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## *Technology and Organization of Labour in the Venetian Copper Industry (16th - 18th Centuries)*

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The subject of this study is a mining and metallurgical centre in the upper Veneto, in the former *capitanato* of Agordo, which today forms part of the province of Belluno. Contemporary maps still bear the place-name *Miniere*, even though any activity has now long come to an end: the place is at the entrance of the Imperina valley, where a stream of the same name flows into the Cordevole, which is a tributary to the Piave. Under the stream-bed, more or less corresponding to the middle part of the valley, there was a deposit of copper pyrites which supplied the Venetian copper industry with raw material for at least four centuries.<sup>1</sup> Several traditions and legends interweave as to the discovery and exploitation of this deposit, but the first definite information comes from Marin Sanudo in 1483. The description by Sanudo is important because it shows that there was already a vertical integration between mining and metallurgical activities, between "buse" (the mines) and "fusina dove si colla rami" (the copper foundry).<sup>2</sup>

In the XVIth century many operators, even small-scale, usually working in

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<sup>1</sup> P. OMENETTO, "Le risorse minerarie della regione di Belluno", in *Atti della giornata di studi geominerari* (7 ottobre 1967), Trento 1968, p. 37.

<sup>2</sup> M. SANUDO, *Itinerario per la terraferma veneziana nell'anno 1483*, a cura di R. Brown, Padova 1847, p. 123.

association, crowded in the Imperina valley to exploit shallow seams that required little capital. Then, in the late XVIth and in the early XVIIth century the depletion of the ore within easy reach, the frequency of floods and the shortage of wood — which was necessary both for timbering mines and for smelting — caused the decline of small and medium-size operations. Firms decreased in number and tended to concentrate, meanwhile entrepreneurs with large capital resources prevailed, since they alone could afford the necessary investments for deeper mining. The Pierobonis, the Paragattas, the Barpos gave way to the Crottas.<sup>3</sup> In the 1620s the Crotta firm gradually achieved a dominating position in the local economy, which it was to keep for over a century albeit with some ups and downs. After 1669 the Crotta firm was flanked by a state concern run directly by the Venetian Republic, which fifty years later reached comparable size and importance.<sup>4</sup> By 1787, with the final renunciation on the part of the Crotta heirs, the state concern ran almost all the mining and metallurgical activities of the Imperina valley.

A diachronical examination of the reciprocal relationships and influences between technology and the organization of labour necessitates establishing some preliminary distinctions. First, the process of production was divided into two main sectors: underground and surface. The former included digging out, transporting and lifting the ore to the surface, as well as sorting; the latter covered the strictly metallurgical activities: roasting, smelting, refining. Each operation was carried out by a category of relatively skilled workers, within the more general distinction between underground workers (miners) and surface workers (metal-workers). These are the essential lines of technical organization and division of labour, whose relationships with the dynamics of production techniques were necessarily immediate and direct. But there was also an organization of workers: a complex of associative forms, of customs and contractual relationships which were passed down over the years, although they too were influenced by changes and innovations in the techniques of production.

The first information on the labour force comes from around 1540, and there are no traces in the Imperina valley of the companies of free miners who were at once capitalists and workers, which had been typical in medieval Europe and particularly in Germany.<sup>5</sup> The distinction between capital and labour was complete; the figure of the wage-earner stood out clearly. Mine holders usually did not manage the workings directly, but leased them to

<sup>3</sup> F. TAMIS, "Il palazzo Crotta", in *Archivio storico di Belluno, Feltre e Cadore*, 35 (1964), p. 131.

<sup>4</sup> A. ALBERTI-R. CESSI, *La politica mineraria della Repubblica veneta*, Roma 1927, pp. 170 seq.

<sup>5</sup> J. U. NEF, "Mining and Metallurgy in Medieval Civilisation", in *Cambridge Economic History of Europe*, II, Cambridge 1952, pp. 473-74.

others, offering a fixed payment for each *misura* of ore dug out (the *misura* was a local unit of measurement, at first probably of capacity or of volume, which soon came to mean a weight of about 250 lbs of ore). But who were the "others"? Sometimes they were simply intermediaries, or speculators who leased out the mines in their turn. On other occasions they seem to have been entrepreneurs who employed workers and organized the excavation for profit. More often they were organized groups of miners who took upon themselves the responsibility for digging out the ore by *misura*. Or else the leasor was a *gotmon* (from the German *hutman*, chief-miner<sup>6</sup>), who was both the organizer of a working group and a wage-earner. They were intermediate figures, who are not always easily definable from the series of rather different contracts in the period from 1539 to 1595.<sup>7</sup> Most of these contracts granted the working group a payment according to the quantity of ore they dug out, i.e. a kind of job wage. Nevertheless, as we read in a document of 1582, "the seams are dug out by *gedin* or by week"<sup>8</sup> (*gedin*, or *ghedin*, is an adaptation of the German *gedinge*, piece-work). In fact there are examples of payment by time, by week or by *sitto* (from the German *schichte*, working shift). On the basis of the few XVIth century documents, it seems that payment by time was preferred in contracts with individuals, while payment by piece-work was the rule in contracts with groups or companies of miners. But little is known of how the total payment was divided among individuals within a group, although from some hints and drawing on analogies with later centuries we might assume that the division was made according to criteria of skill and age. With regard to the surface workers, for whom there is much less documentation, we can only suppose they were almost always employed individually and were paid partly by piece-work (we have an example concerning the production of vitriol) and partly by time.

Whether they worked underground or on the surface, whether they did piece-work or worked by time, the workers were always paid partly in cash and partly in goods (cereals, wine, clothes). The proportion between money-value and goods-value varied greatly: at one time it was 1 to 1, at another 3 to 11, at another 1 to 2.<sup>9</sup> The final example was the pay-structure which became most common, and which appears again in the XVIIth and XVIIIth centuries. In the last decades of the XVIth century the practice of

<sup>6</sup> For this Germanism and others to be found in the technical and working vocabulary of the Imperina valley see R. VERGANI, "Lessico minerario e metallurgico dell'Italia nord-orientale", in *Quaderni storici*, 14 (1979), pp. 54-79.

<sup>7</sup> BIBLIOTECA CIVICA, BELLUNO, ms. 708: *Agordo. Miniere e boschi* (16th c.); ARCHIVIO DI STATO, VENICE (hereafter ASV), *Deputati alle miniere* (hereafter DM), *Registro Atti antichi diversi*, reg. 1570 and reg. 1580-83.

<sup>8</sup> ASV, DM, *Registro Atti antichi diversi*, reg. 1580-83, f. 474 (Jan., 1582).

<sup>9</sup> *Ibid.*, f. 569v (contract for extraction of poor ore, 10 July, 1583).

giving a weekly advance on the estimated payments (the so called *spesa*) even to piece-workers seems to have been general, and this probably consisted in the cereals needed for subsistence.

The technical division of labour in the Imperina valley is briefly described in a well-known *Informazione* of 1576,<sup>10</sup> which has however to be integrated with other sources of the XVIth century. The *canopi* (from the German *knappe*, miner) worked eight hours a day and dug out the ore with bits, wedges and sledges. The *saiberi* (from the German *saüberer*, unskilled miner) carried the ore by hand and lifted it by winches to the wheelbarrows, from where carters took it out of the "mountain" by underground tunnels. Here, in an open site, the *cernidor* (sorter) divided by hand the richest ore (*vena*) from the second-rate ore (*chisso*, from the German *kis*, pyrite) and from the waste. The underground workers (although the sorters actually worked just outside the mines) were generally referred to collectively as "*canopi* and *saiberi*." On the surface *rostidori* were employed in roasting with firewood the *vena* and *chisso*, which were divided into two separate heaps called *roste*. The roasted *vena* was enriched through a series of alternate smeltings with charcoal and further roastings, and in this way reduced first to rough copper and then finally to refined copper. The smelting process was carried out by *coladori* (smelters), who were also called *smilceri* or *smelzeri*, with a local adaptation of the German *schmelztzer*. The roasted *chisso* was lixiviated with water and, through evaporation, from the solution they obtained vitriol, which was in large part composed of iron-sulphate and in small part of copper-sulphate. This series of operations was carried out by *mistri e lavoratori de virioli* (vitriol masters and workers). There were also some categories of workers who did not necessarily labour in the premises, but were often at work in the neighbourhood: woodcutters, who provided wood for timbering and for roasting, charcoal-burners, transporters of wood, charcoal, ore, foodstuffs, etc.

It is not easy to quantify the different categories of workers in the Imperina valley in the XVIth century. A report by the *rettore* of Belluno in 1592 says there were about 300 men.<sup>11</sup> If we start from that number and extrapolate some fragmentary data we have found, we can formulate the following hypothesis for the 1580's:

|                              |    |    |
|------------------------------|----|----|
| Miners, carriers, sorters    | 60 |    |
| total of underground workers |    | 60 |
| roasters and smelters        | 20 |    |
| vitriol masters and workers  | 10 |    |

<sup>10</sup> MUSEO CORRER, VENICE (hereafter MCV), ms. *Cicogna*, 2987/XIV: *Informazione sulle miniere 1576*. Cf. also ALBERTI-CESSI, *op. cit.*, pp. 108-11.

<sup>11</sup> *Relazioni dei rettori veneti in Terraferma*, a cura dell'Istituto di Storia economica dell'Università di Trieste, II (*Belluno-Feltre*), Milano 1974, p. 32.

|                                            |     |     |
|--------------------------------------------|-----|-----|
| firewood-cutters                           | 10  |     |
| charcoal-wood-cutters and charcoal-burners | 170 |     |
| carriers of various goods                  | 30  |     |
| <i>total of surface workers</i>            |     | 240 |
| <i>grand total</i>                         |     | 300 |

This is likely to be an under-estimate, since, whenever the records report figures on workers, they add the reservation: "besides many more temporary workers labouring by day."

On the whole, the situation of the mining industry was remarkably backward in comparison with the Saxon and Hungarian ones described by Agricola. The use of the compass and other instruments of "underground geometry" is documented;<sup>12</sup> but the excavations were shallow and there were no good systems for raising water, such as horse- or water-wheel-machines which were already widely used in Central Europe. The direction and discipline of labour was carried out by chief-miners (*gotmoni*), whose functions and responsibilities are specified in a regulation of 1584.<sup>13</sup>

Metallurgical operations seem to have been closer to the European standard, apart from their dispersion among too many small foundries (11 in 1576, but only 7 in 1592). Of course they were too many in comparison with the production of copper, which fluctuated from about 30 *migliara* a year in 1574 to about 70 in 1609.<sup>14</sup> The division and organization of labour perfectly reflected the individual phases of "classical" copper metallurgy, which had been known for centuries and was to last with very few changes for at least two more. One reason for change was the timber crisis and then the shortage of charcoal, which, while it was a major cause of the decline of the small and medium-size firms, also encouraged the search for technical innovations which would economize on this important resource.<sup>15</sup> But we do not know what results were achieved.

The XVIIth century was a period of movement and transformation on various levels. After 1615 excavations went deeper and the richest part of the copper ore deposit was revealed. Some decades later, maybe about 1640,

<sup>12</sup> ASV, DM, *Registro Atti antichi diversi, Processus mineralium inter foveam S. Annae, agentem, et foveam S. Mariae, se deffendentem*, 1531, f. 14.

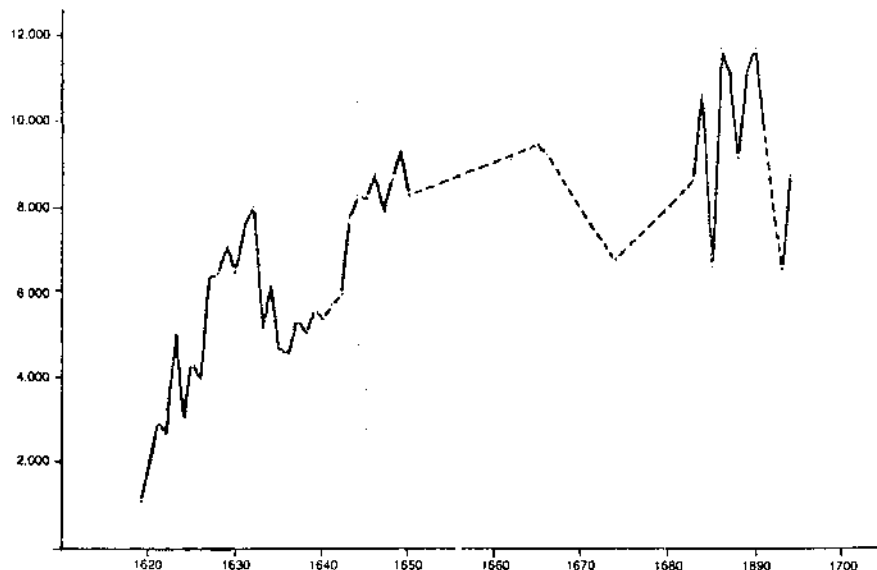
<sup>13</sup> ASV, DM, *Registro delle terminazioni 1584-96*, ff. 24v-26v.

<sup>14</sup> *Relazioni dei rettori veneti in Terraferma*, II, pp. 22, 47 (1 *migliaro* = 1000 Venetian pounds). Evidently production did not meet the copper requirements of the Venetian Republic. The deficiency was made up with German copper, of which Venice was the main redistribution centre towards Eastern and Central Mediterranean countries until about the end of the XVIth century. See U. Tucci, "Il rame nell'economia veneziana del secolo XVI", in *Schwerpunkte der Kupferproduktion und der Kupferhandels in Europa 1500-1650*, hrsg. von H. Kellenbenz, Köln-Wien 1977, pp. 95-117.

<sup>15</sup> ASV, *Consiglio dei dieci, Comuni*, filza 111, 6 June, 1571.

blasting was introduced in the Imperina valley.<sup>16</sup> Compared with the earlier bit-and-sledge method, the new one produced the same quantity of ore with much less labour. It was a typical labour-saving device, in terms of Habakkuk's distinction between labour-saving, capital-saving and resource-saving technical innovations.<sup>17</sup> Elsewhere we have argued that the diffusion of blasting in European mines during the XVIIth century was somehow determined by a shortage of labour.<sup>18</sup> The case of the Imperina valley could confirm that on a local scale. The plague of 1629-1631 killed more than 40 per cent of the rural Venetian population,<sup>19</sup> and, though there are no modern studies, local sources and traditions tell us that it "desolated" the Agordino and its surroundings.<sup>20</sup> The production trends of *vena* (rich ore) in the Crotta mine, which was the most important in the XVIIth century, certainly justifies this

Annual production of the Crotta mine in the 17th century (*misure* of *vena*)



Source: VERGANI, "Gli inizi", p. 134.

<sup>16</sup> R. VERGANI, "Gli inizi dell'uso della polvere da sparo nell'attività mineraria: il caso veneziano", in *Studi veneziani*, n.s. 3 (1979), pp. 130-35. We have no evidence, either before or after 1640, on fire-setting in the Imperina valley, though it was widely used in other European mines.

<sup>17</sup> H.J. HABAKKUK, *American and British Technology in the Nineteenth Century*, Cambridge 1962.

<sup>18</sup> VERGANI, "Gli inizi", pp. 127-28.

<sup>19</sup> D. BELTRAMI, *Forze di lavoro e proprietà fondiaria nelle campagne venete dei secoli XVII e XVIII*, Venezia-Roma 1961, pp. 10-14.

<sup>20</sup> *Relazioni dei rettori veneti in Terraferma*, II, pp. 103, 107, 383; M.A. CORNANI

interpretation. Production collapsed after 1632, probably due to the plague of 1629-31, while the rise about 1640 can be attributed to the introduction of blasting.

This innovation greatly changed the organization of mining. Along with blasting a new elementary working unit was born in the Imperina valley, the so-called "company," formed by two *cavadori* and one *battipalo*. *Cavador* was a dialect synonym for miner; *battipalo* was, at first, the one who struck the borer with a sledge, the borer being a metal stick with a steel point to make blast-holes on rock. In fact *battipali*, as we read in a document of 1720, were "the helpers or the apprentices of *cavadori*," younger miners with less experience.<sup>21</sup> And the preparation of the blast-holes — with one worker holding the borer and turning it a little after each stroke, the two others striking with sledges — was done in turns.

We only know roughly the stages of the transition from the older organization of excavation to the newer one. Nor do we know whether old miners easily learnt the new techniques or, as it almost always happens, "the old skill and the new... were the perquisite of different people."<sup>22</sup> A document of 1669, however, suggests that the *schietpetieri* miners, who were expert in blasting, were still few in the Imperina valley.<sup>23</sup> Though the companies of three miners must have already existed in the Crotta firm in 1669, they appeared for certain only in 1686, in the pay list of the state concern.

In 1669, when the state concern was founded, there were ten private firms in the Imperina valley producing together about 130 *migliara* of copper a year, of which 100 came from the Crotta firm alone.<sup>24</sup> The metallurgical process was by then more complex than that described for the XVIth century. On the one hand they dug out *chisso*, a poor ore giving only vitriol; on the other *vena*, a richer ore, which was roasted and then divided into two parts: a more oxidized outer crust (*terre vergini*), giving more vitriol, and an inner core (*tazzone*), where most of the copper had concentrated, and which was smelted to produce metal.<sup>25</sup> The separation of the two parts was done with hammers by a team of *pestaterre*, usually children or young boys (*putti*). They formed a new category of workers to add to those employed on surface jobs.

So far it was a "dry-way" metallurgical process. In 1670 there was an important innovation in the Crotta firm: a "wet-way" metallurgical process

DEGLI ALGAROTTI, *Dello stabilimento delle miniere e relative fabbriche nel distretto di Agordo. Trattato storico, mineralogico, disciplinare*, Venezia 1823, p. 36.

<sup>21</sup> ASV, DM, *Relazioni. Scontri per revisioni*, busta 1715-57, 18 Sept., 1720.

<sup>22</sup> E.P. THOMPSON, *The Making of the English Working Class*, Harmondsworth 1968, p. 274.

<sup>23</sup> ASV, DM, *Lettere responsive*, Agordo, busta 1666-72, 28 Febr., 1668 *more veneto* (hereafter *mv*).

<sup>24</sup> ALBERTI-CESSI, *op. cit.*, pp. 172-73.

<sup>25</sup> ASV, DM, *Relazioni*, busta 1594-1710, 29 July, 1669.

was introduced, which, in combination with the previous one, considerably increased the total yield of copper.<sup>26</sup> It was the so called *sramazione* (= decopperization) of vitriol. Previously, roasted *chisso* and *terre vergini* were lixiviated with water, giving a solution containing iron-sulphate and also some copper-sulphate. In the new process the solution was treated with iron scraps, so that iron passed into the solution and made the copper that was still there precipitate in the form of a dark mush (*grassure*). This one was then smelted and refined until it yielded metal-copper.<sup>27</sup>

This was a typical resource-saving innovation, because it let the firm produce the same quantity of metal from less ore than before. Its direct and indirect effects on labour were several. As regards underground jobs, it tended to increase mining production and, consequently, the number of miners. In fact *chisso* was of little value so long as it only gave vitriol (which did not sell much), but became more valuable now that it could yield copper as well. This may explain the trend of ore production in the Crotta mine about 1670:

ANNUAL AVERAGE PRODUCTION OF THE  
CROTTA MINE (IN MISURE)

| years   | <i>vena</i> | <i>chisso</i> |
|---------|-------------|---------------|
| 1665-67 | 9340        | 7504          |
| 1684-88 | 10010       | 33190         |

This table shows that while the production of *vena* increased by about 7 per cent, that of *chisso* increased almost four and a half times. We cannot make similar comparisons for the state concern, where the new process of decopperization was introduced in 1695, because disparate criteria were used in those years to calculate mining production.

With regard to surface workings, the introduction of decopperization does not seem to have had important consequences, nor did it create new jobs. Since then vitriol masters and workers made both vitriol and *grassure*, and smelters worked both *tazzoni* and *grassure*. In this case new techniques were adapted to the older organization of labour without upsetting it. They were learnt gradually, through oral transmission and imitation, and then improved by trial and error. We can only guess this for the Crotta firm, but we know that a

<sup>26</sup> ASV, *Consiglio dei dieci, Comuni*, filza 677, 18 Nov., 1670; ASV, *Compilazione di leggi*, busta 282, *Miniere*, 18 Dec., 1670.

<sup>27</sup> The oldest description of how this process was carried out in the Imperina valley can be seen in A. SODERINI, "Lettera II... ad un suo Amico, intorno all'Arte metallica. Della sramazione, o sia, secondo il comune parere, trasmutazione del ferro in rame, per mezzo del vetriuolo", in *Giornale de' letterati d'Italia*, 27 (1717), pp. 186-214.

<sup>28</sup> ASV, *DM, Lettere responsive*, Agordo, busta 1666-72, *Conto delle miniere...* 1668 (for the data 1665-67); ASV, *DM, Quaderno Agordo*, reg. 1684-1719 (for the data 1684-88).

German expert from Ulm, Johann de Kinger, came to the state concern in 1694-95 to teach the skill.<sup>29</sup>

Until the end of the XVIIIth century technological rigidity and steadiness in the division of labour and in jobs influenced each other. We have considerable information on the state concern and very little on the Crotta firm, but their structure and organization were probably quite similar.

In both enterprises the more skilled underground workers (*cavadori* and *battipali*) were associated in a body called "joint company" or "company of the *ghedin*" (from the German *gedinge*, piece-work). A document of the XVIIIth century reports that its origins "were lost in time": it was probably the result of a long evolution of the companies of miners that were already doing piece-work in the XVIth century.<sup>30</sup> In 1686, in the state concern, the joint company was composed of 16 *cavadori* and 9 *battipali* and was paid by piece-work according to the quantity of ore they extracted: one *lira* per *misura* of *vena*, nothing for *chisso*. As accounts were settled at the end of the financial period, every *rason* (i.e. four weeks) the concern gave each worker in advance a fixed payment, 1/3 money and 2/3 goods, maize and cheese.<sup>31</sup> Vacant work-places were assigned by the joint company on a co-optation basis. According to need, one or more chief-miner provided the technical management and disciplinary control, for which the concern granted them in addition to their regular wages a fixed allowance every *rason*. At the end of the financial period the debits and credits of miners were calculated: if in credit they were paid at once, if in debit the concern would make a deduction on their next wages.

The essential features of this organization of the underground workers did not change until 1796, although some minor ones, such as the methods of payment, underwent periodical changes. As rich ore (*vena*) tended to run short, at a certain time they had to pay also for *chisso* (poor ore) to keep miners' wages at an acceptable level. The structure of the periodical prepayment also changed, and after 1707 it consisted only of money and maize.<sup>32</sup> From a certain time onwards the joint company was also bound to a daily extraction, which depended on a variety of factors, as for instance the conditions of underground workings, the total number of miners, the size of smelting furnaces. From 1720 to 1765 this varied between 100 and 200 *misure* a day.

The other underground workers — labourers or *saiberi*, timberers and few others — were paid by time, usually every *rason*. But by 1760 *saiberi* were also admitted to the joint company, so that they could share with miners the duty

<sup>29</sup> ASV, DM, *Lettere responsive*, Agordo, busta 1693-95.

<sup>30</sup> ASV, *Consiglio dei dieci*, Comuni, filza 1337, 29 March, 1796.

<sup>31</sup> ASV, DM, *Relazioni*, busta 1594-1710, Conti Vittali, 1686-89.

<sup>32</sup> *Ibid.*, 3 Aug., 1709.

and the responsibility for the daily extraction.<sup>35</sup>

Underground work was hard and dangerous, but its rhythms — at least in the State concern — seem to have been rather slow, and the management was tolerant and paternal. Working hours — eight from morning to evening — were flexible, the holidays were many, so that the real working days (exclusive of Sundays and Saturday afternoons) were about 210-220 a year. Moreover, miners were divided into two groups, which used to work alternate weeks, not only to have a week off their exacting job, but also to have time for farming in the appropriate season.<sup>36</sup>

Surface activities were more irregular and required fewer men; besides the State concern let them out on contract to private agents from 1692 to 1765, which is why they have left fewer traces. Some categories of workers were paid by piece-work, such as smelters and vitriol masters; others by time, such as foundry caretakers and the chiefs of *pestaterre*. Unfortunately there is only an incomplete table of the surface workers of the state concern in 1765:<sup>37</sup>

|                                    |                          |
|------------------------------------|--------------------------|
| smelters                           | 4-6                      |
| vitriol masters and workers        | 6                        |
| foundry caretakers                 | 5-6                      |
| water-workers ( <i>acquaroli</i> ) | 6                        |
| chiefs of <i>pestaterre</i>        | 2                        |
| sworn controllers                  | 1                        |
| holiday caretakers                 | 2                        |
| <i>pestaterre</i>                  | "according to the needs" |

Roasters, probably three or four, are not included, nor are woodcutters and charcoal-burners, who worked for the concern in the surroundings and might have been in their hundreds. But there are more complete data for underground workers in 1765:<sup>38</sup>

|                  | State concern | Crotta firm |
|------------------|---------------|-------------|
| chief-miners     | 3             | 2           |
| <i>cavadori</i>  | 32            | 26          |
| <i>battipali</i> | 17            | 13          |
| labourers        | 51            | 33          |
| timberers        | 5             | 3           |
| smiths           | 1             | 3           |
| assistants       | 4             | -           |
| machinists       | -             | 4           |
| TOTAL            | 113           | 84          |

<sup>35</sup> ASV, DM, *Lettere Missive*, Agordo, busta 1759-62, 28 Febr., 1759 mv.

<sup>36</sup> MCV, ms. *Correr*, 847, ff. 229v-238v; ASV, DM, *Relazioni*, busta 1746-65, *Carte da Riva*, 1765.

<sup>37</sup> ASV, DM, *Lettere responsive*, Agordo, busta 1764-65, 11 Sept., 1765.

<sup>38</sup> ASV, DM, *Relazioni*, busta 1765-90, *Carte, che si spediscono... al Mag.to... sopra le miniere*, 1765.

In that period the only technical innovation of some importance was the construction in 1733 in the Crotta mine of a water-wheel machine for raising water, which was the first of this type in the Imperina valley.<sup>37</sup> In 1765 it was operated by four machinists, the new category of workers appearing in the table above. It was clearly a labour-saving innovation, since in 1705 the Crotta firm had employed 24 men to perform much less work with hand winches.<sup>38</sup>

From 1759 the state concern began a long battle which lasted over 35 years with ups and downs and aimed to increase the productivity of labour, not so much through technical innovations, which were of little importance in that period, as through a stricter discipline and a tighter control over workers.

From 1764 to 1766 there was an attempt to reorganize the concern conceived by Marco Carburi, a chemistry professor at Padua University, and implemented by Carburi himself and by Vincenzo da Riva, one of the three *Deputati* to the mines of the Venetian Republic.<sup>39</sup> The Carburi - da Riva plan was divided into two parts, one disciplinary and one technical. The former clearly aimed to increase both the number of working days and the load and productivity of digging out: but here it met strong resistance from the miners' joint company, which held da Riva's attempts in check for many weeks. At last they had a programme of 240 real working days a year and a daily production of 180 *misure* of ore inscribed in an ordinance of the Council of Ten:<sup>40</sup> but it is dubious whether these regulations were really carried out. As to the technical part, Carburi's metallurgical experiments proved unable to increase the total copper yield. In the end Carburi's plan had very few practical results, such as scales to weigh the *misure* of ore, which before were evaluated roughly by self-interested workers; yet many of his ideas would yield in the future, as for instance a project for building a main pit and for the rationalization of underground workings, the intention to make a systematic assay of the ores and, more generally, the idea of bringing production into line with science.

By this time the miners' joint company was considered to be a major obstacle to the production policy of the state concern. That is why a decree of 1775 ordered its dissolution, and stipulated that "in the future every worker shall be recorded on the public roll as a single person, separate from the interest of anybody else."<sup>41</sup> But the regulation was not fulfilled, probably because the workers resisted again and because it coincided with the big collapses of 1774-1776, which upset the underground structure of the

<sup>37</sup> *Ibid.*, busta 1731-45, 5 Dec., 1733; 22 May, 1734.

<sup>38</sup> *Ibid.*, busta 1594-1710, 3 Oct., 1705.

<sup>39</sup> MCV, ms. *Correr*, 847, ff. 121-451; and the file referred to at note 36.

<sup>40</sup> ASV, *Consiglio dei dieci, Comuni*, filza 1126, 20 Aug., 1765: *terminazione* 14 July, 1765.

<sup>41</sup> This decree is published in CORNIANI DEGLI ALGAROTTI, *op. cit.*, pp. 167-212. The quotation on p. 169.

Imperina valley and virtually marked the end of the Crotta firm.<sup>42</sup> But these same events laid the conditions for a profound change in the local labour market. The reduction and, some years later, the total interruption of activity in the Crotta mines caused considerable unemployment and increased competition among the workers, which gradually eroded the monopoly position and privileges previously held by the joint company.

After 1778, and more particularly after 1787, there was a series of small but frequent technical, managerial and disciplinary changes aimed at greater efficiency and at the transformation of the state concern along capitalist lines. The principle which had already been included in the decree of 1775, by which the chief-workers depended directly on the manager of the concern and not on the workers who had chosen them, was put into practice. In 1778 "the habit of individual blast-holing" was definitively adopted in underground work, marking the end of the old company formed by two *cavadori* and one *battipalo*, while a regulation of the same year redirected the latter to "more useful and necessary jobs."<sup>43</sup>

In 1787 two brothers, Nicolò and Domenico Zanchi, became supervisors of the state concern. They had such remarkable managerial skills that, without any relevant technical innovations, they succeeded in increasing productivity considerably within few years, through a more efficient exploitation of labour and natural resources.<sup>44</sup> It was in this same period, following the final renunciation by the Crotta heirs, that almost all the mining and metallurgical activities of the Imperina valley were brought together under the state concern. New furnaces were built near the Cordevole which, in comparison with the old ones, allowed over 50 per cent saving of charcoal. In 1790, on the advice of Giovanni Arduino, they began to build stone tanks instead of the very expensive lead cauldrons they had used till then to prepare vitriol and decopperization copper.<sup>45</sup> These were clearly small resource-saving and capital-saving innovations, which had little or no influence on the division and organization of labour, but which, in the meantime, considerably increased its productivity. The recovery of the Crotta mines and the desire to deepen the excavations further revived the problem of raising water, which had earlier been resolved by means of a water-wheel machine which had been destroyed in the collapses of 1774-76. In 1787 hand-pumps were introduced, but soon, because of the high cost of this system, they went back to a water-wheel machine, which was designed and made by Bartolomeo Toffoli, a technician

<sup>42</sup> ASV, *Consiglio dei dieci, Comuni*, filza 1197, 21 Febr., 1776 mv.

<sup>43</sup> *Ibid.*, filza 1205, 5 June, 1778: *terminazione* 14 May, 1778.

<sup>44</sup> As happened, for instance, in a Pennsylvania iron foundry in the second half of the XVIIIth century: P.F. PASKOFF, "Labor Productivity and Managerial Efficiency against a Static Technology: the Pennsylvania Iron Industry, 1750-1800", in *Journal of Economic History*, 40 (1980), pp. 129-35.

<sup>45</sup> ASV, *Consiglio dei dieci, Comuni*, filza 1298, 16 Febr., 1790 mv.

from Cadore, in 1790.<sup>46</sup> It was a typical labour-saving investment, as records expressly point out; the very expensive team of pumpers (from 30 to 85 men per day) was dismissed, while two permanent machinists and one assistant were employed.

New methods, both direct and indirect, to control workers were introduced. The concern began keeping a register of blasting, employed more watchmen and preferred, when possible, temporary workers to permanent ones. Of particular interest is the introduction of regular assaying, which was done not only on samples of ore, to prevent marginally profitable work from being carried on at random or because it was easier for miners; but also on *matte*, *grassure* and *terre*, "to be sure they had given the metal they contained, with no dispersions due to carelessness or ignorance on the part of workers... so from assays the ability, accuracy and attention of foundry masters and workers can be recognized."<sup>47</sup>

This was the atmosphere in which the "untamable" (in the Zanchis' words) miners' joint company was definitively defeated, after avoiding for decades the excavation duties established by several ordinances. Its "corporative" connotations obviously placed it in opposition to the productivity orientation of the management; moreover it had long lost its monopoly position among the underground workers. About 1790, while extraction was increasing, many *appalti* began to be made outside the joint company — these were contracts which the state concern freely agreed upon with one or more masters leading groups of 20 or 30 miners. These contracts fixed the copper percentage the ore was to show when assayed and its price per *misura*, but they did not contain any obligation towards individual workers. It is a kind of contract very similar to the one we have already seen in the XVIth century and which, probably during the XVIIth century, had become more and more rigid until it provided the pattern for the joint company.

In 1795, compared to 100 miners and labourers belonging to the joint company, there were 159 employed through *appalti*. Therefore it is not surprising that in 1796 they "very quietly" accepted a decree of the Council of Ten which "totally" dissolved the joint company and ordered all work to be done "only through *appalti*" from then onwards. The same decree established another important rule, that the state concern was to pay its workers "in cash only."<sup>48</sup> The year before the book-keeper of the *Deputati* to the mines had proposed this in order to simplify and modernize the accounts of the concern.

<sup>46</sup> P. FRESCURA, *Invenzioni e scoperte dell'abate D. Bartolomeo Toffoli*, Venezia 1901, pp. 45-60.

<sup>47</sup> ASV, DM, *Relazioni*, busta 1765-90, 20 Jan., 1790 *mv*; ASV, DM, *Lettere responsive*, Agordo, busta 1787-97, 16 Dec., 1795.

<sup>48</sup> ASV, *Consiglio dei dieci*, *Comuni*, filza 1337, 29 March, 1796; ASV, DM, *Lettere responsive*, Agordo, busta 1787-97, 15 June, 1796.

In 1795 the state concern had reached the size of a large business: it employed 317 miners and other underground workers, 266 surface workers who manufactured copper, vitriol, sulphur and other secondary products, 10 skilled craftsmen, 40 horse-carriers and 28 managers and clerks, besides 632 woodcutters and charcoal-burners working for it in the surrounding.<sup>9</sup> After 1787 copper production increased more and more and in 1795-96 it exceeded 500 *migliara* a year.<sup>10</sup> In 1796 the foresaid decree of the Council of Ten eliminated the last archaic forms of organization and payment of workers, which still existed. Nevertheless, the technical system, and the division of labour based on it, remained stagnant. Their outlines still were the ones which had been formed in the second half of the XVIIIth century. These survived down to the 1890's, when the Venetian copper industry finally collapsed, as a result of international competition.<sup>11</sup>

<sup>9</sup> ASV, DM, *Relazioni*, busta 1765-90, 18-19 July, 1795.

<sup>10</sup> ASV, DM, *Lettere responsive*, Agordo, busta 1787-97, 16 Nov., 1796.

<sup>11</sup> F. SQUARZINA, "Notizie sull'industria mineraria nel Veneto e nel Friuli-Venezia Giulia", in *L'industria mineraria*, 14 (1963), p. 218.