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Tin mining in Myanmar: Production and potential

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ABSTRACT

In 2014, Myanmar (Burma) confounded industry analysts by emerging to become the World's third biggest tin producer, experiencing a 5-year tin production increase of ca. 4900%. This surprise emergence of Myanmar as a major tin producer is a possible Black Swan event that potentially has significant repercussions both for the future of global tin production, and for the economic development of Myanmar. This is a disruptive event that has likely contributed to a substantial drop in tin prices in 2015. The Myanmar production increase came from a new mine site in Wa State, and not from the traditional tin-producing areas in the South. We discuss tin mining and potential in Myanmar and consider whether it could provide a foundation for the economic rehabilitation of the country.

1. Introduction

In 2014, Myanmar (Burma) confounded industry analysts by emerging as the world's third major tin producer (Fig. 1), experiencing a tin production increase over 2009–2014 of circa (ca.) 4900% (Table 1). The squeeze on global tin prices over much of the last decade finally caused new supply to emerge from what has recently been a relatively overlooked minerals jurisdiction. Although Myanmar was a major tin and tungsten producer pre-World War II, since the 1960s much of its mining industry has been an essentially artisanal operation, in 2013 representing less than 0.1% of the country's GDP (Gardiner et al., 2014). This emergence of Myanmar is a potential “Black Swan” event in tin production – an event that was improbable, but nonetheless of high impact (Taleb, 2008). Combined with the decline of traditional tin producers (Kettle et al., 2014b), the sudden rise of the Myanmar tin mining industry has the potential to refocus global tin production over the next decade.

As a minerals jurisdiction, Myanmar was a significant producer of both tin and tungsten pre-World War II, however its industry was considerably downsized in the last 60 years largely due to the domestic political situation (e.g., Gardiner et al. (2014), Gardiner and Sykes (2015)). As the country opens up both politically and economically, we investigate the outlook for the tin industry within Myanmar and ask whether the combination of renewed global interest in tin, and Myanmar's ongoing political and economic change, mean the country can keep its recent momentum and again become a major producer of tin, tungsten and associated metals. Finally, we consider whether renewed growth in Myanmar's tin production sector can help instigate broader and stronger economic growth and social development within the country.

2. Tin production: a global perspective

The tin price crash of the mid-1980s, the result of the collapse of the International Tin Agreement (Anonymous, 1986), resulted in two decades of depressed global tin prices (Fig. 2). The ensuing economic and social impact on the traditional tin-producing regions of Southwest England, Australia and Southeast Asia (primarily Malaysia and Thailand) was considerable, resulting in a legacy of mine decommissioning and the relocation of tin production to cheaper producers such as Brazil, China and Indonesia (Kettle et al., 2014b; Thoburn, 1994). However since 2008, global tin prices have recovered to reach a consistent high of ca. US $20,000/t (per metric tonne) in real terms, a level not seen for over 30 years. This has largely been driven by a combination of new

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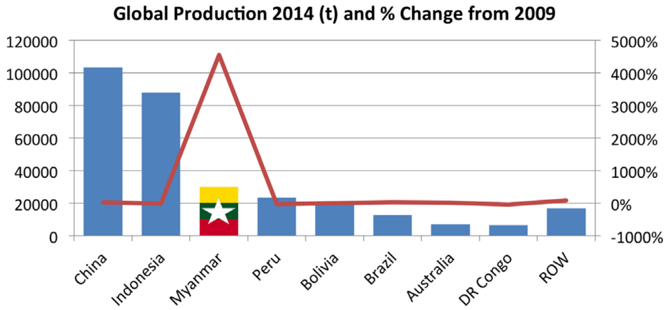

Fig. 1. Major tin producers; tin mine production in 2014; the line indicates percentage change 2009–2014. Sources: Kettle et al. (2014b, 2015b). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

demand usage, especially for solder in the electronics sector; the economic growth of China; and by a restricted supply pipeline, the result of a lack of significant new exploration projects (Kettle et al., 2014b; 2014c).

The recovery in tin prices observed over the last decade was initially due to a structural change in demand reflecting a shifting usage for tin (Kettle et al., 2014b). The dominant driver of tin demand for much of the 20th century has been tinplate, which constituted some 40% of tin use in the 1970s (ITRI, 2012a). However, the collapse of the ITC, coupled with US strategic stockpile selling, the collapse of the Soviet Union, and significant new supply from Brazil, Indonesia and China (Thoburn, 1994), resulted in low tin prices for the tail end of the 20th century-reaching 100-year real term lows in 2002 with annual average prices of ca. US $6500/t. This long period of low prices encouraged substitution into tin and innovation in tin use. In the mid-2000s Europe, North America and Japan all passed legislation banning the use of lead solder in electronics. The then low-priced tin quickly became the substitute of choice, and demand for tin from the electronics sector surged from 50,000 to 100,000 t/a (tonnes per annum), and currently makes up around 50% of tin demand (Kettle et al., 2014b).

This increase in tin demand was initially met from two sources: a rapid increase in placer and artisanal tin supply from Indonesia, and the increased recycling of tin leading to greater scrap supply. However tin mine supply declined from around 325,000 t/a to a low of ca. 275,000 t/a by 2013 (Kettle et al., 2011; 2014b; 2014c), and although tin scrap supply initially filled the supply gap, such scrap supply is ultimately constrained. In summary, there is now a tin demand gap requiring new supply that is most likely to come from mining (Kettle et al., 2011; 2014b; 2014c).

2.1. The current state of tin mine supply

At present, Indonesia and China are each responsible for about one-third of global tin mine supply (Table 1). The surprise rise of Myanmar tin production in 2014 means it ranked third globally for tin mine supply, being responsible for about 10% of world production. However, at present the tin mining industry faces a number of challenges in global tin supply (full review in Sykes et al. (2015)).

Indonesia has suffered from artisanal mining rushes since the 1990s. A characteristic of these rushes is their short-term boom-and-bust nature. Production rises rapidly before quickly collapsing, due to both the low cost and exploitable nature of the deposits, and to the difficulty in predicting grade and tonnage. Indonesian production appears to have peaked at about 100,000 t/a in 2006 and has since gone into decline, with levels now struggling to top 85,000 t/a (Kettle et al., 2011; 2014b). It is likely that Indonesian tin mine production will struggle to hold at current levels and may decline further (Sykes et al., 2015).

Alongside mining for many other commodities, Chinese tin mine production has grown substantially since the 1970s (Thoburn, 1994). However, following a peak in 2000 with production at ca. 100,000 t/a, Chinese tin production has stalled since 2011 at a level ca. 90,000 t/a (Kettle et al., 2014b). The Chinese industry is rapidly maturing, with grades falling at existing operations and few greenfields projects. China is now typically a net importer of tin (Kettle et al., 2014b; Sykes et al., 2015).

The giant San Rafael mine in Peru was the World's single biggest tin mine producer, until the apparent recent rise of the Man Maw mining complex in Myanmar. San Rafael is, however, ageing rapidly, with average worked ore grades of 2.5 wt% tin (wt% Sn) (Minsur, 2014). From a high of over 30,000 t/d in the early 2000s, annual production has been in decline since 2006 and is now close to 25,000 t/a. Although a tailings operation is planned, it is not enough to replace the scale of the main underground mine (Kettle et al., 2014b; 2015b).

Central Africa is another tin jurisdiction that has seen a recent surge and subsequent decline of production. At its peak between 2007 and 2010 it was responsible for about ca. 5% of global tin production (some 15,000 t/a). The majority of resources are located in the North and South Kivu regions of the Democratic Republic of Congo (DRC) (Melcher et al., 2015), an area ravaged by civil war between 1996 and 2003. Many of these mines were controlled by militias, who used the revenues to fund their conflicts. This so-called "Conflict Minerals" trade led to international efforts for supply chain monitoring to stop the supply of Conflict Minerals into the global market (Kettle et al., 2015b).

In summary, several of the major tin mining countries are now facing problems in maintaining previous supply levels.

Table 1
Estimated global tin production 2009–2014 (Mt). Source: ITRI.

Country	2009	2010	2011	2012	2013	2014	% Change
China	86,700	95,600	102,000	89,800	96,600	103,400	19.26
Indonesia	102,900	99,700	104,800	92,200	94,200	86,300	−16.13
Myanmar	600	1400	4700	4800	17,000	30,000	4900.00
Peru	37,500	33,800	29,000	26,100	23,700	23,100	−38.40
Bolivia	19,600	20,200	20,400	19,700	19,300	19,800	1.02
Brazil	10,400	7400	8800	10,600	11,600	12,100	16.35
Australia	5900	6400	5100	5900	6200	6900	16.95
DR Congo	13,100	10,600	6000	5100	5100	5000	−61.83
Other Africa	3300	3200	5100	5700	6200	6700	103.03
Malaysia	2400	2700	3300	3700	3700	3600	50.00
Other Asia	3400	4200	4000	5800	5900	6400	88.24
Russia	300	500	300	400	600	400	33.33
World total	**286,100**	**285,700**	**293,500**	**269,800**	**290,100**	**303,700**	**6.15%**

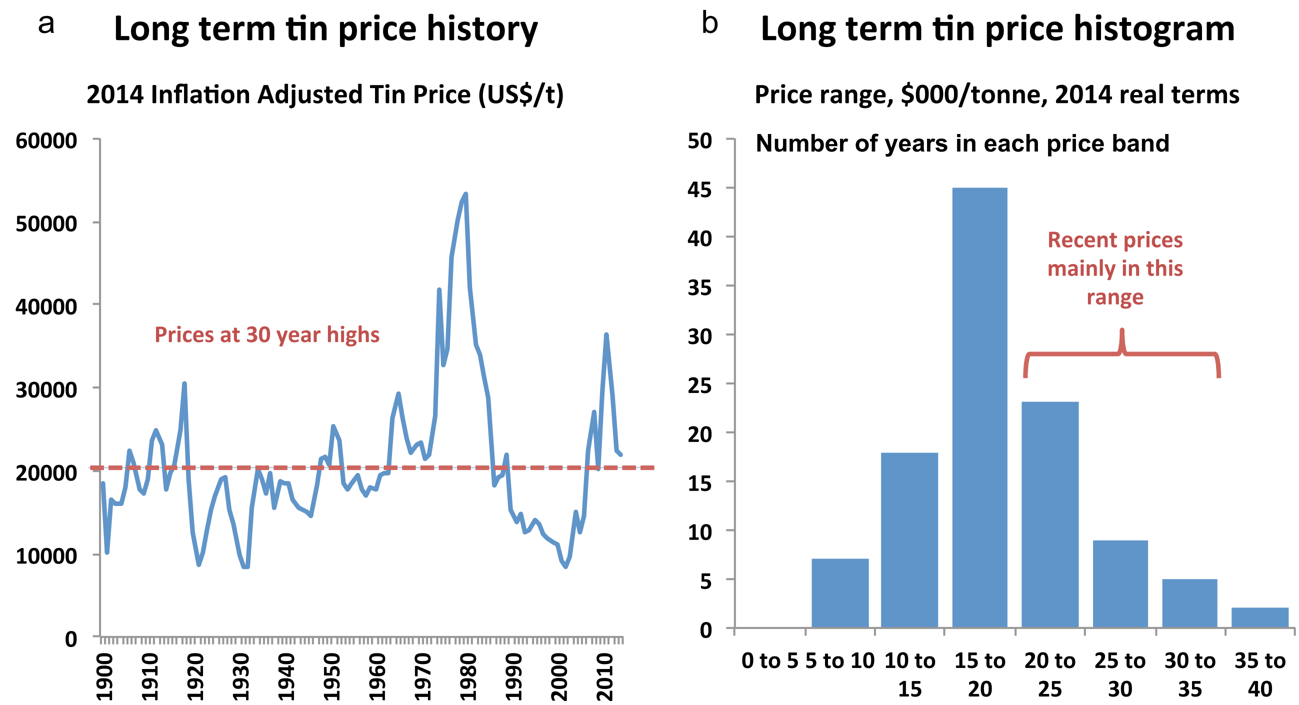

Fig. 2. A (Left) long-term tin price history, inflation adjusted prices. B (right) Tin price histogram 1900–2014, showing number of years in each price band. Sources: Crawford et al. (2015), DiFrancesco et al. (2014), Kettle et al. (2015b).

3. The future of tin mining

With a continual decline in mine production, the tin industry has in recent years focused substantial attention on potential new sources of tin supply. In their analysis of the major current tin projects, Kettle et al. (2014c) found that most projects faced at least one major viability challenge: *Geological Risk*, *Political Risk* or *Technical Risk* (full review in Sykes et al. (2015)).

A number of projects otherwise blessed geologically with resources of significant size and/or quality are located in *politically challenging* countries (e.g., Argentina, Bolivia, Brazil, DRC, Egypt, Kazakhstan, Mongolia, Morocco, Russia and South Africa). Many of these countries score poorly in surveys relating to the political and business climate of the country (e.g. Transparency International (2013) Corruption Perceptions Index; World Bank (2013) "Doing Business" Survey; World Economic Forum Global Competitiveness Index; Schwab et al. (2013)).

Conversely, there are projects in politically stable and favorable locations, but which are more marginal in their economic viability due to fundamentally weaker *geological characteristics* (Kettle et al., 2014c). Such projects are found in Australia, Europe and to a lesser extent, North America, all of which have hosted important tin mining districts in the past. However,the geological risk of tin projects may be mitigated by the presence of valuable by-product or co-products, although this simply presents *technical risk* as these operations become technologically more challenging with multiple product streams. Further, development of tin tailings reprocessing technology, which is common in other metals' mining industries, is still in its infancy. Technical risk is also present amongst placer mining projects, which are difficult to scale economically and rarely provide long-term economic returns (Kettle et al., 2014c; Sykes et al., 2015).

3.1. "Known unknowns", "unknown unknowns" and Black Swans

The tin industry suffers from severe information bias. The future mine project pipeline appears to be dominated by hard rock mining projects in politically developed countries, and owned by public listed mining and exploration companies (Kettle et el., 2014c). However, this does not reflect the *actual* current state of tin mining. The information bias has its roots in the obligation of public listed companies to release information on their projects and plans to the public; an obligation not imposed on private or artisanal operations, or even for state operators. In fact, the majority of new mine production has tended to come from private, state, co-operative and artisanal miners in developing countries, often utilizing placer mining (though not always). Any serious analysis of the future of tin supply must therefore address this information bias. Attempts have been made in the past to identify potential Black Swans and "known unknowns" in the tin mining industry (Sykes, 2013; Sykes and Kettle, 2014; Sykes et al., 2015).

The commercial success of tin tailings retreatment technologies would have a significant impact on the future of tin mining. Estimates suggest that tin tailings projects could contribute in excess of 35,000 t/a of new tin production (Kettle et al., 2014c), representing over 10% of global tin supply at current levels.

The South American Andes may hold hidden potential, although substantial production has only ever come from Bolivia and Peru (Kettle et al., 2014b; Thoburn, 1994). To the east, Brazil retains significant potential for both placer and hard rock mining (Angeiras and Bates, 2006). Australia has by far the most number of tin projects owned by public listed companies (Kettle et al., 2014c), and the country clearly has potential. Russia is home to many of the largest tin mine projects (Kettle et al., 2014c), with at least one substantial project currently ramping up: Pyrkakay, with the potential to produce in excess of 10,000 t/a of tin from 2017 (Konkin, 2012). However, many of the projects are extremely remote, in states in Russia's far east, or require significant refurbishment (Ryzhov, 2012).

Africa has not been much of a focus for the tin industry, and current production is a little over 10,000 t/a, or about 3% of global mine supply, and is mainly focused on the troubled Great Lakes region in the DRC. However, beyond this region the continent also has potential, with recent activity in Morocco, Egypt, and Nigeria.

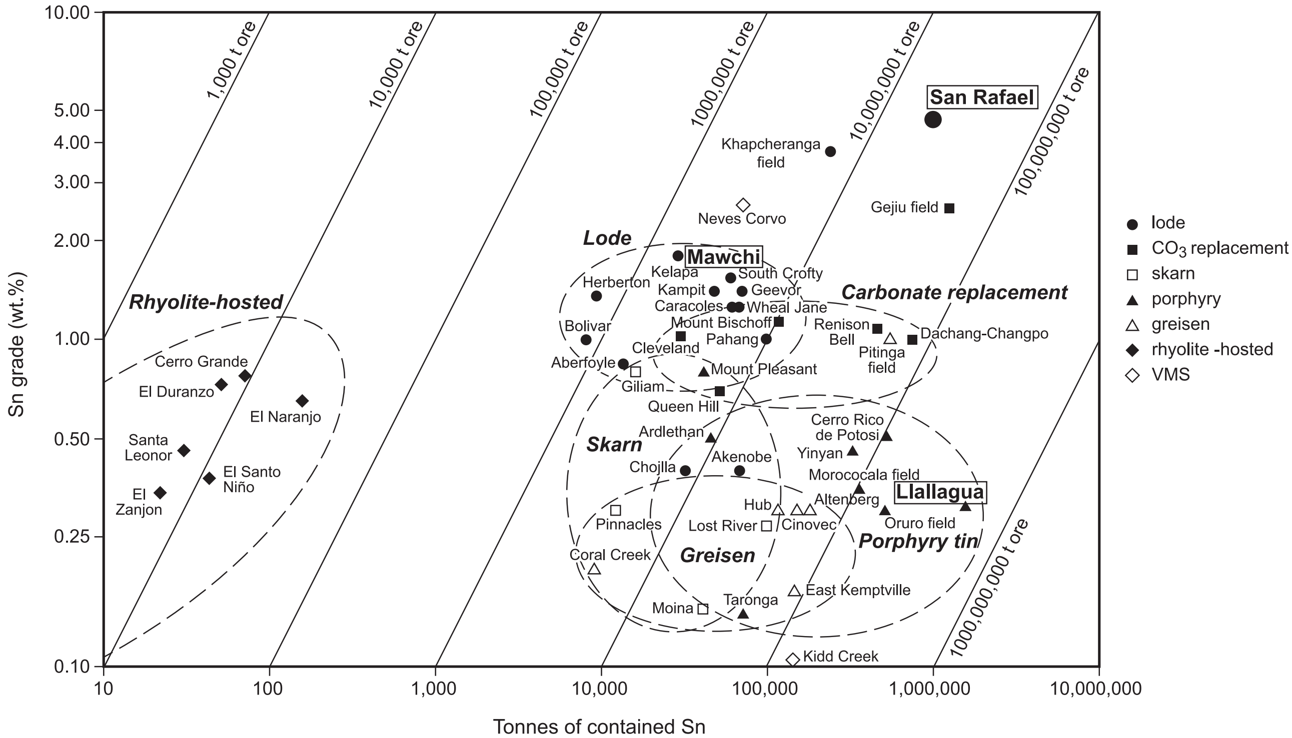

Fig. 3. Grade-tonnage plot of the major tin deposits of the World, by deposit type. After Mlynarczyk et al. (2003).

Further, hard rock mining used to occur in South Africa, where attempts are been made to re-start mining (Kettle et al., 2014c). Although the original placer deposits of both Thailand and Malaysia seem largely mined-out (Anuar and Jaafar, 2010; Kettle et al., 2014b; Thoburn, 1994), the Southeast Asian tin belt still holds some potential. The area remains largely unexplored using modern technology and geological paradigms since the collapse of the ITC effectively ended tin prospecting in these countries. The potential of hard-rock resources in these countries remains uncertain.

3.1.1. *Myanmar*

Perhaps the greatest source of uncertainty in Southeast Asia is the political and economic opening up of Myanmar (Steinberg, 2013). The country has many placer and primary tin deposits and, unlike much of the rest of Southeast Asia, these deposits have remained largely untapped on a major scale since the 1940s due to the country's political isolation (Gardiner et al., 2014). The application of modern mining and exploration technologies therefore has a great potential in Myanmar.

The Black Swan status of Myanmar was recently demonstrated, when in 2013–2014 the rapid exploitation of a previously unknown (at least to outsiders) hard rock tin resource, sited on the border with China, apparently elevated Myanmar from very minor levels of production to the status of the World's third largest tin producing country (Table 1). According to ITRI figures, the Man Maw tin mining district produced nearly 30,000 t last year (2014). Opinions remain divided about production levels in the immediate term, with ITRI forecasting 35,000 t of tin (Sn) production from Myanmar (including 2000 t of Sn not from Man Maw) for 2015, but Yunnan Tin, a major importer of tin concentrates, forecasting 24,000 t of contained Sn for 2015. China imported a massive 177,950 t of tin ores and concentrates in 2014 (gross weight), of which more than 97% was from Myanmar (Kettle et al., 2015a). There is agreement that current production levels are unsustainable and will likely decline rapidly over the next few years (ITRI, 2015; Kettle et al., 2015b). Whilst production is at these levels though, Myanmar is now one of the World's largest tin miners.

4. Tin mining activity in Myanmar

Myanmar is richly endowed in a variety of natural resources: precious and base metals, gemstones, and hydrocarbons (Chhibber, 1934; Gardiner et al., 2014; Soe Win and Marlar Myo Myint, 1998; United Nations, 1996). It has one of the most diverse collections of natural resources in Southeast Asia, and hosts at least three mineral deposits of global significance, as measured by reserves: Bawdwin (lead–zinc–silver); Monywa (copper); and Mawchi (tin–tungsten). Until the late 1930s Myanmar was a major global producer of lead, silver, tin and tungsten, however much of this industry was destroyed during World War II, and in the following two decades. While there is some recent history of exploration and exploitation of mineral deposits within Myanmar, it remains poorly understood and underdeveloped with regards its natural resources (e.g. Cox et al. (1981), Moores and Fairbidge (1997)). The country holds enormous minerals potential.

4.1. *Geological background*

Tin granites globally host major global deposits of tin as well as tungsten, uranium, lithium and other critical metals such as indium, tantalum–niobium, and the rare earth elements. However, such tin deposits are relatively uncommon on a global scale, and tend to have formed in provinces that are specific in terms of their secular and geological setting. Globally, over 95% of historic tin production has been derived from three major areas: Southeast Asia; the Bolivian Andes; and Southwest England, Germany and the Czech Republic in Europe (Lehmann, 1990). A grade-tonnage plot for selected global tin deposits reveals that most mined occurrences typically contain less than 10,000 t of contained metal at grades less than 1 wt% Sn (Fig. 3). The most common deposit types are lode-vein and greisen systems that are typically small in terms of their tin inventory but are often of high-grade, making them

amenable to small-scale selective mining practices. By contrast, porphyry tin deposits, such as those that typify the Bolivian tin belt, are less abundant globally and generally of a lower-grade, but contain total tin resources in the range 100,000–1,000,000 t of contained Sn metal. The San Rafael tin–copper deposit in Peru stands out because of both its exceptional grade and its significant

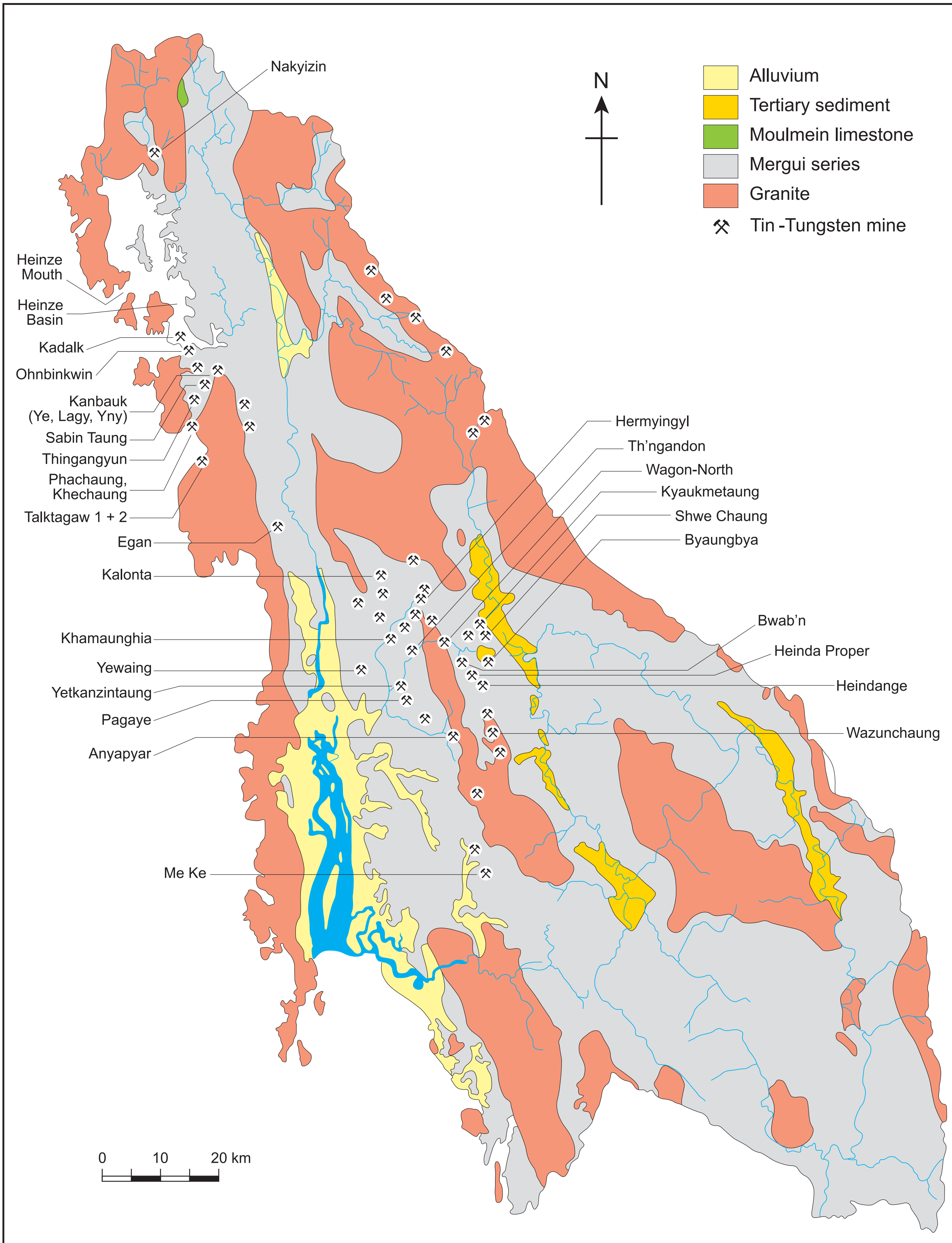

Fig. 4. Map detailing the main historic tin–tungsten mines of the Dawei area.

size. Also highlighted is the Mawchi Mine in Myanmar, which as well as being an historically dominant tungsten producer, is also a significant lode-based tin deposit grading at nearly 2 wt% Sn.

4.2. Major tin producing areas in Myanmar

The tin deposits of Myanmar, Malaysia and Thailand are directly related to the intrusion of a series of granite belts that run broadly N–S for 100 s kms across much of Southeast Asia. Collectively, these belts have been responsible for some 54% of total global tin production (Schwartz et al., 1995), making them the world's premier tin producing region. In Malaysia and Thailand, tin production was largely accomplished through industrial-scale river- and coastal-dredging of alluvial deposits. In Myanmar, however, there are extensive primary deposits alongside the products of weathering of the host rocks: elluvial (in-situ) and alluvial placers (transported and deposited) placers.

Myanmar tin production has been focused in a belt from the east of Yangon extending southwards along the Myeik Archipelago, especially around the port town of Dawei (Tavoy) – which hosts many primary deposits – and Myeik (Mergui) in the far south – where deposits tend to be more of alluvial and elluvial-type. In this region, over 100 primary tin deposits have been historically recognized (United Nations, 1996). However, significant tin mineralization is also found elsewhere within the Western Province, including the historic Mawchi Mine in Karen State, once one of the largest global producers of tungsten as well as tin. Tin deposits have also been reported within the Shan Plateau to the east.

Although many primary deposits exist in Myanmar, the country also hosts extensive placer deposits, the products of weathering of the mineralized granites or host country rocks. This weathering, which in tropical Myanmar can produce lateritic horizons of up to 20 m in depth, produces either in-situ elluvial deposits, or alluvial concentrations of cassiterite in streams and river gravels. Such alluvial deposits are particularly advantageous for the artisanal miner. There is no primary ore to crush; they can be easily excavated using as basic a tool as a shovel, or with more mechanized techniques; and following excavation, a simple gravity separation process (e.g. a sluice or shaking table) allows recovery of tin concentrate of varying grades.

4.2.1. The Dawei tin district

In the south, tin production is centered on the port town of Dawei where over 50 historical mines have been recorded, including the famous mines at Hermyingyi, Heinda, Pagaye, Pachaung and Kalonta (Chhibber, 1934). Fig. 4 shows a map of the Dawei district with major tin mines marked, many of which were developed by the British during the mining boom of the early 20th century. The Dawei tin district hosts large, important tin–tungsten lode mines, typified by the Hermyingyi mine. However, major alluvial deposits are also worked. The Heinda Mine, 25 km NE of Dawei, is a major open-pit placer tin mine that has been continuously operated for over 100 years, and is still a major producer today. Since 1999, Heinda has been operated by Myanmar Pongpipat Co., a Thai company.

4.2.2. Shan States tin

Within the Shan States in eastern Myanmar, tin-bearing granites have been reported. Major Shan producing areas include the Man Maw tin district, Namkham, and Mu Se in the northern Shan States. Than Htun et al. (2014) reported a new tin deposit discovery in 2011 sited near Mong Ton and Mong Hsat-a relatively unexplored part of the southern Shan States close to the Thai border. The Shan States are politically and geographically more remote than the southern tin districts, and accordingly their operations tend to be less well understood. The proximity to China means much tin production tends to be exported directly over the border.

4.3. Historical framework

Artisanal mining and smelting of tin deposits by Burmese and Chinese occurred during mediaeval times, and activity was reported as early as 1599 (Chhibber, 1934). In 1839 a German geologist, Helfer (1839), reported tin-bearing veining at Wumpo near Dawei, later developed as the Egani mine. O'Riley (1862) discovered the Mawchi Mine by tracing cassiterite gravels upstream of the Kemapyu Chaung river. Between 1888 and 1892 a systematic exploration of the Dawei and Myeik tin districts was undertaken under the auspices of the Indian Geological Survey (Hughes, 1889). This survey work was later expanded, most notably under the stewardship of John Coggin Brown, with a particular focus on the geology and mineralization of the Dawei district (Coggin Brown, 1918; Coggin Brown and Heron, 1923).

Under British control, the early 20th century showed an upturn and major industrialization of the Burmese mining industry, and the tin districts did not escape attention. Major tin and tungsten mines were developed during this time largely producing for export. Myanmar was an important producer of tungsten, a strategic war material, during World War I – principally supplied by the Mawchi Mine. Much of colonial Burma was surrendered to the Japanese during the Second World War. The Japanese operated some of the major mines during the period 1942–44 (e.g. Mawchi, the Bawdwin Pb–Zn–Ag mine). However the Allies, now including the Burmese Army (General Aung San aligned with the British as part of a pact for post-war independence), reoccupied Burma in 1944–45.

The immediate post-independence Burma saw a continuation of production and export of a range of commodities, including tin and tungsten. However, in 1962, General Ne Win led a military coup entrenching the rule of the Burmese army. A significant reform was the launch of the “Burmese Way to Socialism”, which pursued the full nationalization of the Burmese economy and a policy of economic isolation from the rest of the World. The economic effects of this nationalization were profound: many commodities only became available on the black market. By 1967 a country that once was the largest exporter or rice was unable to feed itself. As part of this act, all mines within Burma were brought under government control. This period in effect started the long decline of the mining industry and the slide into the largely artisanal operations seen today.

In 1988 Myanmar passed foreign investment legislation allowing external financial and technological investment into country. Since then, and in contrast to the minerals industry, the oil and gas sector has seen significant overseas investment. A major foreign player has been the French oil company Total, who have operated a number of offshore oil and gas installations, including the controversial Yadana gas pipeline, carrying gas from the Andaman sea into Thailand.

In 1994 a new Mining Law was put into place, repealing several colonial-era and post-independence pieces of legislation. The new law allowed prospecting, exploration and the granting of production permits.

4.4. The current industry

4.4.1. Challenges in sourcing tin production statistics

Reliable tin mine production figures for Myanmar from the mid-20th century to present are difficult to ascertain, a problem that is endemic across the tin industry. The large amount of tin sourced from artisanal and state producers makes estimating tin

production very difficult, and the most reliable global figures compiled for tin mining are provided by the USGS (e.g., United States Geological Survey (USGS), 1994; 2014; 2015) and ITRI (e.g., Kettle et al., 2014b). Even for the USGS and ITRI, compiling figures is challenging. At a global level, ITRI believes only three major tin producing countries publish reliable government data on tin mining and smelting: Bolivia, Peru and Malaysia (P. Kettle, Personal communication, 2015). Of the major tin producing countries, Australia produces the most reliable data, where industry-reported figures can be verified against those produced by the Australian government's Office of the Chief Economist.

China has historically had two sources of government data for its tin mining activity: the China Nonferrous Metals Industry Association (CNIA) and the National Bureau of Statistics (NBS). Neither is considered reliable by ITRI, and further in 2013 CNIA ceased publishing statistics. ITRI therefore has to supplement NBS data on the Chinese tin industry with more reliable global trade statistics and local expert sources, maintaining an office in Beijing to accomplish this (P. Kettle, Personal communication, 2015).

For the key tin producing regions of Indonesia and Central Africa a similar approach combining unreliable government data, with more reliable trade statistics and expert local knowledge is also required. However, data collection in Central Africa has improved dramatically in recent years, as a by-product of the ITRI Tin Supply Chain Initiative (iTSCI), which involves physically tracking sources of tin in the region.

These data cover most of the world tin mine and smelter production, however to ensure full global coverage ITRI uses the World Bureau of Metal Statistics alongside local expert knowledge to collate data on minor tin producing countries. In its use of local experts, ITRI is substantially assisted by its member companies, many of which are based in the most data-poor countries such as Indonesia and China. Nonetheless, ITRI believes production estimates from the key country of Indonesia to be amongst the least reliable (P. Kettle, Personal communication, 2015). The problem is now repeated in the key emerging tin mining country of Myanmar, where once again ITRI has to supplement unreliable government statistics with more reliable trade statistics and expert local knowledge. As a result the three largest tin mining countries (China, Indonesia and Myanmar) accounting for nearly three-quarters of tin production are also the three with perhaps the least reliable data available.

Nonetheless, some data, even unreliable data (a “known unknown”), is better than no data at all (an “unknown unknown”). Thus, taking note of the above comments, recent production figures, have been estimated by both the USGS (Table 2), and by ITRI (Table 1).

4.4.2. Observations on tin mining in Myanmar based on field visits

Myanmar has the long-term potential to be a major producer of tin, and therefore efforts are underway to better understand and document its domestic industry. In the absence of reliable government and company information, local expertize remains the main source of information, and therefore in order to source such information field visits are essential to make contact with local experts and verify information (e.g. Gardiner (2015)). Below are some of the observations made by field visits to Myanmar by ITRI representatives and one of the paper authors (NJG).

Tin mining in Myanmar tends to be a seasonal activity, since water required for processing is in short supply by the end of the dry season (early April), and in excess during the summer rainy season – flooding underground workings, and making alluvial excavation impossible (Gardiner, 2015; Kettle et al., 2014a). Hence, tin production and concentration is often only operated eight months of the year, with the remaining four months as either down-time or stockpiling. This is not helped by a lack of physical and communications infrastructure.

Table 2
Recent tin and tungsten production in Myanmar (Mt). Source: USGS.

	2008	2009	2010	2011	2012
Tin, mine output, Sn content[a,b]					
Of tin ores and concentrates	800	1000	4000	11000	10600
Metal, refined	30	30	30	30	30
TOTAL	**830**	**1030**	**4030**	**11030**	**10630**
Tungsten, mine output, W content:[c]					
Of tungsten concentrate	5	4	2	n/a	n/a
Of tin-tungsten concentrate	131	83	161	140	140
TOTAL	**136**	**87**	**163**	**140**	**140**

[a] Production of tin, mine output, Sn content production as reported by the Government was, in metric tons, 2008—499; 2009—518; 2010—374; 2011—350, and 2012—350 (estimated).

[b] Data compiled from the United Nations Comtrade database for tin ores and concentrates imported from Burma by China, Malaysia, and Thailand.

[c] Data are for the production by the state-owned mining enterprises under the Ministry of Mines.

At present, there is no large-scale smelting facility within Myanmar, and tin concentrate has to be exported to Thailand, Malaysia or China. The country does have a state-owned smelter in Yangon, which has operated intermittently in recent years (ITRI, 2014a). Indonesia's state-owned, and biggest, tin miner PT Timah was planning construction of a smelter in southern Myanmar during 2015, but this project was terminated in late 2014 (ITRI, 2014b). The Ministry of Mines has invited expressions of interest from private sector firms to establish smelting and refining plants in the country.

Small-scale miners in particular suffer from rudimentary processing facilities that usually produce poor quality concentrate (Gardiner, 2015; Kettle et al., 2014a). The grade of tin concentrate is often inadequate for direct export to regional smelting facilities. Further, the tungsten richness in some of the primary deposits serves to contaminate the tin concentrate. There are reports of magnetic separation plants being operated in tin districts to cleanup the concentrate. If properly extracted, tungsten provides a valuable by-product to the tin.

4.5. The competitiveness of Myanmar tin production

Despite the basic mining processes described above, the fact that tin mine production from Myanmar is expanding rapidly, even during a period of falling prices, suggests it has a very competitive cost position towards the bottom of the cost curve. Production in this part of the cost curve would secure generous economic rents, sufficient to pay back any capital invested, even in a declining price environment. Though no solid production cost estimates exist for the Myanmar mine production due to the lack of information on the region and the newness of the operations, estimates of production costs for analogous artisanal production for high grade deposits in a developing world setting exist for the DRC, derived via the ITRI Tin Supply Chain Initiative (iTSCI). Here it is estimated the artisanal miners are paid around US$5 to US$6 per kilo of cassiterite (Kettle et al., 2015c). Pure cassiterite would contain 79% tin, so assuming clean ore and full recovery; the approximate cost per tonne of tin in pure cassiterite ore (at this stage effectively a concentrate) would be around US$6500 /t to US $7500 /t. Assumedly the artisanal miners' costs would have to be less than this, otherwise it would not be worth mining. In addition to the fee paid for cassiterite ore by local traders, there would also be smelting costs, some transport costs (usually overseas in the case of Central Africa), and potentially local taxes and fees, together adding a few thousand dollars per tonne of further costs.

However, it is plausible that total costs would remain below US $10,000/t. Again, it seems plausible that the production from Wa state in Myanmar would be in a similarly competitive cost position compared to current tin prices.

The new tin production from Myanmar is therefore likely to be at least partly responsible for the price decline itself. New supply can send a market into surplus, or at least reduce a market deficit; however, the position of the new supply on the cost curve is the main determinant of how much downward pressure is put on prices. If the new supply is marginal in cost, sitting at the end of the cost curve, the price response can be minimal, as any price falls would make the new supply uncompetitive and remove this supply from the market, creating a shortage of supply again, leading to increased prices, thus encouraging the new supply to come back on-stream. The market is self-correcting in this situation. However, if the new supply comes on stream in a lower part of the cost curve, then the more expensive, marginal supply at the top end of the cost curve is no longer required. Prices will fall and this uncompetitive supply will be removed from the market. The more the new low cost supply expands, the more marginal supply is removed from the market and greater the price fall. Dependent on the structure of the cost curve these price falls can be of varying levels. A flat cost curve suggests there is little scope for substantial price falls, and generally leads to more stable prices. However, a steep or stepped cost curve can lead to substantial prices falls. If the new low cost supply is maintained over the long term it can lead to a structural change in industry costs and thus long term prices, rather than the merely cyclical effects of removing and adding marginal cost supply.

Fig. 5 shows a cost curve for the tin mining industry in 2013 taken from Kettle et al. (2014b). The figure demonstrates that Indonesian production, both artisanal and state, makes up the majority of the marginal end of the cost curve, largely dominating the most expensive third of the cost curve. This is a result of the substantial cost inflation within the Indonesian tin mining industry over the last decade, and described earlier in this paper. The 2013 tin mine cost curve of the most recent of this kind in the public domain and suggests 90th percentile costs of around US$20,000/t and costs of about US$17,000/t at the beginning of the 4th quartile. The cost profile of the tin mining industry is not quite this clear though and some changes have occurred since 2013. First, each of the segments of the cost curve for Indonesia, represent a type of tin mine production, not a single mine site; for example: "artisanal gravel pumps", "artisanal suction boats", "state bucket ladder dredges", or "state cutter suction dredges". Though each of the segments has certain cost characteristics, because they are amalgamations of operations there is some variability of costs within each of these segments dependent on the geological quality of deposits and technical ability of various mining operations. The cost for each segment is more like a typical cost, with some operations likely more expensive and some cheaper. As such each of the steps should be seen as a "soft floor" in providing resistance to prices falls, rather than a "hard floor". As prices fall, a whole segment of production may come under economic strain, however within this segment only the most expensive operations will close, whilst the cheaper operations will remain competitive. Secondly since 2013, there has been substantial fall in oil prices, which may have assisted the state and private producers, who use unsubsidized diesel fuel, in lowering production costs by several thousand dollars per tonne of tin produced (artisanal miners saw the prices falls mitigated by the end of fuel subsidies in Indonesia), making the floor slightly lower in 2015. Finally, since 2013, exchange rate movements have been to the advantage of Indonesian miners, reducing costs on average by around US$1000/t (T. Mulqueen, Personal communication, 2015). Recent estimates from ITRI (published in May 2015), suggest that the 90th percentile is now around US$16,000/t and the

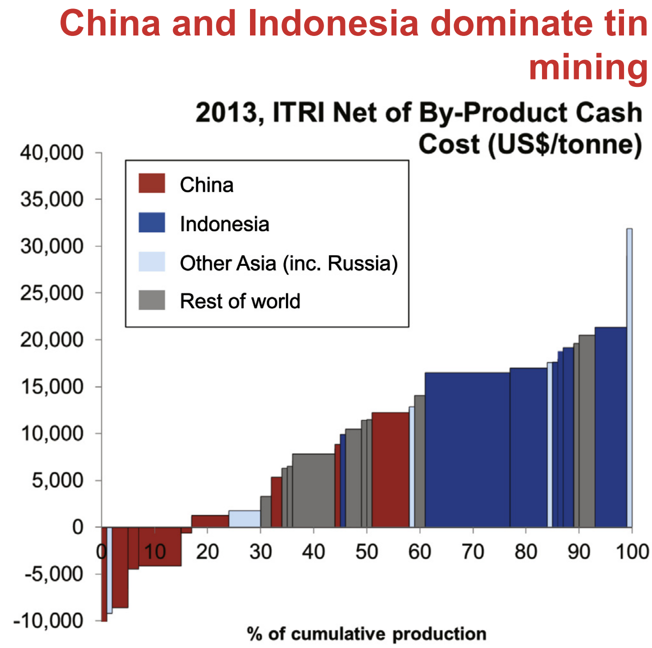

Fig. 5. Tin mining industry cost curve for 2013 provided by ITRI (Kettle et al., 2014b), showing the cost positions of the major tin miners China and Indonesia. Indonesia is the marginal cost producer in the industry. Annual tin mine production is about 300,000 t.

fourth quartile begins at about US$13,000/t (Kettle et al., 2015b).

If the new production from Myanmar, making up around 10% of global mine supply is produced at less than $10,000/t, and thus sits in a lower part of the cost curve, then this new supply will put substantial pressure on the marginal production in the industry, above the 90th percentile of the cost curve – mainly production in Indonesia, which apparently is no longer required by the market. Indeed prices do seem to have dropped to the estimated 90th percentile floor level of around US$16,000/t and there are certainly problems in maintaining profitability in Indonesian tin mining (Kettle et al., 2015a; 2015b; 2015c). If the low cost production from Myanmar is maintained this has the potential to re-shape the industry cost curve, leading to longer-term lower tin prices, and a reduced scale Indonesian industry. This of course, assumes that the new Myanmar production can be maintained over the long term, and that the Indonesia industry is unable to re-structure its cost base – neither is a certain factor. The next sections of this paper therefore discuss the scope for Myanmar maintaining this low cost new tin supply over the long term.

4.6. *Myanmar exploration activity and potential*

The current industry still relies on antiquated geologic data (Kettle et al., 2014a). By 1995 it was estimated that only 51% of Myanmar had been geologically mapped, largely on a 1 in. to 1 mile scale (e.g. Moody (1999)). Resource estimations and grades are imprecise, there being no mandated JORC-style reporting code equivalent operating within Myanmar, and units can be confusing, often mixing obsolete imperial units with metric ones. Myanmar also suffers from a lack of reliable assaying and analytical facilities, and most systematic minerals explorers export samples for routine analysis.

Over the past few decades, several international missions to Myanmar have had a broad aim of identifying potential exploration and production targets. Of note are the United Nations missions in the late 1960s to early 1970s, a German geological mission in the late 1970s, and an Australian initiative run by the Australian

Development Assistance Bureau in the 1980s. Recent private minerals exploration peaked in the mid-1990s with a flurry of activity largely driven by Australian juniors. However, this activity was extinguished by the Asian crisis of the late 1990s. Since the opening up of the country in 2011, there has been renewed interest from foreign companies, albeit again largely Australian juniors (ITRI, 2013). The Department of Geological Survey and Mineral Exploration is seeking to improve its geological database and encourage exploration (Saw Lwin, 2012). However the uncertainty over the Mining Act and the upcoming 2015 election is affecting positive investment.

5. Myanmar – the Black Swan?

In 2013–2014, ITRI estimates imply that Myanmar emerged as the World's third largest tin producer (Fig. 6A), a potentially significant breakthrough and one that surprised industry analysts. Although these are estimates-official production figures tend to be unreliable, and are based upon smelting quantities-they nevertheless imply a significant upturn in Myanmar tin production, with some 4900% increase over a 5-year period (Table 1). ITRI figures for Chinese tin concentration imports paint a similar picture (Fig. 6B), suggesting a significant uptick in imports from Myanmar that help underpin the data.

Analysis has suggested that the bulk of this new production is not sourced from the traditional tin-production regions in southern Myanmar, but instead from an emerging mining area, the Man Maw mining district, situated in Wa State, an autonomous region in the northern Shan States (Gardiner and Sykes, 2015; Kettle et al., 2014a).

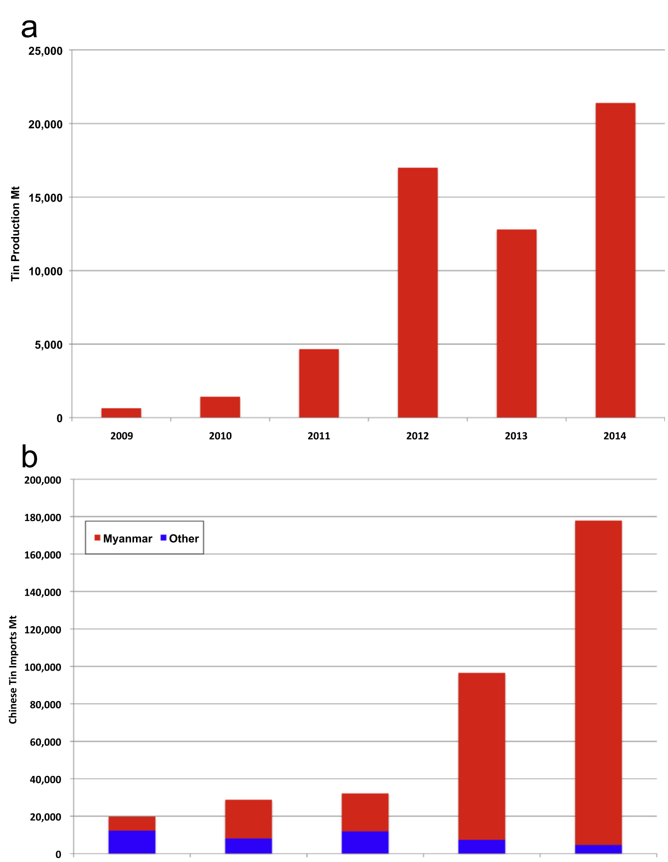

Fig. 6. A: Estimated Myanmar tin in concentrate production 2009–2014. Figures: ITRI. B: Estimated tin ores and concentrates (gross weight) imports into China 2010–2014 split between Myanmar and rest of world. Source: ITRI.

5.1. Wa State and the Man Maw mining district

The Wa State is an autonomous state in the northern Shan States, one that is not recognized by either the Myanmar Government nor international bodies. It is currently subsumed under the Wa Special Region No. 2. Fig. 7 shows a map of Wa State. Wa State is occupied and administered by the United Wa State Army (UWSA), and has an estimated population of ca. 560,000. The Wa people are ethnic Chinese, the working language is Chinese, and the Renminbi is used as a currency. The UWSA effectively runs Wa as an independent state, with its own foreign policy, and with direct business dealings with China. As such, it is probable that most revenues from the tin mining activities go straight to the Wa government, largely by-passing the central Myanmar government.

The Man Maw Mine site is thought to lie ca. 90 km from Pang Kham, the capital of Wa State (Fig. 7). It has been estimated that the mine site area has an extent of some 100 km^2, making it a significant mine within Myanmar (Cui Lin, Personal communication, 2015). Although a single mining area, it is worked by a number of small mining companies. The deposit is reported to be exclusively primary ore, grading 1–2% for the open pit operations and up to 40% for the underground. Annual production has been estimated to reach nearly 30,000 t of contained tin. Most of this production goes over the border into China, either as crushed ore (typically grading at 10% Sn), or as semi-processed concentrate (20–25% Sn).

The future of tin production at Man Maw remains uncertain. It is believed that tin mining in Wa State became active in 2010, but no official figures are available. There is little geological data available, and consequently neither the remaining reserves, nor the mine life expectancy, are known. Local facilities remain poor and roads are in a bad condition, however it is reported that some repair work is being undertaken, and that a new power station is planned. Further, at the time of writing (summer 2015), local fighting in the area has disrupted production.

6. The Myanmar business environment

At present the Burmese government in Nay Pyi Daw remains in control of much of the mining industry, a legacy of the mass nationalization in the 1960s. The Myanmar Ministry of Mines No. 2 Mining Enterprise is the government body that oversees tin and related commodities.

6.1. The Mining Act and the production sharing contract

The current mining law (Myanmar Mines Law, 1994) is currently in revision, and has been so for the past two years. One of the biggest issues with the current legislation, at least from the perspective of foreign investment, has been the Production Sharing Contract (PSC) agreement. This incorporates an agreement between the mining party and the Ministry of Mines, and, under this scheme, the Ministry acts as a non-equity partner entitled to some 32% of minerals extracted, or cash equivalent (although in some cases the exact percentage may be negotiable). In many instances the demands of the PSC is seen as over-punitive, rendering many projects uneconomic.

Other issues, for example the enshrinement of tenure, and simple conversion of exploration to production licenses, are believed to be addressed in the new mining law. This revision has, however, been anticipated for some time, and it remains unclear how much of the 1994 law will be overhauled. It is probable that the scheduled elections in November 2015 will further delay the revision, and this has created some uncertainty in the foreign investment climate.

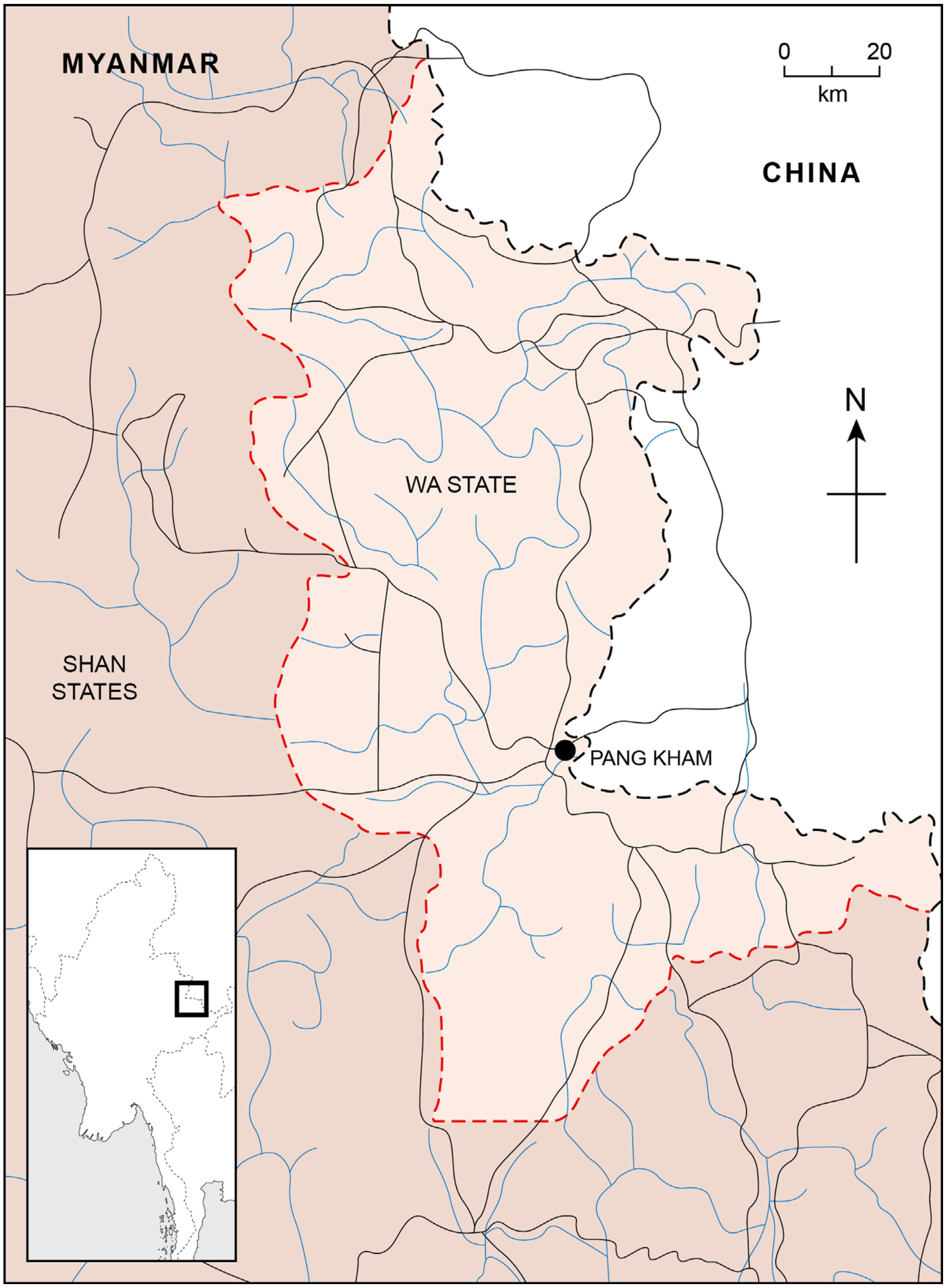

Fig. 7. Map of Wa State. The location of the Man Maw mine site is thought to be some 90 km north or west of Pang Kham.

6.2. International sanctions and exporting

In 2012 economic sanctions against Myanmar were temporarily lifted by the United States, the European Union, Australia, Canada and Japan. Limited sanctions remain, and although variable, in general exclude direct business involvement with the military, government or identified associates. The temporary lifting of sanctions was in response to perceived reforms by the government of U Thein Sein, and followed the 2010 release of Daw Aung San Suu Kyi from house arrest.

6.3. Myanmar currency

The official currency of Myanmar, the Kyat, was moved from a "dual" fixed rate system to a managed floating rate in late 2012. Previously, an official rate fixed at 6.4 MMK:USD was used for government transactions, while unofficially the currency was usually worth 800–1000 MMK:USD.

6.4. Transparency

In 2012 as part of the government reforms, Myanmar stated their plans to join the Extractive Industries Transparency Initiative (EITI), with an aim to improve transparency and accountability in its natural resources industry. The EITI is a global standard to promote open and accountable management of natural resources. In July 2014 Myanmar was formally accepted as an EITI "candidate country". It has until 2016 to produce its first EITI report and be accepted as a full member country. However, Myanmar performs poorly on the Transparency International (2013) Corruption

Perceptions Index.

6.5. International perceptions

Despite recent political and economic changes the international perceptions of Myanmar's mining and business climate remain poor, though undoubtedly they have improved somewhat. The fast-changing domestic political situation, and the lack of recent foreign investment, may mean perceptions do not match actual ground conditions, however, in the interim poor perceptions of the business and mining climate will be a hindrance to foreign investment.

Myanmar ranked in the third quartile of the Fraser Institute's 2013 "Policy Perception Index" (Wilson et al., 2014), only slightly below established mining countries such as India, South Africa and Brazil. However, if Myanmar is to compete with these countries for foreign mining investment, then it should be noted that these countries already have the advantage of incumbency, with established mines, infrastructure and foreign investment frameworks. Analyzing the constituent rankings of the Fraser Institute Survey the geological potential of Myanmar is noted, with it ranking in the second quartile globally for geological attractiveness. The problems therefore lie within the policy realm. The country ranks bottom in the survey for infrastructure provision and the quality of the geological database. The Fraser Institute Survey also highlights uncertainty over existing legislation, bureaucracy, taxation, land claims, trade barriers, political stability, security and the availability of skills as areas of concern. Myanmar is noted as one of the countries with the most "room for improvement" in policy, something which could open up the country to foreign investment, and help re-establish the domestic mining industry. Investments in infrastructure and the geological survey would appear to be critical to encourage this.

Looking beyond the mining industry specifically into the general business climate, Myanmar also performs poorly in the World Bank's (2013) "Doing Business" report and the World Economic Forum's Global Competitiveness Index. Myanmar ranks 182 out of 189 for the ease of doing business (World Bank, 2013). Particular areas of concern were the ease of starting a business; getting credit; investor protection; and contract enforcement. The report did note the corporation tax rates had improved though (World Bank, 2013). In the World Economic Forum's Global Competitiveness Index, Myanmar ranks 139 out of 148 (Schwab et al., 2013). Infrastructure, institutions, financial market development and technological readiness remain generally weak areas of the economy, however the biggest problems for doing business are thought to be lack of financing, political instability, corruption, and an inadequately educated workforce.

6.6. Environmental and social concerns

The 2013 crackdown on civilian protestors at the giant Letpadaung copper prospect, resulting in the injury of 9 protestors and the death of one, led to international condemnation, civil action, and a government inquiry chaired by Daw Aung San Suu Kyi. Letpadaung was originally part of the Monywa copper concession, but was never developed by then-owners Ivanhoe Holdings. Monywa, one of the largest copper deposits in Southeast Asia, was divested by Ivanhoe Holdings in 2011 and the operational mine is now co-owned by the Union of Myanmar Economic Holding Ltd (MEH, a company associated with the Burmese military), Wanbao Mining, a subsidiary of China North Industries, an arms manufacturer, and a minority share owned by the Burmese Government. Letpadaung is in the process of being developed, an operation that in 2012 resulted in the forced expulsion of local villagers from their land. The underlying social and human rights concerns at Letpadaung have yet to be resolved, but this case has highlighted the issue of human rights abuses associated with mining operations in the country.

Over the past two decades Myanmar has attracted a reputation for a lack of environmental and social responsibility in its mining operations (e.g. Molo Women Mining Watch Network (2012), Moody (1999)), partly a result of its rudimentary economy and its political regime. Unsubstantiated reports abound concerning mining malpractice, especially within the Jade mines in Kachin State. It is hoped that external investment combined with a better oversight of mining operations can only serve to improve matters.

7. Myanmar: the future

Although there are numerous tin mine projects around the world, most face geological, technical or political challenges, or a multitude of these (Fig. 3). It could therefore be expected that high tin prices supported by weak mine supply could persist into the medium- and long-term future, and there are some forecasts of this nature, at least under some scenarios (Kettle et al., 2011; 2014b). However, because tin production is characterized by opacity with many of the key mining regions in China, Southeast Asia, Russia, South America and Africa defying detailed economic analysis (Sykes, 2013; Sykes and Kettle, 2014), there has always been the potential for substantial new supply coming from one of these areas to re-balance the tin market – a "Black Swan" or "known unknown" (Sykes, 2013; Sykes and Kettle, 2014).

Over the last two years it has become apparent that Myanmar is the source of this new, unpredicted, but not necessarily unexpected, tin supply-at least in the short term (Table 1). However, the longer-term potential of Myanmar's resurgent tin mining industry is less clear (ITRI, 2015; Kettle et al., 2015b), and to an extent is within the hands of the country itself.

7.1. The potential of Myanmar's tin industry

Once one of the richest countries in Southeast Asia, after a long period of political and economic isolation, Myanmar now stands as the poorest. Myanmar's mining industry is currently estimated to represent less than 0.1% of its US$53 billion economy (CIA, 2013), being worth US$62 million in 2010 (ICMM, 2012). Given the country's extraordinary potential wealth in natural resources, this represents an industry that is currently hugely underdeveloped.

In Myanmar, mining in general, and tin mining in particular, has the potential to materially contribute to economic rehabilitation and growth. The recent activity at the Man Maw mine operation alone has the capability to add a further US$450 million annually to Myanmar's mining industry.[1] Although this would represent a seven-fold increase in the size of the mining industry, as a whole the minerals industry would still be worth less than 1% of Myanmar's GDP. The resources at Man Maw are thought to be limited and are being rapidly exploited, and at current rates production will likely last only a few years (ITRI, 2015; Kettle et al., 2015b). However, substantial undeveloped tin resources are known to exist within Myanmar. Further, given the limited exploration activity within Myanmar over the past 60 years, this inventory does not include the potentially undiscovered deposits - of which Man Maw is an obvious recent example. Therefore, in addition to the rehabilitation of known mines, the country may represent a whole new exploration search space for tin, in addition to a variety of other commodities. Of particular note is Myanmar's richness in tungsten, now considered a critical metal (British

[1] Based on production levels of 30,000 t/a of tin at prices of $15,000/t.

Geological Survey (BGS), 2012). It therefore seems plausible that despite the high political risk, which appears to be declining, Myanmar retains the potential for a significant future role in the tin industry.

7.2. Economic development via tin mining in Myanmar

The small amounts of value created from a single newly-developed tin mine highlights the problem of developing an economy through mining, and exacerbating the so-called "resource curse" (e.g., Collier (2007, 2010)). A definition of "careful exploitation" may therefore incorporate an ultimate aim to replace such depletable sub-soil assets with more sustainable and valuable assets, particularly human capital and physical infrastructure, with longer-term positive growth potential. Collier (2010) suggested a four-part process for how a country might turn its mineral riches into economic wealth, discussed below.

Firstly, discovery of natural assets involves exploration conducted to reveal as much as possible of the nation's non-renewable resource wealth, and allows a government a better appreciation of the value of its sub-soil assets. Such discovery encourages foreign investment and helps rebalance the knowledge asymmetry that developing nations often suffer from when negotiating with a more astute foreign investor. This requires properly trained and equipped geological surveys. In Myanmar there is a significant lack of properly trained local geologists with up-to-date search knowledge and technology within the country. Any effectively trained Burmese geologist is usually trained abroad, and then often stays abroad.

Capturing natural asset economic rents by the government requires appropriate taxation and support systems to be in place to ensure the government receives its fair share of the non-renewable resource revenues. Here, transparency is a priority, and schemes such as EITI discussed earlier will help. Issues surrounding sovereignty of central government, an issue currently within Myanmar as it grapples with its Union, obviously has an impact on central revenues.

Saving of the mining revenues by government requires that non-renewable resource revenues should largely be saved, rather than consumed, to create a national endowment. Norway is the global case study in this instance.

Finally, commitment to investment focused on long-term non-minerals-related growth requires appropriate mechanisms to be in place to ensure the revenues are spent on sustainable assets upon which the economy can be built and grow, such as developing human capital and physical infrastructure.

Undoubtedly not all of the tin, or indeed other mineral resources, have yet been discovered in Myanmar, and thus ideally the country needs assistance to allow it to better understand its domestic geology and metals potential. The history of geological missions operating within Myanmar has served to help improve this knowledge. However, even if further mineral discoveries are made, the country is perceived to have high political risk (Schwab et al., 2013; Transparency International, 2013; World Bank, 2013), which operates to reduce commodity unit value, and therefore total economic size of any resources discovered (as higher discount rates are applied in discounted cash flow calculations, for example). To mitigate this risk, it is therefore key that Myanmar starts to generate larger revenues from mining for a number of reasons. Such activity develops trust in a mining sector partially funded by foreign investors; it develops the capacity of the government to effectively regulate the sector; and it contributes larger tax revenues, which can contribute towards economic development in Myanmar.

With respect to building a much larger mining industry in Myanmar, tin represents a good starting point. Placer tin mines are

Table 3A
The largest mines per commodity based on estimated annual gross revenues. This table demonstrates that it is not plausible for Myanmar to build its economy entirely on growth in tin mining, as these mines are typically economically very small. The country will need to diversify into other bulk and base commodities to develop its economy via mining. Annual gross revenues are calculated based on 2013 commodity prices provided by the USGS (Anderson, 2015; Bray, 2015; Brininstool, 2015; George, 2015; Kuck, 2015; Tolcin, 2015; Tuck, 2015) multiplied by approximate annual production of the largest mine for that commodity, using data from company and independent sources (Norilsk Nickel, 2014).

Commodity	Commodity Price - 2013 (US$/t)	Largest Mine	2013Annual Production (Kt)	2013 Share of Global Production (%)	2013 Estimated Gross Revenues (US$B)	Source
Copper	7326	Escondida, Chile, BHP Billiton + others	1200	7	8.8	Brininstool, 2015; CRU
Iron Ore	7326	Yandi, Australia, BHP Billiton	71000	2	7.4	Tuck, 2015; CRU
Gold	45493241	Muruntau, Uzbekistan, Navoi MMC (estimate)	0.075	3	3.4	George, 2015; CRU
Nickel	16863	Polar Division, Russia, Norilsk Nickel	123	5	2.1	Kuck, 2015; Norilsk Nickel, 2014; CRU
Zinc	1909	Rampura Agucha, India, Vedanta Resources (Hindustan Zinc)	730	5	1.4	Tolcin, 2015; CRU
Bauxite	27	Weipa, Australia, Rio Tinto	26300	9	0.7	Bray, 2015; CRU
Lead	2143	Cannington, Australia, BHP Billiton (now South32)	220	4	0.5	Tolcin, 2015; CRU
Tin	22090	San Rafael, Peru, Minsur	23.7	8	0.5	Anderson, 2015; ITRI

capital light and quick to develop, tin is (generally) metallurgically simple to process, and Myanmar is geographically well-placed close to the world's large custom tin smelters in Thailand, Malaysia and China, meaning construction of expensive domestic downstream facilities are not yet required. The shorter development timeframe for placer tin mines would mean that capital is returned quickly in comparison to the timeframes normally expected in primary mining, which can be several years or decades (Kettle et al., 2014c). All this helps mitigate the impact of long-term exposure to high political risk and provides revenues to the government in a timelier manner.

The likely next stage of developing the country's hard rock tin resources is also relatively simple compared to many of the other hard rock resources in other mineral sectors, since even a large primary tin mine is relatively small compared to other commodities. The world's largest tin mine, San Rafael, an underground operation, can process only around one million tonnes of ore per year (Pareja, 2011), whilst the world's largest underground copper mine, El Teniente, can process around fifty times that amount (Codelco, 2011). Similarly, the processing and smelting technology for tin in oxide form is relatively straightforward for the most amenable deposits (ITRI, 2012b; Smith, 1996).

Ultimately, however, tin mining can never provide large enough revenues upon which to build an economy, as it can support neither big enough mines nor a large enough number of mines in one country. Even world-class tin mines such as San Rafael only generate a few hundred million dollars of revenues per year, much of which is then absorbed by operating and capital costs, leaving much less for tax revenues, as demonstrated in Table 3A and B. The largest bulk commodity and base metal mines (e.g., in copper and nickel) generate billions of dollars of revenues per year. Myanmar will therefore need to develop larger mines in larger commodity markets, such as base metals and bulk commodities; to build its economy on mining (Table 3A and B).

Thus, whilst the size of tin mines suggests that the country cannot be developed on the back of the tin industry alone, the simplicity of tin mining suggests that the tin industry could catalyze the development of a larger and more diversified mining industry, to the benefit of an improved national economy.

7.3. *The potential for mining in Myanmar beyond tin*

Myanmar contains substantial undeveloped and undoubtedly undiscovered resources of a range of other commodities (e.g. Gardiner et al. (2014)). A number of these commodities are genetically linked to tin, the most important of these being tungsten. There is therefore potential in Myanmar for diversification into other mined commodities, including some with the required larger market size and which host economically larger mines. Such commodities include: gold, copper, lead–zinc and silver; and Table 3B describes how Myanmar fits into these markets.

8. Summary and conclusions

Since a rapid rise in demand for tin from electronic solder in the early 2000s, the tin mining industry has struggled to provide an adequate supply response to meet this demand, leading to a period of inflated tin prices. Market analysis focusing on struggling current mine supply, a weak project pipeline and a lack of greenfields exploration suggested that this situation would continue into the future.

However, the tin industry, in comparison to other major commodity markets, is uniquely information poor, and a large number of uncertainties surrounding these forecasts are highlighted here. Amongst these is the unknown potential of the Myanmar tin industry and the political situation since the country opened up in 2012. It was therefore unpredicted, but not necessarily surprising when Myanmar emerged in 2014 to become the World's third largest tin miner. This event, a low probability, high impact event, and only perceptible in hindsight, has repercussions for the global tin market.

The increase in Myanmar production has largely come from a new tin mining district, Man Maw, situated on the Chinese border, further adding to the unexpected nature of the event. With the global tin production pipeline suffering both the decline of traditional producing areas, and evidencing a lack of recent exploration activity, Myanmar's emergence in 2014 may be a harbinger of a its potential as a major minerals jurisdiction.

Current forecasts suggest that the resurgence of the Myanmar tin industry will be short-lived, as the Man Maw deposit is being depleted. However, substantial further tin mining potential exists within Myanmar, suggesting prudent regulation and support of the nascent industry, including investment in exploration, could lead to a larger more sustainable industry. Although Myanmar's economy could not be rebuilt on the tin industry, which is too small at a global level, it could help reinvigorate a larger, diversified mining industry in Myanmar, upon which a resource-oriented economy could be constructed.

In turn, whether Myanmar is able to take advantage of its tin wealth by developing a large and sustainable tin industry, will be an important determinant on the future market balance of the tin industry. If Myanmar succeeds in rebuilding its tin industry, a major new tin region will be reestablished resolving long term

Table 3B
Notable bulk, base and precious metal commodity markets by gross market size. This table again demonstrates that it is not plausible for Myanmar to build its economy entirely on growth in tin mining, as the tin market as a whole is not very large, so even if the country were to host multiple large tin mines it could not base its economy on this activity. The country will need to diversify into other bulk and base commodities to develop its economy via mining. Annual gross market size is calculated based on 2013 commodity prices multiplied by global annual production as estimated by the USGS (Anderson, 2015; Bray, 2015; Brininstool, 2015; George, 2015; Kuck, 2015; Shedd, 2015; Tolcin, 2015; Tuck, 2015). Myanmar 2012 production figures are from USGS (2015).

Commodity	Commodity Price - 2013 (US$/t)	Global Annual Production - 2013 (Mt)	Myanmar 2012 Production (Mt)	Gross Market Size - 2013 (US$B)	Mynanmar Market Value (US$M)	Source
Iron Ore	104.9	3220	–	337.8	–	Tuck, 2015; Fong-Sam, 2014
Copper	7324	18.3	0.019	134	140	Brininstool, 2015; Fong-Sam, 2014
Gold	45493306	0.0028	0.0000001	127.4	4.6	George, 2015; Fong-Sam, 2014
Nickel	16863	2.63	0.005	44.4	84.4	Kuck, 2015; Fong-Sam, 2014
Zinc	2172	13.4	0.01	29.1	19	Tolcin, 2015; Fong-Sam, 2014
Lead	2143	5.49	0.0098	11.8	21	Guberman, 2015
Bauxite	27	283	–	7.6	–	Bray, 2015; Fong-Sam, 2014
Tin	22090	0.294	0.011	6.5	221	Anderson, 2015; Fong-Sam, 2014
Tungsten	45145	0.0814	0.00014	3.7	6.3	Shedd, 2015; Fong-Sam, 2014

supply shortage issues in the tin industry. If Myanmar fails to build a sustainable tin industry, then when the immediately accessible tin resources are depleted the tin industry will return to a period of supply uncertainty and shortage, with associated elevated and volatile tin prices.

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