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ANTONINE PLAGUE AND DEACTIVATION OF SPANISH MINES*

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This note begins by challenging the economic logic of Andrew Wilson's argument that the main reason for the abandonment of shaft-mining facilities in southwest Spain was a disruption caused by the Antonine plague. Specifically, that mining operations were not restarted after a hiatus because of flooding and the difficulties of pumping water out of the shafts effectively enough to allow operations to be restarted. It is suggested instead that the mines were abandoned because higher labor costs resulting from losses in manpower due to the plague made it uneconomic to operate shaft mines in Roman Spain.

During the later second century CE, as Wilson (2002: 28) explains, the major silver and copper mining facilities of Rio Tinto in the southwest of Spain saw a "hiatus" (significant abatement or abandonment) for which "the reasons are not fully clear, the deposits were not exhausted". Unfortunately, not only the reasons for but also the timing of the cessation remains uncertain. The textual sources are uninformative and the available archaeological evidence, including lead pollution data (Wilson 2009: 77–8), should not be regarded as precise. Wilson (2009: 78), however, maintains: "Activity at the settlement at Rio Tinto and its associated necropolis ceased between 170 and 180". For this rather precise dating Wilson relies on Jones' (1980: 159) dating of excavated Samian ware:

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> It shows that the site [Corta Lago, the largest mining settlement of the complex] was principally active from the Flavian period to the third quarter of the second century. The starting date, of course, tallies neatly with the evidence for the development of the Dehesa cemetery. Yet it is the abrupt end of the life-cycle of the site that is of particular interest. The histogram [Figure 6(a)] shows a steep decline in the presence of Samian after A.D. 160–70 and after that there is very little evidence of the presence of later types. In particular the near absence of Form 31, the commonest form of the late Antonine period, is significant. Unless this represents abrupt changes in the character or efficiency of the samian industry (and there appears to be no evidence for this), then the downturn must be reflected in the steep decline in the Corta Lago mining settlement at the time.

Jones (1980: 161) goes on to refer to "the sudden collapse of the mining settlement." I must confess that I regard conclusions based on precise dating of pottery to be rather fragile. Perhaps it is most prudent to speak of the cessation of Rio Tinto mining activities as a process which took place during the last quarter of the second century. Obviously, temporal vagueness works against monocausal explanations, especially those explanations framed in terms of a single decisive event.

Notwithstanding doubts about precise dates the search for reasons has not abated (see Scheidel 2009: 55–6). Most recently, Wilson (2009: 78) links the "hiatus" in mining with a "disruption" caused by the "Antonine Plague":

> Once abandoned even for a short while, large areas of underground mines would have become impossible to work even if the mines were subsequently re-activated. Once underground mines had been abandoned for even a few weeks, galleries below the water table would have flooded while the water-lifting wheels and Archimedes screws that enabled Roman miners to operate below the natural water table were able to cope with the daily influx of groundwater if continuously operated, the dewatering of completely flooded galleries would have been difficult.

That flooding problems in shaft-mines might occur and were taken into account by Roman mining authorities is attested in a labor contract from Dacia (*CIL* III, p. 948 no. x = *FIRA* 3.150a) of 164 CE: a worker (one Memmius Asclepi) agrees: "Should inundation impede [the gold mining work] he shall calculate a proportional reduction (of the wages)" (transl. Berger 1948: 222). Arguably, the main point here is that if Memmius shirks his duties and the mine becomes flooded he will be penalized in his income. Thus, the worker is provided with an incentive to be diligent not provided in a strictly fixed wage contract. The provision for wages to be docked lowers the costs of supervision and hence transaction costs.

Wilson does not, however, support his argument in terms of flooding by citing engineering specifics about Rio Tinto's mining shafts which are not available. The more basic problem with Wilson's "disruption" explanation is that even if it could be shown that mining operations had been directly disrupted by the Plague and even if, as a result, shafts had become flooded and even if the resulting water accumulation was too substantial to be cleared then new shafts could have been opened (Edmondson 1989: 94). In economic life "bygones are bygones." Economic actors had considered revenues and costs and decided it would be profitable to invest in mining shafts in Rio Tinto. The disruption caused by the Antonine Plague and its aftermath did not make shaft-mining there unprofitable. Thus, it would pay to invest in new shafts just as much as it had paid to invest in the original ones. Some Roman investors (like some moderns) might dwell on and be overwhelmed by past misfortunes but others would see the future profits and get started digging new shafts. The argument presented by Wilson is not correct and cannot explain the deactivation of the Spanish mines.

A variant on Wilson's current argument is that the cessation of mining in Rio Tinto was due to the short-lived invasion of Baetica by Moorish rebels in about 171 CE (Birley 2000: 168 with n. 20; Jones 1980: 161–2; Wilson 2002: 28–9, 2009: 78). Damage to mining operations may be attested by an inscription from Vipasca (*IRCPacensis* 121) naming an individual as *restitutor metallorum* "restorer of mines". The inscription has been placed in the reign of Marcus Aurelius or somewhat later and, if dated correctly, it may react to the Moorish incursions in southern Iberia or to the effects of plague or even to some unknown problem (see Hirt 2010: 123–5, 154, 163, 343–4). However, the invaders were expelled and the mines were abandoned (Scheidel 2009: 55 with note 39). Any disruption caused by the invasion would not have made mining unprofitable and consequently work would have resumed and persisted. Again, in economic life "bygones are bygones".

However, the mines in Rio Tinto were deactivated and the Antonine Plague stands out as a possible cause. The failure of Wilson's argument should not preclude further exploration of this connection. There is in fact a viable alternative line of argument. Before examining this alternative it should be noted that there were actually *two* major plagues during the last quarter of the second century. The first began in about 180 CE under Marcus Aurelius and the second shortly after 190 CE under Commodus. I refer simply to "Antonine Plague" without assuming that the causal agents were necessarily identical.

My argument begins by understanding that the Antonine Plague caused significant loss of life across the Roman Empire[1] and deduces that the high mortality resulted in a significant increase in the price of labor-power. The reasons for an increase in wages are straightforward. Plague reduces the available stock of labor power while the stocks of land and material capital are left unchanged. The ultimate result is a higher wage for labor relative to the rental price for land/material capital. This outcome is predicted because the increase in land/material capital per worker raises the (marginal) productivity of (surviving) workers. The last worker employed now contributes more to total output than previously and the value of his/her contribution now exceeds the prevailing wage rate. Therefore, it pays each employer to increase his employment of labor. However, at the old wage the quantity of labor demanded by employers exceeds the quantity sup-

[1] A number of scholars have suggested that the Antonine Plague was responsible for enormous loss of life and dislodged the Roman economy, permanently or for a very long period, from its growth path up to that time (see Gilliam 1961: 225–6). Thus, Jongman (2006: 243) maintains: "Here, I want to draw attention to the possible effects of the Antonine Plague from AD 165. There is no doubt that it killed a significant proportion of the Empire's population, and that it continued to do so for quite a long period. I think it may well have been the ancient equivalent of the Black Death of the fourteenth century. I also think it is our best bet to explain why over such a wide range, things suddenly began to go wrong in the late second century AD." Zuiderhoek (2009: 42–4) argues similarly and estimates that mortality ranged from 7–10 percent to as much as 25–33 percent. The Antonine Plague continued to the end of the second century CE (cf. Nutton 2003: 694). Jongman, in particular, seems to believe that the Antonine Plague was bubonic in nature. Some scholars, however, view such extreme losses of life as unlikely, not least because they think the plague was smallpox. Elsewhere (Silver 2012) I argue that the plague was unlikely to have been smallpox (repeat epidemics in Rome and reported deaths of animals) and likely to have been bubonic (contemporary reports of numerous deaths and rapid transmission).

Scholars have put forward (Duncan-Jones 1996) and refined (Scheidel 2002, 2010) a number of ingenious proxy measures of the demographic/economic impact of the Antonine Plague. These include army discharge certificates (*diplomata*), Egyptian year-dated documents, dated inscriptions (Rome and Italy and elsewhere) recording a statue or a building, brick stamps in Rome, and dated evidence for production in the Phrygian marble quarries. All the measures are valuable and, unfortunately, all have been subjected to some valid criticisms (Bruun 2003; Greenberg 2003). Broux and Clarysse (2009) have facilitated the construction of a direct, albeit geographically and socioeconomically limited, index of mortality during the Antonine Plague. They gathered into five-year intervals some 606 Lydian inscribed stone funerary monuments dated from 50 CE to 279 CE (Graph 2, p. 30). The stelae are from the roughly four thousand square miles around Saittae, a northeastern town, and probably are too expensive to be erected by ordinary working people, who might have relied on wooden monuments. The numbers of funerary stelae reach very distinct peaks in both 165–169 and 190–194. For the severity of the plague under Commodus, see especially Dio 73,14,3 and Herodian 1,12,1–2.

plied (recall the plague). Competition among self-interested employers drives up the wage rate/rental price.[2]

Next, it is recognized that the Spanish mines were especially sensitive to higher labor costs because the extraction of ore by means of shaft-mining techniques is well above average in labor intensity and is much more labor intensive than opencast extraction (Edmondson 1989: 93–4; Strabo 4,6,12 on the ease of opencast gold mining in Noricum; cf. Hirt 2010: 44–6). The labor intensity of shaft mining is well illustrated in the ancient sources. Pliny the Elder's (*nat.* 33,21) remarks on gold mining (probably) in Spain: "By the light of lamps long galleries are excavated into the mountain... The miners then carry the ore out on their shoulders, each man forming a part of a human chain working in the dark, only those at the end seeing the daylight" (transl. Lewis and Jones 1970: 182). More expansively, Diodorus Siculus (5,36–37) explains: "Now at first unskilled labourers, whoever might come, carried on the working of the mines, and these men took great wealth away with them, since the silver-bearing earth was convenient at hand and abundant; but at a later time, after the Romans had made themselves masters of Iberia, a multitude of Italians have swarmed to the mines and taken great wealth away with them, such was their greed. For they purchase a multitude of slaves whom they turn over to the overseers of the working of the mines; and these men, opening shafts in a number of places and digging deep into the ground, seek out the seams of earth which are rich in silver and gold; and not only do they go into the ground a great distance, but they also push their diggings many stades in depth and run galleries off at every angle, turning this way and that, in this manner bringing up from the depths the ore which gives them the profit they are seeking..." (transl. Oldfather).

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[2] Note that even if, as is unlikely due to collusion and enforcement costs, employers of labor power successfully collude and refuse to pay a higher wage, workers may still capture their increased productivity by hiring land/material capital and becoming self-employed (e.g. as independent farmers).

Some evidence for Egyptian wages is available. "Evidence from Tebtunis shows an apparent doubling of daily wages for forms of field labour. Successive documents record rates of 4–7 obols in 152 (median 6 obols, n=12); 8 obols in 166 (n=2) and 10–14 obols in 169/70 (median 12 obols, n=3)" (Duncan-Jones 1996: 124 citing Drexhage). Scheidel (2010; cf. 2002) finds that daily and monthly wages of unskilled rural workers in Roman Egypt rose more than the price of wheat. Examining Scheidel's (2010) Figure 1, it appears that between the 100–160s CE and the 190s–260s CE: real monthly wages rose about 20% while daily wages rose slightly. A final point of some importance is that the real price of donkeys in Egypt rose by 50% from the "pre-plague" to the "post-plague" period (Scheidel 2010: Fig. 1). One interpretation of this finding is that the demand for donkeys increased as users sought to compensate for the severe loss in human labor power due to the plague.

The argument is that by raising the value of labor-power the Antonine Plague raised total costs to a point at which it became uneconomic (unprofitable) to continue working the Spanish shaft-mines. That is, the rise in labor costs made extraction costs exceed the value of the extracted metals, including of gold. To anticipate a possible objection, note that labor costs in shaft-mining would be a central consideration whether the labor power was provided by slaves (*servi*), or by free hired workers (*mercenarii*), or by self-employed miners (*occupatores*, *coloni*). All categories are attested in Spanish mines by two inscribed bronze tablets (Vipasca I ch. 7; Vipasca II Para. 10,13) from Aljustrel (Roman Vipasca) in southern Portugal.[3] It should be stressed that slaves, even convict slaves, have a market value and/or an opportunity cost (the income that might be earned by deploying them in alternative work) which would have been increased by the plague along with the wage of free labor. If the opportunity cost of convict labor and/or coerced local workers (Domergue, Sillières and Martin 1977) is zero – that is, their labor might be productively employed *only* in mining, or more specifically in shaft mining, this would have limited any plague induced rise in total labor costs. However, even this extreme and unrealistic assumption would not eliminate the increase in the cost of non-convict labor-power supporting shaft-mining. In this category we should include the wages of the military personnel needed to keep forced laborers from escaping!

It might be objected that Romans did not, like good neo-classical economists, take labor costs into account in making production decisions. The most famous example of apparent disregard is the response of Vespasian (69–79 CE) when offered a device/plan for transporting columns: "To a mechanical engineer, who promised to transport some heavy columns to the Capitol at small expense, he gave no mean reward for his invention, but refused to make use of it, saying: 'You must let me feed my poor commons' (*sineret se plebiculam pascere*)" (Suet. *Vesp.* 18; transl. Rolfe). However, a number of concrete (and less ambiguous) ex-

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[3] See Domergue 1983: 146f., 1990: 277f.; Thompson 2003: 162–5; cf. Edmondson 1987: 61–70. Strabo (3,2,10), citing Polybius (second century BCE), refers to forty thousand workers deployed in the Spanish mines. Some were miners and others provided support services (Edmondson 1987: 60). According to Patterson (1972: 231): "The required labour in each mining district varied according to the nature of the country rock, the grade of ore, the flow of groundwater, and the mineralogical nature of the ore; but it can be generally estimated on the basis of total required work that 500 to 1,000 slave-years [man-years] were required to produce one ton of silver during Greek and Roman times, irrespective of guard, transport, and supply production labour. Polybius mentioned a figure of this magnitude for Roman mines...."

amples demonstrate that Romans did take labor costs into consideration. Pliny the Elder's (*nat.* 18,38) dictum that "good farming is necessary, perfect farming detrimental, except when the farmer runs his farm by his own family or by persons he has to maintain in any case" (*bene colere necessarium est, optime damnosum, praeterquam subole sua colono aut pascendis alioqui colente*; transl. Bostock and Riley) stands as a testimony to economic rationality and sophistication. Like a modern microeconomist, Pliny is noting that when the marginal cost of labor (incremental cost of employing additional hours of labor) is effectively zero, as it is for already hired labor, labor may appropriately be applied to the point of "perfection" – i.e. to the point where the monetary value of the marginal product of labor (value of its incremental output) is zero. Again, Columella (2,2,12) balances the value of additional land to farm with the cost of additional labor when he advises: "It is easy to clear stony ground by gathering up the stones; and if there is a great quantity of them, parts of the field must be used for building them into piles of some sort, so that the other parts may be cleared off, or the stones will have to be buried in a deep-dug trench. This should be done, however, only if the cheapness of labor makes it advisable" (*Ac saxosum facile est expedire lectione lapidum, quorum si magna est abundantia, velut quibusdam substructionibus partes agri sunt occupandae, ut reliquae emundentur, vel in altitudinem sulco depresso lapides obruendi*; transl. Ash).

Most directly, Pliny the Elder (*nat.* 34,49) explicitly recognizes the importance of differences in labor costs in shaft vs. opencast mining: "Black lead [our lead] is used in the form of pipes and sheets: it is extracted with great labor in Spain, and throughout all the Gallic provinces; but in Britannia it is found in the upper stratum of the earth, in such abundance, that a law has been spontaneously made, prohibiting any one from working more than a certain quantity of it" (*Nigro plumbo ad fistulas lamnasque utimur, laboriosius in Hispania eruto totasque per Gallias, sed in Brittannia summo terrae corio adeo large, ut lex ultro dicatur, ne plus certo modo fiat. nigri generibus haec sunt nomina: Iovetanum, Caprariense, Oleastrense, nec differentia ulla scoria modo excocta diligenter. mirum in his solis metallis, quod derelicta fertilius revivescunt*; transl. Bostock and Riley; cf. Elkington 2001: 63). It is not clear whether the intention of the "law" (convention?) is to protect Spanish producers from low cost competition or to limit production and raise the profit of producers in Britannia. It is clear that labor costs mattered to the Romans.[4]

[4] The Antonine Plague induced rise in the relative price of labor-power might lie behind the adoption of important new technologies in the city of Rome during the earlier third century CE.

To conclude, any "disruption" in shaft-mining operations due to invasion or plague would have lasted only a few years but the plague-induced rise in the price of labor would have lasted for many years and certainly well into the third century. On the other hand, the rise in the price of labor would not preclude working capital-intensive hydraulic mines in the northwest of Spain or elsewhere. Indeed, shaft-mines might be worked in regions whose deposits were more accessible and whose mining operations were consequently less labor intensive than in Spain. This consideration might or might not explain a possible intensification of shaft-mining activity in the central Balkans (Mladenovic forthcoming). The answer cannot be known until research is undertaken with a focus on comparative natural/environmental conditions, mining techniques, and dating. It is hoped that the new arguments put forward in this paper will serve to motivate new research.

What is presently clear is that Spanish shaft-mines were deactivated and for this entrepreneurial decision an explanation in terms of an increase in the price of labor-power due to the Antonine Plague is not only logically coherent but also fits the facts better than alternative hypotheses such as disruptions due to flooding of mine shafts and/or invasions of the mining region.

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Alexander Severus (222–235) reportedly "erected in Rome very many great engineering-works (*opera mechanica plurima*)." (SHA *Sev*. *Alex*. 22,4; transl. Magie). Coarelli believes that SHA refers to the construction of the Janiculum water-mills (cited by Wilson 2002: 13–4). Morel (1993: 227) suggests, "Economizing on manpower was just not in the spirit of the times..." But perhaps it was in times of plague when labor costs surged relative to capital costs!

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