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Review and Outlook of Global Mining Since 2000

Yan Weidong , Guo Juan, Xu Shuguang, Lin Bolei, Sun Chunqiang

Information Center of Ministry of Natural Resources of the PRC, Beijing, 100830, China

Abstract: Since 2000, the global mining industry has cyclically fluctuated with the world economy, and China has become the main driver of the development of the industry. The overall investment in global mineral exploration and development has been insufficient, and new discoveries have declined. The worldwide consumption of mineral products has generally increased, and the demand for new energy and new materials such as lithium and cobalt has surged. Mining companies have shifted from large scale expansions through mergers and acquisitions to asset restructuring and are investing more cautiously. The mineral resources strategy has received widespread attention, and mining regulations and policies have generally tightened. In the future, the world's mineral consumption will continue to rise. South Asia will become a hotspot for mining investments. The energy revolution and artificial intelligence will promote advancements in the global mining industry, and conflicts of interest in mining will be further escalated.
Keywords: world economy; global mining; oil; iron ore; copper

1 Introduction

Since 2000, the global economy has achieved overall growth, driven by emerging and developing economies such as China, despite the impact of a financial crisis. The global mining industry has cyclically fluctuated with the world economy. Investment in global mineral exploration and development is slightly insufficient in comparison to the needs of economic and social development; new discoveries of giant mineral deposits have decreased, and the capability to support consumption in the long term has been affected. The consumption of mineral products such as iron ore has grown rapidly, and the prices of new energy minerals and new materials such as lithium, cobalt, and rare earth elements have surged. After large scale expansion, mining companies have begun to offload non-core assets and invest more cautiously in new projects. Governments are highly interested in critical minerals, and resource nationalism and trade protectionism have posed great challenges to the development of the world's mining industry.

2 The mining industry has cyclically fluctuated with the global economy, and China has become the main driver of the development of the world's mining industry

Hyde Clark, Kondratieff, and Schumpeter et al. believe that the global economy has changed cyclically every 40–60 years since 1780; in more recent times, the world economy has experienced a cyclical crisis every 10 years since the beginning of the 19th century [1]. Since 2000, the world economy has entered a new cycle, and developed economies such as the United States and Japan as well as the European Union (EU) have slowed in terms of growth, whereas developing economies, represented by China, have achieved rapid growth. China's gross domestic product (GDP) increased from 10 trillion yuan in 2000 to 82.7 trillion yuan in 2017, that is, by a factor of

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Corresponding author: Yan Weidong, Researcher from Information Center of Ministry of Natural Resources of the PRC. Major research field is situation analysis for mineral resources in China and abroad. E-mail: wdyan@informail.mnr.gov.cn
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7.3, moving from ranking sixth in the world to second, whereas the world economy increased by a factor of 1.4 in the same period. China's per capita GDP increased by a factor of 8.3 from USD 949 in 2000 to USD 8,810 in 2017, moving from the 112th to the 70th position in the world. In the next two years, China's per capita GDP is predicted to reach the USD 10 000 mark.

The rapid development of China's economy has promoted the development of global mining. At present, China is the world's largest producer, consumer, and trading country of minerals. China's raw coal production increased by a factor of 1.6 from 1.38×10^9 t in 2000 to 3.52×10^9 t [2] in 2017, with its proportion of world production rising from 29% to 45%. Furthermore, China's crude steel production increased by a factor of 5.4 from 1.3×10^8 t to 8.3×10^8 t, with its proportion of world production rising from 15% to 49%. In addition, the production of ten nonferrous metals increased by a factor of 6.0 from 7.838×10^6 t to 5.51×10^7 t, with its proportion of world production rising from 14.5% to 43.2%. Finally, cement production increased by a factor of 2.9 from 6×10^8 t to 2.34×10^9 t, with China's proportion of world production rising from 38% to 57%.

Since 2000, the global mining industry has experienced a cycle of "depression–prosperity–depression" along with the world economy. At the beginning of the 21st century, the price of mineral products was at a historic low after a long-term decline, followed by several years in which global mining prospered. In 2008, owing to the US subprime mortgage crisis, a global financial crisis erupted and the price of mineral products slumped again. After 2009, as the global economy began to recover slowly with a loose monetary policy, investments in global mining reached a peak in 2012. Subsequently, with a deceleration in the growth of developing economies, global mining entered another adjustment period. Although the global mining industry has recovered since 2016, it is still in an adjustment period. Looking ahead, global mining is expected to experience a new round of prosperity that is driven by economic growth in Vietnam, India, and Pakistan.

3 Overall mineral exploration and development has risen, but its proportion of the world economy is still very low

Since 2000, global investment in mineral exploration and development has generally shown an upward trend. Nonetheless, owing to the cyclical fluctuations of the world economy, there have also been cyclical changes in the mining industry from rapid rises to sharp falls. In 2002, the world's investment in non-fuel solid mineral exploration continued its adjustment trend since 1997 and fell to 2 billion USD. The next six consecutive years showed growth, with investment reaching 14.6 billion USD in 2008. However, the world's investment in non-fuel solid mineral exploration was affected by the global financial crisis and decreased sharply to 8.4 billion USD in 2009. After 2010, it began to resume growth and reached a record high of 21.5 billion USD in 2012. However, investment began to decline again after 2013 and was only 7.3 billion USD in 2016. Nevertheless, investment rose again after 2017. The variation trend of global investment in mineral exploration is shown in Fig. 1.

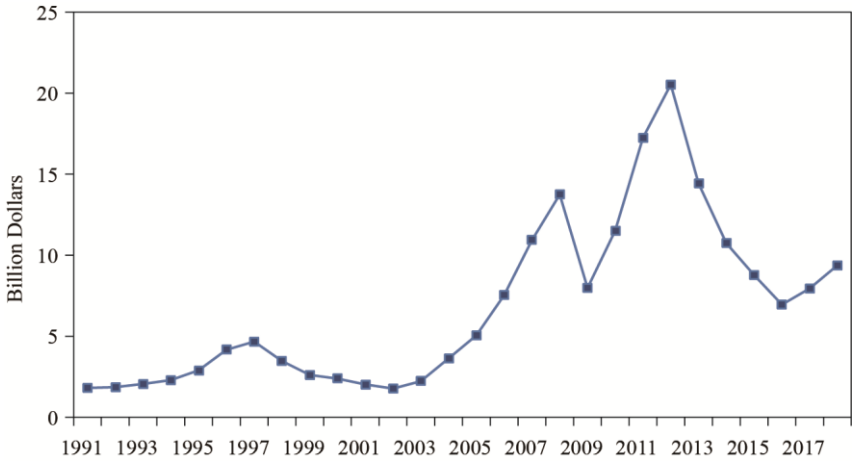

Fig. 1. Variation trend of global investment in mineral exploration.

The authors collected and sorted the major discoveries and achievements of global mineral exploration since 2000 (Table 1). The most abundant achievements of global mineral exploration were made in 2007, and the major discoveries were mainly concentrated in Congo (Kinshasa), Mongolia, Australia, Papua New Guinea, and Namibia.

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Mineral discoveries have been dominated by uranium, copper, lithium, gold, rare earth elements, potash, graphite, and so on. Moreover, copper mines are large in capacity and high in value. For example, the total value of the Pebble Project that holds copper, gold, and molybdenum in the United States is estimated to be as high as 450 billion USD.

Table 1. Major discoveries and achievements in mineral exploration in the world since 2000.

No.	Properties	Country	Deposit type	Reserves & resources	Year	Stage
1	Oyu Tolgoi	Mongolia	Porphyry	Cu 3.222 $\times10^7$ t, Au 1048 t, Ag 8000 t	2001	Operating
2	Pebble	USA	Porphyry	Cu 3.695 $\times10^7$ t, Au 3300 t, Mo 2.56 $\times10^6$ t, Ag 16 000 t	2002	Feasibility
3	Rossing South	Namibia	Alaskite	U_3O_8 5.12 $\times10^5$ t	2006	Operating
4	Carrapateena	Australia	IOCG	Cu 2.77 $\times10^6$ t, Au 130 t	2005	Construction
5	Solwara	Papua New Guinea	VMS	Cu 2.15 $\times10^5$ t, Au 16 t, Ag 90 t	2006	Feasibility
6	Tupi/Lula	Brazil	Pre-salt	Oil 8 $\times10^9$ bbl	2007	Operating
7	Kvanefjeld	Denmark (Greenland)	IOCG	REE 1.112 $\times10^7$ t, U_3O_8 2.7$\times10^5$ t, Zn 2.4$\times10^6$ t	2007	Feasibility
8	Simandou	Guinea	Sedimentary metamorphism	Iron ore 5$\times10^9$ t	2007	Feasibility
9	Mbalam	Cameroon	Sedimentary metamorphism	Iron ore 4.2 $\times10^9$ t	2007	Construction
10	Qulong	China	Porphyry	Cu 1.036 $\times10^7$ t, Mo 6.2 $\times10^5$ t, Ag 7500 t	2007	Construction
11	Kerr-Sulphurets-Mitchell	Canada	Porphyry	Cu 1.895 $\times10^7$ t, Au 3050 t, Ag 17 530 t	2008	Prefeasibility
12	Wafi-Golpu	Papua New Guinea	Porphyry	Cu 8.7$\times10^6$ t, Au 834 t	2010	Feasibility
13	Kamoa	Democratic Republic of the Congo (DRC)	Sandstone	Cu 4.249 $\times10^7$ t	2012	Feasibility
14	Balama	Mozambique	Sedimentary metamorphism	Graphite 1.51 $\times10^8$ t, V 2.7$\times10^6$ t	2013	Operating
15	Colluli	Eritrea	Sedimentary	K_2O 1.15 $\times10^8$ t	2014	Construction
16	DuoLong	China	Porphyry	Cu 1.349 $\times10^7$ t	2015	Exploration
17	HuoShaoYun	China	SEDEX	Pb+Zn 1.8$\times10^7$ t	2016	Exploration
18	Cascabel	Ecuador	Porphyry	Cu 1.09$\times10^7$ t, Au 720 t	2017	Exploration
19	Manono	DRC	Pegmatite	Li_2O 4.25 $\times10^6$ t, Tin 2.2 $\times10^5$ t, Ta 1.1 $\times10^4$ t	2017	Exploration
20	Kharmagtai	Mongolia	Porphyry	Cu 2.25 $\times10^7$ t, Au 160 t	2017	Prefeasibility

Global investment in mine development has presented a cycle from "prosperity to contraction" since 2003. According to statistics from the Swedish Raw Materials Group and Industrial Info Resources, the world's investment in mineral development grew for 10 consecutive years from 2003 to 2013; however, it declined for five consecutive years since 2013 (Fig. 2).

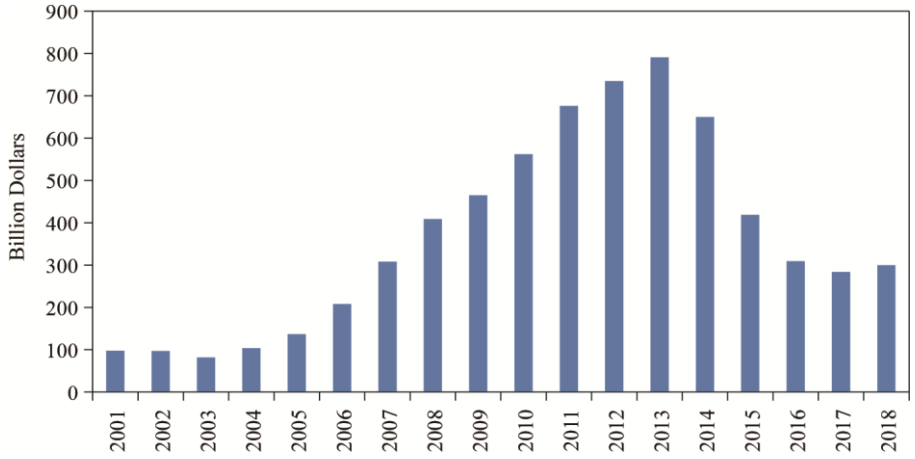

Fig. 2. Variation trend of global investment in mineral development since 2000.

Since 2000, China's investment in mineral exploration and development has also experienced a similar process from boom to contraction. From 2000 to 2012, China's investment in mineral exploration and development increased every year, reaching a peak in 2012, when investments in mineral exploration increased by a factor of 5.6 from 19.57 billion yuan in 2000 to 129.68 billion yuan in 2012. Moreover, investments in mining fixed assets increased by a factor of 21.6 from 58.94 billion yuan to 1330.08 billion yuan. However, China's investment in mineral exploration and development gradually decreased since 2012 [3].

Although the world's investment in mineral exploration and development increased in general, the industry's contribution to the world economy is still not substantial. With 2012 as an example, the world's investment in non-fuel solid mineral exploration was USD 21.5 billion, a record high, but it only accounted for 0.03% of the world's GDP in that year. Investment in mine development was USD 735 billion, accounting for only 1% of the world economy, and China's investment in mineral exploration was 129.68 billion yuan, accounting for only 0.2% of China's GDP in that year (only 0.09% if oil and gas are excluded).

4 Consumption of mineral commodities has increased in general, and new energy and new materials have experienced explosive growth

Since 2000, the global consumption of mineral commodities has shown an overall growth trend, and China has become the main driver of the global consumption of mineral commodities (Table 2).

With the rapid growth of emerging industries, the world's demand for new energy and new materials surged. In 2000–2017, the consumption of lithium carbonate increased by a factor of 2.7 from 6.5×10^4 t to 2.4×10^5 t. The consumption of cobalt rose by a factor of 2.8 from 3×10^4 t to 1.13×10^5 t. The consumption of rare earth rose from 7.9×10^4 t to 1.3×10^5 t, an increase of 65%. Similarly, China's consumption of mineral commodities for its strategic emerging industries also increased significantly. In the 2000–2017 period, China's consumption of lithium carbonate increased by a factor of 12 from 1×10^4 t to 1.25×10^5 t, accounting for 52% of the global consumption of lithium in the same period.

5 Mining companies have shifted from large scale expansions to asset restructuring and are investing more cautiously

Since 2000, mergers and acquisitions (M&As) in global mining have seen a cycle that has been characterized by rapid growth and a peak followed by a slow decline. In 2002, M&As in global mining amounted to USD 5 billion, the lowest level in nearly 20 years. It was followed by rapid growth, reaching USD 95 billion in 2006, the highest point in nearly 20 years. Subsequently, it fell rapidly; although it rebounded to USD 50 billion in 2010, the overall downward trend has not changed, and global mining amounted to only USD 15 billion in 2017 (Fig. 3).

Mining giants expanded on a large scale when the industry was booming and pursued M&As of companies and

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mine assets. However, after years of operation, particularly after the financial crisis, mining companies found that their non-core assets were not bringing profits but causing massive losses. Consequently, the mining giants began to divest from peripheral businesses and focused more on their core businesses. For example, in 2001, BHP merged with Billiton to become BHP Billiton. However, in 2014, BHP Billiton split the original Billiton assets and established a new company named South32. Vale of Brazil had a similar experience: it purchased iron ore assets from West Africa and coal mine assets from Mozambique during the mining boom; however, the two assets did not bring cash flow to the company, and a large scale reduction was initiated.

Table 2. Variation trend of consumption of primary mineral commodities since 2000.

Mineral commodities	Unit	World			China		
		Year 2000	Year 2017	Growth rate (%)	Year 2000	Year 2017	Growth rate (%)
Oil	$\times 10^8$ t	35.8	44.7	24.9	2.2	6	172.7
Gas	$\times 10^{12}$ m^3	2.4	3.7	37.0	0.0245	0.24	879.6
Coal	$\times 10^8$ t	47.3	74.7	57.9	13.6	36.5	168.4
Crude steel	$\times 10^8$ t	7.9	15.9	101.3	1.4	7.4	428.6
Copper	$\times 10^4$ t	1325	2349	77.3	193	1179	510.9
Aluminum	$\times 10^4$ t	2531	5985	136.5	340	3500	929.4
Lead	$\times 10^4$ t	560	1100	96.4	66	474	618.2
Zinc	$\times 10^4$ t	850	1420	67.1	150	700	366.7
Nickel	$\times 10^4$ t	110	218.5	98.6	5.8	110	1796.6
Tin	$\times 10^4$ t	25	35	40.0	3.96	18.4	364.6
Tungsten	$\times 10^4$ t	3	9	200.0	1.1	5.37	388.2

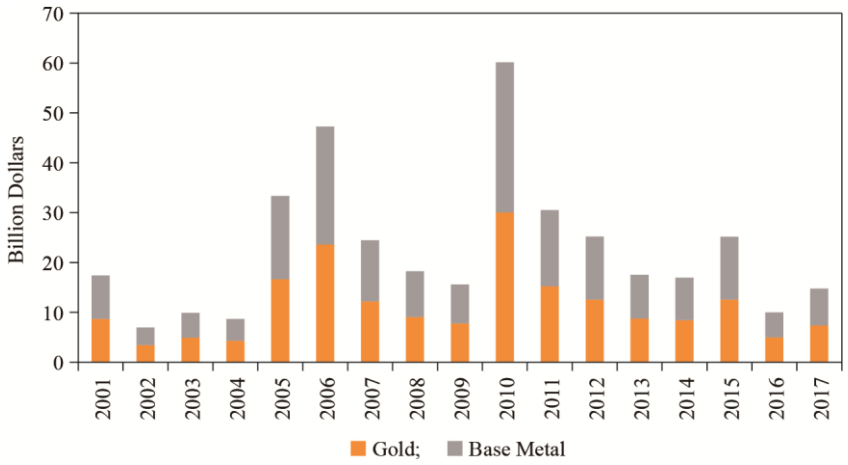

Fig. 3. Variation trend of M&As in global mining since 2000.

A research report from Morgan Stanley shows that after the 2008 financial crisis, the world's top 40 mining companies invested more than USD 1 trillion, but approximately one-third of the investments failed. Mining companies are now more cautious and no longer make investment decisions readily.

Since 2000, Chinese mining companies have gradually become an important force in the M&As of global mining. They have acquired some important mine assets in Peru, the DRC, Australia, Zambia, Tanzania, Guinea, Argentina, Canada, and other countries. These companies have had successful experiences and have learned lessons from their failures. Although some mine assets are still in dispute, China has played a major role in the global mining market.

From an industrial perspective, in the past 20 years, non-traditional oil and gas resources as well as new energy and new materials have become the main targets of M&As. Ernst & Young's latest survey results predict that M&As in mining will rebound significantly. In particular, M&As related to gaining minerals linked to new energy

and new materials, such as battery metal minerals, will increase sharply. In 2019, M&As in the global mining industry will enter a new cyclical growth cycle; large scale M&As will take place, and the amount of M&As will also increase.

6 The mineral resources strategy has received widespread attention, and mining regulations and policies have been generally tightened

Many factors, such as an ultra-long period of mining boom, the general uptrend of mineral prices, nationalism over resources, and growing trade protectionism have forced countries to pay greater attention to their mineral resources strategies.

The EU and developed countries such as the United States and Japan have released key minerals and strategic minerals catalogs to ensure the supply of energy and raw materials for high-tech industries. For example, the United States introduced a catalog of key minerals with 35 minerals (classes) in 2018, including the following: uranium, chromium, manganese, vanadium, titanium, aluminum, magnesium, cobalt, tungsten, tin, antimony, bismuth, platinum group metals, niobium, tantalum, beryllium, lithium, strontium, rubidium, cesium, zirconium, rare earth metals, scandium, germanium, gallium, indium, hafnium, rhenium, fluorite, sylvine, barite, arsenic, graphite, and helium. The EU expanded its key minerals to 27 in 2017, and China released a catalog of 24 strategic minerals in 2016 (Table 3).

Countries such as Brazil, India, South Africa, and the DRC have also studied strategic minerals and have formulated corresponding tax policies. For example, Brazil adjusted the basis of royalty levying from net sales to gross revenue and increased royalty rates. Some countries, such as the DRC, also increased the royalty rates of strategic minerals while developing a catalog of strategic minerals. In 2018, Zambia increased royalty rates (3%–9%) by 1.5% in general. Moreover, it plans to add an export tax of 15% to precious minerals (gold and gemstones) and an import tax of 5% on copper and cobalt concentrates.

Faced with the great economic and social challenges posed by the instability of the world oil market, some members of the Organization of the Petroleum Exporting Countries have started focusing on economic diversification. One of their principal interests is the development of the mining industry. For example, Nigeria has strengthened its mineral exploration and development and has invested mainly in bauxite, lead, zinc, and gold projects. Furthermore, Ecuador is becoming an important mining country; it has actively improved its mining investment environment, attracted foreign mining investment, and made significant progress in copper and gold mines.

To strengthen environmental protection, some countries have also introduced considerably strict measures, raising the standard of environmental protection in many industries, including mining. For example, El Salvador has imposed a blanket ban on metal mining; Zimbabwe has prohibited mining and ordered the withdrawal and cancellation of all existing permits for alluvial deposits near bodies of waters; Chile now stipulates that the development of large scale mines at high altitudes will be restricted by the *Glacier Protection Act*; and Peru has implemented new environmental standards since 2014, considered to be the strictest in the world, which include a reduction of the sulfur dioxide emission standard from 80 mg/m^3 to 20 mg/m^3. Some major projects have been delayed in terms of development, such as the Pebble Project in Alaska, USA, the Pascua-Lama copper and gold mine in Chile, and the Rosia-Montana Gold Mine in Romania.

Looking ahead, the global mining industry is certain to change drastically, as the global economic landscape changes. The authors consider the following development trends to be worthy of further attention and research. (1) Given the development of the world economy, the overall upward trend of global mineral resources consumption will remain unchanged and more potential uses of raw mineral materials will be explored and applied. (2) The rapid economic development of South Asian countries will attract capital, industry, and trade, and mining in this region will become a hotspot for investment. (3) The energy revolution centering on supply diversification will cause mining developments to erase limitations in the conventional power supply; moreover, independent power sources, such as solar and wind power, will provide new solutions for mining development in remote areas. (4) On the one hand, artificial intelligence will bring a new revolution to global mining, and there will be explosive demand for new energy minerals and new materials; on the other hand, mining exploration and development will become faster, safer, and more convenient, thereby allowing further exploration and development. (5) As mineral resources become more closely associated with national economies and national defense, countries with the world's major mineral resources will exercise stricter control over such resources, and conflicts of interests among governments, corporations, and communities will become more frequent.

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Table 3. Catalog of key minerals.

Mineral commodity	USA	EU	Japan	China*
Antimony	✓	✓	✓	✓
Chromium	✓		✓	✓
Cobalt	✓	✓	✓	✓
Fluorite	✓	✓		✓
Indium	✓	✓	✓	
Lithium	✓	✓	✓	✓
Niobium	✓	✓	✓	
Platinum Group	✓	✓	✓	
Potash	✓	✓		✓
REE	✓	✓	✓	✓
Tantalum	✓	✓	✓	
Tungsten	✓	✓	✓	✓

Note: * strategic minerals for China.

Source: *Final List of Critical Minerals 2018* from the Daily Journal of United States Government.

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