver fir. The longest individual sequence, consisting of 83 growth rings, appeared in the wood sample from Glucholazy, uncovered after the last collapse of the terrain. Shorter sequences were noted at two samples from Zlate Hory; each of them contained 55 increments, including the last, underbark rings. Absolute dating demonstrated that the fir trees represented by the analysed samples were cut down at the end of the fifteenth and at the beginning of the sixteenth century. In the case of wood from the Czech mine the exact dating (with one-year accuracy, thanks to preserved underbark rings) pointed at 1491 AD (Fig. 4). In a little bit younger timber from the mine in Glucholazy, the last growth ring was dated to 1501 AD (Fig. 5).

#### Mines of polymetallic ores in the Sowie Mountains

In the case of wood from four mines in the Sowie

Table 2. Results of dendrochronological analysis of wood samples from the mine in Marcinków.

No	Lab. code	Locality	Species	No of growth rings	Sequence dating	Date of felling the tree	Correlation with the standard t and r values
1	2MARC4	Shaft, Upper Adit	<i>Pinus sylvestris</i>	57	1807-1863	after 1863	5.19 0.56
2	2MARC6	Upper Adit	<i>Pinus sylvestris</i>	55p	1809-1863	1863	4.44 0.48
3	2MARC7	Upper Adit	<i>Pinus sylvestris</i>	41	1786-1826	after 1826	4.19 0.40
4	2MARC8	Upper Adit	<i>Pinus sylvestris</i>	41	1786-1826	after 1826	4.23 0.48
5	2MARC11	Lower Adit	<i>Pinus sylvestris</i>	34	1836-1869	after 1869	3.98 0.41
6	2MARC16	Lower Adit	<i>Pinus sylvestris</i>	36	1798-1833	after 1833	4.46 0.47
7	2MARC17	Upper Adit	<i>Pinus sylvestris</i>	40	1575-1614	after 1614	4.29 0.47
8	4MARC1	Upper Adit	<i>Larix decidua</i>	63	1748-1810	after 1810	5.20 0.54
9	4MARC6	Upper Adit	<i>Larix decidua</i>	61	1748-1808	after 1808	4.98 0.52
10	4MARC8	Upper Adit	<i>Larix decidua</i>	70	1746-1815	after 1815	5.33 0.56

p = underbark ring

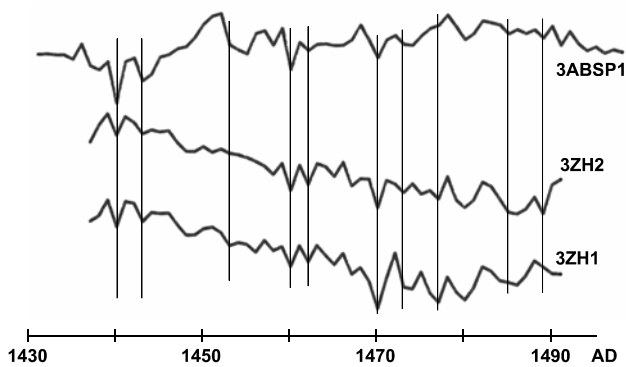


Fig. 4. Dendrochronological dating of fir growth sequences 3ZH1 and 3ZH2 from the gold mine in Zlate Hory on the basis of the S Poland standard (3ABSP1).

Mountains, three samples were absolutely dated; from the Silberloch adit, the graphite mine, and the little adit on the hillside of Mt. Mała Sowa. Two timbers sampled in the Silberloch adit turned out to be fir and spruce. Both yielded rather short sequences (51 and 37 growth rings), and both retained the last, underbark ring. Only the fir sample, however, was successfully dated – to 1909 AD (Fig. 6). So, it turned to represent almost contemporary wood, coming from the time when the old mine, having already been closed for two centuries, was only a tourist attraction. Taking into account rather long history of the mine, reaching back to the fourteenth century, older wood could be expected. Low amount of rings in the spruce sample rendered its dating impossible.

Two samples taken from the graphite mine, representing spruce, also had quite short sequences (43 and 63 growth rings). Both, however, retained the last, underbark ring. Dendrochronological dating was successful in the case of one sample – dated to 1672 AD (Fig. 7). This indicates that the analysed wood from that mine came from the spruce cut down in 1672.

The third mine, a sample was taken from, was the lit-

tle mine on the hillside of Mt. Mała Sowa. The analysed piece of wood, representing Scots pine, proved to contain 46 annual growths, including the youngest underbark ring. Dendrochronological analysis dated this sample to 1858 AD ( $t=5.21$ ,  $r=0.67$ ) – the exact year of cutting down the pine tree represented by the timber taken from the bottom of the mining gallery.

In the case of wood from the fourth mine, Augusta, dendrochronological analysis could not be successful, because the collected piece of wood contained only 14 growth rings. Only the tree species was determined – *Picea abies*.

#### 4. DISCUSSION AND CONCLUSIONS

The dendrochronological investigations carried out in eight mining objects from Lower Silesia resulted in 28 absolute datings of wood samples coming from wooden casings of mining galleries and chambers and mining devices preserved there. The dates obtained range from the fifteenth to the twentieth century. The oldest analysed wood came from the mine in Zlate Hory in the Czech Republic (the end of the fifteenth century) and the mine in Głucholazy (beginning of the sixteenth century). In both cases it was fir wood. In the gold mine in Złoty Stok, the graphite mine in the Sowie Mountains, and in Marcinków the seventeenth- and eighteenth-century wood was determined. Generally the nineteenth-century wood was prevailing, and in three cases even relatively young, twentieth-century wood was encountered in the mine in Złoty Stok and in the Silberloch adit. The investigations carried out were the first, preliminary dendrochronological studies on wood from the mines from Lower Silesia. They provided, however, hard data, in form of absolute datings of timbers collected there. A broader research would certainly contribute to the mining history and the chronology of mining works in the region Lower Silesia, as it took place in the case of the studies conducted in Austria, in the salt mine in Hallstatt. Den-

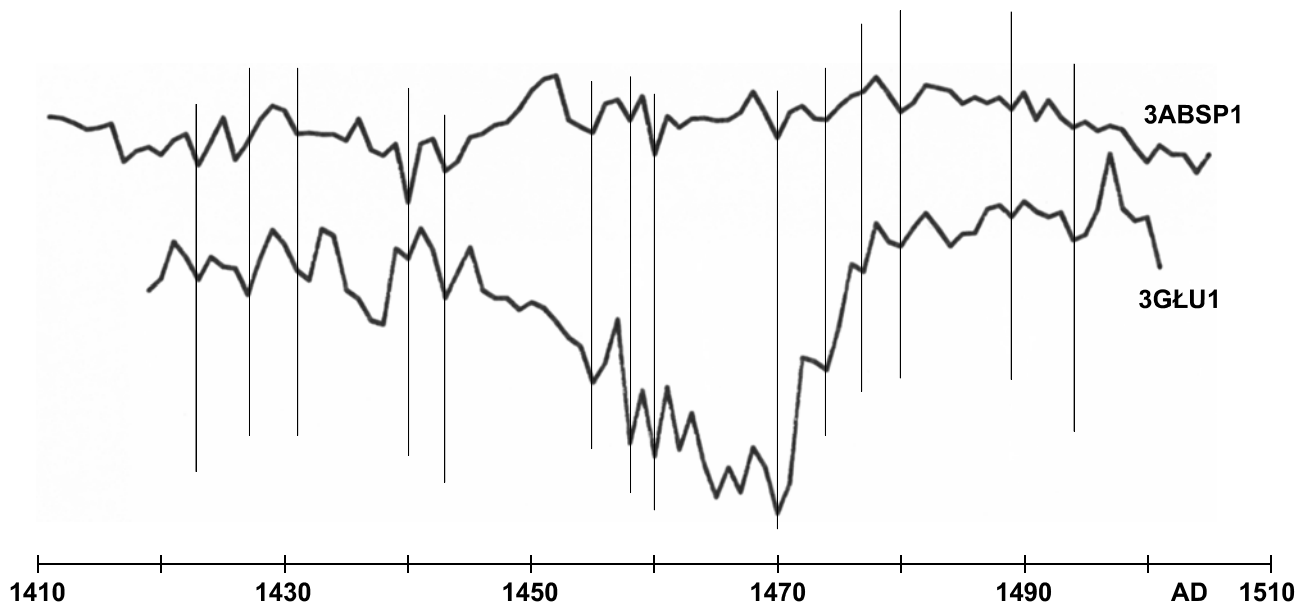


Fig. 5. Dendrochronological dating of fir growth sequence 3GLU1 from the gold mine in Głucholazy on the basis of the S Poland standard (3ABSP1).

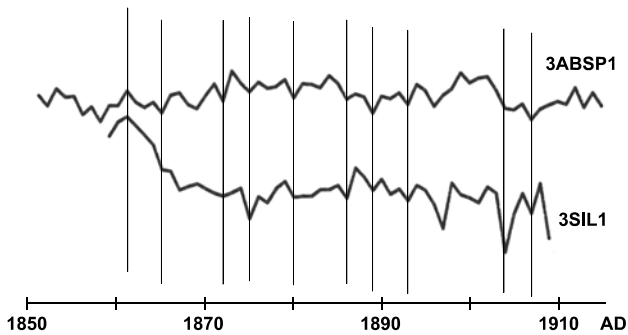


Fig. 6. Dendrochronological dating of fir growth sequence 3SIL1 from the Silberloch mine on the basis of the S Poland standard (3ABSP1).

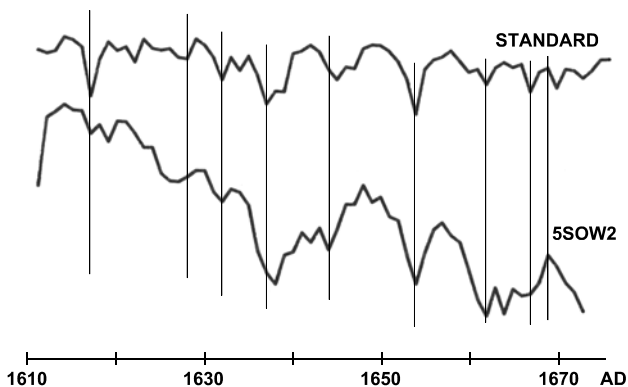


Fig. 7. Dendrochronological dating of spruce growth sequence 5SOW2 from the graphite mine in the Sowie Mountains on the basis of the Czech standard.

drochronological studies in this mine started in 1974, at first on a limited scale, like the investigations presented here, but thanks to continuing them for several consecutive years, they resulted in establishing chronologies for the spruce, larch and fir, enabling to date wooden elements from that site (Grabner *et al.*, 2006; Hollstein, 1974; Ruoff and Sormaz, 1998, 2000).

One should remember that old mines are, in fact, huge stores of wood, representing considerable time intervals, which constitute an excellent base for creating practical dating tools, i.e. dendrochronological standards. Thanks to such local and regional chronologies it is possible to date even single samples containing relatively small numbers of growth rings. The remains of the old mining works in Lower Silesia open such possibilities, because in numerous old mines, shafts, galleries or mining chambers huge amounts of wood are stored.

## ACKNOWLEDGEMENT

The author is grateful to E. Szumska, M. Sc. and M. Stysz, M. Sc. for help at taking samples in the mines. Financial support for this study was provided by the AGH-UST grant no 11.11. 140.917.

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