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China Mineral Resources

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Foreword

Under the guidance of Xi Jinping Thought on Ecological Civilization, adhere to overall development and safety, China has continuously promoted the reform of mineral resources management and green development in mining sector, and significant progress has been made in the exploration and development of mineral resources. In order to make people at home and abroad who care about and support natural resources conditions understand exploration and development, management and reform progress of mineral resources, the Ministry of Natural Resources (MNR) organized the compilation of the *China Mineral Resources* (hereinafter referred to as the Report).

This year's Report focuses on such information since 2021 as the new progress made in China's geological survey; reconnaissance, exploration and development of mineral resources, mine ecological rehabilitation and green mine construction; new changes in policies and regulations related to mineral resources; new measures taken in management of mineral resources; new scientific and technological innovation; and new achievements obtained in the international cooperation on geological and mineral resources with countries participating in the "Belt and Road Initiative". The Report presents the achievements in the field of mineral resources with a feature since the 18th CPC National Congress.

Till the end of year 2021, a total of 173 kinds of mineral resources have been discovered in China, including 13 kinds of energy minerals, 59 kinds of metallic minerals, 95 kinds of nonmetallic minerals and 6 kinds of water and gases. The year 2021 witnessed the growth of investments in geological exploration by 11.6%, of which the investment in geological exploration of non-oil-gas minerals has achieved positive growth for the first time since 2013. In 2021, 95 mineral deposits were discovered throughout China. Breakthroughs were made in oil and gas exploration in Ordos Basin, Dzungar Basin, Tarim Basin, Sichuan Basin, Bohai Bay Basin, etc. Major progress was made in the exploration of coal, gold and three rare minerals (rare earth, rare metal and rare-scattered elements).

The basic geological survey work has been continuously improved, and important progress has been made in the survey of mineral resources. The geological survey of maritime areas, the survey of oil and gas resources in maritime areas and the geological survey of ocean have been carried out continuously.

In China's mining industry, fixed-asset investment was increased, manifested by the continued growth of the production volume of major minerals, accelerated optimization of the energy consumption structure continuously, and significant achievement in the conservation and intensive and comprehensive utilization of mineral resources.

Efforts were made to prepare a plan for ecological rehabilitation of mines during the 14th Five-Year Plan period, so as to facilitate the examination of historical mines. More emphasis was put on the ecological rehabilitation of historical mines in key river basins and areas. The *Specification for Green Geological Survey and Mineral Exploration* was implemented and publicized, and projects for demonstration of green exploration were further carried out. Through looking back on green mines, construction of green mines was pushed forward with high quality.

Measures were taken to further strengthen the legislation and regulation in the field of mineral resource exploration and development, continue to promote the modification to the *Mineral Resources Law*, publish and implement the *Regulations on Groundwater Management*, enclose the professional qualifications of mineral rights appraisers in the *National Vocational Qualification Catalog (2021 Edition)*.

Formulating and implementing the mineral resources planning at all levels; standardizing the public disclosure of information on exploration and exploitation of mining rights, strengthening the construction of the integrity system in the mining sector, and enabling the national supervision and service platform for the geological exploration industry. Efforts were made to push forward the full implementation of reform measures for the management of mineral reserves, build internal supervision mechanism for mineral reserves review and calculation quality, provide supervision and guidance services, and promote the informatization of mineral resources & reserves management; the regulations on registration of the transfer of mining rights were released to make public the registration information; provisions were made to strictly normalize the approval procedure for excavation, inward and outward of paleontological fossils.

A wealth of significant scientific and technological achievements were made in the field of mineral resources; 8 national standards and 115 industrial standards were published and implemented in the field of geological and mineral resources.

Innovate the ways of international exchange and cooperation in the field of mineral resources, actively maintain contact with relevant countries and international organizations; promote practical cooperation and further consolidate friendly cooperation relations in the field of geology and minerals through exchange platforms such as China International Mining Conference, China-ASEAN Mining Cooperation Forum and Promotion Exhibition, etc.

Statistics in the Report are mainly from the MNR and the National Bureau of Statistics of the People's Republic of China. Statistics from the Hong Kong Special Administration Region, the Macao Special Administrative Region and Taiwan Province are not included in the Report.

Contents

Foreword

Chapter I Geological and Mineral Resources Surveys

and Evaluations1

I. Basic Geological Survey 1

II. Mineral Resources Surveys and Evaluations 2

III. Marine Geological Survey 4

Chapter II Mineral Resources6

I. Energy Minerals 6

II. Metallic Minerals 7

III. Nonmetallic Minerals 8

Chapter III Exploration 10

I. Investments in Geological Exploration 10

II. Progress in Oil and Gas Exploration 14

III. Progress in Exploration of Non-oil-Gas Minerals..... 15

Chapter IV Development and Utilization 16

I. Fixed-asset Investment in Mining Industry 16

II. Production and Consumption of Mineral Products 18

III. Conservation and Comprehensive Utilization of Mineral Resources 20

Chapter V Ecological Rehabilitation of Mines and Green Development	23
I. Ecological Rehabilitation of Mines	23
II. Green Exploration	24
III. Construction of Green Mines	25
Chapter VI Policies and Regulations on Mineral Resources	27
I. Laws and Regulations	27
II. Rules and Reforms	28
III. Taxes on Mineral Resources	29
Chapter VII Mineral Resources Management	30
I. Mineral Resources Planning	30
II. Geological Exploration Management	31
III. Mineral Reserves Management	32
IV. Mining Rights Management	33
V. Credit Management for Mining Right Holders	34
VI. Paleontological Fossils Protection Management.....	35
Chapter VIII Geological Data Management and Services.....	36
I. Geological Data Management System	36
II. Geological Data Collection	37
III. Geological Data Services	37
Chapter IX Scientific and Technological Innovations in Mineral Resources	40
I. Technological Milestones in Field of Mineral Resources	40
II. Technical Standards in the Field of Mineral Resources	42
III. Technological Innovation Platforms in Field of Mineral Resources	43
Chapter X International Cooperation	45
I. Bilateral and Multilateral Cooperation Mechanisms	45
II. International Mining Cooperation Platforms	47

Chapter I

Geological and Mineral Resources Surveys and Evaluations

The level of basic geological survey work has been continuously improved. Major progress was made in the survey of important mineral resources. The evaluation was completed on the groundwater resources throughout the country. Work continued in the geological survey and oil & gas resources survey in territorial waters, and oceanic geological survey.

I. Basic Geological Survey

In 2021, with financial funds from the central government, efforts were made to complete the regional geological survey across an area of 15.90 thousand square kilometers on a scale of 1 : 50,000, the geochemistry investigation across an area of 429 square kilometers on a scale of 1 : 50,000, the gravity survey across an area of 542 square kilometers on a scale of 1 : 50,000, the airborne geophysical prospecting along 23 thousand kilometers, and the regional gravity across an area of 6000 square kilometers on a scale of 1 : 250,000.

In Wangjiang-Wuwei basin of Lower Yangtze region, Tianshan-Xingmeng tectonic belt, Gonghe basin, Ordos basin, and North China Plain, regional geological survey and comprehensive studies were carried out, and contrastive analysis was made in terms of the structural characteristics of strata and rock mass to solve key fundamental geological problems, providing basic supports for expanding prospecting idea and space.

A series of maps were prepared and released, including 1 : 2,500,000 national geological map, 1 : 1,500,000 geological maps covering six regions including North China and Northeast China, 22 pieces of 1 : 50,000 geological maps, and geological-geophysical series of maps for the Qiangtang basin.

II. Mineral Resources Surveys and Evaluations

1. Solid minerals survey and evaluation

1 : 50,000 mineral geological survey of 12 thousand square kilometers has been completed, 55 mineral exploration prospecting targets has been delineated and 11 ore-fields were newly discovered. In the area of Xuanwei in East Yunnan, 2 sedimentary rare earths target areas were identified and 1 new ore-field was discovered. In Xinjiang Ruoqiang County, through drilling verification, 1 fluor spar ore-field was discovered, and 5 fluor spar ore bodies were delineated in Xiaobaihegou Fluorite prospecting targets. One lead-zinc deposit was discovered in Nuocang South, Cuoqin County, Tibet, with 16 lead-zinc ore bodies and 9 copper ore bodies traced. One tin polymetallic ore-field was discovered in the Dayishan area of Hunan, with an average thickness of 3.43 meters of the main ore body. Major progress was made in the survey of tin in the northern part of the Xianglin mining area in Shannan district, Tibet.

2. Oil and gas resource survey and evaluation

Major progress was made in oil and gas survey and evaluation. Qianshuidi 1[#] well in Guizhou obtained an industrial shale gas flow of 11,000 m³/day in the Southern Carboniferous, making a major breakthrough in the survey of new areas, new strata and new types of shale gas. The gas testing by vertical well hydrofracturing in the Carboniferous system of the Qingdecan

1[#] well on the Qaidam Basin, Qinghai yielded 2,172 cubic meters of natural gas flow per day, establishing the Carboniferous system as the fourth petroliferous system of Qaidam Basin, and making major discoveries in oil and gas surveys in Qaidam Basin. Through the first-layer testing on the Xinyongdi 1[#] well, Zhunnan area, Xinjiang, 12,980 cubic meters of natural gas were obtained per day, and a small amount of heavy oil was found, showing a good prospecting. Chuanmudi 2[#] well intersected strong oil and gas display in the Leikoupo formation, Triassic System in southwest Sichuan.

3. Geothermal resource survey and evaluation

Breakthroughs were made in the test on hot dry rocks in Gonghe, Qinghai, showing a key step of developing dry hot rocks. 240 groups of the terrestrial heat flow measurement were carried out through the country, including the northeast margin of Tibetan plateau, central and western Gansu and mountainous region in north-central Xinjiang.

In Xiong'an New Area, a heat recovery test was made on the 4,200 m-long gravity heat pipe, which is the longest of such pipe at home, supporting the development and utilization of geothermal resources, and technologies for efficient development and utilization of deep thermal energy. Supports were also given for the formulation, release and implementation of the *Technical Specifications for Monitoring Geothermal Mining Wells and Recharge Wells in Xiong'an New Area (Trial)* and the *Technical Specifications for Geothermal Dynamic Monitoring System and Special Monitoring Well in Xiong'an New Area (Trial)*.

4. Investigation, evaluation and monitoring of groundwater

Evaluation was made on the groundwater throughout the country. There were around 37.4 trillion m³ of fresh groundwater reservoir in China, including 35.5 trillion m³ in North China, accounting for 95% of the total; 1.9 trillion m³ in South China, accounting for 5% of the total. There were around 14.7 trillion m³ of saline groundwater reservoir in China.

The national groundwater monitoring project was completed and accepted, enabling the efficient operation and maintenance of 10,171 automatic monitoring stations.

Feature 1-1 Achievements of geological survey and evaluation of minerals since the 18th CPC National Congress

Since the 18th CPC National Congress, a series of major prospecting breakthroughs or new discoveries have been made in the geological survey of minerals, including the survey across an area of more than 700 thousand km² on a scale of 1 : 50,000, and geological work has been greatly improved. More than 2500 prospecting targets were delineated, and more than 300 new ore-fields were discovered, facilitating the formation of a batch of large mineral resources bases, including Huangyangshan graphite orefield and Malkansu manganese orefield in Xinjiang, Duolong copper orefield in Tibet, and thus greatly secure the availability of resources and the development of strategic emerging industries.

Major breakthroughs were achieved in the shale gas exploration in the Yangtze River Economic Belt, a number of shale gas exploration and development areas, such as Zheng'an in Guizhou and Yichang in Hubei, have been newly opened up. A series of major discoveries and breakthroughs were made in the oil and gas survey in Xinjiang, supporting the formation of new energy bases, the transfer of 25 oil and gas exploration blocks, and the rules reform on oil & gas exploration and development. Significant growth was also made in the survey of non-conventional oil & gas in the Songliao basin, contributing to the construction of national-level demonstration zone.

Surveys have been made on the shallow geothermal resources in 336 main cities, geohydrothermal resources in 31 provinces (autonomous regions, municipalities), and dry-hot-rock geothermal resources. Based on the above surveys, we have figured out the occurrence conditions, distribution characteristics, development and utilization state of geothermal resources in China, and preliminarily evaluated the amount of geothermal resources nationwide. According to the survey result, the annual recoverable amount of shallow geothermal resources was equivalent to 700 million tons of coal equivalent in 336 main cities of China, guaranteeing the heat and cool supply to 32 billion m² of buildings, and the annual recoverable amount of geohydrothermal resources was equivalent to 1.9 billion tons of coal equivalent.

III. Marine Geological Survey

1. Basic marine geological survey

Continued efforts were made in the geological survey of maritime areas under China's jurisdiction, acquiring important measured data and new geological knowledge. The 1 : 250,000 marine regional geological surveys and aerial geophysical surveys were carried out in three key areas in the East China Sea, the offshore of Hainan Island and the Zhongsha Islands. The 1 : 50,000 marine regional geological surveys were carried out in 4 key areas, including Changshan

islands, and Caofeidian, Bohai Sea, and a large-scale marine geological survey technology system was initially established. More efforts were made to summarize the achievements in the 1 : 1,000,000 marine geological surveys in the sea areas under the jurisdiction of China, compile the 1 : 2,000,000 geological map, tectonic map, topographic map, geomorphologic map, map of environmental geological factors, map of surface sediment types, basin distribution map, and the *Report on 1 : 1,000,000 Regional Geological Surveys in China's Sea Areas*. Through magnetotelluric sounding of the crust-mantle structure of the Southwestern Sub-basin, South China Sea, we obtained the electrical structure profile of residual spreading ridges up to 100 km deep, revealing the lithosphere crust-mantle structure of South China Sea for the first time. Surveys were carried out on the sand resources in the west offshore area of Gancheng-Yinggehai Town, Hainan, with an estimate of about 2.7 billion m³ of prospective resources.

2. Marine oil and gas survey

Surveys continued on oil and gas resources in new areas and new strata in the sea areas under the jurisdiction of China. Evaluation was made on 50 local structures in South Yellow Sea; 5 favorable structural traps were preferred; 1 oil and gas survey parameter well in the mesozoic erathem, Northeast of the South China Sea was targeted. 3 potential blocks for oil and gas exploration in the northern South China Sea were preferred to support the reform of the oil and gas system. Surveys were carried out on oil and gas resources in key areas of South China Sea, more efforts were made to consolidate the basic geological survey on oil and gases, and oil and gas exploration scope was expanded.

3. Deep-sea geological survey

The third round of China-Pakistan joint geological survey was completed in Indian Ocean, basic geological survey and research were systematically carried out in the exclusive economic zone of Pakistan, serving the development of an all-weather strategic partnership between China and Pakistan.

The 11th voyage of deep-sea geological survey was completed, and 27,000 km² of deep-sea rare earth prospecting targets in the Western Pacific and 50,000 km² of cobalt-rich nodules enrichment area were delineated; 4 different gradients of deep-sea rare earth reference materials were developed for declaration as national reference materials. Research was made on the mineral resources in the waters of the Arctic and key geological science issues, and the *Atlas of Marine Geology, Mineral Resources and Environment in the Arctic* were prepared.

Chapter II Mineral Resources

Till the end of year 2021, a total of 173 kinds of mineral resources have been discovered in China, including 13 kinds of energy minerals, 59 kinds of metallic minerals, 95 kinds of nonmetallic minerals and 6 kinds of water and gases.

I. Energy Minerals

Table 2-1 Reserves of Main Energy Minerals in China in 2021

No.	Minerals	Unit	Reserves
1	Coal	Billion tons	207.89
2	Oil	Billion tons	3.69
3	Natural gas	Billion m ³	6339.27
4	Coalbed methane	Billion m ³	544.06
5	Shale gas	Billion m ³	365.97

Note: The data for oil and gas (oil, natural gas, coalbed methane, and shale gas) reserves are remaining proved technically recoverable reserves as per *Classifications for Petroleum Resources and Reserves (GB/T 19492-2020)* and those of other minerals are the total of proved reserves and probable reserves as per *Classifications for Mineral Resources and Mineral Reserves (GB/T 17766-2020)*.

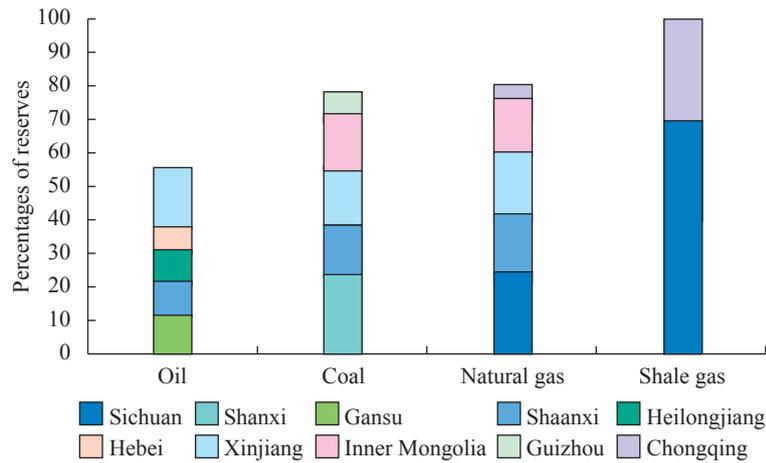


Fig. 2-1 Regional Distribution of Main Energy Minerals in China

II. Metallic Minerals

Table 2-2 Reserves of Main Metallic Minerals in China in 2021

No.	Minerals	Unit	Reserves
1	Iron ore	Billion tons	16.12
2	Manganese ore	Million tons	281.69
3	Chromite	Million tons	3.09
4	Vanadium	Million tons of V ₂ O ₅	7.87
5	Titanium	Million tons of TiO ₂	223.83
6	Copper	Million tons of metal	34.95
7	Lead	Million tons of metal	20.41
8	Zinc	Million tons of metal	44.23
9	Bauxite	Million tons of ore	711.14
10	Nickel	Million tons of metal	4.22
11	Cobalt	Million tons of metal	0.14
12	Tungsten	Million tons of WO ₃	2.95
13	Tin	Million tons of metal	1.13
14	Molybdenum	Million tons of metal	5.85
15	Antimony	Million tons of metal	0.64
16	Gold	Tons of metal	2964.37
17	Silver	Tons of metal	71783.66
18	Platinum-group metals	Tons of metal	87.69
19	Strontium	Million tons of celestite	24.64
20	Lithium	Million tons of Li ₂ O	4.05

III. Nonmetallic Minerals

Table 2-3 Reserves of Main Nonmetallic Minerals in China in 2021

No.	Minerals	Unit	Reserves
1	Magnesite	Million tons of ore	579.91
2	Fluorspar	Million tons of minerals	67.25
3	Refractory clay	Million tons of ore	284.89
4	Pyrite	Million tons of ore	1318.71
5	Phosphorite	Billion tons of ore	3.76
6	Potash	Million tons of KCl	284.25
7	Boron rock	Million tons of B ₂ O ₃	11.19
8	Sodium salt	Billion tons of NaCl	20.63
9	Mirabilite	Billion tons of Na ₂ SO ₄	37.80
10	Barite	Million tons of ore	91.55
11	Limestone for cement	Billion tons of ore	42.11
12	Glass-making siliceous rock	Billion tons of ore	1.65
13	Gypsum	Billion tons of ore	2.13
14	Kaolin	Million tons of ore	752.40
15	Bentonite	Million tons of ore	332.72
16	Diatomite	Million tons of ore	170.62
17	Veneer granite	Billion m ³	1.70
18	Veneer marble	Billion m ³	0.53
19	Diamond	Kilograms of minerals	183.19
20	Crystalline graphite	Million tons of minerals	78.26
21	Asbestos	Million tons of minerals	17.90
22	Talc	Million tons of ore	71.75
23	Wollastonite	Million tons of ore	64.39

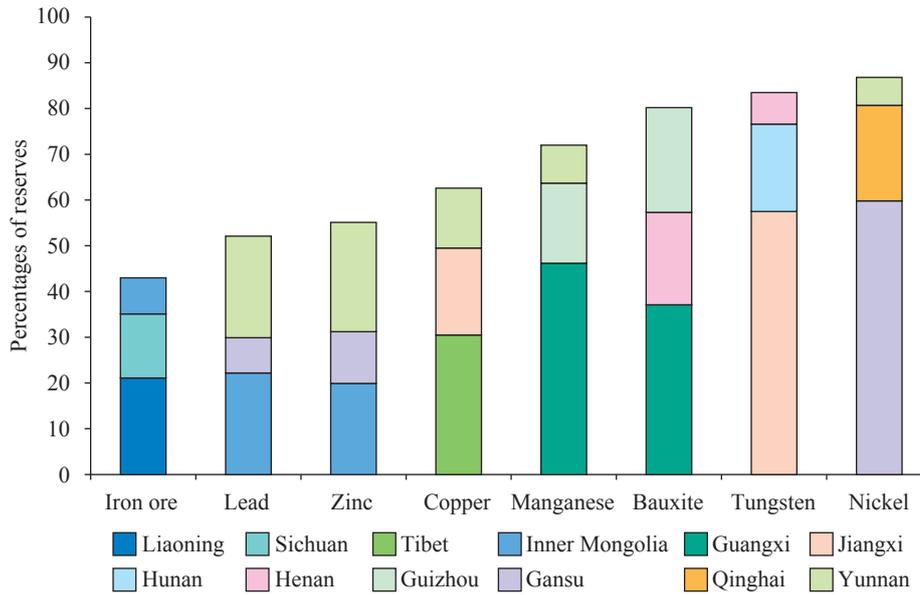


Fig. 2-2 Regional Distribution of Main Metallic Minerals in China

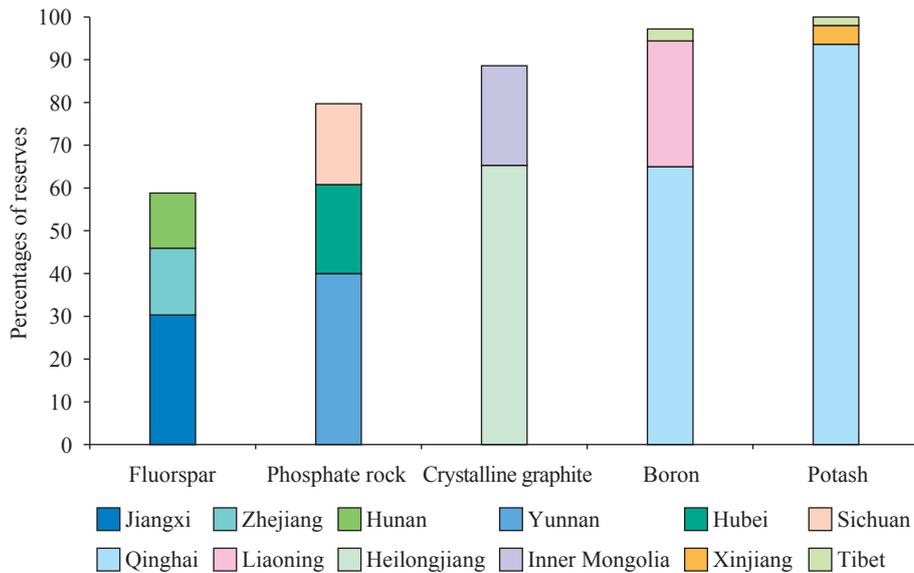


Fig. 2-3 Regional Distribution of Main Nonmetallic Minerals in China

Chapter III

Exploration

In 2021, China's investment in non-oil-gas mineral exploration increased for the first time since 2013. Breakthroughs were made in oil and gas exploration in Ordos Basin, Dzungar Basin, Tarim Basin, Sichuan Basin, Bohai Bay Basin, etc. Major progress was made in the exploration of non-oil-gas minerals including coal, gold and “three rare minerals”.

I. Investments in Geological Exploration

In 2021, the investments in geological exploration were RMB 97.29 billion in China, up by 11.6% from the previous year, including RMB 79.91 billion of investment in exploration of oil and gas, up by 12.5%; RMB 17.38 billion of investment in exploration of non-oil-gas minerals, up by 7.5%, and by 1.0% from 2019 before the outbreak of the pandemic, indicating the first positive growth since 2013 (Fig. 3-1).

2787 wells were drilled for exploration of oil and gas and the drilling footage reached 8.36 million m, down by 5.7% and 0.5% respectively; a total of 12,900-km 2D seismic data was

acquired, decreased by 57.0%; and a total of 37,700 km² 3D seismic data was acquired, decreased by 11.8%.

Among the investments in exploration of non-oil-gas minerals, the investments in mineral exploration was RMB 8.59 billion, up by 4.1% and accounting for 49.4% of the total; the investments in basic geological survey was RMB 1.33 billion, decreased by 33.2% and accounting for 7.7% of the total; the investments in hydrogeology, environmental geology and geological disaster survey and evaluation was RMB 4.59 billion, up by 33.0% and accounting for 26.4% of the total; the investments in geological science and technology and comprehensive research was RMB 2.56 billion, increased by 16.4% and accounting for 14.7% of the total; the investments in geological data service and informatization was RMB 0.32 billion, up by 15.4% and accounting for 1.8% of the total (Fig. 3-2).

Among the investments in exploration of non-oil-gas minerals, the national financial investments reached RMB 11.85 billion, accounting for 68.2% of the total, including RMB 4.21 billion from the central government, decreased by 9.1% and accounting for 24.2% of the total, and RMB 7.64 billion from local governments, increased by 19.7%, accounting for 44.0% of the total. There was RMB 5.53 billion of social investment, up by 7.4% and accounting for 31.8% of the total (Fig.3-3).

The investments in exploration of non-oil-gas minerals were dominated by coal, gold, lead-zinc, uranium and copper, totally accounting for 51.2% of total investments in mineral exploration. Compared with 2020, investments were increased in such minerals as iron ore, potash, phosphorite, and graphite. A total of 6.37 million meters of drilling was completed in the exploration of non-oil-gas minerals, a year-on-year growth of 20.6% (Table 3-1).

In 2021, the provincial funds invested in geological exploration reached RMB 2.57 billion, including RMB 1.76 billion in mineral exploration, which accounts for 20.5% of the total national investments in mineral exploration (RMB 8.59 billion) and 39.9% of the national fiscal investments in mineral exploration (RMB 4.42 billion). 414 mineral exploration projects were implemented, among which gold, geothermal water, copper, bauxite and

China Mineral Resources 2022

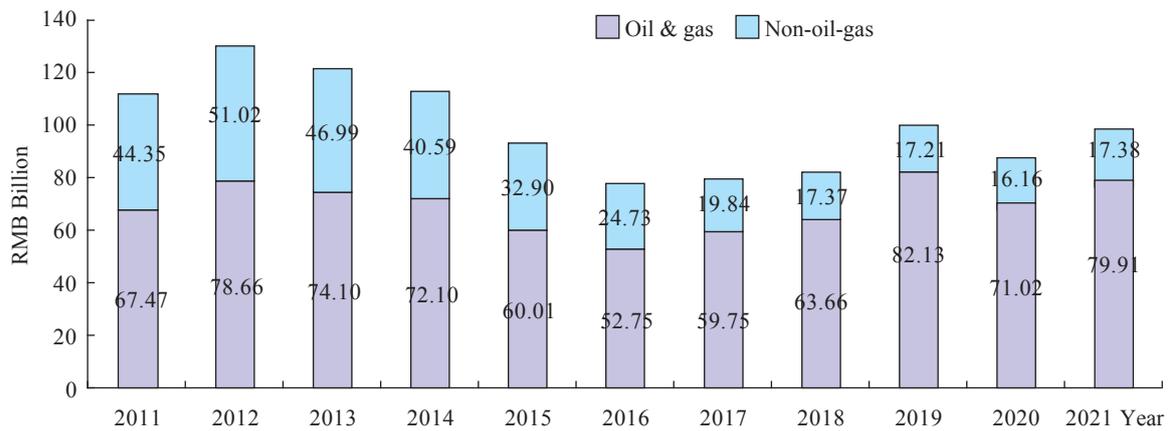


Fig. 3-1 Investment in Geological Exploration in China from 2011 to 2021

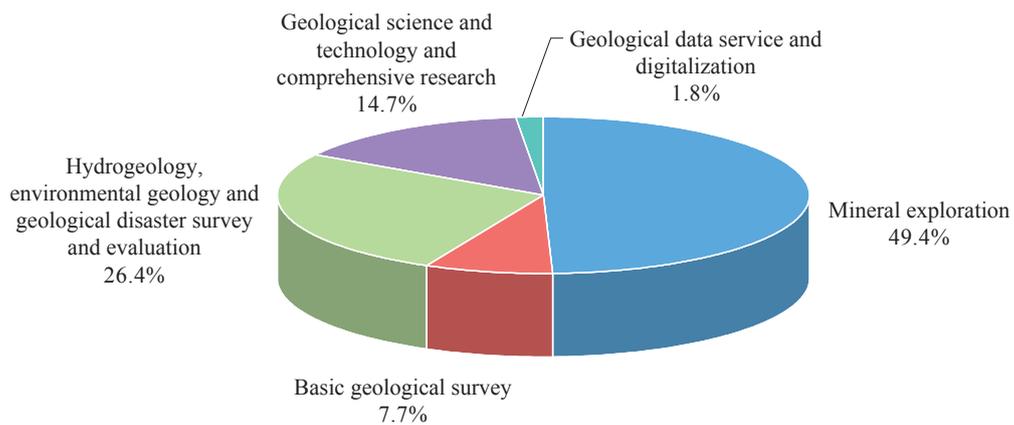


Fig. 3-2 Structure of Investment in Exploration of Non-oil-Gas Minerals (by Category)

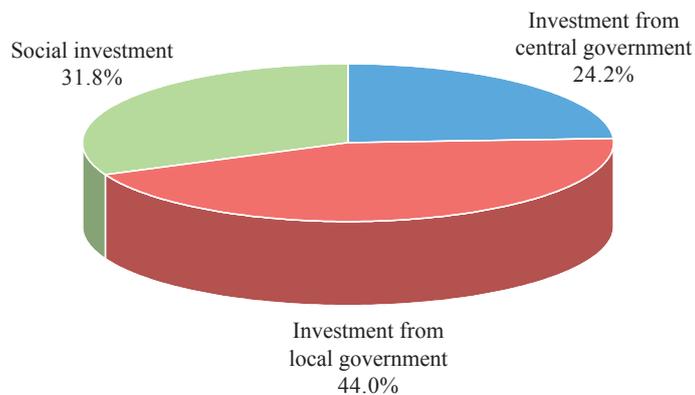


Fig. 3-3 Investment Structure of Non-oil-Gas Geological Exploration (by Fund)

Table 3-1 Investments in Exploration of Non-oil-Gas Minerals in 2021

Mineral	Investment RMB million	Year-on-year growth / %	Meters drilled million meters	Year-on-year growth/%
Nationwide	8585	4.1	6.37	20.6
Coal	1349	10.3	0.52	-46.9
Iron ore	434	75.0	0.35	75.0
Manganese ore	80	-48.1	0.04	-50.0
Copper	655	6.9	0.33	-2.9
Lead-zinc	595	-7.2	0.60	30.4
Bauxite	304	5.6	0.29	-9.4
Nickel	45	4.7	0.01	-50.0
Tungsten	158	-0.6	0.15	25.0
Tin	38	-50.6	0.04	0.0
Molybdenum	55	-6.8	0.05	25.0
Gold	1090	4.3	0.76	8.6
Silver	112	-18.2	0.08	-11.1
Phosphorite	146	18.7	0.10	11.1
Graphite	180	13.9	0.15	36.4
Potash	102	21.4	0.03	50.0

coal exploration took up the largest shares of investment in a descending order. A total of 85 mineral deposits were delineated under the provincial funds invested in geological exploration, including 35 large, 29 middle and 21 small deposits. Results mainly focused on the minerals including coal, fluorite, lead-zinc, granite for construction, cement limestone, gold, graphite and geothermal water.

II. Progress in Oil and Gas Exploration

Major breakthroughs were made in exploration in new strata, new types and new areas in Ordos Basin, Dzungar Basin, Tarim Basin, Sichuan Basin, Bohai Bay Basin and other large oil-gas-bearing basins.

1. Conventional oil and gas exploration

Progress was made in the oil and gas exploration in several basins. In the central and eastern Ordos Basin, a high-yield breakthrough was achieved in the subsalt high-pressure gas reservoir for the first time. Several exploratory wells in the eastern ring belt of Fukang Sag in the eastern Junggar Basin have achieved high yield, showing the potential of multi-layer 3D exploration in Fukang Sag. A number of wells in the Tarim Basin were characterized by high-yield oil and gas flow, and 3 new oil-gas-rich fault zones were discovered in Fuman, realizing the overall oil-bearing connection between the north and the middle of the Tarim. With the large-scale exploration of the Central Sichuan Paleohigh in the Sichuan Basin, a trillion cubic meters of gas area is emerging. The Kenli 10-2 oil and gas field in the Bohai Sea has been built into the first shallow lithology 100 million-ton oil field in China. In the Xinglong tectonic zone of the Hetao Basin, a new 100 million-ton production area with high-quality, high-efficiency and large-scale reserves has been established.

2. Unconventional oil and gas exploration

New progress was made in shale gas exploration. In relation to Sichuan Basin, evaluation was mainly made on the shale gas in Luzhou block, and 513.80 billion cubic meters of newly proven geological reserves and 769.50 billion cubic meters of newly predicted reserves, forming the first 1 trillion cubic meters of deep shale gas reserve area in China. There were 550 million tons of newly proven geological reserves in Qingcheng Chang-7 oil-bearing bed in the Ordos Basin. Major new progress was made in the unconventional oil exploration in Gulong, Daqing in the Songliao Basin, with new predicted geological reserves of 1.27 billion tons.

III. Progress in Exploration of Non-oil-Gas Minerals

A total of 95 mineral deposits were discovered throughout the country, including 38 large, 34 middle and 23 small deposits. Geothermal energy (7 deposits), veneer granite (7 deposits), limestone for cement (6 deposits), granite for construction (5 deposits) and sandstones for ceramics (5 deposits) ranked the top five minerals in terms of newly discovered mineral deposits.

Staged exploration has been completed in 338 mineral deposits in the country, including 103 general surveys, 174 detailed surveys, and 61 exploration sites. The top 5 in terms of the number of mineral deposits in which staged exploration have been completed include: coal (23 deposits), limestone for construction (20 deposits), limestone for cement (19 deposits), iron (17 deposits), and gold (12 deposits).

Chapter IV

Development and Utilization

In China's mining industry, fixed-asset investment was increased from a decline in 2021, manifested by the continued growth of the production volume of major minerals, continuously accelerated optimization of the energy consumption structure, and significant achievement in the conservation and intensive and comprehensive utilization of mineral resources.

I. Fixed-asset Investment in Mining Industry

In 2021, fixed-asset investment in the mining industry increased, from a decline, by 10.9% over the previous year, and fell by 14.1% from the same period in 2020, which was 6.0 percentage points higher than the national growth rate of fixed asset investment. The fixed-asset investment in coal, ferrous and non-ferrous metal mining increased by 11.1%, 26.9% and 1.9% respectively over the previous year, and has returned to the level before the pandemic; the fixed-asset investment in oil and natural gas mining increased by 4.2% over the previous year, but decreased by about one third from 2019; the fixed-asset investment in non-metallic mining and dressing increased by 26.9% over the previous year, maintaining a sustained growth momentum (Fig. 4-1).

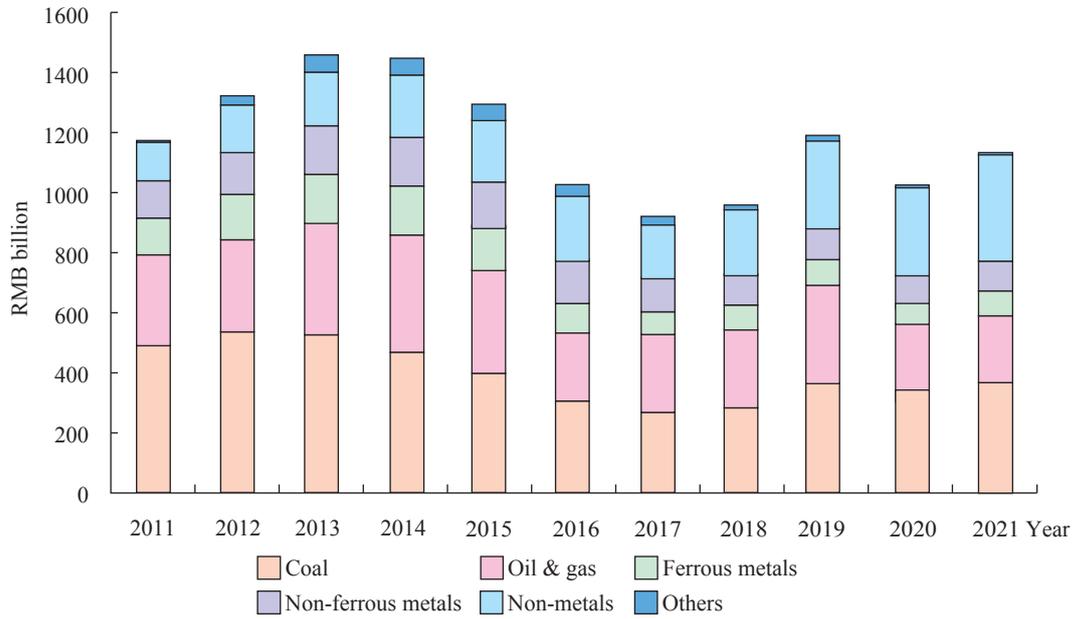


Fig. 4-1 Changes in Mining Fixed Assets Investments in China

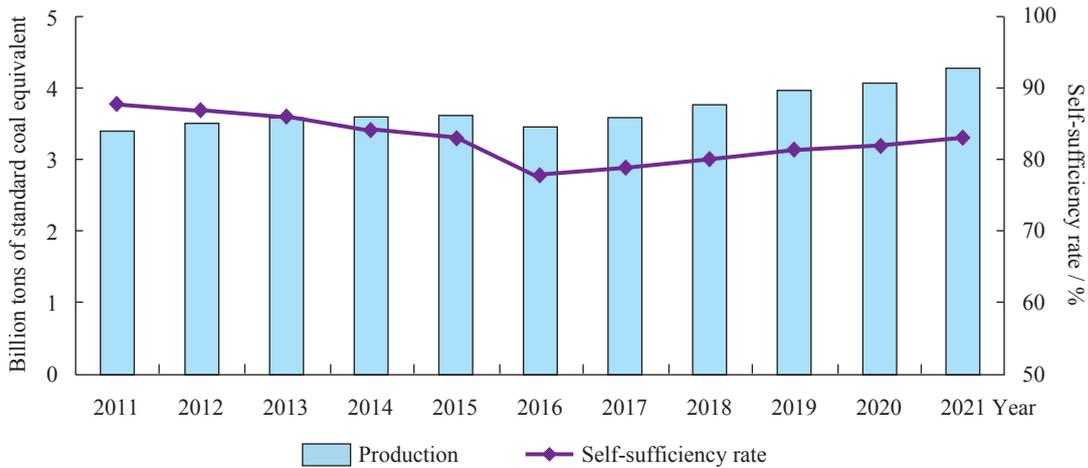


Fig. 4-2 Production of Primary Energy in China

II. Production and Consumption of Mineral Products

1. Energy

Energy production was increased in an accelerated way. In 2021, the total primary energy production reached 4.33 billion tons of coal equivalent, an increase of 6.2% over the previous year (Fig. 4-2). In the energy consumption mix, coal, oil, and natural gas accounted for 67.0%, 6.6%, and 6.1% respectively, and non-fossil energy such as hydropower, nuclear power, wind power and photovoltaic accounted for 20.3%. The total energy consumption reached 5.24 billion tons of coal equivalent, an increase of 5.2%. The energy self-sufficiency rate was 82.6%.

China's energy consumption mix has kept improving. In the energy consumption mix, coal, oil, and natural gas accounted for 56.0%, 18.5%, and 8.9% respectively, and non-fossil energy such as hydropower, nuclear power and wind power accounted for 16.6% in 2021. Compared with the past decade, the proportion of coal in energy consumption decreased by 14.2 percentage points, while the proportion of non-fossil energy such as hydropower, nuclear power and wind power increased by 8.2 percentage points (Fig. 4-3).

China produced 4.13 billion tons of coal in 2021, increased by 5.7% over the previous year, and consumed 4.23 billion tons of coal, increased by 4.6%. 199 million tons of oil were produced, up by 2.1% (Fig. 4-4), and 720 million tons of oil were consumed, up by 4.1%. 207.58 billion cubic meters of natural gas were produced, increased by 7.8%, and 369.00 billion cubic meters of natural gas were consumed, increased by 12.5%.

2. Metals

In 2021, 980 million tons of iron ores were produced, increased by 9.4% over the previous year, and the apparent consumption (domestic production + net imports) of iron ores was 1.52 billion tons (60%-grade ore); 1.04 billion tons of crude steel were produced, down by 2.8% (Fig. 4-5). Among the main nonferrous metallic minerals, the production of copper, lead and zinc in concentrates was 1.86 million tons, 1.55 million tons and 3.16 million tons, increased by 10.9%, 16.9% and 14.1% respectively. 64.77 million tons of ten non-ferrous metals were produced, an increase of 4.7%, including 10.49 million tons of refined copper (an increase of 4.6%) and 38.50 million tons of electrolytic aluminum (an increase of 3.8%).

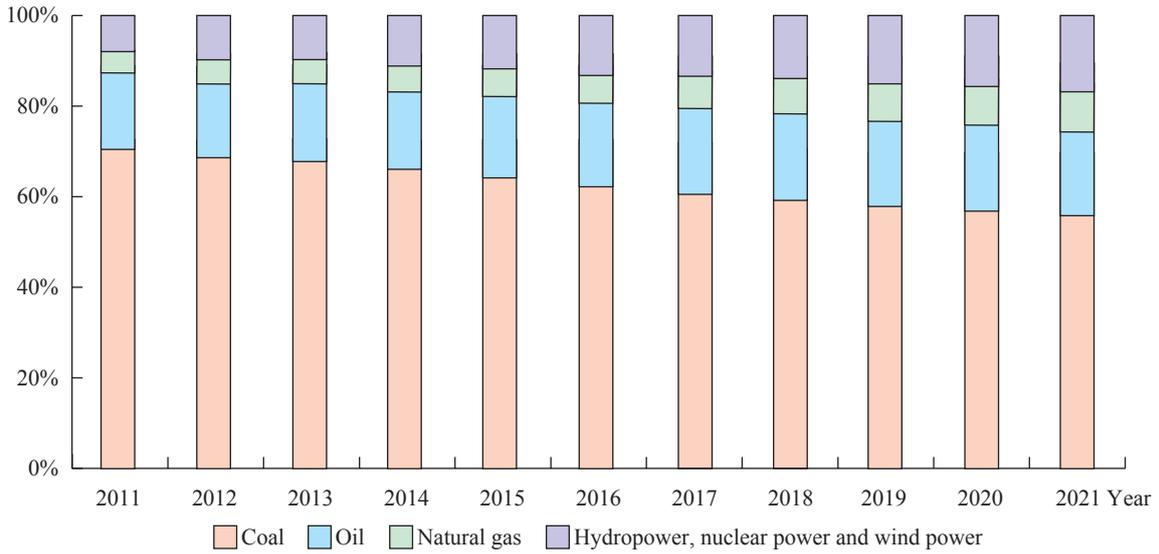


Fig. 4-3 Primary Energy Consumption Structure in China

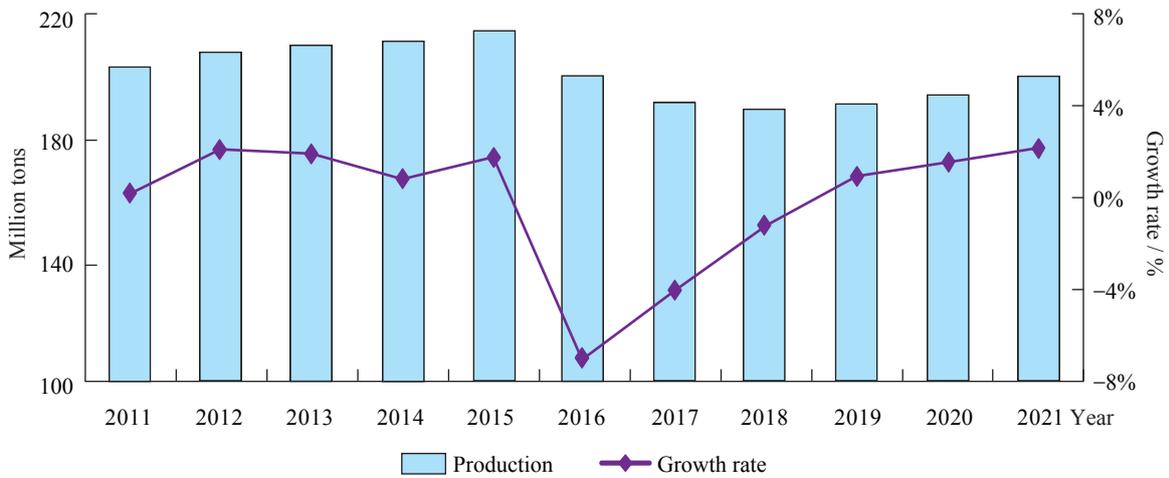


Fig. 4-4 Crude Oil Production in China

3. Nonmetals

In 2021, China produced 102.90 million tons of phosphate rocks (30% of P_2O_5), increased by 13.8% over the previous year, and 2.38 billion tons of cement, decreased by 0.4% (Fig. 4-6).

III. Conservation and Comprehensive Utilization of Mineral Resources

1. Building a complete “three rates” indicator system

The research of the “three rates” of 36 minerals such as powdered quartz has been completed. According to different deposit types, mining methods and separation processes, the minimum requirements of “Three Rates” for the rational development and utilization of mineral resources were proposed, and released. By 2022, the “three rates” had been formulated and released for a total of 124 kinds of mineral resources, initially covering all the minerals involved in the mines in production, and establishing the full “three rates” indicator system for mineral resources in China. Incorporate the “Three Rates” indicators into the construction of the standard system, and the *Letter of the General Office of the Ministry of Natural Resources on the “Three Rates” Standard Research Concerning the Rational Development and Utilization of Mineral Resources* was issued.

2. Conducting a new round of technology catalog update of advanced and applicable technologies

The *Letter on the Evaluation of Advanced and Applicable Technologies for Conservation and Comprehensive Utilization of Mineral Resources* was issued to start a new round of updating the catalog of advanced and applicable technologies. After recommendation and preliminary examination by provincial natural resources authorities, Chinese central State-owned enterprises, industry associations and units affiliated to the China Geological Survey, enterprises and research institutes, etc., and back-to-back independent evaluation by organized experts and expert group meeting, 317 advanced and applicable technologies were finally selected from the 425 recommended technologies, covering 46 geological exploration technologies, 82 mining technologies, 56 mineral processing technologies, 58 comprehensive utilization technologies, 30 green low-carbon technologies and 45 digital intelligent technologies, and *Catalog of Advanced and Applicable Technologies for the Conservation and Comprehensive Utilization of Mineral Resources (2022 Edition)* finished and announced.

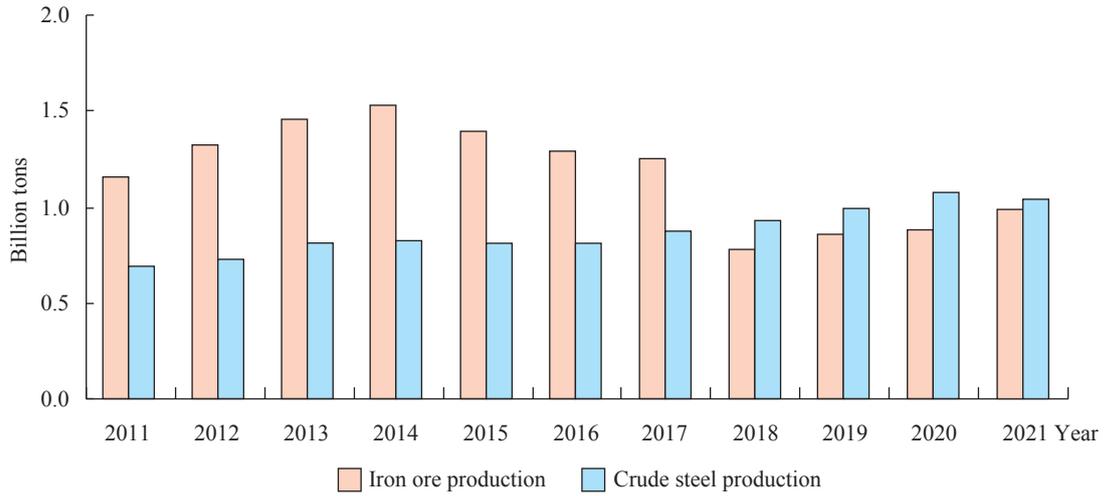


Fig. 4-5 Iron Ores and Crude Steels Production in China

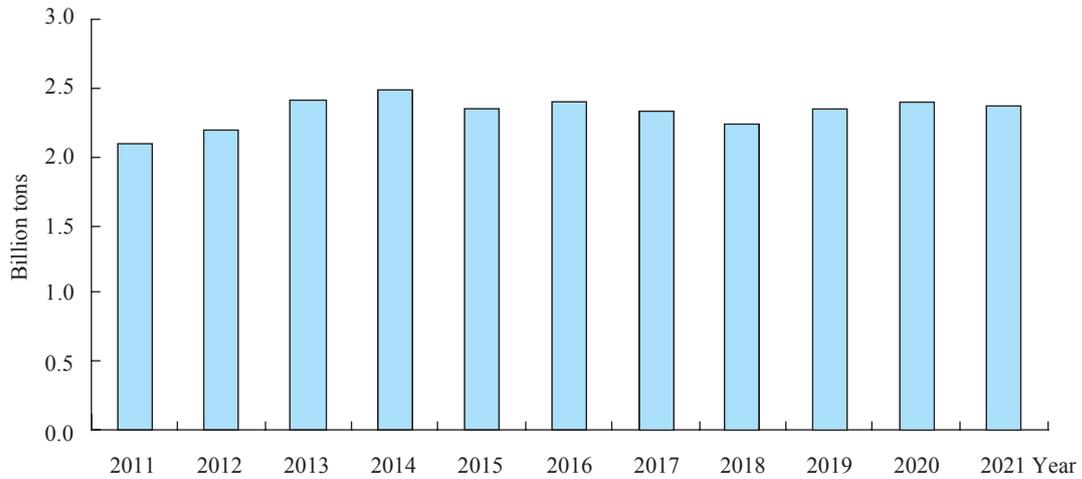


Fig. 4-6 Cement Production in China

Feature 4–1 Positive achievements in conservation and comprehensive utilization of mineral resources since the 18th CPC National Congress

Since the 18th CPC National Congress, the natural resources authority promoted the comprehensive conservation and high-efficiency utilization of China's mineral resources by implementing the decisions and arrangements of the CPC Central Committee, adhering to the basic national policy of resource conservation and environmental protection, taking resource conservation and green development as the fundamental and a series of measures, yielding positive achievements in the comprehensive utilization of mineral resources. First, the *Opinions on Promoting the Comprehensive Conservation and Efficient Utilization of Mineral Resources* were issued, which put forward specific tasks and requirements for strengthening exploration and development management, researching, developing, promoting and applying advanced and applicable technologies, giving play to the mandatory and leading role of standards and norms, and establishing long-term mechanism, and put the requirements of conservation and efficient utilization throughout the process of mineral resources exploration and development, establishing the direction for comprehensive conservation and efficient utilization of mineral resources in the future. Second, together with the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Finance, and the National Energy Administration, the *Work Plan on the Survey and Evaluation System for the Development and Utilization Level of Mineral Resources* was issued, initially establishing the survey and evaluation system for the development and utilization level of mineral resources. Third, research was made on the minimum requirements of "Three Rates" for a total of 124 kinds of mineral resources, initially covering all the minerals involved in the mines in production, establishing the full "three rates" indicator system for mineral resources in China, and laying a foundation for strengthening the comprehensive utilization, evaluation and supervision of mineral resources. Fourth, a system for publishing the catalog of advanced and applicable technologies was established. The formulation and release of the *Catalog of Advanced and Applicable Technologies for the Conservation and Comprehensive Utilization of Mineral Resources (2019 Edition)* and *Catalog of Advanced and Applicable Technologies for the Conservation and Comprehensive Utilization of Mineral Resources (2022 Edition)* played a positive role in accelerating the transformation of advanced technologies, realizing the industrial development of comprehensive utilization, and improving the utilization efficiency of mineral resources.

Chapter V

Ecological Rehabilitation of Mines and Green Development

Efforts were made to prepare a plan for ecological rehabilitation of mines during the 14th Five-Year Plan period, and carry out the inspections of historical mines. More emphasis was put on the ecological rehabilitation of historical mines in key river basins and areas. The *Specification for Green Geological Survey and Mineral Exploration* was implemented and publicized, and projects for demonstration of green exploration were further carried out. Through looking back on green mines, the construction of green mines was pushed forward with high quality.

I. Ecological Rehabilitation of Mines

1. Preparing for the long-term ecological rehabilitation of mines during and after the 14th Five-Year Plan period

Key projects concerning ecological restoration of mines were deployed in the 6 special plans under the *Overall Plan for the Major Projects of Key National Ecosystem Protection and*

Rehabilitation (2021-2035). The *Action Plan for Ecological Rehabilitation of Historical Mines During the “14th Five-Year Plan” period* was prepared. Inspections were made on historical mines throughout the country. Together with relevant departments, guidance was given for the survey and evaluation of the ecological damage and pollution of historical mines in the Yellow River watershed in the 9 provinces (regions) along the Yellow River.

2. Strengthening the ecological rehabilitation of historical mines in key river basins and areas

Guidance was provided for relevant provinces to scientifically organize the ecological rehabilitation of historical mines in the key areas of the Qinghai-Tibet Plateau and along the Yellow River. Efforts were made to strengthen project system construction and performance target management. Work continued on the exploration of the construction of a market-oriented mechanism, and typical cases on the ecological rehabilitation of mines were released at the COP15 conference of the Convention on the Conservation of Biological Diversity to guide the pilot demonstration in qualified areas. Research was carried out on such major issue as ecological rehabilitation of mines in typical areas such as the Yellow River watershed and the Lijiang River watershed. Technical specifications for ecological rehabilitation of mines (General Rules) and special rules for individual minerals were formulated.

II. Green Exploration

1. Implementing and promoting the industrial standards for green exploration

Since the *Specification for Green Geological Survey and Mineral Exploration* was implemented on July 1, 2021, actions have been taken to actively guide the formulation of local green exploration standards in Shandong, Qinghai, etc., and implement the requirements for green exploration, and adhere to the green exploration concept throughout the process of design, construction, environmental restoration, inspection and acceptance of geological exploration

projects. The *Specification for Quality Management of Geological Exploration Activities* is being modified.

2. Pushing forward the green exploration demonstration projects

In accordance with the requirements of the *Notice of the General Office of the Ministry of Natural Resources on Implementing the Green Exploration Demonstration Projects*, through selection and declaration by the provincial natural resources authority and expert review, the Ministry of Natural Resources announced the second batch of green exploration demonstration projects covering 77 projects including “Pre-Feasibility Exploration of Hot Dry Rock Geothermal Resources in Yanggao County-Tianzhen County, Shanxi Province”.

III. Construction of Green Mines

1. Actively promoting the construction of green mines in regions

26 provinces (autonomous regions, municipalities) put emphasis on the construction of green mines as a part of mineral resources management, and have issued local regulations or normative documents, such as the regulations on green mine management released by Ordos in Inner Mongolia and Benxi in Liaoning. 15 provinces (autonomous regions, municipalities) have issued local standards for green mines. 29 provinces (autonomous regions, municipalities) have issued green mine management measures, construction or action plans jointly drafted by provincial people’s governments or several departments, bureaus, commissions and offices. For example, Jiangxi issued the *Green Mine Management Measures in Jiangxi Province (Trial)*; Liaoning and Zhejiang issued the *Three-Year Action Plan for Green Mine Construction in Liaoning Province (2022-2024)* and the *Three-Year Action Plan for Further Improvement of Green Mine Quality in Zhejiang Province (2021-2023)* respectively.

2. Carrying out green mine “looking back” work

All regions need to seriously follow the standards requirements to carry out comprehensive green mine “looking back” work, and all green mines shall be verified on the spot one by one. Guiding mines with problems to develop corrective measures, rectifying immediately or within a time limit; green mines that do not meet the standard requirements and have not completed the rectification, will be resolutely removed from the national green mine list. We will rectify, improve and remove one batch of each, and comprehensively consolidate and improve the achievements of green mine construction, and continue to promote green mine construction with high quality.

Feature 5-1 Achievements in the construction of green mines since the 18th CPC National Congress

Since the 18th CPC National Congress, the construction of green mines has become an important platform and vivid practice for promoting the construction of ecological civilization in the mining field from the initiative exploration, to the pilot demonstrations, and then to the joint promotion.

In 2018, green mine construction standards and specifications were released for 9 industries including non-ferrous metals and coal, and local standards were developed and published in 15 provinces according to local conditions, showing the substantial establishment of green mine standards. National green mine selection was carried out in 2019 and 2020. There are more than 1100 national-level green mines in China. In 2020, it was planned to develop 50 green mines into demonstration zones. Since the construction of green mines, it has played a great role in promoting the conservation and efficient utilization of resources, ecological rehabilitation and governance, and building a harmonious relationship between mining communities, and contributed to the ecological civilization construction in the mining industry in practice.

Chapter VI

Policies and Regulations on Mineral Resources

The legislation and regulation have been further strengthened in the exploration and development of mineral resource, modification to the *Mineral Resources Law* continuously promoted, the *Regulations on Groundwater Management* published and implemented, new requirements for the professional qualification of mining rights appraisers regulated, and the use scope of temporary land related to geological exploration delineated.

I. Laws and Regulations

Work continued on the revision of the *Mineral Resources Law*. Since 2021, the Ministry of Natural Resources, in cooperation with the Ministry of Justice, has carried out work such as soliciting opinions, field research, expert discussions, and department coordination, and further revised and improved the *Mineral Resources Law (Revised Draft)*.

The *Regulations on Groundwater Management* was approved at the 149th executive meeting of the State Council dated September 15, 2021, published on October 29, 2021, and implemented from December 1, 2021. According to the Regulations, the competent natural resources and other departments of the State Council shall survey and monitor groundwater and carry out other related work according to the responsibilities of their divisions; the competent natural

resources and other departments of local people's governments at and above the county level shall survey and monitor groundwater and carry out other related work in the related administrative regions according to the responsibilities of their divisions.

II. Rules and Reforms

On April 11, 2022, the *Notice of the Ministry of Natural Resources, National Administration of State Secrets Protection on the Issuance of <Rules on the Management of Confidential Geological Information>* was issued to further strengthen the management of classified geological information and related regulations, which improved the policy of graded and classified management of geological information, refined the qualification of users of classified geological information and the scope of use, strengthened the confidentiality management of users and units, simplified the service process, and confirmed to inspect the management of confidential geological information, so that the management of classified geological information is consistent with the relevant requirements of the current confidentiality laws and regulations.

On November 23, 2021, the *National Vocational Qualification Catalog (2021 Edition)* was announced, specifying that mineral rights appraisers are professional qualifications for level evaluation. In May 2022, the *Notice of the Ministry of Natural Resources on the Issuance of <Tentative Provisions of the mining rights appraisers Professional Qualification System> and <Implementation Measures of the mining rights appraisers Professional Qualification Examination>* was issued to make new requirements for the professional qualification rules for mining rights appraisers, and specifying that establishment of a professional qualification rules for the level evaluation of mineral rights appraisers. The Ministry of Natural Resources is responsible for formulating the professional qualification rules for mineral rights appraisers, and guiding, supervising and inspecting the implementation of the professional qualification rules for mineral rights appraisers. CAMRA is responsible for the evaluation and management of the professional qualifications of mineral rights appraisers.

On November 4, 2021, the *Notice of the Ministry of Natural Resources on Regulating the Management of Temporary Land Use* was issued, further clarifying and specifying the details of temporary land use. Land used for temporary living rooms, temporary work sheds, exploration operations and their auxiliary works, access ways, transportation roads, etc., including the

land used for drilling and supporting facilities such as drilling well sites, supporting pipelines, power facilities, and access ways, can be defined as the scope of temporary land in the mineral resources exploration, engineering geological exploration, and hydrogeological exploration.

III. Taxes on Mineral Resources

In 2021, the national resources tax revenues, which accounted for 1.32% of the national tax revenues, totaled RMB 228.8 billion and up by 30.4% year on year. In 2021, the granting of prospecting rights, mining rights concession was 138.83 billion yuan.

The Ministry of Finance and the State Taxation Administration issued the *Announcement on Extending the Implementation Period of Some Preferential Tax Policies*, extending the implementation period to December 31, 2023 after the reduction of the shale gas tax by 30% expired on March 31, 2021.

The Ministry of Finance, the Ministry of Natural Resources, the State Taxation Administration, and the People's Bank of China jointly issued the *Notice on the Transfer of Government's Non-tax Income Including proceeds from the granting of State-owned Land Use Rights, Special Income from Mineral Resources, Sea Area Use Fund, and Uninhabited Island Use Fund to Tax Authorities for Collection*, clarifying that all the special income from mineral resources collected by the natural resources department should be transferred to the tax authorities for collection from January 1, 2022.

The *Regulations on Groundwater Management* stipulate the taxation on water resources, and require the levy of water taxes on a pilot basis on firms and individuals who extract and use groundwater. The groundwater taxes are subject to differential tax rates according to the local groundwater conditions, the type of water used and economic development, and the charge standard is reasonably raised. Where water resources taxes are levied, water fees shall not be levied; provinces, autonomous regions, and municipalities directly under the Central Government where no water taxes have been levied on a pilot basis, the charge standard for groundwater shall be higher than that for surface water. The charge standard for the areas where groundwater was over-exploited shall be higher than that for the non-over-exploited areas, and the charge standard for the areas where groundwater was seriously over-exploited shall be much higher than that for the non-over-exploited areas.

Chapter VII

Mineral Resources Management

Supports were given to push forward the formulation and implementation of mineral resource plans at all levels. The supervision and service platform was enabled for the geological exploration industry of China. Efforts were made to push forward the full implementation of reform measures for the management of mineral reserves, build internal supervision mechanism for mineral reserves review and statistic quality, and promote the construction of reserve management information systems. The regulations on registration of the granting of mining rights were released, facilitating the disclosure of the registration information of mining rights transfer. Provisions were made to strictly normalize the approval procedure for excavation, inward and outward of paleontological fossils, and replacement was made with a new term of the National Paleontological Fossil Expert Committee.

I. Mineral Resources Planning

A new round of national mineral resource plan was prepared and implemented, and actions were taken to develop mineral resource plans for 31 provinces (autonomous regions, municipalities), Xinjiang Production and Construction Corps, more than 300 prefectures and

cities, and more than 1,500 counties. The Ministry of Natural Resources issued the technical points of the *Technical Regulations for Compilation of Provincial overall Plans on Mineral Resources* and the *Key Points for Compilation of City and County level overall Plans on Mineral Resources*, as well as the *Planning Database Standards*, the *Planning Legends* and other standards. The compilation of the plans at provincial, city and county levels are pushed forward in an orderly way, and mineral resources general plans at all levels are being issued and implemented.

II. Geological Exploration Management

1. Basic situation of geological exploration sector

In 2021, there were more than 2,500 non-oil-gas exploration firms nationwide, with about 428.30 thousand employees, a year-on-year growth of 5.6%, and with a total revenue of about RMB 404.70 billion, a year-on-year growth of 22.6%. The development of non-oil-gas exploration shows the characteristics of “three increases and one decrease”: the steady increases in the size of the industry team, the total income per unit and per capita wages, and the decrease in the net value of special equipment for geological exploration.

2. National geological exploration supervision service platform launched

On December 27, 2021, the national geological exploration supervision service platform was launched. By the platform, the competent department of geological exploration regularly organized the geological exploration companies to fill in, report and publicize the latter’s basic information, geological exploration activities and other information, etc., publicize the information of supervision and inspection, implement the management of the abnormality list and the list of seriously untrustworthy entities, and establish a new regulatory mechanism based on credit constraint. As of June 30, 2022, more than 5,000 geological exploration unit accounts have been registered on the national geological exploration supervision service platform, in which 4,100 have been publicized. Positive progress has been made in the construction of the supervision service platform.

3. Supervision and management of geological disaster prevention and control activities

Oversight through the random selection of both inspectors and inspection targets and the prompt release of results for prevention and control of geological disasters was implemented nationwide. On May 2021, the Ministry of Natural Resources issued the *Notice on Oversight through the Random Selection of Both Inspectors and Inspection Targets and the Prompt Release of Results for Prevention and Control of Geological Disasters*, requiring the implementation of oversight through the random selection of both inspectors and inspection targets and the prompt release of results for prevention and control of geological disasters. In 2021, a total of 589 qualified units were randomly selected for inspection across the country, and 47 units in which problems were found in the 2020 inspection were re-examined. The inspection focuses on three aspects, including legal compliance of geological disaster prevention and control activities, management and professional capabilities, and operation safety. The inspection results showed that no obvious problems were found in 522 units, and 67 need to correct their problems.

III. Mineral Reserves Management

Actions were taken to push forward the reform of mineral reserves management. The internal monitoring mechanism was built for mineral reserves review and statistic quality. Efforts were made to promote the construction of reserve management information systems.

1. Reform of reviewing and filing of mineral reserves promoted

Comprehensive measures were taken to implement the reserve management reform requirements, supervise and track the implementation in all regions. Multi-level investigation and 5470 questionnaires were organized and collected, fully and objectively complete the evaluation report on reserves management reform. A request was proposed to the provinces where problems were found for correction within the specified period. Daily monitoring mechanism was built for the review quality, and the *Work Plan for Supervision and Guidance of Mineral Reserves Review Quality* was issued, supervision and guidance were carried out for the review of mineral reserves in some provinces. The management system for reviewing and

filing of mineral reserves was included into the “One Map of Natural Resources” platform, and national review and filing data sharing mechanism was built.

2. Statistic quality of mineral reserves under the new classification standard improved

The emerging situation and requirements of statistical work was investigated, detailed plans were formulated for the data conversion from old to new classification system, tracking guidance, joint review of data and quality control. To improve the quality of statistics and better understand domestic resources, daily monitoring mechanism was established for statistic quality, and the *Guidelines for Monitoring of the Statistic Quality of Mineral Reserves* were issued, data cleaning, on-site key inspections and comprehensive assessments were implemented in provinces, and statistics of 2021 mineral resources & reserve completed. Guidance was given to all provinces for strengthening the “Internet + Government Services”, the framework of national mineral reserves management information system designed, and the system construction started.

IV. Mining Rights Management

Reforms to streamline the government, delegate power, and improve government services have been continuously deepened on the registration of mining rights, the “Cross-provincial Registration” service and the application of electronic mining license have been promoted, so as to improve the services on mining rights.

1. Setting of mining rights

As of the end of December 2021, 10,202 exploration rights were registered nationwide, with a registered area of 2.69 million km², down by 1.6% and 2.9% year on year respectively; 32,536 mining rights were registered nationwide, with a registered area of 276,000 km², down by 6.1% and up by 7.3% year on year respectively.

2. Regulations on registration of mining rights transfer promulgated

In December 2021, the Ministry of Natural Resources issued the *Regulations on Registration of the Transfer of Mining Rights (Trial)*, specifying the mining rights transfer process at ministerial level, including block selection, procedures, the signing of contracts, registration requirements, the issuance of mining rights certificate and other operations.

3. Registration information on mining rights transfer publicized further

In 2021, 4786 pieces of public information on the registration of mining rights transfer were published via the ministry's portal website, including 1910 notices concerning transfer by tender, auction and listing, 1430 notices of results of granting by tender, auction and listing, 202 notices of agreement-based assignment, 658 notices of transfer, and 586 pieces of new mining right acceptance information.

4. Mining right governmental services level improved

In November 2021, the *Notice of the General Office of the Ministry of Natural Resources on the Requirements for Unifying the Names of the "Cross-provincial Registration" Matters under the Mining Rights-related Government Services* was issued to guide the provincial competent department of natural resources for unifying the names of the "cross-provincial registration" matters subject to the approval for exploration and exploitation of mineral resources, and to better serve the holders of mining rights.

V. Credit Management for Mining Right Holders

The annual information disclosure of exploration and development by mining rights holders, application of spot check with an oversight model of random inspection and public release, and the management of the exception list and the list of serious violations, etc., have been organized and completed. The information disclosure system has been effective in improving the efficiency of government supervision, expanding social supervision and strengthening the role of corporate credit constraints.

According to the national mining right holder exploration and mining information disclosure system, the national public disclosure rate of exploration rights in 2021 was 98.9%, and the national public disclosure rate of mining rights was 99.1%. As of the end of 2021, the spot check rate of natural resources authorities at all levels was 8% for exploration rights and 12.9% for mining rights.

By the end of 2021, 508 mining rights were included in the exception list and 55 mining rights were moved out of the exception list. There were 141 exploration rights listed in the exception list, involving 121 mining rights holders. 367 mining rights listed in the exception list, involving 360 mining rights holders.

VI. Paleontological Fossils Protection Management

Strict actions were taken to normalize the approval procedure for excavation, inward and outward of paleontological fossils. 5 excavation projects and 1 inward and outward project were approved. The identification and recovery were organized for suspected Chinese paleontological fossils intercepted abroad, and the National Inter-Ministerial Joint Conference on Comprehensive Management of Anti-smuggling and the Inter-ministerial Joint Conference on Cultural Relics Safety were assisted. 10 times of identification of involved fossils seized by public security, customs and other departments has been participated, with 1639 samples identified. The identification of suspected Chinese paleontological fossils abroad were carried out for 2 times.

Replacement was made with the new term of National Paleontological Fossil Expert Committee, the fourth National Paleontological Fossil Expert Committee was established, and the provincial paleontological fossil expert committee was established by the way of demonstration and guidance.

Chapter VIII

Geological Data Management and Services

The competent departments of natural resources and geological data collection agencies at all levels across the country continued to accumulate a wealth of geological data resources, submitted all the geological data on oil and gas, expanded the public access and sharing of geological data, and strengthened the geological data information construction.

I. Geological Data Management System

In order to further implement the requirements of the reforms to streamline the government, delegate power, and improve government services, the *Notice of the General Office of the Ministry of Natural Resources on Further Standardizing the Management of Geological Data Repatriation* was issued to further standardize and improve the management system of geological data in terms of strengthening the supervision of geological data submission, constructing the integrity system of geological data submission and standardizing the requirements of geological data submission, which effectively reduces the burden of

submitter and provides institutional guarantee for the good management and service of geological data.

II. Geological Data Collection

1. Achievements and original geological data

By the end of 2021, geological data collection institutions at the ministerial and provincial levels had a total collection of 694.80 thousand files and 17.98 million pieces of geological data achievements, 56.60 thousand files and 3.27 million pieces of original geological data. In addition, the entrusted unit maintained a total of 3.32 million files and 10.12 million pieces of original geological data.

2. Physical geological materials

By the end of 2021, geological data collection institutions at the ministerial and provincial levels kept a total of 2.92 million meters of cores, 260.30 thousand bags of cuttings, 108.60 thousand specimens, 256.80 thousand pieces of polished thin section, and 7.41 million bags/bottles of samples. The entrusted unit maintained a total of 1.62 million meters of cores and 39.33 million bags of cuttings.

III. Geological Data Services

1. Collection service

Geological data collection institutions at the ministerial and provincial levels received 17.70 thousand users, provided data utilization services for 13.22 million times, 36.23 TB of data replication, and 11.85 million geological data catalogs online. For the collection institutions at all levels, the number of geological data website service visits reached 6.01 million. We actively promoted “Online Ordering and Application”, and provided business consulting and borrowing services via the Internet, telephone, mail and other means. We further pushed

forward social services, and actively provided special services for the construction of major national projects, resource security, plan preparation, ecological rehabilitation, and earthquake relief.

The disclosure of information on geological data management and services has been promoted in an orderly manner. 2355 delivery voucher information of geological data of prospecting rights were provided to the national e-government information sharing and exchange platform in 2021. We released 7.68 million archive-level and file-level catalogs of geological data from 31 provinces (autonomous regions, municipalities), and publicized 111.00 thousand pieces of information such as submission vouchers, data reminders, and abnormality lists.

The portal website of the National Geological Archives Data Center has been launched, providing more than 200 thousand geological data collections and online services for more than 4,700 domestic and international geological maps, and publishing twenty-two 1:50,000 regional geological survey data sets.

The national digital core system has been put into operation online; there were 20,000 meters of additional core image data among the important physical images, 330 thousand pieces of national physical catalog data updated, 50 thousand additional important borehole data, and 50 new physical geological data information products released, which greatly improved the physical geological data sharing service level.

2. Geological cloud service

Structured data were launched to serve 100 thousand important geological boreholes; original point data on geological survey were shared on cloud; 1:1,500,000 geological map spatial data was launched to achieve full coverage of geological map data on 6 major scales between 1:200,000-1:2,500,000; the medium-scale aeromagnetic data (679 pieces), geochemical data (2.70 million survey points) in land areas nationwide were fully integrated into the cloud; more than 2.20 million pieces of data from 10,171 national groundwater monitoring sites were

used to provide online social services. More than 5,000 pieces of information products, 780 thousand pieces of remote sensing data, 200 thousand pieces of geological data, and digital products on 800 thousand meters of important core were newly released.

In 2021, “Geological Cloud” has 85 thousand registered users, with 4.83 million visits, 800 thousand views and 369 thousand downloads of data products. Its social satisfaction and recognition were constantly improving.

Feature 8–1 Achievements of Geological Data Management since the 18th CPC National Congress

Since the 18th CPC National Congress, the system of geological data management has been vigorously strengthened, *the Regulations on the Management of Geological Data* revised, *the Measures on the Management of Physical Geological Data*, *the Notice on Strengthening the Management of Geological Data*, and *the Guidance Opinions on Further Strengthening the Socialization Service of Geological Data*, etc. issued, and the management of the three major categories of geological data (result, original and physical materials) further standardized. The submission rate of geological data has increased to 91% in 2021 from 32% in 2012; the national collection stock has exceeded 30 million pieces and the physical rock cores have exceeded 4.5 million meters; 3.58 million pieces of oil and gas geological data have been submitted; the digitization of 10.41 million pieces of historical paper of geological data has been completed and all the data in the collection has been digitized; the National Geological Archives Data Center and the unified management service platform have been established to monitor the online process and provide timely government services. In 2021, more than 15 million pieces of geological data and online browsing services were provided. Geological data management has made breakthrough progress with the joint efforts of natural resources authorities and geological data collection institutions at all levels.

Chapter IX

Scientific and Technological Innovations in Mineral Resources

In 2021, significant scientific and technological achievements were made in the field of mineral resources; 8 national standards and 115 industrial standards were published and implemented in the field of geology and mineral resources.

I. Technological Milestones in Field of Mineral Resources

1. Major improvements

New progress has been made in the development of a theoretical method for intelligent prediction of deep mineral resources. A theoretical methodology has been proposed for the prediction of deep mineral resources based on the “ternary” big data, such as prospecting model-3D modeling-quantitative prediction, and a deep comprehensive information prediction and evaluation platform has been established.

Breakthroughs have been achieved in the development of key technologies of cyclically connected heating, reservoir monitoring and evaluation, and high-efficiency power generation for the exploration and pilot production of hot dry rocks in the Gonghe Basin in Qinghai. A dual control technology has been developed for induced earthquakes based on real-time monitoring and dynamic risk assessment, with control of wellhead pressure and accumulated fluid volume as the core.

Major progress has been made in deep-sea detection technology. Key technologies for deep-sea high-precision detection have been developed, and the deep-water double-vessel towed marine electromagnetic detection technology has been formed through independent innovation.

2. Major achievements

By actively driving the implementation of national science and technology planning projects, such as the national key research and development plans, a number of important results have been yielded.

Natural gas hydrate fine exploration technology system and comprehensive evaluation system for pilot production targets have been established; adaptability evaluation method has been innovated for production technology; technologies of safe drilling, sand flow management and control, pilot production, and platform optimization design have been created; a four-in-one environmental monitoring system has been developed for pilot production.

Research on metallogenic law of potash orefields and demonstration of deep exploration technology have achieved a breakthrough in prospecting and increasing reserves. Two new large potash resource sites, Dalangtan-Heibei Sag in western Qaidam and Puguang in northeastern Sichuan, have been discovered. 3 favorable potassium prospective areas have been delineated, offering a strong guarantee for expanding the deep potash resource potential.

Significant achievements have been made in the deep exploration technology and reserve increase demonstration of the metallogenic system in the important mineral resource bases of

the Qinghai-Tibet Plateau. There is a complete set of technical capabilities for deep resource exploration in the metallogenic system of the porphyry-skarn-epihydrothermal deposit, and 10 deep prospecting targets have been delineated.

China's first large-depth fixed-wing time-domain aerial electromagnetic exploration system, key technical equipment for intelligent geological drilling of 5,000-meter ultra-deep holes, deep thermal in-situ mining and reservoir enhancement and stimulation technology, and core multi-parameter digital technology and equipment have been successfully developed and applied.

II. Technical Standards in the Field of Mineral Resources

In 2021, 8 national standards and 115 industrial standards were released and implemented in geology and mineral resources.

To secure the guarantee of energy resources, 4 industrial standards were issued and implemented, including the *Technical Requirement of Survey and Evaluation for Shale Gas Resources*, the *Assessment Specification of Coalbed Methane Resources*, and the *Technical Requirements of Prospective Survey and Evaluation for Oil and Gas Resources on Land*.

To support the development and comprehensive utilization of mineral resources, two national standards, the *Exploration Specification of Hydrogeology and Engineering Geology in Mining Areas* and the *Specifications for Special Hydrogeological Exploration in Coal Mines*, and five industrial standards including the *Specifications for Smart Mine Construction*, the *Classification of Tailings for Solid Mineral Resources*, and the *Index and Computation Method of Resources Utilization for Mine Solid Waste*, were released and implemented.

To speed up the promotion of green and sustainable development of the geological exploration industry, the industrial standard - *Specification for Green Geological Survey and Mineral Exploration* was published and implemented. As required for survey, evaluation, monitoring

and utilization of groundwater resources, 85 industrial standards concerning the *Methods for Analysis of Groundwater Quality* were issued and implemented.

To promote the transformation of technological innovations in mining industry, 5 national standards, including the *Specifications of Survey for Geological and Mineral Resources Exploration*, and *Methods for Chemical Analysis of Tungsten Ores and Molybdenum Ores (Part 19 - Part 22)* and 19 industrial standards, including the *Code of Practice for Digital Mapping of Regional Geological Survey*, the *Technical Requirements on 3D Geological Modeling for Solid Mineral Exploration*, and the *Technical Specifications for Shallow Sample Drilling*, were issued and implemented.

The industrial standard *Technical Requirements of Physical Geological Data Sorting* was published to enhance the management of physical geological data. The national standard *Specifications for Risk Assessment of Geological Hazard* was published and implemented to strengthen technical supports for prevention and control of geological disasters.

III. Technological Innovation Platforms in Field of Mineral Resources

As for the national-level science and technology innovation platform, we actively declare the construction of national engineering research center, and the national engineering research center for natural gas hydrate exploration and development has been approved for construction, and four national engineering technology research centers such as the national comprehensive utilization of non-metallic mineral resources have been built.

As for the Ministry's science and technology innovation platform, The Ministry of Natural Resources has planned and built of 40 key laboratories, 24 engineering technology innovation centers and 38 field scientific observation research stations in the field of mineral resources, with research areas covering geological and mineral survey and evaluation, mineral resources exploration, mineral resources development and utilization, mine ecological rehabilitation and other fields.

In 2021, outstanding achievements were made of the relevant science and technology innovation platforms in terms of the research on superconducting time-domain surface-to-air electromagnetic detection, land-sea coordinated real-time monitoring and safety warning system, key metal reference materials and analysis and testing standards, continental shale oil and gas formation mechanism and exploration, and deep exploration of Jiaodong gold mine, etc.

Feature 9-1 Scientific and Technological Achievements in Mineral Resources since the 18th CPC National Congress

In 2012, the “Theoretical and Technological Innovation and Major Breakthrough in Prospecting of Mesozoic Concealed Metal Deposits in Eastern China” won the Second National Award for Science and Technology Progress.

In 2015, the “Fully Hydraulic Geological Core Drilling Equipment and Key Instruments Within 2000m” won the Second National Award for Science and Technology Progress.

In 2016, the “Yanshanian Large-scale Metallogenic Dynamics Model in Eastern China” won the Second National Natural Science Award; the “Aerial Geophysical Exploration Technology System” won the Second National Award for Science and Technology Progress; the “Deep Exploration and Breakthrough in Prospecting in East Dabie Mountains” won the Second National Award for Science and Technology Progress.

In 2017, the “Theoretical Innovation in Exploration of Replaced Resources in National Crisis Mines and Major Breakthrough in Prospecting” won the Second National Award for Science and Technology Progress.

In 2019, the “Metallogenic Theory of Collision-Type Porphyry Copper Deposits” won the second prize of the National Natural Science Award.

Chapter X

International Cooperation

In 2021, the ministry strengthen international cooperation in the field of mineral resources, actively maintained ties with relevant countries and international organizations through innovative ways of exchange and cooperation, and kept promoting pragmatic cooperation in the field of geological and mineral resources and further consolidate cooperative relations through exchange platforms such as China Mining and China-ASEAN Mining Cooperation Forum & Exhibition.

I. Bilateral and Multilateral Cooperation Mechanisms

1. Bilateral cooperation

The Ministry actively boosted the pragmatic cooperation with Kazakhstan, Saudi Arabia, Russia, Morocco, Liberia, Rwanda, Turkey and other countries in the field of geology and mineral resources, and further strengthened cooperation in geoscience research, geological survey, mineral resources development and management, mineral exploration technology and methods, mining investment, etc.

The 10th meeting of the Mineral Resources Sub-Committee of the China-Kazakhstan Cooperation Committee was kicked off. Geoscience experts from the two countries had an in-

depth exchange of views on the progress and existing problems of the 1:1 million joint map compilation and map connection in the China-Kazakhstan border area, discussed the geological problems of common interest such as the comprehensive evaluation of oil and gas basins in the Sino-Kazakh border area, and reached a consensus on the next step of cooperation.

The bid was won for the “Renovation of Core Library and Construction of Digital Core Museum in Saudi Arabia”, and work continued on the promotion of Sino-Saudi cooperation in the field of geoscience and the enrichment of contents of Sino-Saudi cooperation under the “Belt and Road initiative”.

Measures have been taken to steadily advance the Sino-Russian cooperation in geology for the Year of Scientific and Technological Innovation. The “Earth CT” International Continental Drilling Program was jointly carried out to deepen bilateral cooperation in geoscience technology.

2. Multilateral cooperation

China was elected to chair the steering committee of the new Coordinating Committee for Geo-science Programmes in East and Southeast Asia (CCOP), and domestic geological and mineral units were organized to attend the 57th annual meeting and the 77th steering committee meeting of CCOP. The CCOP Research Center on Urban Geology was established, and the secretariat was established in Nanjing Geological Survey Center.

The Ministry participated in the 54th and 55th Steering Committee meetings of Group on Earth Observations (GEO) and GEO Asia-Oceania meeting. The Ministry also attended the 14th ASEAN+3 Mining Senior Officials Consultation, discussing the work plan for cooperation between the Ministry and ASEAN in the field of geology and minerals.

The 12th Annual Meeting of the United Nations Resource Management Expert Group was attended to upgrade the alignment document of China-United Nations resource standards, complete the draft for comment on the English translation of the reserve classification standard, and boost the exchange and cooperation with the United Nations Economic Commission for Europe and other international organizations in China’s new classification

standard. The Ministry participated in the 12th Annual Meeting of the Committee for Mineral Reserves International Reporting Standards (CRIRSCO), reporting the progress of application for membership. A work group was established to boost the process of joining CRIRSCO.

At the invitation of the Mineral Reserves Commission of Russia and the Economic Commission for Europe, the Ministry participated in the round-table meeting of the Tyumen Oil and Gas Forum and the 30th annual meeting of the Sustainable Energy Committee of the Economic Commission for Europe, having in-depth exchanges with Russia on matters related to mutual recognition of both countries' resource standards.

The Ministry held the 2021 International Training Course on Geochemical Mapping Technology, the 2021 International Training Course on Karst and Sustainable Development, and Training Course on the CCOP-ASEAN Geoscience Data Processing Capacity Building and Geophysical Mapping Project, with an aim to promoting China's technical standards in geology and minerals to the world.

II. International Mining Cooperation Platforms

1. China Mining 2021

Despite the impact of the COVID-19 pandemic, China Mining 2021 (the 23th session) was kicked off by offline + online as scheduled. China Mining 2021 was themed by "Multilateral Cooperation for the Development and Prosperity in the Post-pandemic Era". The Ministry of Natural Resources and leaders in Tianjin, and diplomatic envoys in China from 8 countries including South Africa attended the opening ceremony. The Conference and Exhibition gathered 230 enterprises from 36 countries and regions, with 1 theme forum, and 20 special forums including the "Belt and Road"-based Mining Cooperation Forum and the China-Africa Geological Survey Director Forum. The online "national promotion" activity was attended by 10 countries including Argentina and Sudan.

2. China-ASEAN Mining Cooperation Forum & Exhibition

The China-ASEAN Mining Cooperation Forum & Exhibition 2021 was kicked off by online and offline in Nanning. The Forum & Exhibition was themed by “Joint Construction of the Belt and Road, and Joint Development of Green Mining”, where discussions were made on “peak carbon emissions and carbon neutrality”, development of green mining enterprises, mechanism and prospect of geoscience cooperation, application of and cooperation in satellite remote sensing technology, mine ecological restoration standard and exploration practice. Leaders of the Ministry of Natural Resources and Guangxi Zhuang Autonomous Region, and representatives of ASEAN countries’ diplomatic envoys in China attended the opening ceremony. A total of more than 700 people participated in the activity offline, including representatives of embassies and consulates in China and business representatives from 14 countries. During the period, the China-ASEAN Geological Survey Directors Forum, the China-ASEAN Geological University Principals Forum, and the Malaysia-Laos Mining Promotion Conference were held.

3. Euro-Asia Economic Forum – “Belt and Road” Forum for International Geoscience Cooperation and Mining Investment

The Euro-Asia Economic Forum - “Belt and Road” Forum for International Geoscience Cooperation and Mining Investment 2021 was kicked off by online and offline. The Forum was themed by “New Start for Pragmatic Cooperation in Geosciences and New Journey for Mining Investment Development”, including the first Shanghai Cooperation Organization National Geological Survey Director Forum and the “Belt and Road” Forum for International Geoscience Cooperation and Mining Investment. At the 1st Shanghai Cooperation Organization National Geological Survey Director Forum, representatives of national geological and mineral management agencies and diplomatic envoys in China made deep exchange and discussions for the international cooperation in the fields of geoscience and mining investment in the post-pandemic era, technological innovation in geology and minerals, early warning, forecasting and governance of geological disasters, and talent cultivation. At the “Belt and Road” Forum for International Geoscience Cooperation and Mining Investment, participants discussed the opportunities and challenges of mineral resources investment in the region.