Gold Rush Legacy: American Minerals and the Knowledge Economy

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Most historical accounts date the American “knowledge economy” from around the turn of the twentieth century, with the rise of science-based technologies, research universities, and corporate laboratories. Claudia Goldin and Lawrence Katz, for example, write that “something fundamental changed around the turn of the twentieth century,” when “technological shocks” in scientific disciplines generated economically important findings that swept the “knowledge industry.” The founding of the American Association of Universities marked the emergence of research universities as a self-conscious group, with particularly rapid expansion in applied sciences and engineering.¹

In this paper, we argue that many features of this configuration began much earlier in the minerals sector, including synergies between higher education and industry, federal support for scientific research and infrastructure, deployment and diffusion of codified forms of useful knowledge, and economic progress based on extension of the knowledge frontier. In many major universities, the mining school was an early center of market-oriented science that helped to chart the path of institutional evolution for the distinctive U.S. innovation system.

These developments did not originate with the California gold rush. Benjamin Silliman offered a fully-illustrated course in mineralogy and geology at Yale early in the century and founded the nation’s leading scientific journal in 1818. By the 1840s Michigan’s rich copper deposits were attracting geologists and chemists away from Yale into industrial consulting.² But the quantitative expansion of mineral-related knowledge investment was a function of the scale of the U.S. minerals sector, and in turn of the

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policy regime of open-access to the public domain for minerals exploration. These institutional features date from the time of the California gold rush and became entrenched during the 16-year span between the discovery at Sutter’s Mill and enactment of the first federal mining law in 1866. Thus to call the knowledge economy a “gold rush legacy” is only modest exaggeration.

Unlike much modern science, these forms of knowledge had strong geographically-specific elements, a consideration that emerges as one of the keys to successful resource-based development in modern times. The U.S. case stands in contrast to mineral-endowed but underachieving nations whose mining sectors remained “closed-access”; and with poor countries whose minerals are developed by “outside” investors with little sustained interest in individual countries.

The Institutional Configuration of U.S. Minerals

Most national mining systems descend from the tradition that valuable minerals belong to the lord or ruler, who granted use rights as “concessions” in exchange for a share of the revenue. The U.S. government was by no means immune to the attractions of mineral revenues. Continuing colonial-era practice, the Land Ordinance of 1785 reserved for the federal government “one third part of all gold, silver, lead and copper mines, to be sold or otherwise disposed of, as Congress shall direct.” Although minerals were not mentioned in the land laws of 1796, 1800, and 1804, Congress did act in 1807 (spurred by the prospect of armed conflict as well as revenue) to reserve lead mines in the Indiana Territory. Between 1824 and 1846, the government maintained a leasing system in the Galena District of Illinois, Iowa and Wisconsin: Miners were given exclusive permits to work certain areas, and in return were required to bring their ore to one of the officially licensed smelters, who were required to pay a 10% royalty. The plan worked reasonably well in the 1820s, as production and federal revenue both grew. It fell apart in the 1830s, however, when nonpayment and noncompliance became widespread. Authorities in Washington lacked enforcement power, even over their own agents, who abetted evasion by smelters and fraudulently sold valuable mineral lands at minimum farmland prices, almost surely with side payments for personal profit. The mining expansion of 1836-1840 thus generated no government revenues, leading British observer
Frederick Maryatt to comment: “How weak must that government be when it is compelled to submit to such a gross violation of all justice.”

During the 1840s, the Ordnance Department attempted “reluctantly and halfheartedly” to reinstitute a leasing system for Michigan copper lands, but the results were no more successful, and the efforts were abandoned in 1846. Thus, on the eve of the California gold rush, the federal government had abolished all administrative apparatus and enforcement machinery pertaining to minerals on the public domain.

Once the rush began in 1849, Congress considered many proposals to generate federal revenue from the gold fields, including mining licenses, auctions, leases, and sale of small mining tracts at farmland prices. But the prospects for effective enforcement were even more daunting at a distance of 3000 miles than they had been in the midwest, and after several early measures failed to gain support, both executive and legislative branches acquiesced in a policy of non-intervention. Inaction was further supported by the arrival of political representatives from the new western states, who opposed any measures that might constrain the extension of the mining frontier and drain revenue from the region. As a result, no federal mining legislation was passed until 1866.

Federal inaction did not mean lawless anarchy. Groups of miners in local areas adopted rules for recording and protecting claims, and these codes have come in for extensive study as examples of spontaneous or private-order legal systems. In our previous work on this topic, we argued that Mining District codes should not be understood as conventional property rights, but as systems for maintaining order in the context of an open-access “race” to discover high-value ore deposits. As such, the codes succeeded in reducing violence though not a rising volume of litigation, as disputes spilled into the state court system for lack of an alternative venue.

Our point here is that political pressure, in California and elsewhere in the West, predominantly reflected the desire for rapid development of mineral resources. Though often referred to as the “mining interest,” this perspective also reflected the interests of those who stood to gain from expanded mineral production, such as merchants,

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3 This paragraph draws upon Wright, *The Galena Lead District*, chapters 2 and 3.
5 Clay and Wright, “Order Without Law?” We show that the mining district codes typically gave equal attention to the rights of claim-jumpers as to claim holders.
developers, and producers of mining equipment. The distinction is illustrated by the enactment of the Foreign Miners’ Tax by the California legislature in April 1850, imposing a $20 monthly license fee on all non-citizen miners in the state. After a chorus of opposition from merchants and editors, the tax was repealed in the following year, and re-enacted at a more moderate rate in 1852. As mining activity spilled out from California into other western states and territories, and from placer gold to a range of hardrock minerals, political priorities of both legislatures and courts favored rapid exploitation of mineral wealth.⁶

The federal mining laws of 1866, 1870, and 1872 largely confirmed what by then was a well-established “free mining” precedent, abandoning hopes that public-domain mining might be a major federal revenue source. Although these acts all confirmed the pre-emption rights of existing claims, and paid lip service to respecting the codes and customs of local districts, in practice mining law adapted over time to the growing importance of large-scale operations and heavily-capitalized technologies. Thus, limits on the size and number of claims became largely irrelevant, while recognition of “extralateral rights” to pursue a vein underground became firmly established. But exploration for minerals on the public domain remained open. In his exhaustive 1918 review of international mining laws, Van Wagenen concluded that prospecting was nowhere else as free as in the USA.⁷

Indeed, the role of the federal government became primarily one of promoting regional development by investment in the infrastructure of geological knowledge, thereby greatly enhancing public perceptions of the practical value of science. In 1867 Clarence King, having worked for the first state geological survey of California after graduating from the Sheffield Scientific School at Yale, approached the Corps of Engineers with a proposal that the War Department allocate funds for the Geographical Exploration of the Fortieth parallel. The first publication from this project appeared in 1870, with contributions not just on the location of gold and silver deposits, but on methods and equipment for digging and equipment for treating ores at the Comstock.

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⁷ *International Mining Law*, pp. 117, 287.
The report was praised by *The American Journal of Science* as “the most valuable contribution yet made to the literature of the Mining Industry of the United States.”

When Clarence King exposed a fraudulent mining scheme in which an area had been secretly seeded with uncut diamonds, the *San Francisco Bulletin* lauded

...the practical value, in the ordinary business of society, of scientific education and research...These public surveys ‘pay’ in more senses than one, and even those who care nothing for wider and fuller knowledge for its own sake, must hereafter admit that Government spends no money more wisely and usefully.

King was subsequently besieged by offers to examine property, and according to a friend, “he never charges less than $5000 to look at a mine.”

The United States Geological Survey, which emerged in 1879 under King’s direction as the consolidation of several separate projects, became a leading center for topographical and metallurgical research in the post-Civil War era. The Survey soon became known as a valuable employer for young men beginning a career in the industry, a “great graduate school of instruction” in he words of a mining journal.

In 1882, under King’s successor J.W. Powell, the Survey was authorized to enter older parts of the country, to support metallurgical analysis for iron, coal, and oil, and to begin preparation of a geological map of the entire country, not just the public domain. Thus it may fairly be said that the California gold rush enhanced and encouraged development of the entire national minerals sector, not just the western region.

**Growth of the Minerals Sector**

The result of this open and accommodating institutional setting was a vast expansion activity in the minerals sector of the economy. When news of the gold strike was confirmed by President Polk in December, 1848, the number of miners in California jumped from less than 5,000 to more than 40,000 within a year, ultimately peaking at 100,000 in 1852.

Most gold-rush miners were amateurs who tried it for a while and then left – the gross total may have been two or three times as high. Despite high

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10 Spence, *Mining Engineers*, pp. 113-114.
11 Spence, *Mining Engineers*, p. 60.
12 These figures reflect contemporary estimates, summarized in Paul, *California Gold*, p. 43.
turnover, this one-time surge of population had a lasting impact on California’s population, wage levels, and development.

More to the point of the present paper, the gold rush jump-started the western regional minerals enterprise. Figure 1 shows the evolution of number of miners in the West over time – miners in the East almost exclusively mined coal. The number of western miners fell between 1860 and 1870, and then rose again beginning in 1880. Opportunities in California declined as production shifted from surface mining of placer gold to more mechanized sub-surface mining of quartz gold. But many miners migrated to other western states. Figure 2 shows that more than 20 percent of the adult male population were miners at some point in the state history in six western states – California, Arizona, Colorado, Idaho, Nevada, and Montana. In every case except Arizona, miners were the largest share of the population in the first year of enumeration. For example, they were 35 percent of the population of Colorado in 1860, 60 percent of the population of Idaho in 1870, 49 percent of the population of Montana in 1870, 56 percent of the population of Nevada in 1860. Mining clearly drove settlement of these states. One can see this in the maps of population distribution as well. The first map of this type was produced by the census in 1870, and it shows that population in California, Colorado, Idaho, Nevada, and Montana was clustered in key mining districts.

Many of the western miners came from overseas. Table 1 shows the number of immigrants to the United States who gave their occupation as “miner” at the time of entry. The lasting impact of the gold rush is evident. A total of less than 2,000 miners entered the country before 1850, but more than 35,000 did so during the gold rush decade. Miner immigration actually increased during the 1860s and remained high for the rest of the century. Figure 4 shows that the share of foreign-born miners was high in most mining states in most years. Figure 5 shows the distribution of nationalities of all foreign-born miners over 1850-1910. The largest share was from the United Kingdom – England, Ireland, Scotland, and Wales. Chinese miners were the second largest share, followed by Nordic, Mexican, Italian, German, Canadian, and other nationalities.

Although we have no way to measure their prior experience, many of these foreigners brought expertise that was highly valued in mining areas. In 1850s California, it was considered a great advantage to have a Cornishman or Chilean in one’s party. The
shift to quartz mining if anything increased the prominence of skilled foreigners, because of their experience in deep-mining methods and ore-reduction processes such as pulverizing rock.\textsuperscript{13}

Figure 6 shows the course of gold production over time. The California series displays the classic pattern of a “rush” to discover a fixed number of rich ore deposits: Production peaked along with the number of miners in 1852, and drifted downward until 1865. But a focus on a single state is somewhat misleading, as exploration spread to other western states (primarily Nevada and Colorado), whose rising gold production partially replaced California’s declines. After 1885, total national gold production began to rise (led by Colorado) and by the 1890s had surpassed the peaks of the gold rush era.

But silver mining in the West was also a direct consequence of the California Gold Rush. The discoverers of the fabled Comstock Lode in what is now Nevada were gold prospectors who inadvertently stumbled on silver. Placer miners from California had worked a gulch called Gold Canyon for some years, unaware of the riches under their feet. Only in 1858, when more knowledgeable diggers detected bluish-quartz mixed with the gold dust and had it assayed, was the area known to be rich in silver. A newspaper notice in July 1859 kicked off the Comstock Rush, in turn triggering searches for silver throughout the territories. Nevada became known as the Silver State, but its silver output was soon surpassed by Colorado, Montana and Utah.\textsuperscript{14}

Figure 7 shows the dramatic growth of silver after 1860. If we combine gold with silver, the picture that emerges is not one of boom-and-bust, but of nearly steady growth throughout the century (and beyond). From this perspective, the years of decline in California gold constituted a relatively minor setback in the larger story of expansion.

\textbf{Inputs, Outputs, and Learning}

To be sure, much of this expansion can be interpreted as the rise of inputs as much as outputs, and from this perspective, one may question a linkage to common notions of a knowledge economy. But gold-mining was technologically dynamic virtually from the beginning of the rush, so that the efficacy of mining labor improved


over time, despite ongoing depletion at particular deposit sites. Furthermore, the
geographic expansion of the mining frontier was itself a learning process, deploying
increasingly sophisticated forms of exploration and adaptation to new conditions.
Perhaps most importantly, there was a positive complementarity between these two
sources of progress, in that improvements in techniques of extraction, ore separation, and
refining facilitated the extension of mining into locations and ore qualities that would
otherwise have been unprofitable – in effect creating new mineral resources from an
economic standpoint.

The earliest placer miners extracted the metal from the gravel with a circular hand
method performed by a single man with a pan. As early as 1848, miners began to make
use of a larger machine called a “rocker” or “cradle,” with which three or four men
working together could produce a larger volume of “dirt” in a day. During the winter of
1849-50, the “long tom” was first introduced in California. This instrument was a still-
larger version of the cradle, with two 12-foot sections operated by three to six men, and
requiring a continuous stream of water. Because the long tom allowed many of the finer
gold particles to escape, a further improvement was implemented the following year in
the form of the “sluice” or “sluice box,” an open trough with riffle boxes perforated to
allow gold particles to lodge. By the latter part of 1849, all of these techniques were
enhanced by the use of quicksilver or mercury for more efficient separation of gold from
the sand. Historian Rodman Paul writes that this package of innovations (together with
investments in canals and ditches) constituted “a complete revolution in mining,” noting
that reductions in the unit cost of materials allowed miners to “extend their work into
comparatively low-grade auriferous ground that had not previously been considered rich
enough” for exploitation.\footnote{Paul, \textit{California Gold}, p. 65, and more generally, pp. 50-66.}

At that early stage, one could hardly have claimed that California mining
technology was more “advanced” than elsewhere in the world. The use of mercury in
gold mining was an ancient practice, and the transition from panning to rockers to sluices
did little more than recapitulate similar progressions in smaller previous rushes in
Georgia and North Carolina. Prior to the late 1860s, Americans who wanted advanced
training in mineral sciences were likely to enroll in one of the prestigious European
mining colleges, in Sweden, Freiberg or Paris.\textsuperscript{16} Giving due allowance to all of these considerations, however, one may still detect an emerging American pattern of progress in the minerals sector, in which higher-order forms of knowledge were deployed to address new technical challenges, and relationships between mining and other industries became increasingly complex. Many of these linkages were functions of the scale of the mining sector. David St. Clair details many of them in his essay on the beginnings of California industry: Leather hoses for the mines were made in San Francisco beginning in 1857 and soon were exported to fire departments around the world. For quartz mining, San Francisco foundries and machine shops produced drills, belts, cables, explosives, pumps, and steam engines. By 1870, manufacturing per capita in California was well ahead of Midwestern states like Ohio and Illinois, and many industries that originated to serve the mines developed technologies with multiple additional uses, such as cable cars, shipbuilding, hydroelectric power, and sugar cane processing.\textsuperscript{17}

Linkages from minerals to technology and science were accentuated with the shift from placer to quartz mining, and even more so with the rise of silver mining on the Comstock and elsewhere in the West. Barger and Schurr write that silver “ended the poor man’s day in mining and ushered in the era of the financier and the engineer.”\textsuperscript{18} An important example of innovation endogenous to these new challenges was “square-set timbering,” in which rectangular sets of timbers replaced the ore as it was removed, increasing the strength of support and making possible the development of large underground ore bodies. The system was invented in 1860 by a German engineer who had been in California since 1851, and soon became standard throughout the Comstock, an object of study and imitation by visiting experts from around the world.\textsuperscript{19}

Of equal importance was a stream of innovations in methods of working ores, extending the intensive mining frontier for complex ores and low-grade deposits. An early breakthrough was the Washoe pan amalgamation process for separating silver and gold, developed in 1862 by Almarin Paul -- another forty-niner, who began by transferring stamp mill technology from California quartz mining, and then extended to

\begin{enumerate}
\item A list of Americans enrolled appears in Read, \textit{Mineral Industry Education}, pp. 27-28.
\item Barger and Schurr, \textit{The Mining Industries}, p. 101. The authors cite an old Mexican adage: “It takes a gold mine to open a silver mine.”
\item Paul, \textit{Mining Frontiers}, p. 64.
\end{enumerate}
incorporate heavy iron “mullers” that would grind as well as mix the pulverized rock. Although the standard historical narratives record Paul and the Washoe process as the technological breakthrough, he was only the most successful of the many gold rush veterans who were experimenting along related lines. Nor did the processes of innovation and adaptation stop there. For example, when the Washoe process was found not to work well for ores with arsenic or antimony sulfides, a variant known as the Reese River process (in which the ore was roasted with salt to convert silver sulfides into silver chlorides)) was developed and used in a number of new silver-mining districts. In the 1860s and 1870s, the Comstock became known as a world center for hard-rock mining techniques, the “mining school of the world.”

Roughly simultaneous with the Comstock, but posing special geophysical challenges, was the gold-silver mining industry of Colorado. Although miners flocked to the area in large numbers between 1859 and 1865, output growth was inhibited by the extreme depths of the ores, and even more so by the fact that Colorado gold ores were found in chemical combination with sulphides, constituting what miners called “sulpherets” or “refractory ores” that resisted amalgamation. Initially the main adaptation was a local variation of the California stamp mill, which gave the ores and longer and finer crushing and a longer exposure to the action of mercury. Ultimately, Colorado investors reached out to scientists for a solution, recruiting Nathanial P. Hill from Brown University, an applied chemist who also maintained a vigorous consulting business. After visiting Colorado and gaining an appreciation for the technical challenge, Hill made trips to Britain and continental Europe to study techniques for smelting ores. In 1868, Hill built a smelter, largely copied from one in Wales. Its costs were prohibitively high, however, so that the major breakthrough in smelting came only in 1871, when Hill allied himself with Richard Pearce, son of a Cornish miner who had studied both at the Royal School of Mines in London, and at Freiberg. Their success provides a striking example of deployment of world-class scientific knowledge towards the solution of a regional mining problem. Here again, however, the initial breakthrough

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was only the first step in an ongoing regional learning process, in which both foreign-born and native-born metallurgists played prominent roles. 21

Successful development of Colorado smelting set the stage for the silver discovery at Leadville in 1877, a bonanza that was in many ways endogenous to the emerging regional technology. Leadville in turn became one of the first priorities of the United States Geological Survey, newly established in 1879. The USGS monograph (Geology and Mining Industry of Leadville) prepared under the leadership of Samuel F. Emmons and published in 1882, was known for years as “the miners’ bible.” Paul writes: “More than any other event, the publication of this scientific study convinced skeptical mining operators that they could learn something of cash value from university men.” 22 Within a few years, other mining districts were petitioning the USGS for comparable surveys in their own localities.

**Higher Mining Education**

The expansion of mining and consequent encounters with new technical and scientific challenges gave rise to indigenous training institutions adapted to American conditions. The earliest efforts pre-dated the Gold Rush, such as the Lawrence Scientific School at Harvard, which included mining and metallurgy as part of the founder’s intended purpose in 1847. In practice, the Lawrence School concentrated on pure-science aspects of biology and chemistry. The first growth spurt for mining schools came only in the 1860s. Although several of the eastern schools had strong links to in-state mining activity (such as Michigan and Pennsylvania), the most successful of them all had no such connection, but was clearly producing mining engineers for a national market. When Columbia College in the City of New York opened what became the nation’s first successful school of mines in 1864, twice as many students (29) appeared on the first day as had been expected. Within a year, that number had more than doubled! Visitors were impressed by the rigor of the Columbia curriculum, one of them writing in 1867: “A graduate of the School of Mines will be well worthy of his degree.” A well-informed

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21 This paragraph draws upon Paul, “Colorado as a Pioneer of Science”; and Fell, *Ores to Metals*, Chapters 1 and 2.

1871 survey declared Columbia “one of the best schools in the world – more scientific than Freiberg, more practical than Paris.”

The Columbia School of Mines was dominant for the next quarter-century. In 1893, Samuel B. Christy, a professor of mining and metallurgy at the University of California, noted that the USA had more mining students than any country in Europe except Germany, and nearly half of the national total as of that year had studied at Columbia. (See Figure.) The three-year program included mathematics, stochiometry, physics, electricity, inorganic chemistry, mineralogy, metallurgy, geology, assaying, and the theory of veins. Over time, the school also sought to expose its students to practical aspects of the mining industry. Professor Robert H. Richards developed the “Mining Laboratory,” where problems in ore-dressing and metallurgy could be worked out by students. Professor Henry S. Monroe developed the “Summer School of Practical Mining,” which helped students become familiar with working conditions they would meet after graduation.

The majority of Columbia graduates stayed in the east, but many found work throughout the western states. They were sufficiently numerous in Colorado by 1884 for the Mines Alumni Association to establish a branch in Denver. The school journal reported Columbia clusters in Colorado, Utah, California, Arizona, Nevada and Mexico, and many more ranged in and out of the West on consulting trips. Clearly Columbia was supplying mining expertise for a national market.

Nonetheless, demands arose over time for mining schools in closer proximity to the mining districts. These efforts were an expression of state developmental impulses dating from the early nineteenth century, combined with the undeniable geographic specificity of much of the relevant knowledge relating to minerals. Inspired by the gold rush, many states initiated or revived geological surveys in the 1850s. When an 1867 proposal by a Nevada Senator for a National School of Mines was unsuccessful, the states quickly moved in. Established by the territorial legislature in 1870, the Colorado

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23 Read, *Development of Mineral Industry Education*, pp. 23, 47-50; Spence, *Mining Engineers*, pp. 37-38; Church, “Mining Schools in the United States,” p. 79. Read reports the opening-day enrollment at Columbia as 24, and 97 in 1865-66; Spence puts the figure at 29, followed by 79 in 1865-66.


25 Christy, “Growth of American Mining Schools,” 461; Columbia College Catalogues (1754-18940 are accessible through Google Books.

26 Based on reports in the *School of Mines Quarterly*, summarized in Spence, *Mining Engineers*, p. 40.
School of Mines was the first to be set up as a separate institution, beginning instruction in 1873. Mining education at the University of California began in the 1860s, though the first degree was not awarded until 1873. Mining schools were also established in Missouri, Michigan, South Dakota, Arizona, Nevada, and New Mexico. At Berkeley, registration at the mining college grew tenfold between 1893 and 1903, supporting the school’s claim to be “without doubt the largest mining college in the world.”

Professionalization in American mining engineering was well ahead of its counterpart in Great Britain. Founded in 1871, the American Institute of Mining Engineers was one of the earliest professional organizations (second in engineering only to the American Society of Civil Engineers). At the first meeting of the British Institution of Mining and Metallurgy in 1892, the organizers (according to its historian) “found it more than a little irksome to have to acknowledge that in the U.S. some such organization had been operating successfully for nearly twenty years.” The difference may have been mainly a matter of scale: Whereas the AIME by that time had over 2000 members, Britain “would be hard pressed to muster more than a couple of hundred.”

Advanced degrees and professional organizations do not of course necessarily imply that mining engineers and other scientifically-trained personnel actually had a significant impact on mining technology and practice. But testimony is abundant that there was indeed a gradual transition from reliance on the skills of apprenticeship-trained “mining captains” – often foreign-born – to deployment of college-trained engineers. The extension of the mining frontier to lower-quality ores was driven by scientific advances in geology and metallurgy, and by a complementary technological shift towards nonselective “mass-production” methods, and both of these coincided broadly with the eclipse of traditional miners’ skills in favor of professional engineers. The acceptance and legitimation of mining engineers is perhaps best indicated by their increasing presence in managerial and executive roles within large firms, an expectation that came to be reflected in the curricula of mining schools.

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28 Wilson, The Professionals, pp. 8-9, 21.
29 The association between the shift to nonselective mining methods and the rise of mining engineers is argued by Hovis and Mouat, “Miners, Engineers, and the Transformation of Work,” pp. 429-439. On the
Sections To Be Completed

The following sections are planned for the final version of the paper (but not necessarily in time for the All-UC Conference)"

Mining Innovations and Patents
Career Paths of Mining Engineers
Comparative Mining Development
Reflections on the Concept of a “Knowledge Economy”
References


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Figure 1. Miners by Census Year

![Graph showing the number of miners in the West and California from 1840 to 1920. The graph indicates a peak in mining around 1860, followed by a decline and then a steady increase towards 1920. The lines represent the number of miners in the West (blue) and California (red).]
Figure 2: Miners as a Share of Adult Males, 1850-1910

Source: Authors’ calculations based on IPUMs samples for 1850-1910. Adult males are all men ages 15-60.
Figure 3: Population Density in the Western United States in 1870
Figure 5: Nationalities of Foreign Born Miners, 1850-1910

Source: Authors’ calculations based on IPUMs samples for 1850-1910.
Figure 6. Gold Production, California and US Total, 1835-1900
(thousands of dollars)

Source: Berry, *Early California*: pp. 74, 76, 78.
Figure 7. US Silver and Gold Production, 1835-1900

Source: Berry, *Early California*, p. 78.
Figure 8: Cumulative Mining Engineering Graduates, US Total and Columbia University, 1867-1992

Source: Engineering News, August 11, 1892