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World-System History and Global Environmental Change

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6

Silver, Ecology, and the Origins of the Modern World, 1450–1640

JASON W. MOORE

THE DEBATE OVER THE "RISE OF THE WEST" has sharpened in recent years, particularly with the New World History's critique of Eurocentric historiography (Frank 1998; Pomeranz 2000). In the process, however, the specificity of Europe's overseas expansion has often been eclipsed (e.g. Richards 2003). This is unfortunate, because Europe's early modern expansion—while not the talisman of technological or economic superiority once assumed—expressed a new and destabilizing crystallization of socioecological power and process, one predicated on the endless accumulation of capital. But far from a narrowly social logic, endless accumulation embodied a globalizing mode of producing nature that presumed the endless export of ecological problems. This was something new. For ecological degradation was not simply a consequence of European expansion, but constitutive of capitalism's very essence—its (presumably) limitless drive to accumulate capital.

Early modern silver mining sheds light on the ways that environmental transformations were at once cause and consequence of the rise of capitalism. Clustered geographically in a central European zone encompassing parts of present-day southern Germany and southern Poland, Hungary, and the Czech Republic, Europe's mining and metallurgical sectors at the end of the long medieval crisis expressed a remarkably prefigurative form of capitalist production. From the 1450s, central Europe's booming mining regions were sites of huge capital investment, large-scale industrial production, and aggressive monetization. "In no other branch of the economy did early forms of capitalism develop so fast or entrench themselves so firmly as in the mining industry" (Kellenbenz 1976:80). The extraction of ore and production of metal was closely and strategically articulated with leading agencies of capital accumulation, foremost among them the Augsburg-based Fuggers (Nef 1964; Lynch 2002). Out of this peculiar set of local-global antagonisms emerged a specifically capitalist configuration of nature-society relations predicated on the endlessly globalizing conquest of nature.

Silver loomed especially large in this movement of endless conquest. The modern world's first extractive efflorescence predated American silver, nourishing the arteries of accumulation in a European economy "desperately" short of "sound money" at the dawn of modernity (Yun 1996:119). This infusion of sound money at the scale of accumulation was articulated in the closest fashion with transformations in the division of labor. Foremost among these latter were the rapid extension and deepening of commodity relations in the central European countryside, propelled at once by silver mining's profitability and the environmental degradation that consistently threatened to undermine such profitability. These interlinked transformations at multiple scales—not simply local and global, to be sure[1]—fueled a significant accumulation of monetary wealth in the hands of (so-called) "merchant" capitalists such as the Fuggers, who were directly involved in extractive enterprises from Castile to Sweden to Hungary. By itself such newfound monetary wealth would have achieved little that was new. What gave this accumulation its revolutionary character was the world-historical alchemy of transforming "wealth" into "capital." For the era's metallurgical sectors were producing not only wealth qua "sound money" and resources, abstractly conceived. They were implicated in the production of a new set of socioecological relations—significantly, the formation of large-scale industrial capital and a quite prefigurative metallurgical proletariat (Kellenbenz 1976:80–81)—that compelled and presupposed infinite growth. It was this very presupposition that underpinned the metallurgical sector's significant contribution to world accumulation and compelled and enabled a subsequent geographical shift in silver mining—and a renewed wave of global capitalist expansion—by the mid-sixteenth century.

This chapter tells the environmental history of this global shift through the optic of the commodity frontier and the relocation of silver mining from central Europe to Potosí in the 1540s. The socioecological contradictions set in motion by the silver commodity frontier in late-sixteenth-century Peru (including present-day Bolivia), by the 1640s would in turn give way to another round of geographical expansion, as silver mining's center of gravity shifted to New Spain (Mexico). In this the silver frontier expressed a broader pattern—including tobacco, fisheries, wheat, timber, indigo, and dyewood, but sugar and silver above all—namely, capitalism's

tendency toward an unusually rapacious and globally expansionary form of what Gadgil and Guha call "sequential overexploitation" (1992). In one region after another, ecological sustainability was increasingly subordinated to the imperatives of profit-maximization and empire-building: a strategy whose short-run gains were realized through rising ecological problems (and costs) over the middle run. Typically within fifty to seventy-five years, these contradictions undermined regional profitability and compelled a shift in the frontier's center of gravity.

Capitalism did not invent large-scale mining. But if mining and its monstrous record of environmental devastation dates back to antiquity (Hughes 2001:63–66), its revival in the 1450s embodied and enabled broader changes in Europe's political economy. Metallurgical production of all sorts rose dramatically, particularly war-driven copper and iron output. The annual output of central Europe's silver mines expanded fivefold between 1460 and 1530, an astounding production figure not reached again until the nineteenth century (Nef 1964:42). While Europe's fifteenth-century silver boom resembled premodern extractive cycles in certain respects, its articulation with European expansion made a crucial difference. The rapid geographical expansion effected by Europe's overseas empires meant that mining's socioecological contradictions could now be attenuated—and extended—through global expansion.

These contradictions were evident from the 1450s. Even at this early date, central Europe's gigantic ironworks "filled [the air] with such a stench and smoke as to trouble travelers as well as inhabitants" (Nef 1964: 44). Even contemporary boosters were forced to concede that "the strongest argument of [mining's] detractors" was environmental degradation—the poisoning of streams and the ensuing destruction of fisheries, widespread deforestation, the "extermination" of wildlife, and soil erosion (Agricola 1556:8). A significant share of this pollution derived from the confluence of the economic expansion with a new smelting process involving a gigantic volume of lead—on the order of 50 kilograms of lead for every kilogram of silver extracted (Lynch 2002; Novak et al. 2003:439).[2] Much as mercury would do in the sixteenth century, most of this lead found its way into rivers and streams, effectively enclosing the riparian commons as a dumping ground for metallurgical capitalism. It would do much the same to workers' bodies, who suffered not only predictable forms of silicosis but also—in the great Joachmistal mining town especially—from lethal exposure to uranium ores (Mould 2001; Agricola 1556:6).

Of much more direct concern to the world-historical trajectory of central Europe's mining boom was the enclosure of the forests. Everything turned on wood, it seemed. And it was not just the volume but the speed at which the new demands were made, for construction and above all for fuel. For no silver or iron could be produced without wood fuel, and lots of it. The metallurgical commodity zone expanded into the forests at a ferocious pace. A pound of pig iron—which except for cast-iron products typically required further processing—consumed approximately 15–20 lbs. of charcoal, reduced from about 75–100 lbs. of wood (Smil 1994:150, 156). While central Europe boasted enormous forest resources, what counted was proximity; charcoal's fragility limited transport to about five miles, less if the terrain was treacherous (Hammersley 1973:606). This attenuated but did not eliminate a generalized condition of sharply rising demand on the region's forests after 1450, stemming from the broad-based upsurge in multiple extractive activities, comprising lead, copper, and zinc in addition to iron and silver. Of special importance was iron. After 1450 central Europe emerged not only as the leading silver producer but also its leading iron manufacturer, accounting for half of Europe's output by 1500 (Cameron 1993:118).

Producing some 30,000 tons of iron annually, a figure rising fast through the first half of the sixteenth century, demanded access to forests on a massive scale. Looking at England in the early seventeenth century, Hammersley proposes that one ton of pig iron could be produced on a sustainable basis from the "natural increment" of 8–10 acres. Factoring in additional fuel consumption for wrought- or bar-iron manufacture, on this basis we might estimate conservatively the sector's consumption at 400,000 acres (give or take), not a large figure relative to regional forest cover. But except under very unusual circumstances sustainability was not the rule; especially in boom years (and there were many in the century after 1450), early modern smelters would have been under enormous pressure to expand production beyond the "natural increment." This increased profitability and cut costs over the short run but undermined the ecological basis for it over the middle run of a quarter-century or so. Even if we assume a modest rate of relative deforestation, say 5 percent annually of the forests engaged by iron smelters,[3] we would have a fairly consistent pattern of "original" forest clearance, somewhere on the order of 15–20,000 acres each year, or somewhere on the order of 1.1–1.5 million acres for the period between 1450 and 1525.

Is this an overestimate? Probably quite the opposite. Kellenbenz (1974:256) cites a 1564 forestry report on the Neusohl copper smelters that puts annual consumption at twenty-four thousand loads of charcoal; surely an exaggeration, but if true this would have required the "natural increment" of 580,000 acres.[4] Moreover, smelters, especially iron smelters, relocated frequently as local forest stocks dwindled. This relocation, in turn,

favored a transition from hardwood forests such as oak to softwoods like pine and fir. These latter assumed a virtually monocultural presence in mining regions such as the Upper Palatinate by the end of the sixteenth century; forests outside the sustained grasp of the metallurgical sectors retained their diversity for several centuries (Westermann 1996:938). Although the softwoods grew faster than hardwoods, they were poor substitutes in charcoal manufacture, which meant consuming even greater numbers of trees.

This metallurgical revolution devoured central Europe's forests with unprecedented velocity. By the sixteenth century there was "a general deforestation in Europe, which surpassed that of the thirteenth" (Appuhn 2000:865; for Germany, see Blickle 1981:37–39, 73–74; Westermann 1996; Williams 2003). What took some six centuries for feudal Europe to effect (Darby 1956), the emergent capitalist order achieved in just over a century. The new scale of metallurgical production surely played a crucial role in this, even if we recognize with Michael Williams (2003) that the demographic recovery of the peasantry was statistically predominant in aggregate forest clearance. Two points here deserve special attention. First, in mining-intensive regions such as the Upper Palatinate the direct metallurgical activities of extraction and smelting constituted about half of peasant consumption; a similar figure holds for the great mining center of Joachmistal in the early sixteenth century (Westermann 1996:934–35, 937). Second, the demographic expansion can in no way be considered autonomous—although not mechanically derivative—from the transition to capitalism. While the old seigneurial-agrarian demographic order retained some vigor (Seccombe 1992), the remarkable expansion of "proto-industrial" activities was taking its toll on Braudel's allegedly stable "biological *ancien regime*" (1981). Mining and metallurgical production loomed especially large in this destabilization, their expansion constituting favored "secondary occupations" for peasant households (Kellenbenz 1974:263). To the extent that such semiproletarianization proceeded—central Europe's metallurgical sector alone was reported to have employed upward of one hundred thousand workers in 1525 (Nef 1964:43)—sociobiological reproduction was correspondingly unhinged from access to land and the conditions established for rapid population growth (Seccombe 1992).

It was, then, less population expansion qua independent variable (pace Williams 2003) than the demographic transformations—not to mention the social tensions (Scott 2002)—associated with the penetration of commodity production and exchange into peasant society. The social organization of human nature and the social organization of extra-human nature together worked new pressures on central Europe's forests. From this standpoint it is scarcely surprising that fuel costs moved sharply upward from the last quarter of the fifteenth century. "From 1470 onward, in all of central Europe, the price of wood was rising, slowly at first, *then rapidly*" (Cipolla 1976:229). Charcoal was by far the largest item in the budget of any smelter, sometimes as high as 70 percent of operating costs (Kellenbenz 1974:257). Already by the 1460s, fuel scarcity had compelled Nuremberg—not coincidentally the first site of modern "forest sowing" (Powers 1999:265)—to relocate its copper smelters some two hundred kilometers northward following the industry's virtual shutdown; that is, at the very moment when the extractive boom was commencing, and therefore precisely at the time when demands on the forest were escalating most rapidly (Wellmer and Becker-Platen 2002:725). Fuel demands intensified still further with declining ore quality. The rich veins tapped, tin yields declined by nearly half and silver yields by more than 90 percent over the course of the fifteenth century (Blanchard 1978:88). The ensuing escalation of the fuel/ore ratio entrained rapid forest exploitation, by 1500 bringing some metallurgical complexes to the brink of "economic collapse" (Powers 1999:264). The following half-century would bear witness to a cascading series of such socioecological crunches, of which rising fuel costs were only the tip of the iceberg (Kellenbenz 1974:256–257; Cameron 1993:118).

Ecological politics entered into this situation in three important ways. First, by the later fifteenth century, territorial states began to actively regulate forest access for their own revenue-maximizing interests, above all favoring fuel-intensive commodity sectors (Kellenbenz 1974:257; Waring 1987:239). These measures "regulated" forest access typically by seeking to limit peasant access (Westermann 1996), which predictably generated a kind of Polanyian countermovement of the "self-protecting society" (1957). Forest enclosures intensified the contradictions of the peasant demographic regime and set in motion increasingly serious resistance. This took the form of a series of agrarian revolts beginning in earnest by 1476, culminating in the German Peasants' War of 1525 (Brady and Middlefort 1981). Access to forest commons loomed large in the revolt's famed "Twelve Articles" (Blickle 1981:198–199). The timing is important, for it coincided with the very apex of the central European mining boom. The contrast with the situation a century earlier was sharp indeed. In 1450, "there were still extensive forests, so there were few conflicts between peasants and forest overlords. . . . By 1525 the situation was *entirely changed*" (Blickle 1981:73, emphasis added). Not forest scarcity in the abstract but forest enclosures were central to the concerns of the movement. The radical cleric Thomas Munzer in 1524 decried these enclosures through which "every creature should be

transformed into property—the fishes in the water, the birds of the air, the plants of the earth: the creatures too should become free" (quoted in Marx 1972 [1843]:49). Finally, mining and working-class formation were, then as now, closely interwoven. Worker unrest intensified after 1500, and wages rose accordingly, inducing a further squeeze on profitability (Blickle 1981:120–122; Kriedte 1983:39; Lynch 2002:34–35; Nef 1964:49; Waring 1987).

By the 1540s these contradictions had reached a boiling point. Braudel (1982:325) puts this well:

> Europe, because of her very expansion, was acting as if she had decided to delegate the trouble of handling of the mining and metallurgy industries to dependent regions on her periphery. In the heart of Europe, not only were falling yields limiting profits, but the 'fiery furnaces' were destroying forestland, and the price of wood and coal was becoming prohibitive, so that the blast furnaces could only operate part of the time, thus immobilizing fixed capital to no purpose. Meanwhile wages were going up. Small wonder then that the European economy as a whole applied to Sweden for iron and copper; to Norway for copper; before long to distant Russia for iron; to America for gold and silver.

Braudel's perceptive observation reveals the dialectical connection between the rise of capitalism and the global extension of extractive industries. Ecological contradictions were interwoven with those of market, state, and class in central Europe's decline. This may well be a useful means of conceptualizing ecological crisis, positing environmental determina*tions* as opposed to a narrow environmental determin*ism*. As we have seen, central Europe's metallurgical-led ecological revolution crystallized an unstable cocktail of rapid commodification with the largely "premodern" structure of peasant society. The competitive dynamics of the silver commodity complex—articulated closely with financial capital on a continental scale—gave rise to new large-scale mining enterprises that devoured forests with unprecedented speed, while the resilience of peasant society limited the possibilities for fundamental internal restructuring. Within fifty to seventy-five years, these reached a crescendo that signified the demise of central Europe's extractive regime as central to world accumulation. Large-scale mining did not disappear; the region's centrality was however displaced through global expansion. It was the inability of regional socioecological formations—such as central Europe's extractive regime—to regain the competitive edge (once lost) that expressed early capitalism's profound geographical restlessness. Thus did central Europe's silver regime give way to Potosí in the mid-sixteenth century.[5]

The relocation of silver mining to the New World offered a near-perfect combination of relatively favorable ecological and social conditions: fabulously rich ore deposits and accessible sources of cheap labor power. If Europe's mining complex faced formidable obstacles at home, in the New World it could play a crucial role in reshaping the hemisphere's socioecological order. Among other things, while the peasantries of western and central Europe remained formidable political actors, the Andean peasantry had been politically disarmed by virtue of epidemiological assault and brute force following Pizarro's 1532 invasion. By 1600, Europe produced only one-tenth of the American bullion arriving in Seville, and this was only a portion (albeit a large one) of New World bullion exports (Brading and Cross 1972:545).

City-building was the lynchpin of Spain's colonial strategy. This approach, "the direct opposite of the British gradualistic model, permitted Spain to conquer and control an entire continent in a few years with a very small occupying force" (Portes 1977:61). In Peru, this urban-imperial logic was carried to an extreme. At once dominant and dominated, mining boomtowns ruled over their hinterlands, even as they were subordinated to broader imperial and economic structures. They were the organizing centers not only of underdevelopment in the economic sense, but of a profoundly unequal ecological exchange between American peripheries and European cores, enabled by a new, multilayered and globalizing town-country antagonism. The mining frontier thereby created an increasingly serious rift in the metabolism between the country and the city—a "metabolic rift"—within Latin American regions and at the scale of the world-economy (Foster 1999). Ecological wealth flowed from country to city in the New World, and thence from urban centers in the periphery to the core. Such wealth could take the form of agricultural and pastoral commodities as final products, or constitute crucial industrial inputs for extractive centers. Mineral wealth above all represented an astonishing crystallization of organic energy. Among the chief consequences of this globalizing metabolic rift was a pattern of "sequential overexploitation" (Gadgil and Guha 1992:121), whereby the exhaustion of local ecological wealth (including local sources of labor power) necessitated the geographical expansion of commodity relations, either through the progressive extension of city-hinterland relations within regions or the outright relocation of production.

Nowhere did the socioecological contradictions of the extractive-driven metabolic rift appear more starkly than in Potosí, located in the viceroyalty

of Peru (present-day Bolivia). The New World accounted for 74 percent of the world's silver production in the sixteenth century (Barrett 1990:225). Potosí's output dwarfed its closest competitor, Zacatecas (Mexico), by a factor of seven (Garner 1988:911). Almost overnight, Potosí emerged as one of the capitalist world-economy's largest cities; with 100,000 residents in the 1590s and 160,000 by 1611, it was in the same league as London, Seville, and Amsterdam (Larson 1988:89; Hanke 1956:54; Mols 1974:42). Together with the mercury mines of nearby Huancavelica, Potosí's silver complex pioneered a rapid expansion of commodity production throughout the viceroyalty of Peru, with profound implications for the health of land and labor alike.

Potosí's dramatic ascent owed as much to Europe's expansionary political economy as it did to geology. In the quarter-century following the discovery of silver in 1545, the path from rock to pure silver was circuitous indeed. In this era, mining remained largely under Indian control. Indians mined silver ore, much of which found its way into Spanish hands as tribute. These tributary payments were then sold back to the Indians, who smelted the ore in thousands of dispersed *guayras*, small wind-ovens specially designed for the high altitude. Subsequently, the Spaniards acquired the pure silver through the market, where their purchasing power was augmented by their control of the highly lucrative coca leaf trade (Stern 1988:850–851). Coca, it seems, was the opium of the sixteenth century.

This system worked as long as ores remained rich. As ore quality declined, more and more fuel was necessary to extract less and less silver. By the 1560s smelting was no longer an effective—that is to say profitable—means of extracting silver (Cobb 1947:124). Fuel costs began to rise, and silver output fell two-thirds between 1546 and 1571 (Bakewell 1987:239). Mine work became correspondingly more arduous and less remunerative for Indian workers, who increasingly decided that the game was not worth the candle. By 1561, there were 20,000 Indians living in Potosí but just 300 working the mines, 94 percent fewer than a decade earlier (Cole 1985:4). "In short, the pillage/conquest economy established after 1532 had reached its limit" (Andrien 2001:49).

Potosí's socioecological crisis did not go unnoticed from above. Spain's imperial ambitions fed on American silver (McNeill 1982:109). The contraction of silver production was a very serious matter indeed, all the more so as it was followed by: (1) "an enormous increase" in military expenditures after 1566; and (2) an increasingly severe fiscal crisis within Castile, where Philip II tripled taxes and thrice declared "bankruptcy"—in reality converting short-term into long-term debt—between 1557 and 1577

(Parker 1974:561–569). As if to go from bad to worse, Philip's financial woes were underpinned by an impending agroecological crisis that would only deepen in the closing decades of the sixteenth century (Phillips 1987). It was in this context that the Crown convened a "special junta" in 1568 to address the emerging crisis, empowering a new viceroy—Francisco de Toledo—to implement a sweeping reorganization of the Peruvian mining frontier (Assadourian 1992: 56–58).

Toledo's challenge? Find a cost-effective solution to the problem of declining silver output. Potosí's revival depended on two decisive innovations: (1) the replacement of smelting with an amalgamation process that used mercury to extract silver from the ore; and (2) the large-scale replacement of voluntary with forced labor through a system of rotating forced labor drafts, called the *mita*.[6] The first presupposed the second. The perfection of an amalgamation process adapted to Andean conditions preceded by just a year Toledo's proclamation of a geographically expansive *mita* in 1572. Mercury amalgamation made possible the profitable extraction of silver from low-grade ores, but it demanded a huge and tractable labor supply. Thus amalgamation and the *mita* were at the core of a series of socioecological transformations that were profoundly implicated in the commodification of land and labor throughout the region and its deepening articulation with a globalizing capitalist system.

This era of accelerated social and environmental transformation unfolded at multiple geographical scales. At the point of production, control passed from Indian to European hands, replaying on an extended scale the earlier transition from small-scale artisanal mining to lárge-scale industrial extraction in central Europe a century earlier (Waring 1987; Cole 1985:18). Gone were the small wind-ovens used by Indian miners. In their place were huge stone tanks, capable of holding 5,000 lbs. of crushed ore (Bakewell 1987:214). The ore itself was crushed in stamping mills (*ingenios*) powered by hydraulic infrastructures that outstripped by a considerable margin their European predecessors (Lynch 2002). Some thirty dams stored water accumulated during the brief and torrential wet season, driving 140 *ingenios* (Craig 1993:218). Silver production skyrocketed nearly 600 percent between 1575 and 1590 (Bakewell 1987:242). In equal measure, the ambitious reshaping of the region's waterscapes generated ecological contradictions that would ultimately seal Potosí's fate. "Potosí was [consistently] plagued by disastrous floods," likely intensified by widespread deforestation (Brown and Craig 1994:305). The collapse of the principal reservoir dam in 1626 killed several hundred and destroyed many *ingenios*, adding to Potosí's cumulative woes on the eve of the seventeenth-century crisis. From this disaster, "the *ingenios* of Potosí never fully recovered" (Craig 1993:145).

Relative to smelting, mercury amalgamation was a "cold" rather than "hot" technology. Yet, because it enabled such a large increase in output over so short a time, the consequence was more, not less, deforestation. Mercury extraction itself demanded a considerable volume of charcoal, resulting in deforestation around the mercury mines at Almaden (Spain) and Huancavelica (Peru) (Parsons 1962; Brown 2000). Moreover, the mercury-silver amalgam required further heating to get at the pure silver. A 1603 source reports 2,000 Indians bringing wood and firewood to Potosí, with another thousand transporting and making charcoal; this compared to 4,600 working directly in the mines (Cole 1985:29). The surrounding area was quickly stripped of trees, and timber for stamp mills was trucked in from as far as 200 miles away (Bakewell 1984:24). By 1600, rising fuel costs led refiners to stop heating the stone tanks containing crushed ore and mercury (Bakewell 1987:214).

Deforestation weighed particularly heavily on highly vulnerable mountain ecosystems, which suffer from high rates of soil erosion and enjoy only a "fragile stability, easily upset by unintentional human action" (McNeill 1992:352). By the mid-seventeenth century, one contemporary would observe that there "is no sign" that the mountains surrounding Potosí "ever had a forest," although

> when it was first discovered it was fully covered of trees. . . . Today, not even weeds grow on the mt., not even in the most fertile soils where trees could have grown. The barrenness is most alarming because the mt. is now merely a conglomerate of loose gravel with little or no fertile land, pockmarked with sterile mineralized outcroppings. (quote from Burke 2000)

Ecological contradictions degraded bodies much as they denuded the landscape. The course of events in Potosí captures what seems to be the basic socioecological pattern of early modern commodity frontiers.[7] In the early stages, high yields translate into high wages and decent working conditions. But sooner or later yield declines. When this happens, profitability begins to hinge on (1) rising capital intensity, manifest not only in surface infrastructures but also in deeper mines; and (2) securing cheap labor power. While technological and social innovations could temporarily check rising costs, they could not do so indefinitely *within the region*.

Drawing workers either from outside the commodity economy, or only loosely articulated with it, mineowners found themselves in a favorable position not only to enjoy the fruits of cheap labor but to exploit them with little regard to their workers' health (Tandeter 1981:104). In itself, the death and bodily damage suffered by Indian mineworkers posed no serious threat to profitability over the short run. In contrast to African slavery, however, the exploitation of the *mitayo* "did not place any investment at risk. . . . Immediate profitability was the overriding consideration of the entrepreneur in his relation with the forced laborers" (Tandeter 1981:104). To this extent, the *mitayo* regime may have been even more lethal than slavery. This problem was reinforced further as the practice of hiring out *mitayos* increased in the later sixteenth century. As we shall see, such overexploitation represented not only a monstrous legacy of early European expansion, but also favored the reconstitution of the region's division of labor in a strongly capitalist direction.

Potosí's renaissance was driven initially by the exploitation of tailings, ore that resisted the smelters. But these were exhausted by the end of the 1570s. The solution? Dig deeper. A rising proportion of *mitayos* was put to work in the increasingly deeper, and as a consequence increasingly dangerous, mines. Work-related fatalities and disease escalated sharply. Mineowners increasingly disregarded colonial prohibitions and imposed fixed quotas, dramatically extending the working day. In the 1570s, for instance, the colonial state prohibited more than two trips a day for *apiris*, workers who carried the ore from the mine depths to the surface. By the 1580s they were carrying as many as two dozen loads of 25 kilograms upward some 300 meters. Mine shafts often flooded, forcing *mitayos* to work "knee-deep in water," rendering them susceptible to all manner of respiratory diseases, especially pneumonia. Rest periods—originally two weeks for each one worked—were increasingly disregarded (Cole 1985:23–25; Cobb 1947:86–89). By 1600, "the proprietors decided they were losing time changing shifts, so they started keeping the workmen underground continuously from Monday evening to Saturday" (Rowe 1957:174). The mines, said mineowner Luis Capoche, had become a "harsh executioner of Indians, for each day it consumes and destroys them, and their lives are made misery by the fear of death" (quote in Bakewell 1984:145). Notwithstanding this increasingly brutal labor regime, ecology proved stubbornly resistant. Yields continued to decline. By the mid-1580s, "workers were taking out only half the amount formerly produced" (Cobb 1947:77).

The contradictions that flowed from the point of production were enabled by the imperial refashioning of Latin American political ecology. The late-sixteenth-century silver boom presupposed a radical recomposition of Peru's ecological wealth and its sociospatial division of labor in ways that favored the maximization of commodity production in Potosí, and the

progressive commodification of internal and external nature (labor and land) throughout the region. All of Peru was to be at the service of Potosí.

Our attention goes first to labor recruitment. Needless to say, the Indians were not in a hurry to work for the Spaniards. The solution was found in the *mita*, a rotating annual labor draft. Imposed in 1572, the *mita* conscripted one in seven adult males for work in the mines, textile workshops, "and any other task . . . deemed worthy of the state's patrimony" (Stern 1982:82). The Potosí *mita* was by far the largest and most geographically expansive. In the 1570s, the annual draft mobilized some 13,500 workers, drawn from a region that stretched some 800 miles north to south and as much as 250 miles east to west (Bakewell 1987:222).

This large-scale mobilization of bodies was predicated on the large-scale reorganization of space. The *mita*'s immediate precondition was the empire's reorganization of village life throughout the Andes. Beginning in 1567, the colonial state initiated the "wholesale resettlement of the native population"—perhaps as many as 1.5 million people, roughly the population of contemporary Portugal—into "Spanish-style towns" (Rowe 1957:156). These nucleated villages (*reducciones*) effected three major socioecological transformations, reinforcing their obvious advantages for tax collection and political control (Gade 1992). In the first instance, the concentration of Indians into more densely populated encampments provided fertile epidemiological terrain for Eurasian diseases (Andrien 2001:57). Second, large-scale resettlement often entailed the removal of Indians from lands prized by Spanish colonials (Ramirez 1996:71–72). Third, the *reducciones* undermined pre-conquest political ecology based on "verticality," the core strategy of which involved "working as many different microenvironments as possible" so as to minimize ecological vulnerability (Stern 1982:5). Throughout the Andes, the close proximity of distinct regional environments—"the coast, the piedmont, the altiplano highlands, and the tundra steppe (puna)"—encouraged highly interdependent agropastoral linkages. Potato cultivation in the highlands, for instance, was supported by fertilizer (guano) supplied by coastal communities, which in turn consumed highland foodstuffs. Throughout the Andes, there had evolved a "synchronized [pattern of] ecological relationships between coast, piedmont, highland, and puna," constituting "a finely calibrated system of food transfers" (Wolf 1982:59, 134–135).

The *reducciones* insisted on a new agroecological order corresponding to the labor demands of the silver frontier. At its center was common-field agriculture, a cultivation system that emphasizes agropastoral linkages, access to commons, and community regulation of landholding (Thirsk 1964). Where verticality presumed exchanges across ecological zones, such that farming and herding were geographically discrete, common-field agriculture sundered such exchanges by stressing agro-pastoral integration. From the standpoint of the colonial state, the great advantage of the common-field system was its geographically expansive character, emphasizing land as a means of maximizing the productivity of scarce labor in place of older, intensive land-use practices. The new system minimized the labor formerly allocated to supervising and guarding herds and fields, and maintained soil fertility by substituting European livestock for vertical guano transfers (Godoy 1991). Its adoption was accelerated by viceroy Toledo's 1575 "edict mandating a plow and oxen for each Indian agglomeration" (Gade 1992:469). This technological innovation promised an important change in Andean socioecology, shifting from a labor-intensive to a land-extensive approach—one also linked to the sharp reduction of agricultural diversity that preconquest peasants deployed to safeguard against crop failure (Wolf 1959:198–199; Zimmerer 1996:44–55).

The livestock-plow system was complemented and indeed made possible by a second moment of "ecological imperialism": the invasion of Europeans' favored crops, wheat above all. Commercial production dates from the late 1530s. "In some locales [Indians] were growing it as . . . a food staple by the late 16th century" (Gade 1992:465). If the common-field system reduced necessary labor by cutting supervision costs, and the livestock-plow system effectively substituted land and animal power for human labor, wheat offered a further labor-saving (but land-consuming) bonus. Relative to indigenous crops, wheat demanded little labor and enabled plow agriculture by tolerating the new animals' grazing patterns (Godoy 1991:407). In contemporary Europe, the chief ecological trade-off was its tendency toward low yields and soil exhaustion: wheat "devours the soil and forces it to rest regularly" (Braudel 1977:11). It was the colonizers' great fortune, however, that the New World's fertile soils attenuated this tendency. Initially, wheat cultivation in Peru supported seed/yield ratios three to six times higher than Europe's average, liberating still more labor from the demands of subsistence production (Slicher van Bath 1963:330; Super 1988:20–22). American soil favored the transfer of a European agronomic complex that created a relative surplus population in the face of demographic contraction, and provided a crucial subsidy for the mining economy.

The increasing frequency of famines and the generalization of malnutrition that ensued (Cook 1981) expressed the dietary moment of what we might call "disarticulated primitive accumulation" in the Americas. An ecological surplus was extracted from the bodies and fields of the indigenous peasantry in a way that paralleled the extraction of surplus labor, in

both instances for the benefit of accumulation centers abroad rather than the creation of a home market.[8] This was the "disarticulated"—and therefore intrinsically globalizing—nature of the New World's metabolic rift in the transition to capitalism. Silver was central to an epochal reworking of nature-society relations in the long sixteenth century, a reworking that was cause no less than consequence of the rise of capitalism. The large-scale transformation of nature was not new. But its global and theoretically endless transformation certainly was. The sociotechnological capacities that enabled overseas expansion also, crucially, enabled (and indeed necessitated) capitalist and territorialist agencies to "jump scale" when the going got rough in any particular locale—this is the story of the silver commodity frontier, and not the silver frontier only.

The globalization of capital that was part and parcel of the rise of capitalism created everywhere, but in the Americas most dramatically, a globalizing rift in the metabolism of town and country. The silver mining frontier not only ensnared whole regions in its commodity-producing web but ensured that ecological wealth would flow from countryside to (mining) town, and from colonial city to imperial metropole. At each step nutrient cycling was disrupted as local ecologies were harnessed to Europe's territorial and capitalist ambitions. In classic Polanyian fashion (1957), the ensuing "fictitious" commodification of labor and land undermined the socioecological bases for regional accumulation regimes, setting the stage in these instances not just for the eventual resurgence of the "self-protecting society" but also for a new round of global expansion. Hence the recurrent waves of global conquest, from central Europe to Peru to New Spain. By the sixteenth century, it seems, Europe's ruling strata had discovered not just America, but a new and radically transformative political ecology of civilizational expansion.

Notes

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1. See White's important—and largely unheeded—essay (1999) on environmental history and geographical scale.

2. Silver ore was found in combination with a heavy concentration of either copper or lead in central Europe's mining regions, and this naturally affected the volume of lead imported for smelting purposes.

3. Westermann (1996:938) believes the rate of deforestation was higher—around seven percent annually for iron producing Upper Palatinate in the sixteenth century. This figure, he stresses, must be taken as a "minimal estimate" that does not account for unusual periods of high demand.

4. Calculated from Smil (1994) and Hammersley (1973).

5. This is not to deny the significance of Japan's silver production for the history of east Asia during this period (Frank 1998). From the standpoint of the rise of capitalism, however, Japanese silver was not decisive, quite aside from the quantitative predominance of American silver production (Flynn and Giraldez 2002). The real distinction rests in the distinctive historical geographies of the Japanese and American complexes. In stark contrast to the former, the Potosí-centered silver frontier was a *commodity* frontier. In this respect, it expressed and contributed to a movement of endless global expansion whose success or failure turned on the generalization of commodity production and exchange. Japan's silver frontier did not.

6. The Incas deployed a broadly similar system of labor drafts, also called the *mita*. Stern (1982) distinguished the two systems by calling the Inca institution the *mit'a* and the Spanish, the *mita*.

7. The resemblance to the sugar frontier is striking (Moore 2000b).

8. The European peasantry too was subjected to a similar logic of dietary immiseration, albeit with less gruesome consequences (Moore 2003b).

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7

Trade, "Trinkets," and Environmental Change at the Edge of World-Systems: Political Ecology and the East African Ivory Trade

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DURING THE LAST two thousand years the capitalist world-system and its predecessors have flooded the unincorporated areas of the world with vast amounts of glass beads, cowries, pieces of cloth, brass, copper, and iron, guns, tools, and utensils (Guyer 1995; Einzig 1949). Such trade occurred in the absence of political domination or alienation of producers' access both to the means of production and to raw material extraction. Unfortunately, with respect to this type of trade there is very little theoretical guidance to understand the linkages between regional historical developments and world-systemic processes. Because the populations are not forced to participate through political means, Chase-Dunn and Hall (1997:63) suggest that such areas should be regarded as being only weakly incorporated into world-systems. Accordingly, I call this type of economic interaction "unincorporated trade." The ivory trade of precolonial eastern Africa is an example of economic relationships that have been common for millennia between world-system centers and areas not directly under their political and economic control.

During the nineteenth century, the ivory trade system in East Africa underwent two related transformations that are salient to my analysis. First, there was a change from a decentralized system of trade without any clearly defined exchange nodes to a pattern of well-defined trade routes and nodal points of commerce. Second, the decentralized trade was controlled by the communities of the coastal hinterland while in the later development trade was conducted and controlled by coastal merchants and international capital. This historical change enables me to examine the effects of changes in the spatial and organizational parameters of long-distance trade