Seeing the Copperbelt

Science, Mining and Colonial power in Northern Rhodesia

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Abstract

This article explores the relationship between science and the extension of colonial power through an examination of the rise of the Northern Rhodesian (later, Zambian) Copperbelt in the 1930s. The rise of the Copperbelt rested in part on scientific prospecting operations perhaps unparalleled in size and scope in the world at the time. These operations brought new 'scientific' prospecting techniques to the area which enabled the Northern Rhodesian subsurface to be 'seen' in new ways. The seemingly universal and fixed knowledge scientists produced served both political and commercial aims, animating the civilising project of imperial power and transforming a newly acquired territory into a profitable annex to empire. Two prospecting operations are explored in detail: (1) the first large concession floated as the Rhodesian Congo Border Concession and (2) the first attempt to use geological science to generate a complete geological map of mineral resources on the Copperbelt in the Nkana Concession. Examining the efforts of these two prospecting operations reveals the methodological, theoretical and epistemological challenges of producing a viable mineral investment and practicing science in the periphery. Finally, the disconnects between the logics and goals of science and those of colonial extraction in Africa are explored. Here it is argued that it was the very malleability of the knowledge produced by European scientists, rather than its abstract fixity or placeless universality, that enabled it to become part of wider

political and economic flows.

Introduction

In 1926 Northern Rhodesia¹ stood on the cusp of what the government described as “one of the greatest mineral developments ever experienced.”² Within a few years the Nchanga, Nkana, Roan Antelope and Mufulira mines of the Northern Rhodesian Copperbelt would sweep onto the world investment stage in a shower of publicity. Between 1930 and 1964 Northern Rhodesia was transformed from a colonial ‘backwater’ into a key asset of the British Empire and one of the world’s largest exporters of copper (Parpart, 1983). As one journalist noted in the early days of this change:

“In no other area of the world has there been, during the present century, such a transformation of social values, such a development of commerce and industry and transportation, or such an intensive application of scientific knowledge to so large a region previously so primitive and so little known” (Letcher, 1932, p. 15)

Only a few years previous, the future had looked bleak. In contrast to the success of mining in the Katanga region of Congo just a few dozen miles to the north, the challenges of mining in Northern Rhodesia had earned it a reputation as the graveyard of mines, not their birthplace (Gann, 1969). A sparsely populated land-locked country with few resources and little investment had poor prospects in a policy climate which demanded that the colonies pay their way. It was a dramatic turnaround.

This dramatic rise was no mean feat. It rested in part on a prospecting operation perhaps unparalleled in size and scope in the world at the time. Capital poured into Northern Rhodesia as prospectors walked millions of miles and deployed a range of expensive and cutting-edge technologies to uncover one of “the world's great subterranean storehouses of wealth” (Rhodesian Mining Journal, 1932, p. 457). Bringing new prospecting techniques to the area enabled the Northern Rhodesian subsurface to be ‘seen’ in new ways. Centrally, these operations revealed copper sulphide ores which had previously been “masked by deceptively poor-looking outcrops” (Wilson, 1992, p. 132). This article examines the complexities of this

¹ This article uses the term ‘Northern Rhodesia’ to describe the territory of colonial Zambia before 1964. This is done for reasons of simplicity and clarity as the territory held multiple names and administrative forms prior to amalgamation in 1911 (Gann, 1969, p. 80 f.n.).

² National Archives of Zambia, Lusaka (henceforth, NAZ) RC 1375 Mining and geology, General review mines department staff and work 1932 p.2

process of prospecting on the Northern Rhodesian Copperbelt and its role in the extension of colonial power. Two prospecting operations are explored in detail: (1) the first large concession floated as the Rhodesian Congo Border Concession (RCBC) and (2) the first attempt to use geological science to generate a complete geological map of mineral resources on the Copperbelt on the Nkana Concession. Examining the efforts of these two prospecting operations reveals, the methodological, theoretical and epistemic challenges of producing a viable mineral investment and practising science in the periphery. The final section then considers the imbrications of knowledge production and economic and political goals in the late colonial period, arguing that disconnects between the logics and goals of science and those of capitalist extraction meant that the linkages between knowledge production and colonial power were problematic and often tenuous. Before all this, the paper begins by exploring debates on the key linkages between science and empire.

Seeing colonial natures

The idea that knowledge generation underpins the extension of colonial power has much traction in contemporary geographical research, and for good reason. Science has provided the basis for the expansion of European colonial power from its earliest days with European colonialism “as much a scientific process as an economic and military one” (Sörlin, 2000, p. 51). Much has been written on these processes in the early colonial period (Hodge, 2011). Exploration cartography, in particular, has come to be an emblematic study for exploring the linkages between knowledge production - or ‘science’ - and the extension of colonial power into new areas and relationships (Butlin, 2009; Craib, 2004; Escolar, 2003). Certain practices of scientists in the colonies flourished as the knowledge produced served both political and commercial aims, animating the civilising project of imperial power and transforming newly acquired territories into profitable annexes to empire (Drayton, 2000). This section discusses how the activities of scientists, and geologists in particular, work to enable the extension of colonial power before reviewing recent critiques of the relationship between colonialism and science that draw on detailed examination of the practices of scientists.

European colonial powers’ capacity and mandate to rule was founded upon the apparent universality, solidity and pre-eminence of scientific truths. Scientific appraisals produced a systematic and understandable totality from colonial natures useful to commercial and governmental actors through simplification, abstraction and ordering. James Scott describes

the process of simplifying complex realities, such as the colonial natural environment, as rendering 'legible' (1998). Rendering legible classifies and orders the complexity and chaos of the natural environment into a rationalised, standardised and “administratively more convenient format” (Scott, 1998, p. 3). This rendering legible is a central process in the conversion of nature from biophysical environment to an object of human action, of producing nature (Bridge, 2007; Howitt, 2001). Scientific descriptions, charts and formulae offered an appearance of secure understanding upon which to intervene, invest and re-order social and environmental relations, imposing regularity, order and clarity on distant complexity (Livingstone, 2003; Stafford, 1990). These appraisals worked to render natural resources visible, legible and – through the imposition of 'scientific order' – calculable (able to be represented in numerically quantifiable ways which could then be used in calculations), enabling nature to be understood and depicted in ways which encourage and support investment (Demeritt, 2001; Gregory, 2001; Scott, 1998). Through the knowledge produced by European scientists, colonial natures were simplified to produce both natural order and disordered nature (Gregory, 2001; Scott, 1998). Foreign unruly natures might be tamed to the path of development and their resources unlocked. In the colonial setting, as Joseph Hodge argues, "staging science as an expression of western dominance was an important facet of colonial rule, lending legitimacy to the ideologies of improvement and rationality that underpinned the new structures of state power" (2011, p. 12). The activities and knowledges of European scientists actively conjured a space which could be known and thus acted upon confidently, legitimating and supporting the rise of “interventionist colonialism” in the early twentieth-century (Tilley, 2011, p. 11).

Geological science in the colonial period was advantageously placed at the intersection of commercial and governmental interests, particularly in a territory like Northern Rhodesia where mining was at the heart of the ambitions of the colonial state (Stafford, 1990; Zeller, 2000).³ The exploratory nature of geological science performed multiple political and economic functions in extending claims to space and enabling the development of extractive commercial relations. Geology has long been imbricated with the ideologies of empire with some of geology's leading lights being among the strongest proponents of the expansion of British Empire in the nineteenth-century (Secord, 1982). Geological maps were key

³ This article consciously skirts detailed discussion of the history of geology as a science. For more comprehensive explorations of the science's intriguing history, see Roy Porter (1978), the works of James Secord (e.g. 1982, 1991), Robert Stafford (e.g. 1989; 1990) and Martin Rudwick's remarkable *Bursting the Limits of Time* (2007).

ideological and commercial tools as they "symbolised regularity and improvement: they graphically charted the European conquest of the peripheral wilderness"(Stafford, 1990, p. 73-74), enclosing landscapes and extending the dominion of colonial power (Naylor, 2011; Secord, 1982). In symbolically taming the wilderness of the African interior and revealing them 'in truth', scientific maps of the Northern Rhodesian subsurface produced a stable and detailed understanding upon which plans for manipulating the newly visible natures could be made. Geological science appraised nature in ways which held commercial significance. The geological maps drawn up in the nineteenth century not only charted the potential contours of strata and geological formations; they charted the probability of the occurrence of specific potential mineral deposits, deposits which held economic value. As Bruce Braun argues, geological knowledge linked nature with distant investment markets as the "geological language of probability speaks in the tongue of an economic and political language of possibility" (2000, p. 25). Through the work of prospectors and geologists, the Northern Rhodesian subsurface was produced as a 'resource' and made amenable to specific forms of analysis and understanding. Difference was produced. Gone was the homogeneity of the flat, gently undulating plateau of the Copperbelt, rendered into sight was its 'inner architecture', its distinct strata, layers, contours, ruptures, continuities, folds, faults, varying mineral properties, and with this, its potential economic value (Braun, 2000; Gregory, 2001). Through the practices of economic geology, elements of nature were able to move into the logics of capital as a commodities which could be priced and exchanged on global markets (Castree, 2003). Linking commercial and territorial expansion, geology, like its sibling geography, was an archetypal imperial science.

While the role of science underpinning the extension of colonial power has been relatively uncontroversial, recent analyses have sought to complicate directly instrumentalist understandings of the relationship between science and empire through careful examination of the practices and networks of science and scientists. One strand of analysis destabilises scientists' claimed ability to establish 'universal' and placeless truths, while a second highlights the often awkward relationship between scientists and their masters in colonial bureaucracies. To begin with this first strand, European science's claim to authority stemmed from producing a placeless 'view from nowhere', understandings which are 'objectively true' everywhere, transcending the location in which they were originally produced (Bourguet et al., 2002; Naylor, 2005; Shapin, 1998). Counter to this, a number of recent studies have highlighted how making science and knowledge travel was a problematic endeavour which

relied upon multiple explicitly spatial practices of “standardization, calibration and reproduction” to produce abstract and mobile forms of knowledge (Livingstone, 2003; Powell, 2007, p. 321). Practices to build trust, reliability and establish common standards so as to enable knowledge to be sufficiently disarticulated from local conditions were by no means given or straightforward, they were precarious, requiring consistent effort to distinguish ‘scientific’ from ‘unscientific’ practices and knowledges (Livingstone, 2003). Further, while in official discourse alternate forms of knowledge were often seen as somehow ‘lesser’ than European science, these studies highlight the hybridity and interpenetration of knowledges. Despite being largely invisible in the final scientific reports and presentations, colonial subjects were often central to the knowledge production process, challenging the notion of a purely European, non-local practice of science (Beinart et al., 2009; Livingstone, 2003; Tilley, 2011). Indeed, as David Livingstone argues, “the ‘view from nowhere’ turns out to always have been a ‘view from somewhere’” (2003, p. 184). This claim to foundational truth, objectivity and universality, then, is in part a performance; a set of cultural practices used to legitimate the forms of knowledge produced and its producers. The practices of science simultaneously generated knowledge and performed authority.

A second strand of criticism has undermined previous analyses that place science, and scientists, unproblematically at the service of imperial aims. Indeed, close attention to the work of scientists in colonial contexts reveals “the ambiguous part science played in the colonial encounter” (Hodge, 2011, p. 23). The work of scientists in the periphery produced a remarkable amount of auto-critique as scientists became acutely aware of the gulf between their theoretical understandings and assumptions and the ontological realities which they faced (Tilley, 2011). Further, the knowledge generated by scientists could pose awkward questions of colonial rule, highlighting mistakes and failures (Beinart et al., 2009; Tilley, 2011). While they often served it, the logics of science were never fully subservient to the needs of colonial rule as “scientific ideas and processes possessed a certain relative autonomy shaped ... by scientific theory, debates, institutional politics, personal ambitions, knowledge, networks and beliefs” (Beinart et al., 2009, p. 425). Recent historical work on the British Empire often highlights how “multiple colonial projects and discourses existed in tandem, and often in competition and opposition with each other” (Hodge, 2011, p. 16). Colonial scientific projects were no exception.

This article takes up these two strands of critique to explore the complexities of producing

'scientific' geological knowledge in inter-war Northern Rhodesia. The case examined in this article represents a pivotal moment in which a remarkably sparse colonial presence was transformed and dramatically 'thickened' in the space of a decade (Frederiksen, 2010). This transformation hinged on the Northern Rhodesian subsurface becoming visible, and visible in ways which encourage investment; it required the application of new technologies of understanding and appraisal. Applying these technologies relied upon and reproduced the pre-eminence of European science, lending legitimacy to the actions of those who later used that knowledge to extend colonial control over the people and nature of the Northern Rhodesian Copperbelt. As we shall see, there were good reasons why three decades of prospecting had not rendered the 'inner architecture' of the Copperbelt visible for all. The subsurface is, by its very nature, hidden from view. Viewing it therefore, requires effort and extrapolation. Generating knowledge with the degree of accuracy and certainty required for large-scale investment in the remote tropical African interior was a challenge. As the RCBC and other prospecting groups took over rights to explore the subsurface of vast swathes of Northern Rhodesia they took on these challenges. The following section investigates the early years of the RCBC operation exploring the challenges they overcame to produce the forms of knowledge that enabled significant investment. The subsequent section explores the efforts of geologists to develop a definitive geological map around Nkana— a master key to unlocking the geological secrets of the Northern Rhodesian subsurface. In considering these two efforts, the practical and theoretical challenges of 'knowing' the Northern Rhodesian underground are engaged before examining the links between these knowledges produced and the political economic processes of colonialism. The picture that emerges from this investigation demonstrates the both convergent and divergent logics of science and empire and the contingency of scientific knowledge in the extension of colonial power.

The Rhodesian Congo Border Concession

When the RCBC's manager in Africa, Raymond Brooks, arrived on the Northern Rhodesian Copperbelt in early 1923, evidence of the impact of 30 years of colonial rule was scarce. That same year, Northern Rhodesia's total copper output was 6,600 tons; 30 miles away across the border in Katanga, annual copper production was over 80,000 tons (Coleman, 1971; Schmitz, 1979). The Bwana Mkubwa mine at Ndola operated only fitfully and Brooks became one of a handful of Europeans in the area (Coleman, 1971). There was one road which connected Bwana Mkubwa with the regional administrative centre Ndola, cut as much for the manager

of Bwana Mkubwa to ride his motorcycle to and fro as for the transportation of ore from the troubled mine (Brooks, 1944c). Brooks began organising his operations from an office in the back of a small private home. He was largely unsupported by the government of the time and few, outside of a smattering of ever-optimistic mining investors, held much hope of finding economically significant mineral resources on the Copperbelt (Brooks, 1944a). This section examines the first systematic large-scale efforts at prospecting what became the Northern Rhodesian Copperbelt. Three facets are explored: an early reliance on African knowledge of copper deposits, the attempt to generate an objective view from above and the shift to an alternate visual register of chemistry and maps. In exploring these, the fallibility of the scientific methods used and the recalcitrance of nature in yielding up its mineralogical structure become apparent. If European science was to provide a confident basis for action, it manifestly failed in these early days.

Brooks was the vanguard of a much larger presence. Between 1922-5 135,000 square miles of the surface of Northern Rhodesia – nearly half of the territory – came to be covered by six vast prospecting licenses; by 1940, this had increased to 70% of the country (See Figure 1, Drysdall, 1972). These new licenses granted exclusive access to large areas of territory for a period of five years on condition of a minimum annual investment in the area (Coleman, 1971) This was a radical departure from earlier approaches as it was increasingly recognised that the numerous obstacles to prospecting could only be overcome by well-financed groups able to mobilise the resources necessary to undertake rigorous scientific prospecting operations in the African interior (Gann, 1969).⁴ Such groups demanded extensive exclusive prospecting rights in order to make substantial investment worthwhile. The first of these new concessions was floated as the 52,000 square mile Rhodesian Congo Border Concession on February 16th 1923 for £150,000 (Coleman, 1971). With this size, a working capital of £45,000 and a promise of an annual investment of £9000 for five years, the RCBC license ushered in a new era of mineral prospecting in Northern Rhodesia (Bridge, 2007; Coleman, 1971). What followed was an unprecedented effort to unlock the secrets of the Northern Rhodesian subsurface. Hundreds of geologists, engineers and prospectors and thousands of Africans employed between 1923-40 laboured on one of, if not *the*, largest mineral prospecting effort of its kind at the time (Drysdall, 1972). The concessions came to total 203,000 square miles, of which 156,000 square miles, 54% of the entire country, was

⁴ The previous approach adopted in 1912 was of allowing anyone willing to pay for a £1 license to prospect practically anywhere in the territory and had failed to produce a meaningful mining industry.

prospected in detail. Prospectors walked over 3,000,000 miles through the Northern Rhodesian bush looking for minerals in this period (Frederiksen, 2010). A new era of large-scale, modern, capital-intensive prospecting had begun in Northern Rhodesia.

Figure 1: Map showing extent of prospecting concessions in late 1920s. Adapted from Rhodesian Anglo American (1929).

Both physical and theoretical obstacles hampered prospecting in Northern Rhodesia, prior to the arrival of RCBC. In contrast to the ores found across the border in Congo, the geology of the Northern Rhodesian Copperbelt was almost entirely unknown. Compared to its northern neighbour, prospecting for mineral deposits in Northern Rhodesia was an uphill struggle. *First*, there were few outcrops. The ore was underneath laterite soils with prospectors complaining that "the country is so densely forested that prospecting is a difficult and monotonous task" (Rhodesian Anglo American Limited, 1929, p. 10). In Katanga, the ore literally stood out from the landscape "in large bare kopjes or hills standing prominently above the level of the country" which "obviously attracted attention at once" (ibid.). Ore was

more difficult to see in Northern Rhodesia than its northern neighbour. *Second*, what outcrops there were gave little indication of richer ores below. Where, in Congo, surface outcrops contained rich mineral deposits, in Northern Rhodesia "mineral indications on the surface of copper deposits are, almost without exception, negligible" (Rhodesian Anglo American Limited, 1929, p. 12). *Third*, it was assumed that the geology on the Northern Rhodesian Copperbelt matched that on the Congolese side where ore grades tailed off sharply at depth. Experimental shafts sunk beneath the water table in the Congo had demonstrated that "the tenor of the ore above water level was representative of the orebody as a whole" (Rhodesian Anglo American Limited, 1929, p. 11). This proved to be a crucial theoretical error. In assuming, not unfairly, that the geology on the southern side of the border was largely analogous to that on the northern side, early prospectors placed themselves at a massive disadvantage. They overlooked deposits which did not match their view of copper ores in this region. When the search took on a different focus, and used a different register, the economic landscape of Northern Rhodesia was rapidly transformed.

For the most part, the RCBC relied on the same rudimentary methods used previously by prospectors which were only able to locate ore bodies with a surface expression, often simply by taking over mines previously worked by Africans. However, the RCBC brought a new scale and "rigidly systematic" approach to the enterprise which meant little was overlooked (Drysdall, 1972, p. 59). The RCBC's 'systematic approach' had two facets: systematically covering the entire concession on foot looking for evidence of mineral deposits, and systematically visiting every African settlement and offering large rewards for anyone who led them to outcrops. The archive is largely silent on which was more effective.⁵ As European prospectors were employed – twenty in total – the first task lay in cutting a road to the concession acquired in Nkana, 35 miles away (Brooks, 1944c). Brooks then dispatched ten two-man teams, each with around 20 African helpers, into the field every dry season who conducted traverses of specific areas looking for evidence of minerals such as soil and vegetation changes ('dambos' or 'copper clearings' where copper content in the soil stunted vegetation growth – particularly, large trees) and rock outcrops. These teams cut and then burned a base line through the bush and then burned two parallel lines 5-7 miles either side of

⁵ This is not strictly true as many accounts, with the common penchant for 'the lonely prospector' myth, paint the prospecting process as one carried out by individuals with the dozens of Africans involved written from the process. However, from the geological reports from the RCBC prospecting parties that remain, the providence of the original find is not always clear. Raymond Brooks was at pains to point out the importance of African help in finding copper outcrops (Brooks, 1944b).

the original line (Rhodesian Anglo American Limited, 1929). With stations marked every quarter-mile on all these lines, traverses were conducted between corresponding stations on these strips "using a prismatic compass and a wheel equipped with a bicycle cyclometer" noting any changes in vegetation, outcrops and other geographical features such as streams, taking samples where pertinent (Brooks, 1944a, p. 83; Rhodesian Anglo American Limited, 1929).⁶ Walking around 12 miles each per day these teams could "thoroughly prospect between 85 and 100 square miles per month" (Brooks, 1944a; Rhodesian Anglo American Limited, 1929, p. 30). Rudimentary technology was paired with a structured approach to produce an unprecedented amount of information about the Copperbelt.

The innovations the RCBC brought to enlisting Africans to help find outcrops were twofold – firstly they paid a great deal more than previous prospectors, and secondly they armed Africans with geological hammers. Working on the assumption that the local peoples would have seen any interesting outcrops they showed some samples of the types of rock they were looking for and then offered £5 (the equivalent of an annual salary at the time) "for disclosure of any formation in place that showed even minor evidences of copper staining or other metal content" (Brooks, 1944b, p. 84). By contrast, previous prospectors had offered beads, calico and blankets in exchange for such information (Bradley, 1952; Coleman, 1971; Gann, 1969). The hammers enabled Africans to collect samples of outcrops which their own tools could not. After three years of prospecting along these lines, the RCBC, relying almost entirely on African knowledge, made 141 new discoveries of (predominantly copper) ore occurrences (Brooks, 1944a).⁷

The RCBC efforts revealed an abundance of mineral outcrops with traces of copper minerals. The prospectors had no doubt they were in 'copper country' (Brooks, 1944b). These weak mineralisations indicated that they may be close to areas with more concentrated mineralisations; levels which would be economically attractive. Pitting, trenching and drilling were then used to explore beneath the surface. As the prospecting project demonstrated the presence of copper ores, the RCBC increased its use of modern cutting-edge technologies to locate minerals. In particular, the RCBC were the first to conduct drilling on the Northern

⁶ Archives of Zambia Consolidated Copper Mines – Investment Holdings, Ndola, Zambia (henceforth, ZCCM) 3.8.1c - Report from Prospecting Party No.2

⁷ Many of these were very small deposits. Bancroft derisively commented later that the specimens collected sometimes sampled the entire occurrence (Bancroft, 1961).

Rhodesian Copperbelt and pioneered the use of electro-prospecting and aerial surveys for prospecting in Africa (Rhodesian Mining Journal, 1932). All of these technologies however, were rarely straightforward in their operation in the bush and often unreliable in their results.

Perhaps the most significant technology the RCBC brought to bear on the Northern Rhodesian Copperbelt which had not been used previously, was drilling. As surface outcrops were an unreliable guide to what lay beneath, 'seeing' the subsurface was very important. This inability to trace ores at depth had proved a serious obstacle to the establishment of mining prior to the First World War. Without drilling, measuring the extent of ore bodies at depth had only been possible through digging a shaft down to the ore – an expensive and labour intensive task. With drilling, directly sampling ores deep underground was possible giving a clearer picture of the extent of ore beds. Drilling also made it much easier to prospect below the water table which had previously proved an important physical barrier.⁸

More fundamental an obstacle initially however, was the belief that prospecting much below the water table was pointless. Believing that the geology of the Northern Rhodesian Copperbelt would closely match that of the Congolese Copperbelt, prospectors and miners believed that all ores of worth would be found above the water table. When the Copper Venture Syndicate (CV) first took a holding in the Copperbelt, before they applied for the larger concession which was floated as the RCBC, they bought the rights to a small claim called Nkana (see Figure 1 above). This claim held some promise, with evidence of African copper mining, malachite outcrops, and some development shafts with ores assaying at 3-6% copper that had been intermittently developed for a number of years.⁹ When CV took over the property, a total of 22 prospecting pits and shafts had been dug but only four of these had attempted to go beyond the waterline (usually only by a few metres) and only one had gone deeper than 100 feet.¹⁰ So deeply ingrained was the belief that there was little purpose in looking further, and so costly was it, that it was not attempted.

Drilling overcame the liminal water table with comparative ease but substantial financial backing was required to carry out a drilling programme on the Copperbelt in this period. The

⁸ NAZ A3/33/4 Northern copper company, A report by Mr. Bentley 1910

⁹ Archives of the London School of Economics' British Library of Economics and Political Science, London (henceforth, LSE) Selection Trust Papers G/37 Nkana Northern Rhodesia 1922

¹⁰ LSE Selection Trust Papers G/37 Nkana Northern Rhodesia 1922

equipment was expensive and drill operating a skilled task. Drilling cost around 30 shillings per foot and a team could drill approximately 300ft per month.¹¹ As many of the minerals which eventually came to be mined often lay over 500 feet down, this meant that drilling a single hole to 'prove' the existence of ore could take 2 months and cost hundreds of pounds. Aside from the costs of buying and operating the drill, simply moving them around on the Copperbelt was problematic. For example, moving the first drill to Nchanga (which discovered the fabled 'river lode' - the first discovery of rich copper sulphides in Northern Rhodesia) took the combined efforts of a British engineer employed specifically for the job and 128 African labourers nearly a month to drag the 5-ton drill and boiler a distance of 53 miles across the Northern Rhodesian bush and the Kafue river (Brooks, 1944c).

The drill revealed two important things: the mineral content of an ore and the specific location of that ore in space. Drilling, however, was not a straightforward task, frequently proving to be a technical challenge and fallible as a way of 'knowing' the underground. *Firstly*, accurately fixing the original location of the sample was not always easy.¹² The drill would be deflected from a straight line by differing angles of the beds and the transition from soft to hard ores. Further, core samples in the drills could break, fragment and/or slip down the barrel of the drill blurring the picture of the subsurface being developed. *Secondly*, with the difference between 'payable' and 'non-payable ores' as little as a single per cent of mineral concentration, accuracy was of paramount importance. The mineralised ores were particularly prone to fragmenting when the sulphide vein was reached often leading to over or underestimates of the mineral content of the ore. To counter this, the prospectors inched the drill bit forward four feet at a time then pumping water until it ran clear to make sure all the sludges had been caught and then slowly removing the core. The unreliability of the drill core made the recovery and accuracy of sludges particularly important. These too often gave misleading results as sediment from higher up the hole could cave into the drill hole diluting the sample, the oil used to lubricate drills collected the copper sulphides they were seeking to measure, and if the drill path crossed a geological fault, the sludges would simply drain away (Squirrell, 1953-4).

¹¹ LSE Selection Trust Papers G/29 Report on W Selkirk's visit to Rhodesia 1926

¹² This discussion comes from ZCCM16.2.1e PHC 26 Notes on drill sampling

Northern Rhodesian prospecting lore is littered with accounts of multi-million pound deposits narrowly missed by a few feet, or mistakenly 'discovered' due to unreliable sludge and core samples (Bradley, 1952; Coleman, 1971; Squirrell, 1953-4). The combined challenges of drilling meant that even after 30 years of experience in the area, core recovery was often around 33% and many holes were abandoned if it was considered 'bad drilling ground' (Squirrell, 1953-4). As individual drill samples could be unreliable, dozens were often commissioned if the area seemed promising. Even then, drilling would only trigger further development as none of the prospecting techniques used could replace sinking a development shaft (Hunter, 1946). Only when trained human eyes and hands had directly encountered the ore, would full-scale mine development be contemplated.

Given the usefulness of variations in vegetation in indicating copper content in underlying rocks, and the difficulty of travel in the region, aerial surveys were ordered to quickly assess vegetation over large areas.¹³ Objective and accurate technology could most efficiently reveal the hidden truths of the Northern Rhodesian landscape and guide the application of capital. Fresh from forest surveying in Burma, between 1926-7 the Aircraft Operating Company photographed 12,000 square miles of the Northern Rhodesian Copperbelt to look for 'copper clearings' (Coleman, 1971; Rhodesian Mining Journal, 1932; Walker, 1929).¹⁴ This technique however, was more expensive and less effective at providing an objective view of the landscape than had been hoped. Firstly, insurance regulations required that planes flying at less than 10,000 feet should always be within 10 miles of an emergency landing ground (Bancroft, 1961). This required the clearing of landing strips at 20-mile intervals along the length of the area to be surveyed.¹⁵ Clearing these strips was costly and arduous as they were liable to flood in the rainy season and cleared vegetation quickly grew back. The regular appearance (and rapid reappearance, often overnight) of termite and ant hills, which were resistant to dynamite blasting, made levelling the ground for the landing strips cumbersome (Bancroft, 1961; Drysdall, 1972). This cost meant RCBC directors quickly abandoned plans to photograph the entire concession and settled for its eastern-most portion (Brooks, 1944b).

¹³ Many of the earliest prospects pegged on the Copperbelt like Roan Antelope were discovered using this method.

¹⁴ While unlikely the first surveying of its type in the world, this was pioneering use of the relatively recent technology of aerial photographic surveys which were first regularly used during the First World War (Cronin, 2007). Large aerial surveys for mineral prospecting in Northern Rhodesia predated similar efforts in Canada for example (Cronin, 2007).

¹⁵ These strips were not an excessive precaution; the survey experienced two 'forced landings' in its early operations: (Walker, 1929).

The resulting pictures either revealed little – during the rainy season clouds obscured the ground and during the dry season dust and smoke from grass fires did the same – or were too general to be of use. The clearings which were found could also be caused by swampy soils and hill slopes which both inhibited tree growth (Hunter, 1946; Walker, 1929). Further, for the copper content of the underlying rock to affect vegetation, the soils needed to be relatively thin. 95% of ores in the large Nchanga Mine were covered with forest and the Roan Antelope ore continued two miles beyond the clearing which had originally given prospectors clues to its presence (Walker, 1929). The leading Anglo-American geologist of the time, J. Bancroft, described their information as "misleading rather than helpful" (Bancroft, 1961, p. 86). As technology and infrastructure improved, the aerial survey came to be a regular fixture of mineral prospecting in the area (Garlick, 1953-4). At this early stage, however, it was of limited use.

Collectively, the RCBC's efforts of traversing the landscape, systematising African geological knowledge, drilling below the water table and photographing the concession from above fundamentally changed the way the Copperbelt was understood. In the process of deep drilling, RCBC prospectors encountered extensive veins of copper sulphide ores which came to form the basis of future Copperbelt development. These sulphide ores, while still lower grade than those of the copper oxides across the border, were far more amenable to concentration and processing technologies and thus very commercially valuable (Coleman, 1971). This band of ore was simply a grey shale, unremarkable in appearance and not widely recognised as copper-bearing ore. Its copper content only came to light because drill samples were routinely assayed for copper content. This discovery of a previously unseen form of copper ore transformed the search for copper in Northern Rhodesia. All previous prospects were now subject to deep drilling to see if the weak surface deposits hid deeper rich sulphides. A flurry of interest in the region brought new concessions, new capital and new prospectors and an on-going prospecting effort. Groups already active in the region snapped up the adjacent concessions. As opportunities for expansion receded, concession owners were forced to make the most of the land they had. With almost every single surface outcrop demonstrating copper content logged by the RCBC – and these outcrops numbered into the 100s – the challenge lay in deciding which of these merited further exploration. The RCBC response was further traverses and an aerial survey. A neighbouring group on the Nkana concession, the Selection Trust, took a different approach. They decided instead to produce a definitive account of the Nkana concession's subsurface; in so doing they produced the first

scientific geological map of the Copperbelt.

Geologising the Copperbelt

In 1923, a young engineer, Russell Parker, was dispatched to reassess the development work carried out, 20 years previous, at the Roan Antelope and Rietbok claims. Parker was under explicit instructions to look for the possibility of sulphide ores underlying the surface oxides (Beatty, 1931). Exploring the development shafts, Parker noted that the original workers had not discerned that the width of the mineralised shales increased with depth and increased in concentration. Importantly, working from a visual register shaped by Congolese outcrops, they simply stopped digging the shaft when the green oxidised ore petered out. Parker sampled the ore at the base of the shaft and found rich copper sulphides, implying that they underlay the exposed ore (Wilson, 1992). Working on the possibility that the two parallel reefs may be a syncline (an inverted arch of ore) they began a drilling programme between the two outcrops at intervals of 1000 feet (Coleman, 1971; Wilson, 1992). They quickly discovered that a wide mineralised band of ore continued at a depth of 500 feet (Wilson, 1992).

With Parker's discovery, a new approach was taken to the Nkana concession. Instead of looking for old mines and trying to see if they were worth following up, the entire Nkana concession would be subjected to comprehensive geological mapping. Taking a more theoretical approach, it was assumed that the same stratigraphic series of rocks occurred throughout the concession and that copper would be found in or near "a well defined series of sedimentary rocks" (Parker and Gray, 1935-6, p. 332). If the inner architecture of the entire concession could be mapped, then they could divine where the mineralised ore existed but showed no surface manifestations. Geological theory was to be brought to bear to develop a new view of the region's resources. Parker supervised a three-year programme led by geologists Anton Gray and TF Andrews to develop a comprehensive geological map of the 18,000 square mile area (Parker and Gray, 1935-6). The mapping had two objectives: The first was to define areas for further detailed prospecting and drilling, the second was to find indications of payable mines within the concession.¹⁶ The process was structured over three dry seasons from 1926-9: the first aimed at noting every single outcrop and surface

¹⁶ ZZCM 16.2.1e PHC 25 Geological reports and reconnaissance maps Nkana concession/Letter to Selection Trust Secretary from Russell Parker 17/12/27

occurrence of every single mineral, the second followed up with detailed pitting and mapping, the final with pegging claims for future exploration (Parker and Gray, 1935-6). These much-reduced claims would be then be drilled. Rainy seasons were set aside for collating and crosschecking data collected and refining maps. However, divining the geological structure of the concession with any degree of accuracy and detail was deeply problematic, even when backed with substantial resources and expertise.

The Nkana geologists' approach to prospecting was similar to that of the RCBC three years earlier focussing on traverses and looking for surface expressions of underlying geology but this time with a focus on 'contacts' between two different types of rock to develop a picture of the area's strata. With the terrain largely undifferentiated, streams were used as fixed points from which to conduct traverses. Parker and his colleagues opted to divide the concession into overlapping 8-12 mile diameter circles for prospecting (Parker and Gray, 1935-6). Traverses were first conducted along streams as these often held the most outcrops, followed up by radial traverses 15° apart using a Brunton compass from the base station. Traverses noted outcrops, topography, soil and vegetation. As there were very few outcrops, "much of the mapping was dependent on shale float [loose fragments of rock on the surface], soil, vegetation and general impression".¹⁷ None of these were totally reliable. The geologists struggled to establish 'rules' for which vegetation occurred on which type of rock, initially coming to the conclusion that certain 'creepers' were found on the sulphide ores but later coming to doubt this.¹⁸ Soils and 'float' transitioned gradually around geological borders and, where slopes were involved, both moved so as to further complicate the picture. When outcrops were discovered, the geologists were frustrated by their inability to date the rocks due to the absence of fossils and struggled to correlate into a single comprehensive schema covering the entire concession. The seemingly undifferentiated Zambian bush gave rise to a great deal of topographical uncertainty in the prospectors' work, demanding extensive measures for crosschecking and ensuring accuracy. Prospectors alternated routes to double-check the previous day's traverses and later crosschecked these with traverses between previously 'fixed' points of beacons, the railway survey, streams and roads. Rainy seasons were spent on extensive deskwork comparing, correlating and crosschecking samples, maps

¹⁷ ZZCM 16/2/1e PHC 25 Geological reports and reconnaissance maps Nkana concession/ Final report on the reconnaissance of the Nkana concession, Western and Southern Areas by T. F. Andrews p.14

¹⁸ ZZCM 16/2/1e PHC 25 Geological reports and reconnaissance maps Nkana concession/ Final report on the reconnaissance of the Nkana concession, Western and Southern Areas by T. F. Andrews p.12-13

and results to produce the final maps. Confused by the folds, faults and discontinuities of the nature they were charting, they laboured to generate a comprehensive stratigraphic series which would place the ores they discovered in relation to each other physically and chronologically.

After some effort, they came to develop the 'Roan Series' which documented the rocks which overlay and underlay the mineralised shales found and could then theoretically be used to trace the occurrence of the copper deposits across the concession (Parker and Gray, 1935-6). However, while general zones of rock occurrences near the surface (but under soils) were known, the precise boundaries or 'contacts' between the rocks were often unclear. When the production of difference and clarity was the aim, this was something of a flaw. Pages of clauses and conditions about the uncertainty of the final results preface the final map. The detailed geological reports from different areas of the concession attached as appendices are riddled with further clauses and riders on the certainty of findings. For example, T. F. Andrew's description of the Western and Southern areas includes such riders as "mapping is weak in that part" or there being "no mappable areas" in certain parts of the concession and with other areas being "fairly exact" or "very likely right" and at one point a contact (the key information the geologists were looking to plot) being "about right" but could also be a mile either side.¹⁹ Of most concern was that, relying on surface indications, the geologists failed in one of their two aims: they found no new deposits worth mining.

The recommendations of the report hinged upon a weakness of geological knowledge which highlighted the science's taxonomic roots: the geologists had no idea where the copper came from (Naylor, 2011; Secord, 1982). This failure of theory, of being able to understand geology as a dynamic rather than purely taxonomic science, had very real economic consequences. There were two theories – the 'hot water theory' and the 'cold water theory'.²⁰ The 'hot water theory' held that the copper came from fluid movement from below related to igneous intrusions after the shales were deposited. If this theory was correct then future claims should centre on the areas near known granitic rocks or, alternatively, the whole area as there may be intrusions which had no surface outcrops. The 'cold water theory' held that meteoric water had effectively washed coppers down from the surface and they had

¹⁹ ZZCM 16/2/1e PHC 25 Geological reports and reconnaissance maps Nkana concession/ Final report on the reconnaissance of the Nkana concession, Western and Southern Areas by T. F. Andrews p.15-16

²⁰ ZZCM 16/2/1e PHC 25 Geological reports and reconnaissance maps Nkana concession

accumulated (for an unknown reason) in the shales mined at Roan Antelope.²¹ If this theory was correct then the whole area should be retained as the shales could theoretically be found underlaying most of the concession. Cutting-edge geological theory proved itself largely unable to confidently predict where ores may lie and therefore where to claim. Instead, what predictions were made were riddled with so many qualifiers as to give the impression that the suggestions made were simply best guesses.²² The decision of which areas of the concession to retain was left to the directors in London.

Power and the view from nowhere

It is tempting to view this as a story of failure; for the RCBC, a failure of tools, for the Nkana geologists, a failure of theory. However, in indicating the occurrence of large bodies of copper sulphides on the Copperbelt and paving the way for further development, prospecting was ultimately a success. While many of the individual techniques either failed or only unreliably indicated the presence of ores falling far short of the desired definitive, objective account, a rough picture was none the less painted which gave enough confidence to enable further investment. The resulting recommendations from the Nkana effort led to the drilling of an area near the Mufulira stream. Initial scepticism meant that only a small drilling programme was undertaken but this rapidly became the richest ore body discovered on the Copperbelt at the time. Tellingly however, the decision to drill was not taken on the basis of a single indicator, still less on the speculations of geologists, but on the correspondence of a number of indicators. Copper deposits at a nearby spring, thin vegetation, digging pits or trenches and inferences drawn from the geological mapping were all required before the decision to drill could be taken (Parker and Gray, 1935-6). The decision to drill led to the decision to sink a development shaft and then, and only then, was a full-scale mine planned. The work of the Nkana geologists, for all its flaws and hesitant conclusions was hugely influential in shaping understandings of the geology of the Northern Rhodesian Copperbelt. It remained the largest systematic effort in producing a geological map in the region for many years with the 'Roan Series' (later called the 'Mine Series') becoming a definitive register for future mapping (Hunter, 1946).

²¹ This debate continued for decades but subsequent research points to the copper deposits being laid at the same time as the original sediments (Dixon, 1979).

²² Though they were, ultimately, fairly accurate (Coleman, 1971).

Figure 2: Chart showing sulphide copper levels by depth and a rough geological section from two drill holes on the 'River Lode'. Selection Trust Papers G/41 Rhodesia Congo Border Concession plans 1929.

The strength of scientific approaches to prospecting was not the reliability of individual techniques, but their ability to gather, organise and coordinate information. Even where theories about ore formation were woefully ill-equipped to deal with a new mineralogy in the African interior far-removed from the science of geology's European roots, the scientists were able to systematise enough proximate indicators of the presence of minerals to enable further investment. Geological science's strength and weakness lay in its comparative and standardising approach (Beinart et al., 2009). This approach meant that encountering entirely new mineralogical formations was particularly challenging and apt to start from false assumptions. The geology of the Northern Rhodesian Copperbelt was assumed to echo that of

the Congolese Copperbelt, its main, and nearest, comparator. This belief led prospectors to ignore the possibility of ores below the water table which were not evident above it. However, this same comparative method gave the scientific approach the capacity to abstract and organise large and diverse forms of information. Where the immediate visual register of 'green ore' failed, it was replaced by new abstract visual registers of numbers, charts and maps (see Figure 2). The copper content calculated in assaying laboratories enabled the copper to be 'seen', quantified and abstracted from the Northern Rhodesian subsurface and understood on the London Stock Exchange. The search for rules and systems, the abstraction of elements of nature into proximate comparable indicators, enabled Northern Rhodesian nature to be understood in ways which were readily legible across geographical space. The systematic approach which made extensive use of crosschecking for errors, triangulation and aimed for an ever-improving accuracy and fixity of knowledge - the same practices which strived to produce an objective 'view from nowhere' - gave rise to a stable and reliable enough picture for investments to be made (Beinart et al., 2009). Through combining and coordinating different indicators, the geologists, engineers and prospectors of 1920s Northern Rhodesia rendered African nature, quite literally, visible in new ways and in new places. In assembling diverse and unique information points, the scientific endeavour was able to turn the Northern Rhodesian subsurface into a seemingly objective 'systematic totality', which could be assessed by investors and planned upon by managers and board members in distant London (Gregory, 2001).

In the final abstracted report and maps the process of knowledge creation and much of its inherent uncertainty was omitted. While "every geologist when he drew a line on a map contributed to it out of his imagination and presumed a certain continuity", in the final artefact these speculations are silenced (Hallimond in Parker and Gray, 1935-6, p. 338). These cognitive leaps, the widespread lack of topographical certainty in the traverses, the foundational role of African knowledge and the uncertainty about mineral concentrations and extents were subsumed by the charts, maps and tables which scientific prospecting produced. The final product projected a coherent, ordered, stable space with a continuity of knowledge about nature – a 'systemic totality' – upon which action could be decided. Writing this uncertainty from the record, dividing the data from its origins, is central in producing the objectivity and universality of scientific knowledge (Mitchell, 2002). In asserting this objectivity, this supreme 'view from nowhere', alternate ways of knowing, upon which the scientific knowledge often depended, were obscured. Without this claim to the authority of

science, the prospectors were just simply interested travellers strolling through the Northern Rhodesian bush; with it, they were agents of human progress, carving and burning the contours of the future mining industry into the Northern Rhodesian landscape.

As development gathered pace at a number of mines, the mining press initially only dared obliquely to describe potential riches eschewing confident figures of ore reserves at individual mines (S. A. Engineering and Mining Journal, 1929). The geologists on the ground were well aware of the uncertainties of their knowledge and kept to the language of 'indicated' reserves. In London, however, these quickly became 'proved' reserves (McGregor, 1930, p. 270). The uncertainties of knowledge production were further written from the record when presented to the investing public. At the first shareholders meeting of the newly floated Nchanga mine in 1927, for example, reserves were described as "definitely proved".²³ To counter previous hesitancy, the early 1930s saw a promotional blitz of articles on Northern Rhodesian copper fill the pages of the world's mining press. Some of these articles kept themselves to purely the technical aspects of extraction. Many others, however, lauded Northern Rhodesian copper hagiographically and sought to communicate the findings through narratives of past riches.²⁴ Chester Beatty, a key financier of a number of the mines, invited comparisons to ancient tales of mineral abundance in Africa in one article in the mining press:

"There is an account of over-production of copper at the time of Ramses II. Apparently the production of the copper mines of the Sinai Peninsula exceeded all expectation because they speak of the enormous quantity stored in thousands of bars at the palace. In fact, it must have looked like a yard at one of our refineries." (Beatty, 1931, p. 521)

The analogy with the British Empire here is far from subtle. Beatty went as far as claiming that the mines of Northern Rhodesia held 28% of the world's known copper reserves at the time (Beatty, 1931). This was clearly an exaggeration given the uncertainty of much of the information on which the claim was based. However, equally clear was that eight years of prospecting in Northern Rhodesia had uncovered enormous supplies of copper-rich ore. This selling act points to one of the tensions which has dogged the mining industry to this day: that

²³ ZCCM 18/2/9b PHC/NCCM annual reports 1927, 1937-1966, Nchanga annual report 1927 p.5

²⁴ The mining press of the time was of uneven reliability. Some journals had exacting standards of impartiality while others were open to persuasion and often served as promotional brochures for emerging fields (McCarty, 1961-2).

it remains, at heart, a frequently speculative enterprise (Phimister, 2006). Successive decades of applying science to reduce the risks of investment have far from succeeded in removing them altogether, pointing to a deeper tension between mining promoters' need to produce an attractive investment and scientists' desire to provide a precise account of the extent of knowledge and understanding (Tsing, 2000).²⁵

The necessity of mining promoters to sell the authenticity of the geological reports and cast them within larger narratives illustrates how practices of science in and of themselves, however self-authorising they may be, are of little consequence without being linked to economic and political flows. If knowledge underpins the extension of colonial power, then it only ever does so in partial and contingent ways. The knowledges produced by the vast projects of ordering and classifying nature undertaken in the colonial period only enabled and legitimated the assumption of European control in new territories, when they were linked to larger political economic flows. When linked to these, and represented in non-scientific fora and in non-scientific ways (i.e. fused with myths of the Egyptian empire in promotional mining brochures), scientific knowledge held the possibility of being a placeless authoritative understanding that animated wider imperial projects. This 'constructed visibility' of distant natures was central to the colonial enterprise, projecting an apparent objectivity and placed the capacity to see the 'truth' of things firmly in the realm of European scientific knowledge (Gregory, 2001; Mitchell, 1990). In seeing the 'truth' of colonial natures, authority was claimed and other knowledges were implicitly dismissed as inferior. If the best use of resources came from knowledge, and the peoples of Africa were characterised by their ignorance – the 'profligate native' myth - then it followed that the best use of nature came from the assumption of control by Europeans who possessed the requisite knowledge and insight (Drayton, 2000). Dispossession of Africans was seen as a precondition for progress in Northern Rhodesia. Symbolic dispossession of Africans of the rights to the land had already occurred when concessions were first granted based on questionable treaties signed 30 years earlier (Faber, 1971; Krishnamurthy, 1972; Slinn, 1971). It was only further underlined in the creation of vast reams of data and maps and representations which codified a new regime of property rights, in the process erasing previous claims, effectively erasing African presence, from the landscape. This was an empty frontier, there for the taking. In the case of the Northern Rhodesian Copperbelt, the science of geology was instrumental in both legitimating

²⁵ I am grateful to Matt Himley for making this point

this dispossession and unlocking the 'redemptive forces' of territory. The 'view from nowhere' produced by the prospecting operations on the Northern Rhodesian Copperbelt was thus an intensely political one which had very real consequences of dispossession for many Africans living on the Northern Rhodesian Copperbelt.

Conclusion

In the late 1920s, Africa stood on the brink of a scientific quickening. The following decades saw scientific enterprise in Africa reach new scales as the continent became, in the words of Lord Hailey, a "living laboratory" (Hailey, 1938, p. xxiv; Tilley, 2011). Northern Rhodesia's prospectors were, as they walked millions of miles through the Northern Rhodesian veld charting its 'inner architecture', unwitting forerunners of this scientific reimagining of the African continent. Probing the depths of the subsurface, digging many times deeper than anyone had attempted before, revealed a new world of mineral wealth which had been previously, quite literally, overlooked. The information gathered by prospectors transformed aspects of Northern Rhodesian nature into systematic representations of latent economic value. These representations – charts, diagrams, maps, tables and figures – enabled a new set of calculations of the commercial potential of mining in Northern Rhodesia and triggered a new round of investment which ultimately led to the birth of the Northern Rhodesian Copperbelt. By the end of this prospecting operation, the previously cautious press "foresaw a magnificent future for the distant north" (Gann, 1969, p. 209). The late 1920s Copperbelt was in a headlong 'copper rush'. Between 1927 and 1930, the labour force on the Copperbelt trebled from 10,000 to 30,000 as part of a massive construction effort building large mines across the Copperbelt (Gann, 1969).²⁶ By 1932, £17,000,000 had been spent on mines development and annual Northern Rhodesian copper output had reached 88,600 tons with 3,000,000 tons of raw ore being extracted from the subsurface (Berger, 1974; Hailey, 1938; Perrings, 1979). In total around £35,000,000 was spent bringing these mines to production (Hunter, 1946). The Copperbelt was irreversibly changed.

Scientific endeavour fundamentally changed socio-natural relationships in Northern Rhodesia. The accounts and knowledge of these explorers, prospectors and geologists invited

²⁶ NAZ KSN 2/1 Ndola District Notebook. This growth of urban populations is a much-studied facet of Copperbelt history with a sizeable body of work seeking to understand the apparent conundrum of 'modern' urban populations in the heart of 'traditional' rural Africa. James Ferguson's *Expectations of Modernity* is a notable recent intervention in this debate (Ferguson, 1999).

and enabled the penetration of European capital. The geological maps produced represented both the untapped wealth of the Northern Rhodesian Copperbelt but also the extension of control over these areas. As the geological maps represented the Northern Rhodesian underground, they also contained claims to what was represented, acting as "a cartographic summons to further exploitation" (Livingstone, 2003, p. 155). Linking political and economic objectives, they underlined the need for European intervention to release the trapped wealth. In so doing they wrote any previous claims by local African peoples from the landscape. These maps connected the Northern Rhodesian subsurface with centres of political and economic coordination in London and enabled the space to be increasingly understood, managed and manipulated remotely (Allen, 2003). This was an important transformation of the relationship between the African interior and Britain. It effectively drew Northern Rhodesia, and the Northern Rhodesian subsurface, closer to the centres of finance in the City of London. This closer connection translated into increasing flows of capital, people and minerals and the rise of the Copperbelt as a global centre of commodity production.

For many studies of colonial science, directly state-sponsored activities are at the forefront (Beinart et al., 2009; Bennett and Hodge, 2011; Livingstone, 2003; Tilley, 2011). By the interwar period and onwards, a period of remarkable intensification of extractive industry across the colonised world, state agents were not necessarily the vanguards of scientific knowledge generation in the periphery. In sub-Saharan Africa at least, this was also the period which witnessed a growing interventionist agenda, an agenda bankrolled to no small extent by the growth of extractive industry (Berman and Lonsdale, 1992; Tilley, 2011). The growth of the mining industry produced the revenue flows upon which the Northern Rhodesian colonial state was built. The state, in turn, used its growing reach to enable the activities of the mining companies frequently through dispossessing Africans of their land and livelihoods (Berger, 1974; Parpart, 1983; Perrings, 1979). The link then, between colonial science and the extension and intensification of colonial power is far from straightforward. In the case of Northern Rhodesia, the extension of colonial presence and power rested on the activities of commercially-funded scientists. Perhaps unwittingly, the prospectors of Northern Rhodesian Copperbelt became the architects of African dispossession. The knowledge they produced only gained material force when linked to wider political economic processes. Scientific method enabled the disembedding and circulation of knowledge from Northern Rhodesia. Logics and processes of empire saw this knowledge put to the task of radically transforming Northern Rhodesian society and landscape. It was the

very malleability of the knowledge produced by European scientists, rather than its abstract fixity or placeless universality, that gave it such reach.

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