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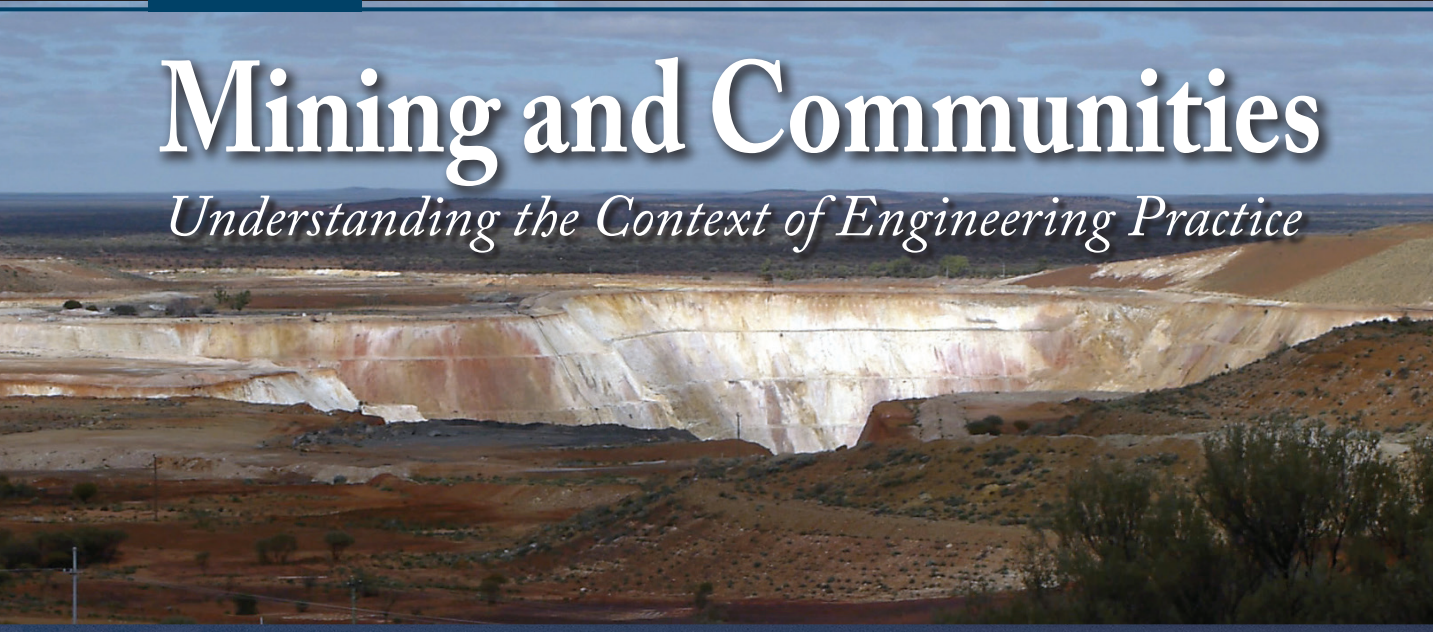
Mining and Communities

Understanding the Context of Engineering Practice



Rita Armstrong
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SYNTHESIS LECTURES ON ENGINEERING, TECHNOLOGY, AND SOCIETY

Caroline Baillie, *Series Editor*

Mining and Communities:

Understanding the Context of Engineering Practice

Synthesis Lectures on Engineers, Technology, and Society

Editor

Caroline Baillie, *University of Western Australia*

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Mining and Communities:

Understanding the Context of Engineering Practice

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SYNTHESIS LECTURES ON ENGINEERS, TECHNOLOGY, AND SOCIETY
 # 21

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ABSTRACT

Mining has been entangled with the development of communities in all continents since the beginning of large-scale resource extraction. It has brought great wealth and prosperity, as well as great misery and environmental destruction. Today, there is a greater awareness of the urgent need for engineers to meet the challenge of extracting declining mineral resources more efficiently, with positive and equitable social impact and minimal environmental impact. Many engineering disciplines—from software to civil engineering—play a role in the life of a mine, from its inception and planning to its operation and final closure. The companies that employ these engineers are expected to uphold human rights, address community needs, and be socially responsible. While many believe it is possible for mines to make a profit and achieve these goals simultaneously, others believe that these are contradictory aims. This book narrates the social experience of mining in two very different settings—Papua New Guinea and Western Australia—to illustrate how political, economic, and cultural contexts can complicate the simple idea of "community engagement."

KEYWORDS

mining and community engagement, mining and social impact, mining and development, Ok Tedi, Boddington, Pilbara

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Preface

INTRODUCTION

Mining, in all its forms, has attracted both praise and criticism. It has brought wealth and suffering to societies all round the world, yet different perceptions of mining are not necessarily aligned in conventional ways. Opposition to mining may come from left-wing anti-mining lobby groups such as Mines Against Communities (MAC 2013) to otherwise conservative local rural groups who wish to protect their farms, their environment, and their community life from the incursions of, for example, coal seam gas extraction. Some governments (such as Norway) have strong regulations on the mining industry and explicitly set aside revenue for public expenditure while the desire of the Australian government to increase revenue in the form of a mining tax has generated a strong backlash from the powerful mining lobby. Governments often welcome the revenue from mining but there is a vast difference between a government's desire to regulate the actions of mining companies and their ability to do so.

Mining can be associated with the extraction of metals such as iron ore, copper, gold, or nickel, or with crystals such as diamonds, but it also includes the extraction of sand, gravel, clay, ceramic, chemical deposits, fertilizer minerals, and other non-metallic minerals (Spitz and Trudinger 2009, p. 222). The scale of operations is also diverse: there are large-scale surface and underground operations operated by multinational corporations operating across the globe including Canada, Australia, Papua New Guinea, and Africa, as well as some of the new frontier zones including Mongolia, Siberia, and Greenland. There are also many forms of legal and illegal artisanal mining operations which are concentrated in less affluent countries of the Global South.

The "bad old days" of mining are usually characterized as a time when underground work conditions were unsafe, wages were poor, environmental impact was ignored, and when no reparation was made to Indigenous people on whose land mining often occurred. Most transnational mining companies, particularly those who are signatories to the International Council on Mining and Metals ICMM (2013), acknowledge this history and agree with the need to define and abide by international standards in environmental and social sustainability. Yet as this book goes to press, mining has received negative media attention for the following types of issues: human rights abuses in Papua New Guinea (Human Rights Watch 2011), criminalization of anti-mining protests in South America (e.g., Urkidi 2011, p. 566), and corporations accused of being virtual enclaves within states with, for example, their use of private security forces (e.g., Ferguson 2005, p. 378).

This book is part of a series of lectures entitled "Engineers, Technology and Society," and has arisen from a larger project which considered the issue of "Engineering Education for Social and Environmental Justice." Each of the books arising from this interdisciplinary Australian education project critiques a different part of engineering "service:" energy and water; waste management, and even, rather alarmingly, "war." This contribution, focusing on mining practices, examines the social effect of large-scale surface mining on communities within the historical, political, and cultural life of two regions: Papua New Guinea and Western Australia. Our overall purpose is to show that this type of understanding, based on interdisciplinary knowledge, is vital if we are to avoid casting the debate about mining into unrealistic stereotypes in which those who support mining are seen as slaves to capitalism, and those who oppose it are dismissed as polemical activists with no grasp of economic reality.

There is also widespread agreement that an informed debate needs to occur if engineers are to move beyond the stereotype that all engineers have a narrow problem-focused mentality. This is evident in publications from mainstream engineering institutions (e.g., UNESCO 2010) to those with a more critical self-reflexive perspective on engineering practice (e.g., Baillie and Catalano 2009). The need to move "beyond the technical" has been voiced for some time in engineering circles but this view has gained momentum in recent years and there are increasing calls for engineers to "pay attention to the underlying structures that define and shape their work" (Riley 2012, p. 125).

In another publication we have argued that many mine managers are very aware of the consequences of their work (Armstrong and Baillie 2012) and it is not that they "cease to act as engineers" but instead are beginning to additionally "think like anthropologists." Despite that finding, it would be fair to say that for most mining engineers—who focus on a very small technical part of mineral extraction (rock mechanics, say), or mineral processing (such as software programming)—it is difficult to think beyond those particular concerns when they have no direct contact with the people who are impacted by the larger project.

This book is intended to fill that gap by providing contrasting narratives of how mining affects community life. We demonstrate, through the use of these narratives, that understanding local needs (which are often contradictory) and local history (a changing play between culture, politics, and economy) does not fit comfortably with an audit culture that determines whether a company is "engaged" with community. Carrying out a social impact survey which entitles us to tick the right box in a sustainability audit may produce legitimacy in the corporate sphere but it does not produce the kind of knowledge that ultimately challenges us to think more critically about our practice and how it affects those around us.

INTELLECTUAL FRAMEWORK

This book narrates mining histories about copper and gold mining in Papua New Guinea, and iron ore and gold mining in Western Australia. These provide a stark contrast in terms of landscape,

state formations, environmental constraints, the culture of the communities who live around the site, and the historical changes that have taken place within the company with regard to community engagement.

The purpose of these narratives is to examine the social reality of the impact of mining in different regions. The narratives, which have been constructed from qualitative research[1] and secondary sources (discussed more fully below) are shaped by an anthropological approach which is deployed within an engineering and social justice framework.

TAKING AN ANTHROPOLOGICAL APPROACH

The anthropological approach, which we use in this instance, refers to a particular way of understanding social life built upon the following assumptions about the kind of knowledge we want to produce:

- Understanding the local's point of view

  This idea has its roots in what Stocking (1992, p. 353) has called "paradigmatic" moments in the history of anthropological thought—the realization that each society operates according to a different cultural logic and that if we are going to understand other people's behavior, we need to see the world through their eyes and understand how their actions may be constrained by particular histories, power relations, and cultural values. Trying to understand other peoples' motivations and desires—particularly as they relate to the complicated field of mining—can be difficult because intention and effect do not coincide, and because people's desires are not always consistent or static. It is for this reason that anthropological methods are often seen as "a licence to explore the curious, the messy, and the unexpected" (Mills and Ratcliffe 2012, p. 147).

  This way in which we approach this task of uncovering the logic or meaning behind the "messiness" of our own, or other's, lives is accomplished by a variety of means, most famously by the ethnographic method whereby a fieldworker spends a lengthy period of time living amongst a community, whether it is in inner city New York or a village in Papua New Guinea, using participant-observation, as well as qualitative tools such as interviews (structured, semi-structured, or open) and surveys. This type of lengthy fieldwork is often associated with postgraduate research and is considered a rite of passage (Mills and Ratcliffe 2012, p. 153) usually resulting in the publication of book-length ethnographies. Much anthropological research however is more short term, albeit with

[1] Funded by the then Australian Learning and Teaching Council (ALTC), now the Office of Teaching and Learning (CG10-1519), "Engineering Education for Environmental & Social Justice."

the same goal, and can also be shaped around particular issues and for particular purposes, and these can be termed "case study" or "extended case study" (see Burawoy 1998).

This book is not ethnographic but it is anthropological in that it is primarily concerned with the core issue of uncovering how people experience and perceive the world (in this case, the world of mining) and with the specificities of that experience. We have used published ethnographic material combined with our own interviews, to convey that experience. We have, therefore, used the term "narrative" rather than "case study" as it more correctly captures the unfolding of different desires, ideals, and goals. Filer and Macintyre, writing about mining in Papua New Guinea, comment that anthropological studies "challenge notions of unified interest or consensus at the local level, revealing ambivalence and contradictions" and that social understanding about the impact of mining is always "inflected by the cultural conceptions of change, wealth, and resources that obtain in a community" (2006, p. 221).

- Understanding the history of specific contexts

The need to pay attention to history is crucial, almost inseparable, from the aims discussed above. Evans-Pritchard, a famous figure in British anthropology, wrote that the importance of history lies not in the chronological relation of events, but in its explanatory value in understanding current social life, in making behavior "sociologically intelligible" (Evans-Pritchard 1950, p. 121). Attitudes toward mining amongst a white community living in a small rural town in Australia or North America are inevitably shaped by the social and economic history of the region, and will inevitably be different to the attitudes of ethnically diverse middle class Australians or North Americans living in urban centers. These are obvious connections, and one does not have to be an anthropologist or an historian to appreciate the importance of context, but translating that appreciation into the public arena of mining and community engagement has significant consequences. Jon Altman, for example, is an anthropologist and economist who has collaborated with Rio Tinto on a research project whose aim was to explain why Rio's Indigenous employment initiatives had not made a greater impact on the social and economic well-being of Aboriginal Australians (Taylor and Scambary 2005, Altman and Martin 2009). Altman remarked that one of the reasons for the "disappointing development outcomes is that mining companies and the Australian state seem to have limited capacity to recognise the deeply-entrenched levels of disadvantage experienced by communities adjacent to remote mines…" (2009, p. 5). Anthropologists are, therefore, interested in how political history has shaped the way we see the world and the need to pay attention to the historical dimension of power relations is evident in Altman's statement above.

- Reflexiveness and critical inquiry

  Reflexivity is the constant reflection and questioning which leads to interrogations about the assumptions and meaning of taken-for-granted concepts, or conditions of social life. This has a particular importance when thinking about the social impact of mining which is often assumed, by states and corporations, to be fundamental to progress and growth. Questioning these assumptions is not unique to academics in the social sciences; indeed, local people in many parts of the world—from Boddington in Western Australia, to the lower Fly River in Papua New Guinea—can speak about "progress" or "development" with ironic quotation marks around both terms. It has long been recognized that the extraction of metals and minerals from the earth's crust is a dangerous enterprise with potential harm for both humans and the environment (see Agricola 1912). Mining corporations are, however, private enterprises that are required to maximize profits, particularly when large sums of money are expended in high risk ventures. Whether corporations can satisfactorily solve the problematic tension between these domains is an area of debate: sustainable mining, for an anthropologist like Stuart Kirsch, is an oxymoron (2010) while for lead agencies such as the International Council of Mining and Minerals (ICMM) it is both desirable and achievable. In order to highlight this reflexivity, we will often use quotation marks around core concepts to indicate that they are contested and the subject of debate.

ENGINEERING AND SOCIAL JUSTICE FRAMEWORK

Our purpose in this series of lectures is to produce knowledge that emancipates engineering practice from narrow territorial confines, and provides anthropologists with some sense of the cultural and technical constraints under which engineers operate. Both disciplines can then contribute to the alleviation of particular inequalities that reflect a much larger and urgent question—not whether mining is sustainable, but whether the cultural framework for mining (in which the scale of operations and technological requirements are determined by consumption needs and economic rationalism) is defensible?

We are influenced in our analysis by the work of Ursula Franklin,[2] Emeritus Professor of Engineering at the University of Toronto, Quaker, and activist for socially just engineering. She has also studied the historical context of metallurgy and metallurgical practices. In her publication *The Real World of Technology* (1990) Franklin emphasizes that "technologies are developed and used within a particular social, political and economic context" (1990, p. 57) and describes the contemporary context as one that is overwhelmingly shaped by the discourse of the "production model"

[2] Franklin's work is discussed more thoroughly in "Engineering and Society: Working Toward Social Justice" in this series, by Caroline Baillie and George Catalano (2009).

(1990, p. 31) in which rational efficiency and technological change is prescriptively shaped by the desire to benefit the few, rather than the many:

> *"The unchallenged prevalence of the production model in the mindset and political discourse of our time, and the model's misapplication to blatantly inappropriate situations seems to me an indication of just how far technology as practice has modified our culture. The new production-based models and metaphors are already so deeply rooted in our social and emotional fabric that it becomes almost sacrilege to question them"* (Franklin 1990, p. 31).

Franklin proposes that there be some sort of accounting system, which looks, not only at the triple bottom line of economic, social, and environmental impacts of any engineering project *before* it is implemented, but to consider also "who benefits and who pays?" within these. Her concern is very much with those at the "receiving end of technology:" "Whenever someone talks to you about the benefits and costs of a particular project, don't ask 'What benefits?' ask 'Whose benefits and whose costs?'" (Franklin 1990, p. 124).

In regarding this question we are reminded that the positive benefits often quoted for certain engineering projects, particularly mining, are in fact directed toward one part of society and the negative benefits affect another, often voiceless part. We attempt to raise these questions in our current text. We are not, therefore, ignoring the significant benefits that mining has and does bring to our lives and lifestyles, but in order to develop a balanced argument overall, we hope to give voice to the potential negative impacts, which often are seen to act against principles of social justice.

METHODOLOGY AND CHAPTER OUTLINE

The following section sets out the structure of the book with an explanation of how the data was collected for the three narratives contained in Chapters 2 and 3.

Before looking at the particular experience of surface mining in two different regions, we sketch out a historical framework of the political economy of mining, by illustrating how successive changes in mining technology have been shaped by the desire to extract more minerals from deeper beneath the earth's surface within an imperial, colonial, or capitalist framework. This is followed by narratives about the local experience of mining in Papua New Guinea (PNG) and Western Australia.

The data on PNG is based solely on the history of the Ok Tedi copper and gold mine, well known for the disastrous impact of riverine waste disposal. This case comprises a rich array of journal articles by anthropologists, lawyers, engineers, and environmental scientists; the official position of the regional government and Ok Tedi Consortium; and reports from the news media. Mining has always been associated with "development" in PNG both as revenue for government and providing "economic growth" for the isolated regions of the interior. The research material reveals that local people, mining professionals, government, and academics are conflicted about the

cost of development, but the majority see "development" as an inevitable trajectory in Papua New Guinea's economic future.

Chapter 3, on Western Australia, compares the experience of Aboriginal people in the Pilbara in the northwest, with white settler Australians in the small town of Boddington in the southwest of the state. The Pilbara is a very different context from PNG where mining coincided with the beginning of self-rule. At that time, the West Australian mining companies excluded Aboriginal people from mining activities, and attitudes only changed after the granting of Land Rights and the moral pressure brought to bear upon corporations to right past wrongs. This material is based on interviews with a range of people working in, or affected by, mining: white settlers (politician, anthropologist, archaeologist, mine manager, engineer, doctor, and community engagement personnel) as well as Aboriginal people (an entrepreneur, a cultural awareness educator, health professionals, Land Rights Council employees). Although there is less anthropological material available (compared to PNG), there was enough historical and anthropological data (from academic journals and books) to supplement our research and thus present a holistic account of how mining companies perceive their role in the Pilbara, and how Aboriginal people view mining activities.

The second part of the chapter examines the impact of mining on white Australians in the country town of Boddington, south of the capital city, Perth. The residents of Boddington are primarily white Australians, whom we also designate as "white settlers" to distinguish them from recent white immigrants and from local Aboriginal people. Interviews in Boddington were conducted with a cross-section of the community including volunteers who worked on the local newspaper, women and men who worked at the mine site, an ex-publican, the owner of the local service station, high school students, retirees, and farmers. Published material on Boddington is even less extensive than that available on the Pilbara. This is due to the fact that for a long while mining was not seen as having such an abiding or negative effect on white settler culture when compared to Aboriginal culture, and research on the way in which mining impacts on mental health and community well-being is therefore a relatively new field (see Tonts et al. 2013 for an overview of research in Western Australia). The Boddington narrative is therefore less historical and more synchronic, capturing a range of community views based entirely on interview material.

The final chapter synthesizes emerging themes in these two narratives. We argue that critical self-reflection is crucial for all engineers, particularly those working in the mining industry where the consequences of intervention are profound. This publication forms part of a larger research project—Engineering Education for Social and Environmental Justice—and the scholars who participated in this project (anthropologists, engineers, historians, educators, philosophers, and lawyers) agreed on this common tenet: that critical understanding of core concepts such as culture, power, or colonialism has transformative possibilities for engineering education, but that, conversely, social science and humanities scholars also need to understand the importance of engineering knowledge and practice in our everyday lives.

This publication fills a unique interdisciplinary space by combining an understanding of mining operations with an understanding of how mining impacts on peoples' lives in different contexts. It is intended to help both engineering and social science students, academics, and teachers begin to question their own assumptions and to frame some appropriate alternative processes of community engagement for contemporary and future mining practices.

CHAPTER 1

Mining in History

Mining is commonly associated with transnational corporations such as the members of the International Council of Mining and Minerals. These include companies such as Rio Tinto, BHP Billiton, AngloGoldAshanti, Barrick Gold, Codelco, Inmet, and Xstrata (ICMM 2013d). A common image which we associate with these companies is of large haul trucks transporting ore around the sides of an open-cut or surfaces mine, often in remote regions.

Figure 1.1: Surface mining, photo provided by Wendy Cumming-Potvin.

Mining has always had its critics and supporters. The use of metals has undoubtedly allowed humans to transform the environment to subsist, produce energy, create shelter, produce status goods, and so forth, but the way in which extraction and production is organized reflects a particular form of economic structure which in turn reflects dominant cultural values. Before we can understand the social impact of mining, we need to understand the historical formation of mining

economies and technologies. The aim of this chapter is to take a brief—and very broad—critical look at that history which will help us to understand the financial and technological scale of contemporary mining practice.

1.1 INTRODUCTION: HISTORIOGRAPHY OF MINING

The way in which the history of mining is framed ultimately depends on the position of the author, and the following brief overview reveals an historical tension between grand modernist narratives which chart a progressive association between mining, modernization, and development, and counter-narratives which question the benefit of mining to society.

The archaeological classification of human history into the Stone Age, the Bronze Age, and the Iron Age reflects the way in which technological development, closely associated with the ability to mine and process metals, is associated with the transformation in human organization from simple to complex societies. Gold and copper, which are non-ferrous metallic ores, provide a useful means of illustrating the historical importance of metals in human societies. Copper and gold were among the first metals utilized by humans; too soft to create tools, pure copper was probably first used in ornaments but when smelted with tin ore, creates an alloy—bronze (Lynch 2002, p. 10). Copper and its principal alloys, bronze and brass, were used as decorative embellishment and, because of their ability to resist corrosion, for more functional purposes. Brass did not come into use until Roman times and, until the production of iron, copper alloys were used predominantly for weapons, tools, weights and measures, water pipes, roofing, household utensils, mirrors, razors, and artistic decoration (Cordero and Tarring 1960, p. 26). Many of these goods were utilized predominantly by the Roman nobility.

The properties of copper (malleability, ductility, conductivity, and ability to withstand corrosion) have continued from ancient times to the present day:

> *"… copper has established numerous crucially important uses in virtually all branches of mature industrial or more newly industrializing economies, most notably construction, transport, telecom, and all kinds of electrical and electronic appliances. Even though substitution in favor of aluminium, plastics and glass fibre is always a threat to copper demand, it is hard to conceive a modern society managing without a large-scale and secure copper supply"* (Radetzki 2009, p. 176).

An economic historian, Radetzki takes a deterministic view about the role of metals in shaping human society. He describes copper as "the third most important metal in the service of man" (2009, p. 176) after iron and aluminium. This view is reflected in much older mining histories, such as the classic *De Re Metallica* written by Agricola in 1556 and in conventional mining textbooks such as *Mining and the Environment: From Ore to Metal* (Spitz and Trudinger 2009). In this publication, the authors assert that "without mining there would be no civilization as we know it"

(2009, p. 2). Both authors acknowledge the environmental cost of mineral extraction and processing but claim that the advantages outweigh the costs to environment and societies. This is a common, progressivist view of mining which is often used in defence of the industry, particularly in response to those who (while using objects comprised of mining products) are critical of the negative social impact and environmental degradation associated with the industry.

1.2 MINING PROCEDURES

Base metal mining is now considered a "capital intensive" activity in contemporary society (Spitz and Trudinger 2009, p. 225); that is, it requires a high volume of production and a significant margin of profit to provide adequate returns on investment. A brief explanation of the mining project cycle will provide a framework for understanding historical precedents which have shaped current approaches to mining.

The process of metal mining generally involves the following phases:

- Exploration

  In the past, mineral deposits were closer to the earth's surface and thus easier to determine by examining visual clues but it is much harder to detect deposits far beneath the ground. Exploration is now carried out with advanced techniques using aircraft or satellites. This is often carried out by junior, or small mining companies who "explore for mineral deposits with a view to negotiating with larger companies or develop a small ore body themselves with their own resources"; the failure rate of these companies can be high due to the financial risk associated with exploration (Rankin 2011, p. 113 and 117).

- Definition and feasibility

  Once mineral deposits are identified, it is then necessary to define the "economically mineable part" of those deposits in which, to be defined as an ore body, the concentration of minerals must be such that it can "be profitably mined and processed with current technology and at current market prices" (Rankin 2011, p. 86). The grade or concentration of an ore mineral, or metal, as well as its form of occurrence, will directly affect the costs associated with mining the ore (Rudenno 2004, p. 6). The depth and the size of an ore body will generally determine how it is mined, that is whether it is extracted through surface mining or underground mining. At the present time, surface mining is more common than underground mining because it is less expensive; usually only high grade ores warrant underground mining (Spitz and Trudinger 2009, p. 191). Engineering and financial models are then used to determine "within a framework of commodity prices and exchange rates, the economic return that can be expected"; these models have also to take into account the development of infrastructure required for

the project (Rudenno 2004, p. 6). If these evaluations indicate there are "insurmountable technical difficulties in mining, mineral processing, or waste disposal…insufficient financial returns …or that regulatory conditions are too onerous" then mining projects may be abandoned at this stage.

- Extraction

  The extraction of the ore from the ground involves drilling, blasting, and transporting the broken ore and waste to a processing location. Tunneling in waste rock for underground mines, or "stripping" the ore body in open pit mining, generates waste rock piles of significant size.

- Mineral processing

  - crushing or grinding it to smaller pieces.
  - different techniques such as smelting or leaching are used to separate the concentrates (valuable minerals) from the tailings (unwanted minerals or unmineralized rock). As ore bodies often contain a large percentage of unmineralized rock, the tailings must be stockpiled and managed to avoid environmental problems.

The technical components of each stage have changed over time and are shaped by the culture, economy, and society in which mining takes place.

1.3 SOCIETY, ECONOMY, AND TECHNOLOGY: MINING IN HISTORY

In this section we will consider the broad historical phases in mining within the European context. As humans had to dig deeper to extract these minerals in order to satisfy the expanding needs of increasingly complex societies, the processes became more capital intensive (thus affecting the formation of social classes) and the associated technologies caused greater environmental degradation. Overall, there is a historical trend from artisanal or small-scale mining of surface ores (organized by and within communities) to the more complex excavation of deeper ore bodies with associated impacts on politics, society, environment, and culture.

The earliest method of extracting copper from a surface ore body was smelting, whereby the minerals (containing copper) were heated and the copper ore was reduced into metal, leaving slag as a waste product (Radeztki 2009, p. 178). The production of bronze probably arose from mining surface ores that contained both copper and tin. The Bronze Age in Europe extended from about 3000-600 BC and the forms of mining in this period were "dictated by the ore body" and by technology: "pits rarely penetrated below about 10 metres below the surface" (Craddock 1995, p. 31).

Large-scale mining of surface ore bodies did occur in ancient times, particularly during the Roman Empire (27BC–476AD) when the Roman state sought both utilitarian metals such as iron, copper, tin, and lead, as well as gold and silver (Duncan 1999). This is because Italy, "although rich in iron, could not provide a sufficient supply of the whole range of metals needed by the Roman state for coinage and by members of the elite for the luxury artefacts that helped to enhance their social status" (Edmondson 1989,p. 84). The rights to mine metals and stone were leased by the state to private entrepreneurs who worked the mines and quarries with slave labor (Rostovtzeff 1957, p. 299).

It was not until the late Middle Ages, however, that we see how technological changes were used to mine on a large scale in Europe, thus generating great wealth for the emerging merchant classes.

1.3.1 LIQUATION: MINING AND MERCHANT CAPITALISM IN EARLY RENAISSANCE EUROPE

Copper ores often contain silver and gold. The process of liquation—separating silver from copper—emerged at the beginning of the Renaissance in the 1450s in the town of Nuremberg from where it spread throughout Germany, Poland, and the Italian Alps (Lynch 2002, pp. 20–21). It is here that we see the beginning of mineral processing as a large commercial enterprise:

> *"Essentially it relied on the fact that when a furnace packed with a mixture of lead and silver-bearing copper ore was smelted, in the process of cooling down, the silver contained within the ore would be absorbed by the lead. The result was a congealing mass of molten metal, in which the silver had moved from the copper to the lead. The next step was to separate the lead from the copper"* (Lynch 2002 p. 22).

This was relatively simple to achieve as lead has a lower melting temperature than copper, but it was efficient (i.e., worth buying the lead required) only if it was performed on a large scale; the operation typically took place in a very large building and was not suitable to backyard, small-scale operations. It was also a difficult process, so the management of liquation remained in the hands of expert metal workers.

Figure 1.2: The process of liquation (Agricola 1912, p. 504).

The emergence of new mining technologies with the beginnings of capitalism at this time meant that large amounts of wealth were generated and controlled by small groups of people. The individuals who experimented with mineral processing—alchemists or artisanal workers—were not those who profited most from the mining booms of the fifteenth and sixteenth century. Investment funding came from merchant banking houses, many of them German (Blanchard 1998, p. 7). Mining attracted investors from the merchant and aristocratic classes who were "after quick returns on their money" (Lynch 2002, p. 23). The process of liquation increased the demand for lead. Thus when new deposits of lead were discovered in Poland, this attracted further investors from Germany, Italy, and Sweden who went on to invest their profits in real estate (Postan 1987, p. 559).

The use of liquation enabled old fields to be re-mined and new fields were mined more extensively. The extent of these operations has also been partially gauged from the level of waterborne metal pollution detected in lake sediments in central Sweden, a historically important mining region in Europe. Focusing on lead, a group of scientists traced mining impacts on rivers draining into the Baltic Sea (Bindler et al. 2009). They found evidence of pollution from lead mining in sediment and peat records dating back to the 10th century but with the greatest impact occurring during the 16th century onward.

The only constraints on the commercial mining of ores were environmental: timber was used as a fuel to smelt ore and the availability of timber provided a limit upon the extent to which a mine could be exploited. But the rising cost of precious metals during the 16th century encouraged investors to take a risk with capital intensive operations and to trial new technologies and procedures which were often dangerous to humans and environment (Miskimin 1977, pp. 28–29). The organization of labor at that time also demonstrates the beginning of the commodification of labor before industrialization. "Having long been independent artisans," Braudel claims, "working in small groups, they [the miners] were obliged in the fifteenth and sixteenth centuries to put themselves under the control of the merchants who alone could provide the considerable investment required for equipment to mine deep below the surface" (1982, p. 52).

This brief account demonstrates how one form of mineral processing—liquation—required a large outlay of money to be effective and thus generated wealth for the merchant classes who could afford to invest in it. The first wage labor in mining appeared in Germany, when mine workers in the 15th and 16th centuries offered themselves as laborers to people who owned the machines in the mines (Graulau 2008, p. 133). Much of our knowledge about the technology of mining in the 16th century comes from Agricola, a physician who lived in Joachimsthal, a mining town in Germany. Agricola's manuscript *De Re Metallica* is both a practical description of, and philosophical justification for, the mining practices of his time:

> *"Without doubt, none of the arts is older than agriculture, but that of the metals is not less ancient; in fact they are at least equal and coeval, for no mortal man ever tilled a field without implements. In truth, in all the works of agriculture, as in the other arts, implements are used which are made from metals, or which could not be made without the use of metals; for this reason the metals are of the greatest necessity to man. When an art is so poor that it lacks metals, it is not of much importance, for nothing is made without tools. Besides, of all ways whereby great wealth is acquired by good and honest means, none is more advantageous than mining; for although from fields which are well tilled (not to mention other things) we derive rich yields, yet we obtain richer products from mines; in fact, one mine is often much more beneficial to us than many fields. For this reason we learn from the history of nearly all ages that very many men have been made rich by the mines, and the fortunes of many kings have been much amplified thereby* (Agricola 1912, p. xxv).

Agricola clearly believed that mining—or rather, metals—benefit society in general and just as clearly recognized that mining reaps great profits for elites. In answering the critics of mining, he said "it is not the metals which are to be blamed, but the evil passions of men which become inflamed and ignited or it is due to the blind and impious desires of their minds" (1912, p. 16).

1.3.2 MERCURY AMALGAMATION: MINING AND COLONIZATION IN 16TH-CENTURY LATIN AMERICA

The Spanish invaded the "Americas"—as they were subsequently labeled by the Europeans—in the 16th century and the search for precious metals was one of the driving forces for this process of conquest and colonization (Dore 2000). As a consequence, the mining, processing and transport of metals were at the centre of the social and ecological transformation of colonial Latin America (Robins and Hagan 2012, p. 627).

Potosi is a town in Bolivia, situated on the eastern slopes of the Cordillera de los Frailes on the Andes ranges, roughly 4,000 feet (1,219 m) above sea level. Prior to the arrival of the Spanish in 1545, it is highly likely that Indigenous peoples in the region were aware of the silver contained in the rocks of the *cerro rico* (rich hill) and would have worked open pits with some tunneling. The ore-bearing rock was softened through fire-setting and then removed with hammers, chisels, and crowbars. Indigenous miners had little difficulty in finding 'native' silver but also mined ores containing chemical compounds of silver. In the former case, ores were carried to streams where a large, rocking stone acted as a crushing mill. The crushed ore was floated along a stone-lined channel of running water diverted from the stream and bits of native metal could be removed by hand using a pan or basin. Indigenous smelting could be done within a hole in the ground or with a furnace made out of stone or clay with vents to allow the wind to fan the flames within (Bakewell 1984, p. 15). Most of the ores which were smelted in this way left a mixture of lead and silver and, in order to separate out the lead, the mixture was heated in a perforated crucible through which the lead would leach out (as it has a lower melting temperature than silver).

With the Spanish colonization of South America and subsequent discovery of silver at Potosi, the scale and extraction methods changed drastically. Mining at Potosi shifted from being a local, intermittent, small-scale surface activity to being a continuous, large-scale underground venture. This shift require the use of timber (to construct tunnels), draught animals (to shift ore and transport food), and food for the miners (Dore 2000, p. 6).

The other major change occurred in the extraction of silver from the ore. By the 1570s the use of the patio process which was based on amalgamating pulverized ore with mercury, then smelting it to remove the silver, enabled the Spanish to mine deeper, lower-grade ores. Mercury is however very toxic; nonetheless the combination of a forced labor system with the technique of mercury amalgamation "enabled sustained, industrial-scale refining of abundant lesser-quality ores unsuitable for smelting" (Robins and Hagan 2012, p. 627).

> *"By the light of torches miners hammered at ore bodies in underground tunnels. In low, crowded and poorly ventilated vaults the temperatures soared. Mitayos spent hours climbing up fragile ladders with heavy sacks of ore, to emerge into snow and freezing temperatures at the surface. They immediately descended into the inferno below to cut and carry another load. Working*

alongside mules, men crushed silver and mercury with their bare feet in large vats. Some died quickly of mercury poisoning; others languished with fevers and sores" (Dore 2000, p. 8).

In this abbreviated account of the notorious silver mine at Potosi, we see how the development of new technologies in a colonial context benefited the ruling classes and merchant elites of the colonizers. As Braudel puts it: "The mining world foreshadowed the industrial world with its proletariat" (1982, p. 198).

1.3.3 DRILLS AND DYNAMITE: THE EFFICIENT USE OF LABOR AND CAPITAL IN 19TH-CENTURY COPPER MINES

Historically we have seen how new technologies have improved capacities to mine larger ore bodies, and to separate minerals from ore more efficiently, yet the beneficiaries of these developments were not the many but the few: the merchant classes and the aristocracy. We shall now present a brief account of copper mining in North America to illustrate how mining at depth during the 19th century was based on vertical integration of mineral processing (i.e., extraction and processing was carried out at the site) which required large financial outlays from investors; this in turn generated large business structures. This narrative also illustrates how the use of new technologies in the 19th century was geared to profitability and efficiency rather than the health and well-being of the workers. The bulk of this material comes from Larry Lankton's *Cradle to Grave: Life, Work and Death at the Lake Superior Copper Mines* (1991).

First Nation Indians had mined copper from deposits on the Keweenaw peninsula in Michigan state long before the arrival of European colonizers in the 1600s who lacked the technology to mine and transport the copper. Copper deposits did not attract lone prospectors—unlike the gold rushes in California in the early 19th century—because it required more than "a modest array of tools" to extract copper from the ore (Lankton 1991, p. 8).

This particular ore body contained 2% copper and only a large mining operation could produce enough copper to justify the construction of their own smelters. At this time the mining industry became concentrated in the hands of a small number of investor groups each of which had "struck it rich at least once" (Lankton 1991, p. 21); this reflected the wider trend in North America where many small mining firms were replaced by fewer, larger companies. In many ways, this was the precursor of current day practice whereby mining firms owned the mine, the mill, the smelter and the connecting railroads. The investors lived in urban centers far removed from the mine sites, which were managed by experienced miners (often from Cornwall) overseeing a large pool of immigrant labor.

Figure 1.3: Kearsage mine shaft, ca. 1900 (Michigan). Used with permission from Michigan Technological University Archives and Copper Country Historical Collections, http://www.mg.mtu.edu/MINE_SHAFTS/shaft9.htm (Neg#01264A).

The Lake Superior copper mines were below ground, with workers tunneling out from the main shaft along narrow, steep lodes. Until the mid-1860s men moved down the shaft on ladders which affected their health and also affected productivity: mechanical ladders and, eventually, elevator-like cages increased the speed and depth to which men could descend. In underground mining, the void that created with the removal of ore is called a stope (Rudenno 2004, p. 89). "Stoping" techniques have changed over time; in the mid-19th century it described the process of digging out the ore in tunnels radiating out from the main shaft; hand tools were used in the earliest forms of stoping and this technique was improved (that is, it could be done more quickly) with the use of explosives and rock drilling machines from 1880 onward.

Steam power radically transformed the copper mining industry in Michigan after the 1840s. Steam power drove shop machinery, powered generators, drove air compressors, and lifted rock up the mine shafts: overall, it modernized surface operations rather than underground ones.

Copper extraction still remained a labor-intensive industry with large numbers of men required to work underground.

The development of new technology required larger investments in mining operations. The industrialization of the mining economy meant that "it took money to make money" and this fostered a reliance on corporations as America's chief mining promoters (Lankton 1991, p. 58). The expense of drilling and blasting rock, for example, accounted for half the total cost of producing copper in the mid-19th century.

The pressure to recoup money as well as understand the new technology led to changes in mining personnel. Prior to 1900 companies did not employ many university-educated mining or civil engineers. The head mining captain's position was "part manager, part geologist, and part mining engineer," a person with a "nose for copper" (Lankton 1991, pp. 59–60) who had learned the business from the bottom up. The head mining captains and surface captains were usually either settler Americans or Cornishmen who were considered the "elite" of the immigrant workers, but over time "mine management came to be dominated by a new, modern breed of experts who prided themselves on applying science, and not archaic rules of thumb, to the winning of metals" (Lankton 1991, p. 58).

Achieving cost reductions in mining proved difficult as the depth of the mine increased and mine owners turned to the new breed of trained engineers to use "scientific problem solving" regarding the efficiency of all parts of the mining operation. Colleges and universities in the U.S. had taught engineering since the Civil War era: the Columbia School of Mines (1864), the Colorado School of Mines (1874), and the Michigan School of Mines (1886) were the most well known (Lankton 1991, p. 73). By 1910, engineering graduates from these schools became the "efficiency experts" who wanted to improve even the lowliest of mining tasks.

The blasting and extraction of ore was one area where mine management strove to improve efficiency. A two-man drill, a mechanical drill operated by compressed air, was introduced in the 1870s, but by 1913, these were replaced by "one man drills."

The one-man drill was a labor-saving and cost-efficient piece of equipment for the company. However it became known as the widow-maker because of increased injuries and fatalities: "A one-man drill meant there wasn't always a fellow worker nearby, meaning reduced safety when working alone, especially on shaft scaffolds and makeshift board bridges" (Copper Country History, n.d). This can be seen in Figure 1.4.

The miners of the so-called Copper Counties in Michigan (Houghton, Keweenaw, and Ontonagon) called a strike on July 23, 1913, with three main demands: (1) an increase in their wages, (2) an 8-hour day, and (3) the return of the safer two-man drill (operated by two miners) that had been replaced by a one-man drill (Garrett and Garrett 2013). While Lankton has pointed to other reasons for the strike—such as paternalism, and the tensions generated by ethnic hierarchies among

the workers—the introduction of labor-saving devices were seen as threatening, often unsafe, and "made hard jobs harder than before" (Lankton 1991, p. 76).

Figure 1.4: A miner using a one-man drill in one of the Calumet and Hecla underground mines, Calumet, Mich. Photo circa 1915, used with permission from Technological University Archives and Copper Country Historical Collections: http://coppercountry.wordpress.com/tag/one-man-drill/.

1.4 MINING IN THE 21ST CENTURY

Mining corporations now wish to avoid the excesses of the past and to conduct their business in a more sustainable and ethical way. Mining companies cannot, and do not wish to, alienate labor on their sites; nor can they ignore the interests of those people on whose land they wish to mine. They continue to face similar challenges such as declining ore grades of variable quality and purity; increased waste rock; and environmental constraints such as the supply of energy and water to remote sites (Mudd 2010). Unlike their 19th century counterparts, however, contemporary companies are now required to exercise "corporate social responsibility." Companies who wish to become members of the International Council of Mining and Minerals, for example, must agree to:

- Implement and maintain ethical business practices and sound systems of corporate governance;

- Integrate sustainable development considerations within the corporate decision-making process;
- Uphold fundamental human rights and respect cultures, customs, and values in dealings with employees and others who are affected by their activities;
- Implement risk management strategies based on valid data and sound science;
- Seek continual improvement of health and safety performance;
- Seek continual improvement of environmental performance;
- Contribute to conservation of biodiversity and integrated approaches to land use planning;
- Facilitate and encourage responsible product design, use, re-use, recycling, and disposal of their products;
- Contribute to the social, economic, and institutional development of the communities in which they operate; and
- Implement effective and transparent engagement, communication, and independently verified reporting arrangements with their stakeholders.

Commitment to these principles, however, can be put under pressure from three different domains.

Firstly, the requirement to generate a profit is proportional to the financial risk in mining, which is greater than ever because of the size of the investment required in exploration and development of modern mines, and the increasing level of technological complexity required to mine a low-grade ore body. Concentrations of metals such as copper and gold are measured as the proportions in an overall deposit. Copper is sometimes measures as a few parts per hundred (eg 3% Cu) while gold is measured in parts per million (e.g., 6 grams/tonne gold) (Mining Journal 20114). The desire to generate profits as soon as possible to cover the capital invested is thus strong and can, as we shall see in Chapter 2, may generate unethical or unwise decisions.

Secondly, there are serious challenges facing companies which mine low-grade ore bodies, particularly in the areas of energy consumption, water consumption, cyanide use (for gold processing), and waste management (Mudd 2007). Water usage in mining is predominantly used in chemical processing, particularly hydrometallugical processing and has major impact on local and regional use. Where mining occurs in remote, arid regions, it will affect the "flow pattern of groundwater through aquifers and affect water availability from bores elsewhere" (Rankin 2011, p. 216). The extent of waste rock is now likely to be at least equivalent to the amount of ore mined and for many minerals is up to several times higher. Mudd reports that "while a major proportion

of this waste rock is likely to be relatively chemically benign, a major quantity is likely to present challenges during operations and rehabilitation due to sulfides present, climate regimes, sensitive environments or communities being adjacent or a combination of these factors" (2010, p. 110).

Finally, commitment to the concept of "social responsibility" is also inhibited by deeper misunderstandings about local culture and economy, and the ways these intersect with the values, not of the mining company, but with the values of the economy it represents. The reality of mining, and the lived experience of those who live alongside mine sites, does not, therefore, always match the commitment to the ten principles listed above. In the following chapters we will look at this disparity more closely by examining the complex engagement between mines and communities in three different settings: the remote tropical highlands of Papua New Guinea; the remote desert regions of northwest Australia; and the rural hinterland of Perth, in southwest Australia.