The history of non-ferrous metallurgy in Slovenia

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ABSTRACT: Modern Slovenia, and the adjoining parts of some neighbouring countries inhabited by Slovenian people, has a rich history of mining and smelting of non-ferrous metals. Lead was produced from the 13th century in Southern Carinthia and flourished during the 17th century. The Bleiberg smelter at Villach was for a long time the most important in the area; the Carniolan process described by Agricola was used there in the 16th century. Another important centre was in the Mežica valley, and there was small scale mining and smelting also in Carniola near Ljubljana. Zinc smelting started in Carinthia in 1799 and in Zagorje in Carniola in 1843, but the main centre was at Celje in Carniola which produced zinc from 1875 to 1970 using horizontal retorts. Mercury was extracted at Idriga in Carnolia from 1490 and the place became renowned for the excellence of its mining and smelting technologies. It flourished for over 500 years, producing in total about 13% of the world's mercury output. Aluminium production is a recent industry which continues today. Minor copper and antimony production is also recorded.

Introduction

As an administrative territory, Slovenia appeared after the Second World War as a republic of ex-Yugoslavia, and in 1991 it became an independent state. Before the First World War it was a part of the Austro-Hungarian Empire, and the countries where Slovenes lived were called Carniola (today the central part of Slovenia), Carinthia (most of which is today in Austria, with a small part in north eastern Italy, and another small south eastern part now in Slovenia and also called Carinthia), and Styria (which today comprises the north eastern part of Slovenia and the south eastern part of Austria) (Fig 1).Those countries also had at that time close economic relations, thus the historical review presented here will also include some neighbouring territories outside the present state of Slovenia. Since the names of towns and places in the Austro-Hungarian Empire were germanized and their German form appeared in all the old documents, I shall add to the Slovenian names the old names in brackets. See Figure 1 for the location of all the places mentioned below.

The metallurgy of the non-ferrous metals in Slovenia includes lead, mercury, copper, zinc, and aluminium, and also silver as an accompanying element in lead ores. Though archaeological excavations discovered hoards with copper ingots and copper objects from the Bronze Age at several places in Slovenia, there was no direct evidence of copper smelting on the territory of Slovenia. Thus the history of non-ferrous metallurgy can be described since the Middle Ages, being confirmed by various written documents.

Lead

The oldest existing documents are on the metallurgy of lead. Mining of lead is mentioned as follows: in the 13th century at Slovenji Plajberk (Windisch Bleiberg) in the Karavanke Mountains (Karawanken) — but a document about the smelter erected there (by Karel Ungnad) is dated from 1583; in the 14th century in the foothills of Mount Dobrač (Dobratsch), in the 15th century in the foothills of Mount Peca (Petzen), and in the 16th century in Rabelj (Raibl) (Wiessner 1951). All these places are in southern Carinthia. In 1226 the place called Pliberk (Bleiburg, originally: Pleyburg (Wiessner 1951) obtained its name from lead (Lead Town). Around Mount Dobrač there are numerous places with the name Bleiberg (in translation Lead Mountain), but the most important is Bleiberg at Villach, which in old times was named Pleyberg pey Villach. The oldest written document on lead from the Slovenian part of Carinthia was dated 1424, and is the account book of Duke Ernest the Iron who bought lead ore, probably mined on Mount Peca. Agricola (1556) mentioned in his descriptions of mining and metallurgical technologies of the 16th century the so-called Carniolan process (Fig 2), used in Bleiberg at Villach. In an arched furnace wood logs were piled on two low walls, crushed ore was placed on the logs, the wood was burnt, and lead trickled into a crucible at the bottom of the furnace. From this crucible lead was decanted by smelters into other crucibles which were then pulled out of the furnace. This lead was very pure.

During the 'Thirty-year War', from 1620 to 1634, trade

in lead flourished, and the Carinthian mines of Bleiberg and Rabelj made great progress. The valley of Mežica (Miesstal), today the Slovenian part of Carinthia, was at that time in the country of Carinthia.

The actual beginning of lead metallurgy in the Mežica valley (Anon 1965) started when Hans Sigmund von Ottenfeld obtained a concession in 1665 to open a lead mine in Črna (Schwarzenbach), though Count Thurn had mined lead ore on his estate in Pliberk since the beginning of the 17th century. There exists also a letter giving evidence that Matevž (Matthew) Ludiger obtained in 1644 a concession for lead mining in the Mežica valley. The manager of Count Thum's estate, named Gajčnik, later von Schlagenberg, who moved from Lower Styria, erected around 1740 the first smelter and in the years 1741 to 1747 he produced about 150t of lead. In 1771 Gregor Kompoš, probably of Hungarian origin, came to von Schlagenberg's enterprise as mine superintendent, but soon he became independent contractor. He constructed a furnace, called Kompoš furnace, which had two hearths, the top one for ore roasting, and the bottom one for calcine smelting, including dust catchers to increase the lead yield in smelting. The furnace was heated by burning wood, later also charcoal was added.

At the end of 18th century the Žerjav brothers, who came to the Mežica Valley from the Labot valley, initially smelted enriched lead ore close to lead mines in Črna, but later they erected a new smelter further down the valley, and the place was named Žerjav after them. The only present-day lead smelter in Slovenia is still there.

In the 19th century the small lead mines and smelters started to join together into bigger companies till in the years 1860 to 1893 all the Carinthian lead mines and smelters were organized in the Bleiberger Bergwerksunion (Bleiberg Mines Union) or BBU. In the 19th century in the Mežica Valley two bigger lead smelters operated, one in Mežica (closed in 1906) and the other in Žerjav (opened in 1746, and operating still today). Until 1882 lead ore from mines around Bleiberg was smelted at Bleiberg (north of Mount Dobrač), then the smelter was moved to Arnoldstein near Gailitz which is south of Mount Dobrač. Before the First World War production of the smelter in Žerjav exceeded the Bleiberg production of lead. Bleiberg was namely for a long time the most important lead smelter in the area.

After the First World War the south Carinthian mines were divided among three newly-established countries: Bleiberg remained in Austria, the Mežica valley became part of Yugoslavia, and Rabelj belonged to Italy. Between the two World Wars the lead mines and smelter in the Mežica valley became the property of a newly established company, Central European Mines Ltd, with its head office in London, but after the Second World War they were nationalized by Yugoslavia.

At the Žerjav lead smelter American hearth furnaces

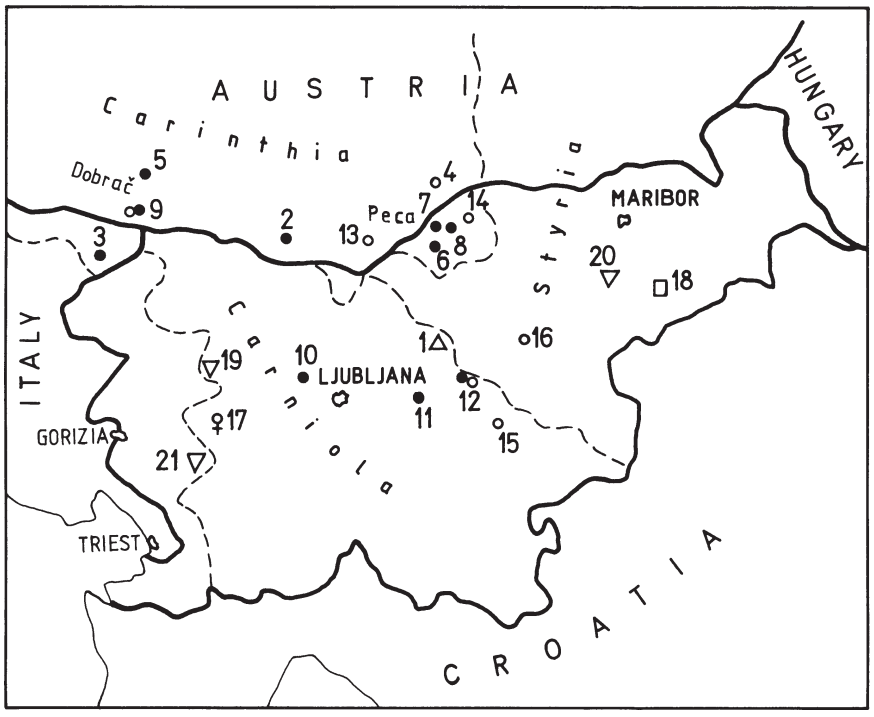

Figure 1: Map of present-day Slovenia and provinces existing in the 19th century on Slovenian territory, with places mentioned in the paper. Solid lines = present state borders, with names of present states in capitals. Dashed lines = province borders, with 19th century province names in lower case.

Mines & smelters:
1 Trojane, 2 Slovenji Plajberk, 3 Rabelj, 4 Pliberk, 5 Bleiberg, 6 Črna, 7 Žerjav, 8 Mežica, 9 Arnoldstein, 10 Knapovže, 11 Litija, 12 Zagorje, 13 Železna Kapla, 14 Prevalje, 15 Šentjanž, 16 Celje, 17 Idrija, 18 Kidričevo, 19 Cerkno, 20 Slovenska Bistrica, 21 Hubelj.

△	*antimony*	♀	*mercury*
●	*lead*	□	*aluminium*
○	*zinc*	▽	*copper*

Figure 2: Carniolan process of lead smelting as illustrated by Agricola in De Re Metallica.
A - Carniolan furnace, B - low wall, C - wood, D - flow of lead, E - big crucible, F - small crucibles, G - stirrer, H - lead ingots, I - air-blowing opening (tuyere).

were installed in 1896, and a blast furnace in 1924. Smelters for primary lead in Žerjav were closed in 1990 and in Bleiberg in 1993, while in both places secondary lead from battery scrap is still produced.

Next to Carinthia, lead was mined and smelted also in Carniola but to a much smaller extent (Šorn 1972, 349-66). There were three areas: at Knapovže (Knappousche) near Medvode (Zwischenwässern), some 20km from Ljubljana, the present capital of Slovenia; around Jesenice; and along the river Sava in the region between Litija (Littai) and Zagorje (Sagor). In the first two areas the lead production was altogether about 150t in fifty years at the end of the 18th and the beginning of the 19th century, then the smelters were closed because of a crisis in the lead market. Production of lead at Knapovže was renewed in 1855 but it lasted only till 1875.

Lead mining at Litija started in 1841, and the ore was initially smelted at the lead and zinc smelter at Toplice (Toplitz) near Zagorje, using brown coal from collieries in the surrounding area. Lead smelting was stopped there in 1861. In Litija, a second lead company was established in 1849 but it was closed in 1868. A new rise of lead metallurgy in Litija was represented by the establishment of Gewerkschaft Littai (Litija Company) in 1878 by Wehrhan, who was born in Saxony (Germany). This smelter was then the Austrian war smelter during the First World War, and its top production was 3660t lead in 1914. After the disintegration of the Austro-Hungarian Empire, the smelter belonged to Yugoslavia, but it was soon closed. Once the ore reserves in Litija were exhausted in the 1890s, the smelter operated with imported ores. As an interesting fact, it can be mentioned that 41kg of silver were produced from Litija lead ore in 1886. Some smaller mines and smelters operated in the 14th and 19th century also elsewhere in Slovenia.

Zinc

Since zinc often appears in nature together with lead, the metallurgy of these two metals is also linked. Winning of zinc in Slovenia goes back to 1820, when zinc was extracted next to lead in Železna Kapla (Eisenkappel) in Carinthia (Šorn 1970, 129-34), where a small lead smelter had already operated since the 18th century, but the smelter was soon closed. In the neighbouring Austrian part of Carinthia two state-owned zinc smelters had operated before this: one in Dellach in the Drava valley, operated since 1799, and the other in Döllach in the Möll valley, operated since 1801, where the zinc smelting technology was similar to that used by Champion in England, *ie* 'per descensum'. Brass was already made in the 16th century in Carinthia by melting copper with calamine under reducing conditions.

In 1824 Count Rosthorn erected a zinc smelter in Prevalje (Prevali) (Čar 1996, 323-5) in Slovenian Carinthia for the needs of the family factory for brass and buttons in Oed (Austria), but the smelter operated only until 1828. Significant winning of zinc started in 1843 and 1844 when the Coal Mining Company in Zagorje on the Sava river (Kohlengewerkschaft in Sagor am Savestrom) established a zinc smelter next to the lead smelter in Toplice (Toplitz), and another at Loke (Lack), both near Zagorje. At first only zinc ore from the neighbourhood was smelted, but later Carinthian ores, mainly from the Rabelj (Raibl) mine were used too. The top production in the Zagorje smelter was 689t in 1893, and it was closed in 1907. From 1845 to 1848 a zinc smelter also operated in Bleiberg near Villach.

A second more important zinc smelter was built in 1863 by the Viennese merchant and industrialist L Kuschel at his colliery in Šentjanž in Carniola. It smelted mainly Carinthian zinc ores. The highest production was 1177t in 1875, but in 1878 it was closed. The third important zinc smelter was the state-owned smelter in Celje (Cilli) in Carniola which started to operate in 1875. It was intended for smelting zinc ore from the state mine in Rabelj, but it also smelted zinc concentrates from Bleiberg and the Mežica valley, both in Carinthia. In 1882 its production reached 1539t and in 1893 2565t. Perceptibly higher production was then achieved only after the Second World War (24,290t in 1964). Zinc was extracted in horizontal retorts, but as the technology became uncompetitive, it was closed in 1970. Together with the smelter, zinc rolling and chemical plant were built, and they are operating still today.

After the First World War Austria did not have a zinc smelter, therefore an electrolytic zinc plant was built at Arnoldstein next to the lead smelter there in 1955, but this plant was stopped in 1992.

Mercury

The metallurgy of mercury in Slovenia has a 500 years old history. The metal was discovered in ldrija (Idria) in 1490. The first miners arrived from Friuli, and shares were initially in the possession of many persons from various places. In 1508 ore was exploited from a depth of 42m, and as early as 1561 from 170m (Čar 1996, 323-5).

The first technology was calcination of ore in baked clay pots (Fig 3), and mercury was extracted 'per descensum'. In 1557 calcination in clay retorts in special furnaces was introduced (Ferber 1774), while in 1635 clay retorts were replaced by cast iron ones, and at the end of 17th century by retorts made of forged iron plates. The Idrija mine with its smelter came under the management of the Hapsburg Dynasty in 1575, thus becoming a state enterprise, and this ownership lasted until 1918.

The ldrija Mine had European significance in the Middle Ages. The records of Dr Pope about the mine were published in 1665 in the *Philosophical Transactions of the Royal Society* under the title 'On the Mines of Mercuri in Friuli', and his report was confirmed by Dr Brown's records, also published in the *Transactions* (Brown 1669, 4-54). Technical experts of that time were especially impressed by a water pump for de-watering the mine with a long wooden

Figure 3: Mercury distillation in 16th-century Germany (possibly representing ldrija Mine technology) as illustrated by Agricola in De Re Metallica

transmission system, called 'kamšt' (from the German word 'Kunst' – meaning art).

After a crisis at the beginning of the 18th century, the mine started to prosper again in the second half of that century. In 1750 new Spanish calcining furnaces were built (Ferber 1774). The end of the 18th century is characterized by an important development of calcining technology, the combining of two Spanish furnaces into one unit called the Franz Furnace, and later two Franz Furnaces into a still bigger unit (the Leopold Furnace) which improved calcining capacities and mercury yields. In 1790 also a new 'kamšt' was built, being driven by a wooden waterwheel of 13.5m diameter, connected with a 68.8m horizontal, and then with a vertical transmission and piston pumps for pumping water, initially from a depth of 235m, and later even 283m. It operated until 1948, only the pumps being changed. The kamšt represents one of the most important technical monuments existing today, since it was preserved in the ldrija Mine on its original site.

Improvements to calcining technology continued in the 19th century. In 1842 Alberti and Glowacky introduced horizontal reverberatory furnaces with inclined cast iron retorts, called Alberti Furnaces, which had a better yield of mercury and lower fuel consumption. In 1849 steam engines for driving pumps in new shafts were introduced. After testing various calcining furnaces used at mercury mines in various parts of the world, mining councillor Exeli introduced in 1870s a shaft furnace with an iron jacket. He also invented the so-called Exeli press, equipment for separating mercury out of the stupp (a mixture of fine mercury droplets, dust, organic substances, and mercury compounds that sticks to the walls of condensers, and is periodically washed into water basins), which is the product of condensing mercury vapours from flue gases. It consisted of a big bowl with a vane-type mixer. Addition of lime dust degreased and dried the sticky stupp, enabling the merging of fine droplets into bigger ones which were then gathering at the bottom of the bowl. They were used still after the Second World War. A special merit for modernization of the smelter belongs to mining councillor J Čermak and calcining-plant master V Špirek who constructed a tile calcining furnace, called the Čermak-Špirek Furnace, and those furnaces spread from the ldrija Mine all over the world, and many were in operation still after the Second World War.

After the First World War the mine belonged to Italy, and in 1947 it became Yugoslav. In 1961 tile furnaces were substituted by rotary furnaces. Because of low mercury prices and very low mercury content (< 0.2%) in the ores, the mine stopped producing mercury in 1996, after extracting about 147,000t mercury (Čar 1996, 323-5) in its 500-year history, representing about 13% of total world mercury production.

Aluminium

Aluminium is the youngest common non-ferrous metal, industrial extraction of which started in Switzerland and the USA in 1889. But already in 1906 the Italian industrialist Count Dr G Guilini started to build an alumina plant near Ljubljana, after Bayer, the inventor of the alumina process, allowed the use of his invention without paying a licence fee. By 1911 the production of the plant reached 4650t of alumina and aluminium sulphate, representing 8% of world production at that time. In 1928 this plant was renamed the Chemical Plant Ljubljana, and it was manufacturing alumina until 1969.

The beginning of aluminium metal production was in 1954 when the Aluminium and Alumina Plant started to operate in Kidričevo. Its history goes back to 1942 when the Germans started to built an aluminium plant for their aeroplane industry, but it was not completed. The first alumina technology there was the tower process, a modified Bayer process patented in 1938 in Germany. Later the continuous autoclave Bayer-Pechiney process was used until alumina production was stopped in 1991.

The first aluminium electrolysis plant with a capacity of 20,000t/ann had 45kA electrolytic cells of prewar generation, with Söderberg anodes. It was closed in 1991. In 1963 the second pot room with a capacity of 25,000t was built, also using cells with Söderberg anodes, which were in the 1990s reconstructed to 75kA cells with prebaked anodes. During 1986 to 1988 a third pot room with a capacity of 30,000t was built which used 180kA Pechiney cells with prebaked anodes. The present production at Kidričevo is about 75,000t/ann of aluminium, while the necessary alumina is imported.

Copper

Though there are some copper ore deposits in Slovenia (in the area around Cerkno), and copper ore was exploited between 1861 and 1870 (38,000t of ore with 375t copper), and by the Italians during the Second World War (in 1943 4000t ore with 80t copper), there are no records of copper extraction. In the 19th century copper was worked into plates and wire, and copper-

ware was made. More information exist on the enterprise in Slovenska Bistrica where copper working in 1825 continued a tradition of old ironworks and forges. There is some evidence of copper working in the 19th century also at the river Hubelj near Ajdovščina where copper scrap was melted, and plates and wire were manufactured. This copper industry was also a successor of old ironworks.

At present, there is only one noteworthy copper plant in Slovenia. It is a copper foundry in Maribor (Maribor Foundry), a successor of a bell foundry established by Austrian contractors, the brothers Bühl, in 1924.

Other metals

Chronicles mention as the first mine that at Št Lenart (St Leonhard) in the Labot Valley (Lavanttal) in the year 890 AD, mainly in connection with gold and iron mining (Anon 1965).

In the 18th century, and especially in the years 1907 to 1913, antimony ore was exploited (Quiring 1945, 90) at Trojane where 150 to 4000t/ann with 3-10% Sb were produced by a Belgian mining company and smelted in a small smelter at Medija, a place in the valley south of Trojane. Still smaller quantities (between 10 and 100t/ann) of antimony ore were mined at Lepa Njiva near Mozirje in the first half of 19th century and at intervals between 1874 and 1940.

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