Global nonfuel mineral exploration trends 2001-2015

by Nick Karl and David Wilburn, U.S. Geological Survey

The mission of the U.S. Geological Survey (USGS) National Minerals Information Center (NMIC) is to collect, analyze and disseminate information on the domestic and international supply of and demand for minerals and mineral materials essential to the U.S. economy and national security. Understanding mineral exploration activities and trends assists government policy makers, minerals industry decision makers and research entities in identifying where future sources of mineral supply are likely to be discovered, the amount and type of these resources and factors that may affect exploration and development.

This review summarizes significant exploration trends related to active sites and budgets, mineral commodities and regional factors for the years 2001-2015. Data were compiled by specialists in the USGS-NMIC, and reported annually in the *USGS-NMIC Minerals Yearbook* series and in the May issue of *Mining Engineering* magazine. External data for these analyses were derived from industry sources, published literature, and SNL Metals & Mining, an offering of S&P Global Market Intelligence (New York, NY).

The USGS-NMIC compiled exploration site data for more than 80 mineral commodities, focusing on base metals, diamond and precious metals. More than $138 billion constant U.S. dollars were budgeted by the minerals industry from 2001 through 2015 to explore more than 16,000 mineral deposits globally (SNL Metals & Mining, 2016a). Annual analyses identified where mineral exploration took place by principal commodity target, ranked the magnitude of activity in each region, identified the factors that most affected changes in exploration activity and highlighted developments that led to changes in global supply or increased diversity of supply to the United States. Geographic classifications noted in this report were Africa, Australia, Canada, China, Latin America, Pacific, Russia, United States and Rest of the World.

Care should be taken when extrapolating trends from time-series data, as commodity coverage, collection methodology, data sources, and/or survey response rates may change over time. Mineral commodity and country coverage may differ from year-to-year as corporate restructuring has taken place and commodity and site priorities changed. Inflation, exchange rates, and mineral commodity price variation all may affect exploration budgets and expenditures. Consequently, an expenditure of $1 million in 2015 would generally yield less exploration activity than a corresponding expenditure in 2001. Unless otherwise specified, this review expresses worldwide exploration budget data in U.S. nominal (current) dollars to simplify comparisons by commodity and region.

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Overview

The global landscape for nonfuel mineral exploration and mining has undergone a transition in the past 15 years. At the end of the 20th century, the major share of global mineral exploration was conducted by Australian, Canadian, European and U.S. companies each with relatively high exploration budgets. By 2015, exploration and mining had become more global. Although companies headquartered in these countries still predominate, companies headquartered in Asia, Latin America and the Pacific have gained market share.

Changing global and regional economic, political and social conditions from 2001 through 2015 resulted in changes in exploration activity. Exploration in Eastern Europe and Asia accelerated with the dissolution of the former Soviet Union as Russia and neighboring Central Eurasian countries increasingly began to allow companies to explore territories previously closed to foreign exploration companies and to grant foreign companies access to exploration data. Demand for mineral commodities in China increased to meet growing demand by its expanding economy and manufacturing sector, and Chinese companies were encouraged by government policies to expand exploration globally and secure access to foreign sources of mineral supply (Basov, 2015). Exploration activity in all of the Brazil, Russia, India and China (BRIC) countries has increased, leading to increased diversity of potential sources of mineral supply for the U.S. industry. Exploration in Latin America increased following revision of mining codes in some countries in the 1990s. After 2010, concern about policies regarding the use of conflict minerals in products and health and worker safety issues affected exploration in

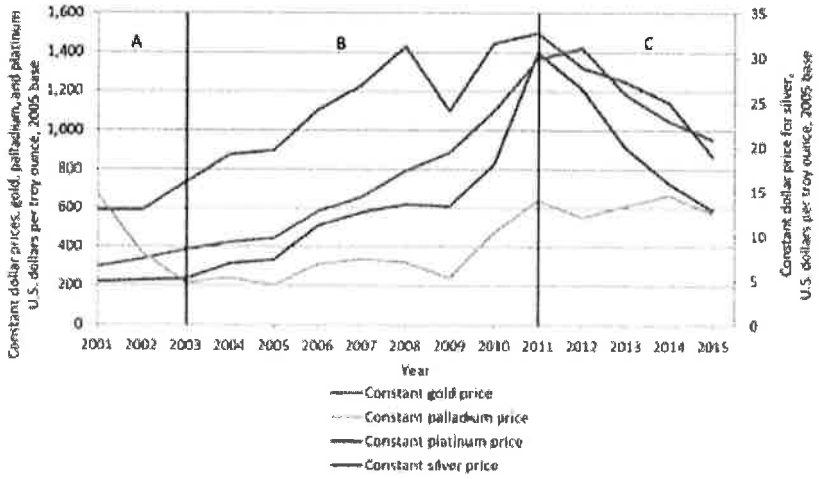
central Africa. Exploration activity in Canada increased following the implementation of mineral exploration tax credits that have been renewed annually since 2002. Canadian regulations implemented in 2012 require aboriginal consultation which have influenced exploration decisions and delayed the potential development of more than 600 mineral projects (Jacobsen, 2014). The 2013 Indonesian ban on export of raw materials reduced exploration activity in the country but stimulated exploration activity in neighboring countries. In the United States, the plan announced by the Environmental Protection Agency (EPA) to protect the fishing industry by restricting mining in the Bristol Bay region of Alaska has temporarily blocked the development of the Pebble copper-gold-molybdenum-silver deposit (Athey and others, 2014).

Shifts in demand for some nonfuel mineral commodities, trade barriers, and technological advancements have also influenced the patterns of mineral exploration. For example, advances in beneficiation technologies stimulated exploration for high-tonnage, low-grade precious and base metal deposits, and technological advances in drilling, geophysics and remote sensing increased the possibilities for the discovery of offshore deposits and deposits located at greater depths. The growth in demand for platinum-group metals (PGMs) for use in automotive catalytic converters stimulated PGM exploration. Concern about the dependence on the supply of rare-earth elements (REEs) from China for high-tech applications led to a global search for alternative sources of these minerals. Although China continues to be the leading producer and supplier of REEs, exploration and production in other countries has increased and may provide greater diversity of supply in the future. The construction of a lithium battery manufacturing plant in Nevada that is designed to produce more lithium ion batteries annually than were produced globally in 2013 will require additional supply sources of lithium and graphite after the plant comes on line (Tesla Motors Inc., 2014). Since Tesla announced its plans in 2013 there has been increased exploration for these mineral commodities, acquisition of companies with promising deposits, and announcements of several potential supply agreements.

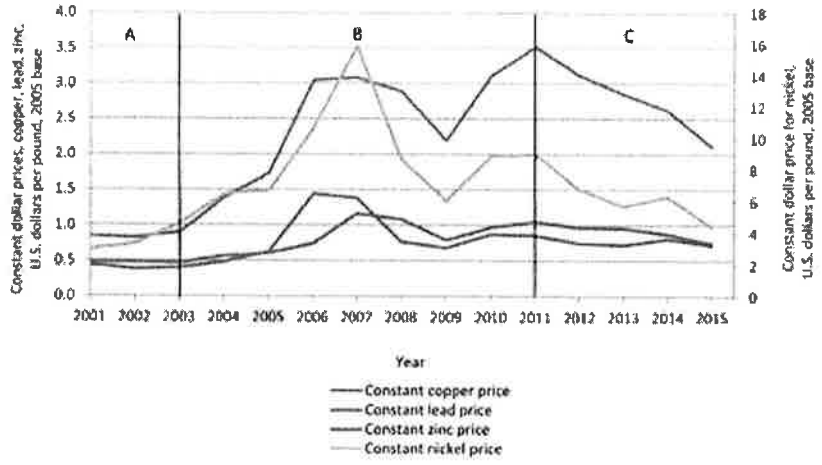
World-class discoveries and identification of mineral occurrences in previously unexplored areas or non-traditional geologic environments have changed the focus of exploration activity. For example, the discovery of the Voisey's Bay nickel-copper-cobalt deposit in Canada stimulated exploration for similar greenfield deposits and provided a successful development model incorporating aboriginal stakeholder participation (Chadwick, 2006). The site accounted for more than 28 percent of nickel, 18 percent of cobalt and 6 percent of copper

Figure 1

Constant dollar prices for selected base and precious metals, 2001-2015. Real dollar prices as reported in U.S. Geological Survey Minerals Yearbook series for the years 2001 through 2013 and Mineral Commodity Summaries 2016, adjusted to a 2005 base using Consumer Price Index, All Urban Consumers.



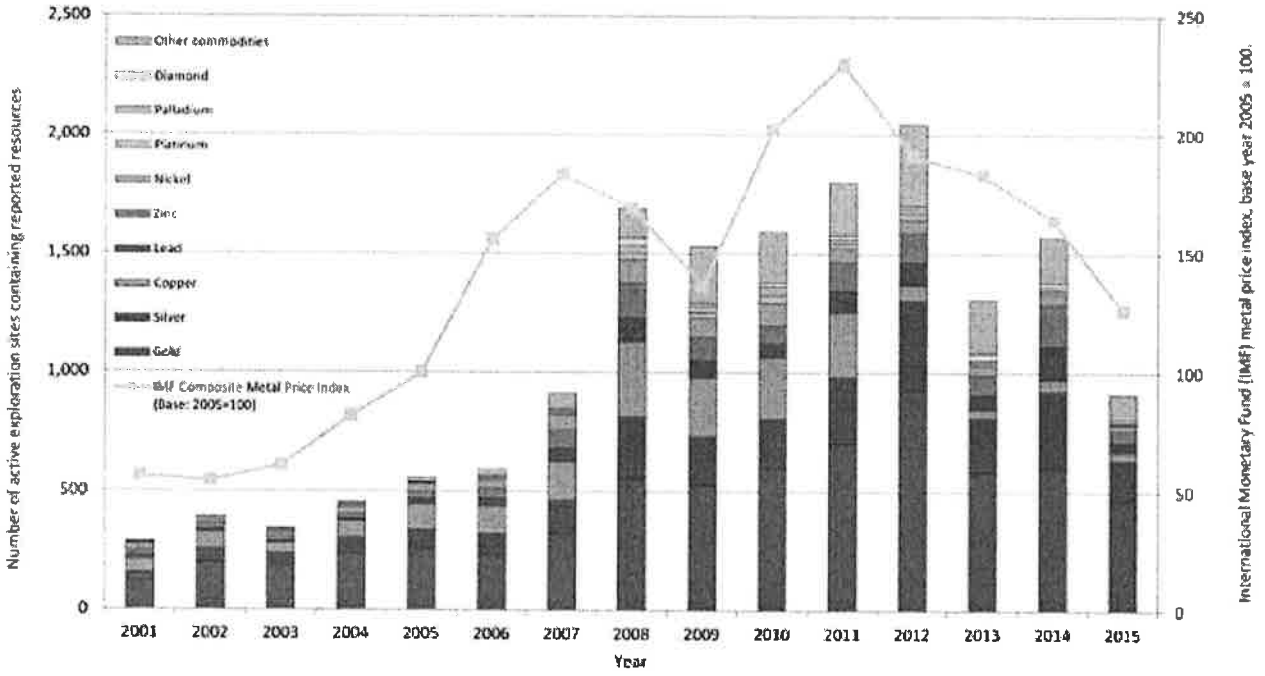
A. Selected precious metal prices in dollars per troy ounce with a base year of 2005



B. Selected base metal prices in dollars per pound with a base year of 2005

Figure 2

Annual exploration activity and metals price index, 2001 through 2015. Annual exploration activity expressed in terms of the number of active sites that reported a resource tonnage for each of the selected mineral commodities in each year. Site data were compiled by the USGS based on copyrighted data from SNL Metals & Mining, 2016a and other published data. Composite price index includes aluminum, copper, iron ore, lead, nickel, tin, uranium and zinc as reported by the International Monetary Fund (IMF) with base year 2005 = 100. Exploration activity focused on non-ferrous base and precious metals. Other commodities include more than 80 minerals and metals, principally graphite, iron ore, lithium, potash, rare-earth elements and uranium.



production in Canada by 2013 (U.S. Geological Survey, 2014; Vale S.A., 2014). The discovery and development of the Ekati Diamond Mine in 1998 stimulated Canadian diamond exploration such that by 2003, Canada became the third-largest global diamond producer on a value basis (Natural Resources Canada, 2015). The discovery of the Oyu Tolgoi porphyry copper deposit in Mongolia in 2001 boosted Mongolia's global ranking (based on exploration budget) from 46th in 2001 to 10th in 2004 (SNL Metals & Mining, 2016a). Discovery of major gold deposits on the Cortez Trend in Nevada and the Donlin Creek gold deposit in Alaska during the last 15 years increased interest in gold exploration in the United States.

Mineral commodity and price trends

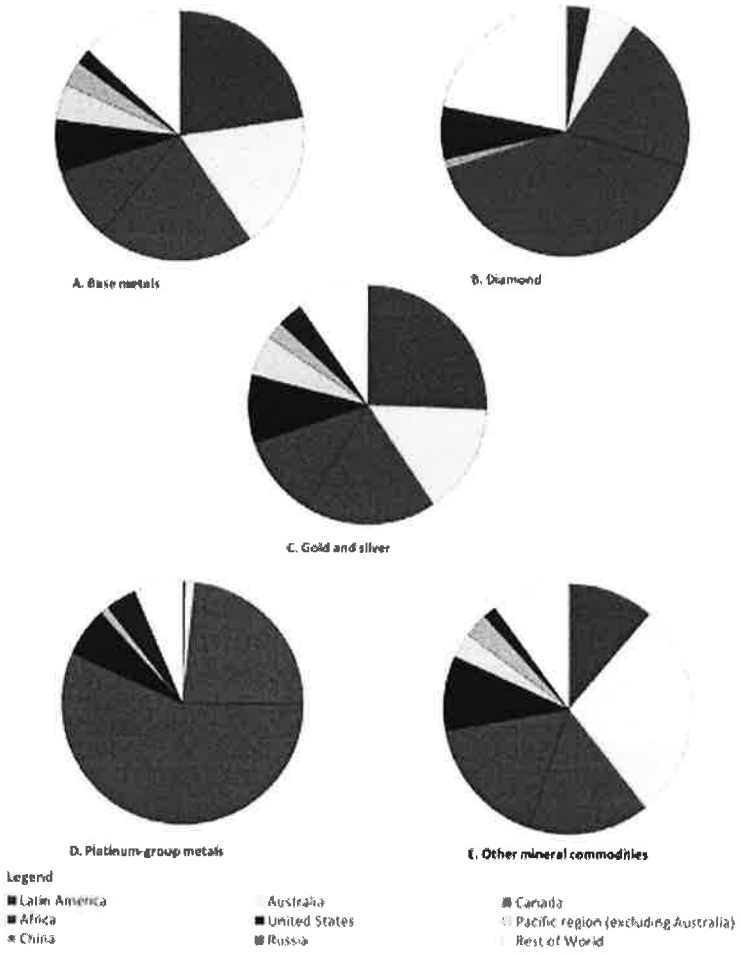
Metal prices are one of the leading drivers of exploration activity; exploration activity tends to increase when metal prices move higher and decrease when prices are low. Exploration companies cut back on exploration as investors reduce funding. Figure 1 shows prices for selected (A) precious and (B) base metals expressed in constant dollars over the period 2001 through 2015. In general, commodity prices were relatively low at the end of the 20th century, and began to increase through 2007. From 2008 through 2010, prices dropped as a result of the global recession then rebounded to decade high levels. Since 2011, prices have decreased as the rate of growth for metal consumption by China has been reduced.

Exploration activity for the period can be linked to mineral price trends that have been divided into three timeframes as shown in Fig. 1. The period 'A' from 2001 to 2003 can be characterized as a period of relatively low metal prices (expressed in constant dollars). During this timeframe, exploration activity remained relatively low and was dominated by major companies expanding resources at existing projects. Early-stage exploration accounted for almost half of the global exploration budget during this period. During this period, major companies accounted for about 56 percent of the global exploration budget, junior companies accounted for about 28 percent, and other company types (intermediate and government owned) accounted for the remaining 16 percent (SNL Metals & Mining, 2016a). Exploration focused on polymetallic base and precious metal deposits, perhaps because revenues generated by the recovery of multiple commodities could offset reduced revenues of low-price commodities.

The years 2003 to 2011, denoted 'B' on Fig.

Figure 3

Regional distribution of exploration sites for selected mineral commodity groups where resource tonnages were reported from 2001 through 2015. Site data were compiled by the USGS based on copyrighted data from SNL Metals & Mining, 2016a and other published data.



1, can be characterized as a period of increasing metal prices, growing investment opportunities, a strengthening global economy and increased Chinese demand. Exploration for copper, gold, and silver continued, and exploration for cobalt, lead, nickel, and zinc increased in response to higher prices and demand for base metals by China. Interest in graphite, lithium, REEs, and tantalum increased as demand for high-tech applications using these minerals increased. An increase in exploration activity for phosphate and potash deposits was driven by higher consumption of fertilizer minerals in China and India. During this period, junior companies accounted for about 45 percent of exploration budget share, major companies accounted for 38 percent, and other company types accounted for 17 percent (SNL Metals & Mining, 2016a). More than 40 percent of the active projects were advanced to the feasibility level. China began establishing agreements to explore and develop infrastructure in return for securing access to resources in Africa, Australia, Canada and the Republic of Korea and other countries in the Pacific region. Higher metals prices and expanded activity by mining companies led to a rise in resource nationalism, whereby some countries increased taxes or royalties for mineral exploitation or established domestic ownership requirements.

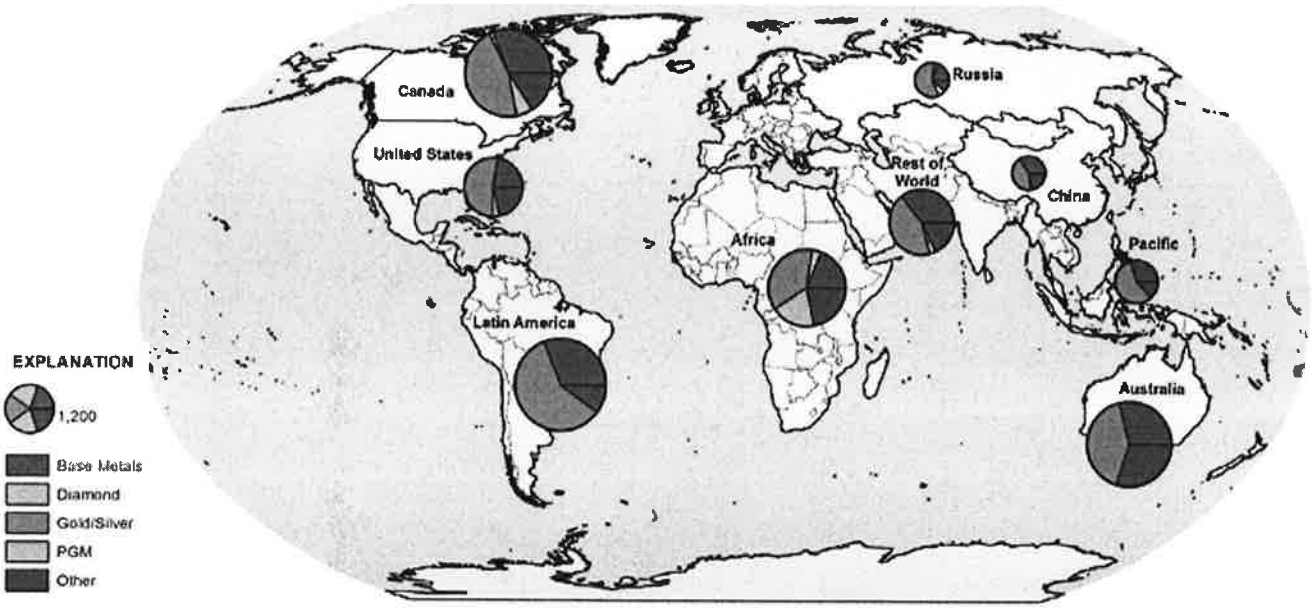
The global recession of 2008-2009 reduced minerals exploration over the short term, but exploration activity rebounded quickly, particularly for mineral commodities such as copper, gold and silver, whose prices remained at historically high levels through 2011 when expressed in constant dollar terms. Concern over China's dominance in REEs and possible supply shortages as a result of China's export quota system stimulated interest in exploring for REEs. Exploration for minerals such as graphite, lithium, and tantalum, considered essential to support the high-tech sectors, remained at a high level.

Metal market uncertainty, global economic instability, growing resource nationalism, and tightening credit reducing the amount of capital available to companies for exploration began to influence exploration activity and metal markets for the years 2011-2015, denoted 'C' in Fig. 1. Major companyies share of the exploration budget during this period increased to about 48 percent, the share of other company types increased to about 19 percent, while junior companies' share decreased to about 33 percent. A slowdown in the rate of growth of Chinese mineral consumption further reduced mineral investment and exploration activity for some commodities. For example, the diamond exploration budget in 2014 was 44 percent of the peak budget reached in 2008. However, exploration for minerals required for high-tech applications continued. Exploration for lithium deposits was further stimulated by the 2013 announcement from Tesla Motors Inc. that it would construct a 35 gigawatt-hour (GWh) capacity lithium battery factory in Nevada (Tesla Motors Inc., 2014).

Figure 2 shows the annual exploration activity from 2001 through 2015 expressed in terms of the number of active sites in each of the study years for which a resource tonnage for a given commodity in that year was reported. Limiting the analyses to active sites with reported resources allowed the determination of the primary mineral commodities of interest. Based on these criteria, gold was the most often reported mineral exploration target for all years of the study period. Silver was often found to be associated with deposits containing gold.

Figure 4

Regional distribution of exploration activity for base metals, diamond, precious metals and other mineral commodities based on active sites that reported a resource tonnage for the years 2001-2015. Site data were compiled by the USGS based on copyrighted data from SNL Metals & Mining, 2016a and other published data. The relative magnitude of the pie is defined as the number of active sites within the corresponding region. Regions depicted are Africa, Australia, Canada, China, Latin America, Pacific, Russia, the United States and the Rest of the World. Africa includes countries on the subcontinent. Latin America includes countries in the Caribbean, Central America, Mexico and South America. The Pacific includes Cambodia, Fiji, Indonesia, Japan, Laos, Malaysia, New Caledonia, New Zealand, Papua New Guinea, Philippines, Solomon Islands, Thailand, Vanuatu and Vietnam. The Rest of the World includes Asia (excluding China), Europe, India, Pakistan, the Middle East and the Central Eurasian countries of Azerbaijan, Armenia, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan and Turkmenistan. Australia, Canada, China, Russia and the United States are treated separately.



Copper was the second most-explored target, a function of its widespread demand in consumer, industrial, and technological applications as well as association with gold and other metals in some deposit types. Copper, gold and silver were the principal target commodities in more than 50 percent of the exploration sites evaluated.

The International Monetary Fund Composite Metals Price Index was included in Fig. 2 to show the correlation between exploration activity and metals prices (International Monetary Fund, 2016). It is not surprising that the general trend in exploration activity was shifted by about one year from reported metals prices because the level of exploration incurred in any given year was usually planned in the previous year.

Rather than replacing mineral reserves by active exploration, some mining companies prefer to secure access to reserves by means of mergers and acquisitions. Data compiled by SNL Metals & Mining suggest that acquisition activity for the 2001-2015 period was highest for the years 2006, 2010, 2013 and 2015 (SNL Metals & Mining, 2016b). As shown in Fig. 2, exploration activity tends to fall off in the years acquisition activity is high, as funds that may be allocated for exploration are diverted to acquiring companies or properties with reserve potential.

Regional trends

Figure 3 shows the regional distribution in exploration activity for (A) base metals, (B) diamond, (C) gold and silver, (D) platinum-group metals and (E) other nonfuel mineral commodities based on the number of active exploration sites reporting resource data from 2001 through 2015. The distribution patterns for precious and base metals are similar, with more than half of the active global exploration sites located in Australia, Canada and Latin America. Africa, Australia and Canada were the leading areas for exploration for other minerals. Exploration in the United States focused primarily on base metals, gold, and minerals considered important to high-tech industries.

Figure 4 is a map that displays the regional exploration activity for principal commodity targets based on the number of active exploration sites that reported a resource tonnage from 2001 through 2015. Commodities included in this diagram are base metals (copper, lead, nickel, and zinc), diamond, precious metals (gold, palladium, platinum, and silver), and other

commodities. Other commodities include, but are not limited to, graphite, iron ore, lithium and REEs.

Pie charts are presented to show principal commodity targets in each region; the size of the pie chart illustrates the relative magnitude of exploration activity in the region based on the total number of active exploration sites reporting resource tonnages during the 15-year period. In descending order, Latin America, Canada, Australia and Africa reported the most exploration activity. Areas such as China, the Pacific region and Russia reported less activity over the same period. As depicted in Fig. 4, gold/silver accounted for the largest exploration focus across all regions. Latin America reported the most sites of any region for both gold/silver and base metals, while Africa hosted the most sites exploring for PGMs. Little exploration activity for diamond occurred outside of Africa, Canada or Russia.

The commodities included in the other category accounted for a large number of sites globally. In Australia, almost a third of the target commodities were represented in this category. Commodity targets in Australia included iron ore, minor metals (including cobalt, molybdenum, tantalum, tin and tungsten), and heavy mineral sands (primarily titanium bearing). Exploration for other minerals in China was focused on metals and minerals used in advanced technologies (including REEs and lithium). In Russia, the majority of exploration for minerals in the other category was focused on iron ore and agricultural commodities such as potash and phosphate fertilizers. In the United States, exploration for minerals in the other category included minor metals, potash, phosphate and uranium.

Figure 5 is a time series of mineral exploration site activity represented by the total number of active exploration sites with reported resources depicted in five–year intervals for base metals, diamond and precious metals. Other minerals were not considered as the coverage for commodities such as iron ore and uranium were not representative over the study period.

The first period shown represents data from 2001-2005. During this period exploration was fairly balanced across all the regions other than Canada and Latin America, where higher levels of exploration activity took place. For this period, China, the Pacific, Russia and the United States reported the lowest amount of exploration activity for the selected mineral commodities.

From 2006 to 2010, exploration activity increased at different rates for various regions. Growth in activity was apparent for all regions other than China and Russia. Canada and Latin America continued to show the greatest amount of exploration activity; Africa and Australia also

Figure 5

Changes in regional exploration activity displayed as a time series for the years 2001-2005, 2006-2010 and 2011-2015. Site data were compiled by the USGS based on copyrighted data from SNL Metals & Mining, 2016a and other published data. Exploration activity was represented by the total number of active exploration sites with reported resources for copper, diamond gold, lead, nickel, palladium, platinum, silver and zinc. Regions depicted are Africa, Australia, Canada, China, Latin America, Pacific, Russia, the United States and The Rest of the World.

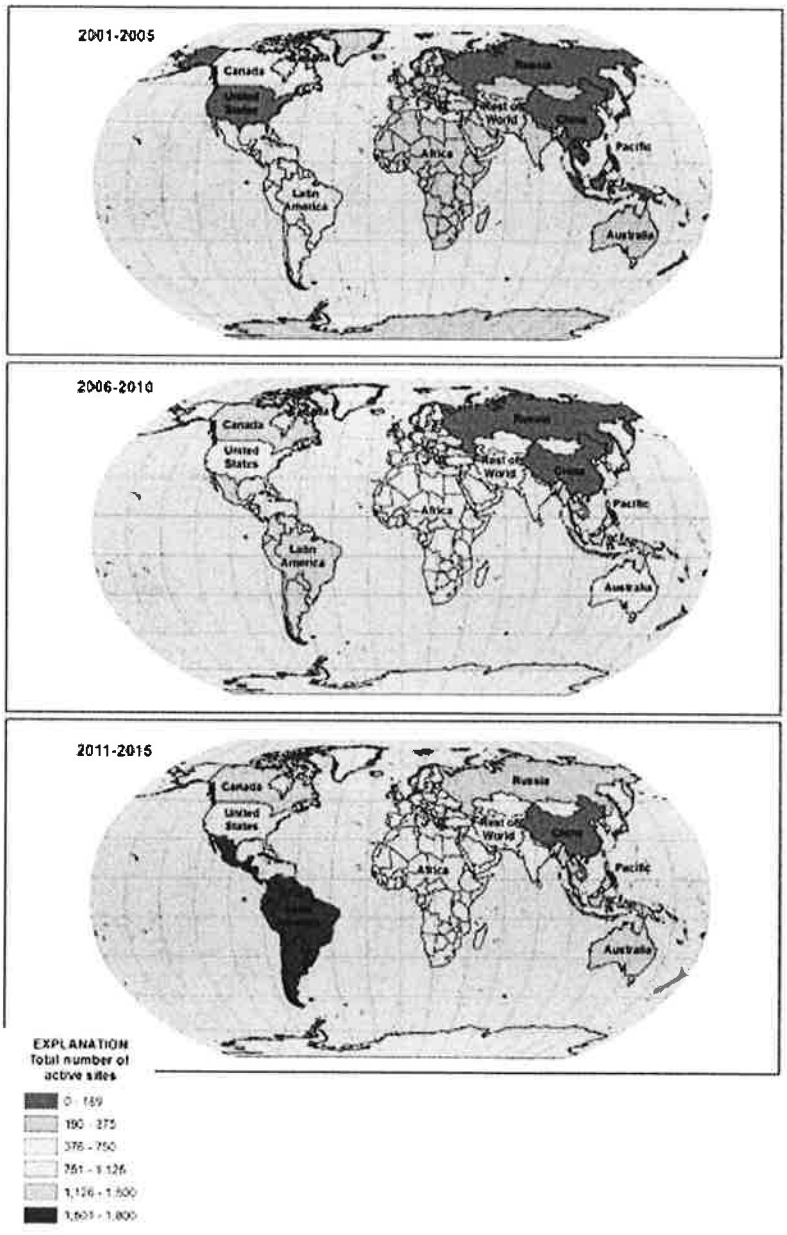
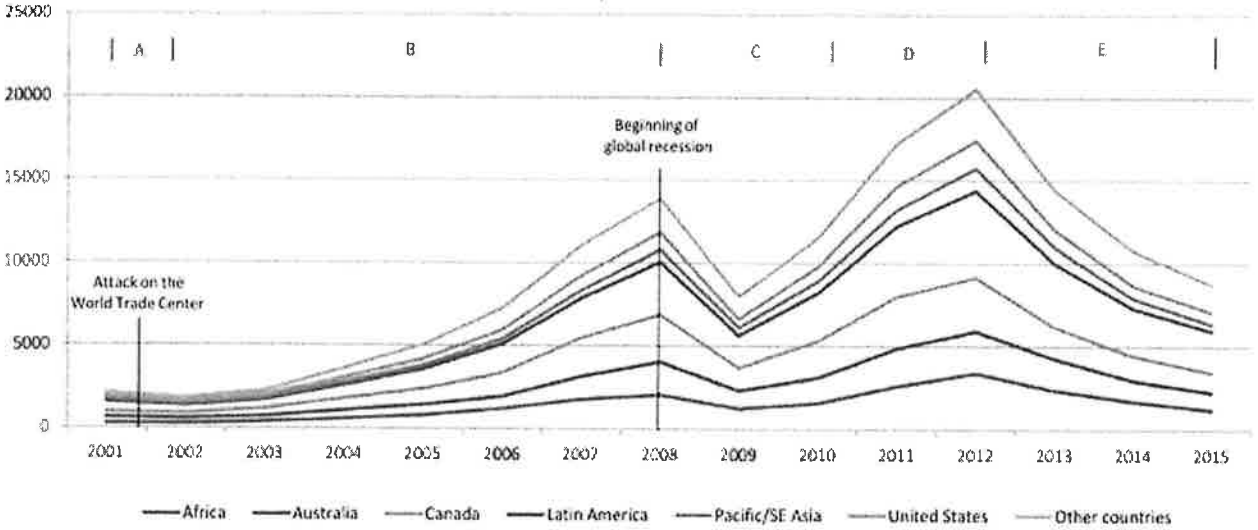


Figure 6

Regional distribution of annual nonfuel mineral exploration budgets, 2001 through 2015. Budget data were compiled by the USGS based on copyrighted data from SNL Metals & Mining, 2016a and other published data.



[A] 2001-2002 - Bre-X scandal in 1997 reduced investor confidence, making financing for junior companies more difficult. Decrease in exploration owing to lower prices, investor wariness, abundant inventories, and financial uncertainty in Asia. Investment in China, CIS, and Eastern Europe delayed because of low prices. Exploration in Africa reduced owing to perceived instability, rise of HIV/AIDS, and lack of infrastructure. Threat of war following the attack on the World Trade Center increased political risks and strained investment. Increased exploration for diamond and platinum-group metals in Africa and Canada. Increased as environmental concerns increased costs and risks for mineral exploration and mining.

[B] 2002-2008 - Canadian tax incentives stimulated exploration. Increased access by foreign companies to China, Commonwealth of Independent States, Eastern Europe, and India. Increase in Chinese mineral consumption. Rise in U.S. exploration because of advancement of technology, rising mineral commodity prices, and new discoveries. Increased focus on advanced stage projects. Interest in China and Mongolia owing to improved access and investment policies. Chinese companies encouraged to invest overseas. Rise in junior company exploration because of higher mineral commodity prices and easier access to financing.

[C] 2008-2010 - Slowdown in industrial growth and global recession. Increased exploration by Indian and Russian companies in Africa. Chinese companies explored in Africa, Australia, and the Pacific. Increase in offshore exploration activity for diamonds, gold, and other mineral commodities. Exploration activity increased as prices, market liquidity, and global economy improved. Countries with growing economies expanded exploration activity outside their borders. Resource nationalism increased. Conflict mineral legislation enacted.

[D] 2010-2012 - Sustained high metal prices supported historically high exploration levels. Western mining companies increasingly competed with Chinese and Indian investors. Interest in graphite, lithium, potash, and rare earth elements increased with demand for high tech applications and concerns about Chinese trade policies of REEs. Illegal mining increased in Africa and Latin America. China invested globally. Increased political and social pressures in Latin America. South African experienced labor and energy issues. Australia enacted carbon tax and minerals resource rent tax.

[E] 2012-2015 - Slowdown in Chinese consumption and declining prices reduced exploration investment. Continued challenges in South Africa. Aboriginal consultation issues affecting more than 600 projects in Canada. Resource nationalism in Indonesia led to ban on ore exports, affecting Pacific exploration activity. Lack of capital for junior companies. EPA decision on Pebble project influenced activity in Alaska. Lithium exploration stimulated by Tesla battery plant plans.

showed significant levels of activity.

During the third period 2011-2015, Latin America assumed the number one spot in terms of exploration activity based on the number of active sites targeting the selected commodities. Activity in Australia continued to increase. Latin America, Canada and Australia remained the top three regions for mineral exploration activity in order of decreasing activity. For the first time, Russia experienced an increase in activity while the level of exploration in China remained at a lower level, possibly owing to under-reporting by government-controlled entities.

There was an increase in overall growth in exploration activity for each period in Australia, Latin America and the Rest of World regions. Africa, Canada, the Pacific region, and the United States showed increased exploration activity for the period 2001-2010, then activity stabilized during the 2011-2015 period. Russia showed signs of exploration growth after showing little growth from 2001-2010.

Budget trends

Figure 6 shows the annual nonfuel minerals exploration budget by region from 2001 through 2015, based on data reported by SNL Metals & Mining and the USGS. SNL budget data suggest that trends for all regions are similar over the 15-year period. The figure also provides a summary of the leading factors that influenced exploration activity.

The most notable trend in exploration activity over the past 15 years was the accelerated rate of growth in near-mine site exploration compared to the reduced rate of growth in early-stage (pre-feasibility stage or lower) exploration budgets. From 2001 to 2015, early-stage budgets increased from $1,067 million in 2001 to $2,547 million in 2015 demonstrating a total rate of growth over the period of about 9 percent. Late-stage (reported at the feasibility stage or higher) budgets increased from $585 million in 2001 to $3,223 million in 2015 demonstrating a total rate of growth over the period of about 30 percent. Exploration budgets taking place near existing mine sites increased from $446 million in 2001 to $3,001 million in 2015 demonstrating a total rate of growth over the period of about 38 percent.

The data suggest that over the study period,

while decades of previous exploration has identified many mineral prospects, investor focus on grassroots exploration decreased in favor of exploration for identified resources located near existing mines and infrastructure or late-stage deposits with greater potential for economic viability (SNL Metals & Mining, 2016a). Exploration in established mining areas can be advantageous as it (1) often requires less infrastructure development, (2) is lower cost because it can draw upon existing labor, equipment, and transportation structures, (3) may be able to use existing permits, (4) relationships with local stakeholders and government entities have been previously developed, (5) greater chance of discovery by comparing existing exploration data with new data.

A second notable trend was the apparent inverse relationship between the activity of major exploration companies and junior exploration companies. Budget data reported by SNL show that during the period from 2001 through 2007, the exploration activity by major companies decreased from about 59 percent of the global exploration budget in 2001 to about 30 percent in 2007, at the same time the exploration activity by junior companies increased from about 26 percent in 2001 to about 55 percent in 2007. Since 2007, however, the junior company budget allocation decreased to about 29 percent in 2015 and the major company budget allocation increased to about 49 percent in 2015 (SNL Metals & Mining, 2016a). Since the majority of junior companies depend on equity financings to fund exploration, their spending capacity largely depends on investor interest and market conditions, which in turn are influenced by current and forecast market prices.

Many factors have influenced the scope and direction of mineral exploration since the turn of the century. Changing global economic conditions, demand for minerals, and regional issues have modified the exploration patterns for selected minerals. The increased globalization of the sector over the last decade and technological improvements have also provided greater opportunities for the identification and development of more diverse supply sources. These trends will continue to shape the future direction of mineral exploration activity. ■

For more information

The USGS collects and analyzes data on more than 100 mineral commodities in the United States and worldwide. This article draws from public and private sector sources and the knowledge and expertise of USGS mineral commodity, country, and mineral-resource specialists. More detailed information on the material covered in this article may be obtained from the lead author, Nick Karl, U.S. Geological Survey, National Minerals Information Center, P.O. Box 25046, MS 750, Denver Federal Center, Denver, CO 80225-0046; telephone 303-236-5206; fax 303-236-4208 or nkarl@usgs.gov. For additional USGS information on mineral commodities and international mining activities, inquiries may be directed to Steven Fortier, U.S. Geological Survey, National Minerals Information Center, 988 National Center, MS 988, Reston, VA 20192; telephone 703-648-4920 or sfortier@usgs.gov.

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