Example of Continental-Scale Mineral Resource Assessments

U.S. Geological Survey National Mineral Resource Assessment—An Estimate of Undiscovered Deposits of Gold, Silver, Copper, Lead, and Zinc in the United States

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Introduction

The U.S. Geological Survey (USGS) conducted a 5-year scientific study—the National Mineral Resource Assessment—to estimate in probabilistic terms, for the first time, the amounts of gold, silver, copper, lead, and zinc that could be present in yet-to-be discovered mineral deposits 1 kilometer or less below the surface of the United States. Results for the conterminous United States were published in 1996 (Ludington and others, 1996). Results for the entire United States, including Alaska, were released in 2000 (U.S. Geological Survey National Mineral Resource Assessment Team, 2000). The national assessment shows that it is likely that the United States still contains at least as much gold, silver, copper, lead, and zinc in conventional-type deposits as has already been discovered.

Why a National Mineral Resource Assessment Was Needed

The USGS undertook the National Mineral Resource Assessment to provide timely, objective, credible mineral resource information for land and resource planning and decisionmaking. As the Nation's economy matures, progressively greater attention is given to land use and environmental quality, as well as to sustainability of mineral supplies to provide for the needs of future generations. National mineral resource assessments provide a framework for addressing these issues by monitoring the Nation's mineral wealth and by contributing to deliberations about resource extraction and protecting the environment. Responsible stewardship of the Nation's lands, resources, and environment requires information on where future mineral resources may exist, the amounts of a mineral commodity or commodities that these resources might contain, and what environmental impacts might result from extraction and development of such resources.

Starting in the early 1990s, the tempo and politicization of land, resource, and environmental planning and decisionmaking in the United States began accelerating (again). An estimated 190 million acres of public lands, although lacking modern mineral assessments, was being proposed for withdrawal from areas available for mineral exploration, discovery, and production. This situation virtually assured that large deposits of undiscovered mineral resources would be withdrawn unknowingly and without consideration of alternative supplies.

For a number of reasons, detailed conventional large-scale mineral assessments were an impractical response to the burgeoning need for minerals information that accompanied the accelerating planning and decisionmaking process. (1) Deadlines were too short and unpredictable to conduct new assessments targeted to specific areas under consideration for withdrawal. (2) Locations of areas of concern were unpredictable and the areas under consideration were becoming very large (up to tens of millions of acres). (3) The boundaries of these areas were uncertain.

Because of this growing unpredictability, it was recognized that what was needed was a nationwide mineral assessment database available in advance of the planning process for all areas of the country. Unfortunately, the cost of providing such comprehensive data at traditional large, detailed scales was too high. For example, we estimated that collecting comprehensive mineral resource data just for public and enclosed private lands at a scale of 1:250,000 would cost between $2 billion and $3 billion over a period of 15 years. Such a cost was too high, and the time too long. The National Mineral Resource Assessment described herein was proposed

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and conducted as an alternative mechanism for developing, organizing, consolidating, augmenting, and maintaining large geological, geochemical, geophysical, and mineral resource digital databases capable of supporting mineral resource and associated mineral environmental assessments and research, at multiple scales and levels of detail throughout the country.

How the Assessment Was Done

The nature of available data and current technology, combined with limitations of time and money, dictated that the national assessment be undertaken from a regional perspective. The country was divided into 19 geographic regions that were selected to provide broad geologic groupings of the Nation's mineral-producing areas. Each region was assessed by a scientific team composed of from 6 to 24 geologists, geochemists, geophysicists, and resource analysts knowledgeable about the region and its mineral deposits.

The method used to estimate the quantity and quality of undiscovered deposits of gold, silver, copper, lead, and zinc was the three-part quantitative assessment procedure (Singer, 1993), applied by the USGS increasingly since 1975. This procedure is based on mineral deposit models, which consist of sets of geoscience data that describe a group of deposits having similar geologic settings and distinctive grade and tonnage characteristics.

The first part of the three-part assessment is to prepare maps that identify and delineate tracts permissive for the occurrence of undiscovered deposits by deposit type (fig. 1). A permissive tract is defined by its geographic boundaries such that the probability of deposits of the type delineated occurring outside the boundary is negligible. Tracts for the national assessment were delineated to allow estimates of undiscovered resources to be made to a depth of 1 kilometer below the surface where possible. Areas that were covered by more than 1 kilometer of rock known or inferred to be barren were excluded from the assessment. Permissive tracts were delineated by interpreting and integrating existing geologic, geophysical, and geochemical data and information available on known deposits in the area, all compiled onto maps at scales of 1:500,000 and 1:1,000,000.

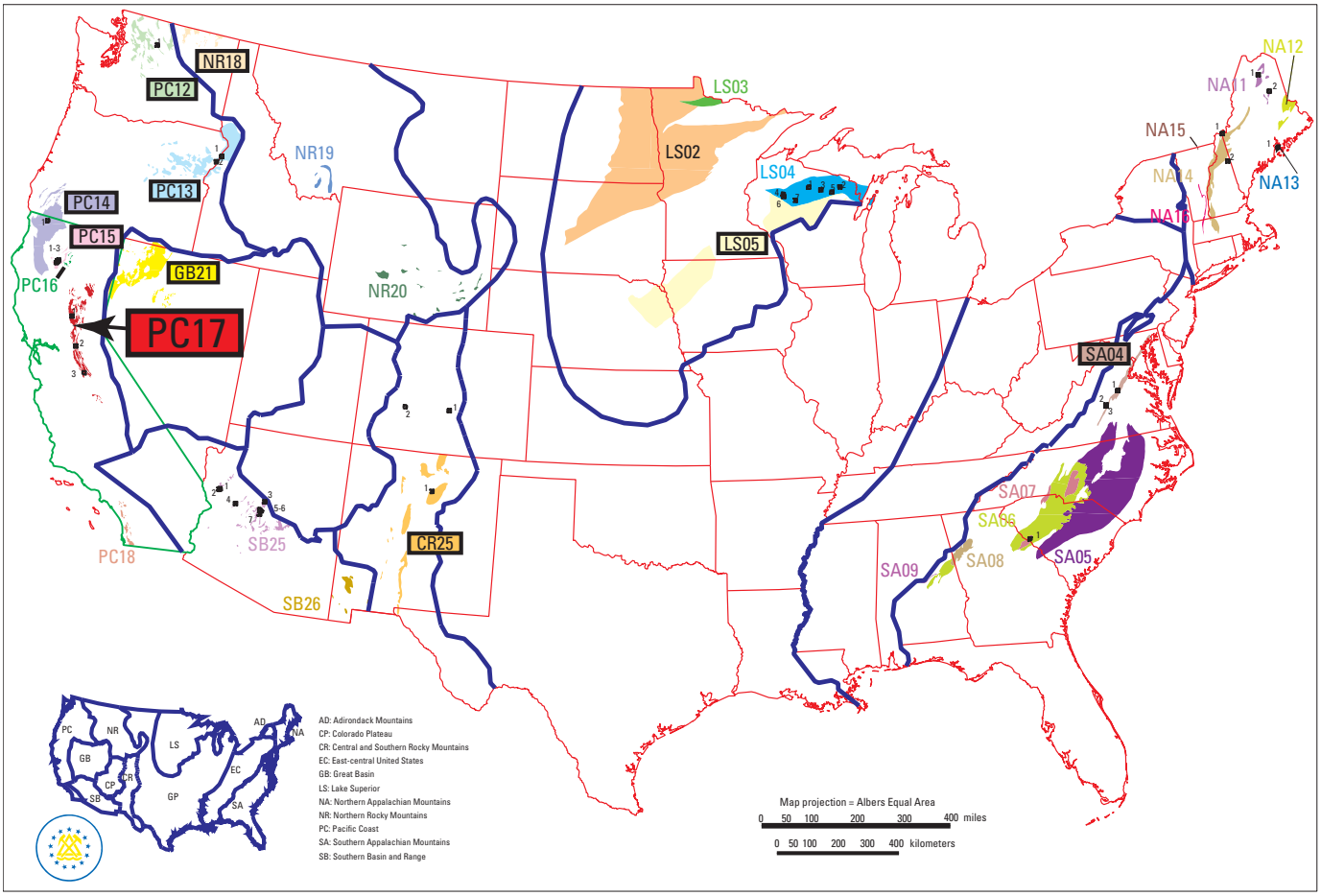

Figure 1. Tract map for kuroko massive sulfide deposits in the conterminous United States showing areas where the geology is permissive for the formation of this type of deposit. Favorable areas are shown by different colors and labels. From Luddington and others (1996). Estimates of undiscovered deposits and metal resources in tract PC–17 are shown in figures 2 and 3.

The second part of the assessment method is estimating the number of undiscovered deposits of each deposit type in those permissive tracts where available information allows quantitative estimates. The number of undiscovered deposits is expressed as a probability distribution, with estimates of the number of undiscovered deposits made at the 90th, 50th, and 10th percentile confidence levels and sometimes at the 5th and 1st levels (fig. 2). The estimates are made by subjective interpretation and extrapolation of available earth science information by geoscientists having detailed knowledge about the area and (or) the selected deposit type(s). The estimates of numbers of undiscovered deposits are constrained by the

Estimated Undiscovered Deposits

There is a 90% or greater chance of 2 or more deposits.
There is a 50% or greater chance of 13 or more deposits.
There is a 10% or greater chance of 25 or more deposits.
There is a 5% or greater chance of 25 or more deposits.
There is a 1% or greater chance of 25 or more deposits.

Estimated amounts of contained metal and mineralized rock, in metric tons

Quantile	Cu	Au	Zn	Ag	Pb	Rock
0.95	700	0	0	0	0	97,000
0.90	12,000	0	12,000	18	0	690,000
0.50	140,000	16	260,000	710	46,000	8,500,000
0.10	310,000	45	815,000	2,700	200,000	19,000,000
0.05	360,000	55	990,000	3,400	250,000	22,000,000
Mean	160,000	20	340,000	1,100	76,000	9,200,000
Probability of mean	0.46	0.43	0.40	0.38	0.38	0.46
Probability of zero	0.04	0.06	0.06	0.05	0.10	0.04

Figure 2. Chart summarizing probabilistic subjective estimates by experts of numbers of undiscovered kuroko massive sulfide deposits in tract PC–17, California (see fig. 1). From Ludington and others (1996). Corresponding amounts of contained metal and mineralized rock were estimated by Monte Carlo simulation.

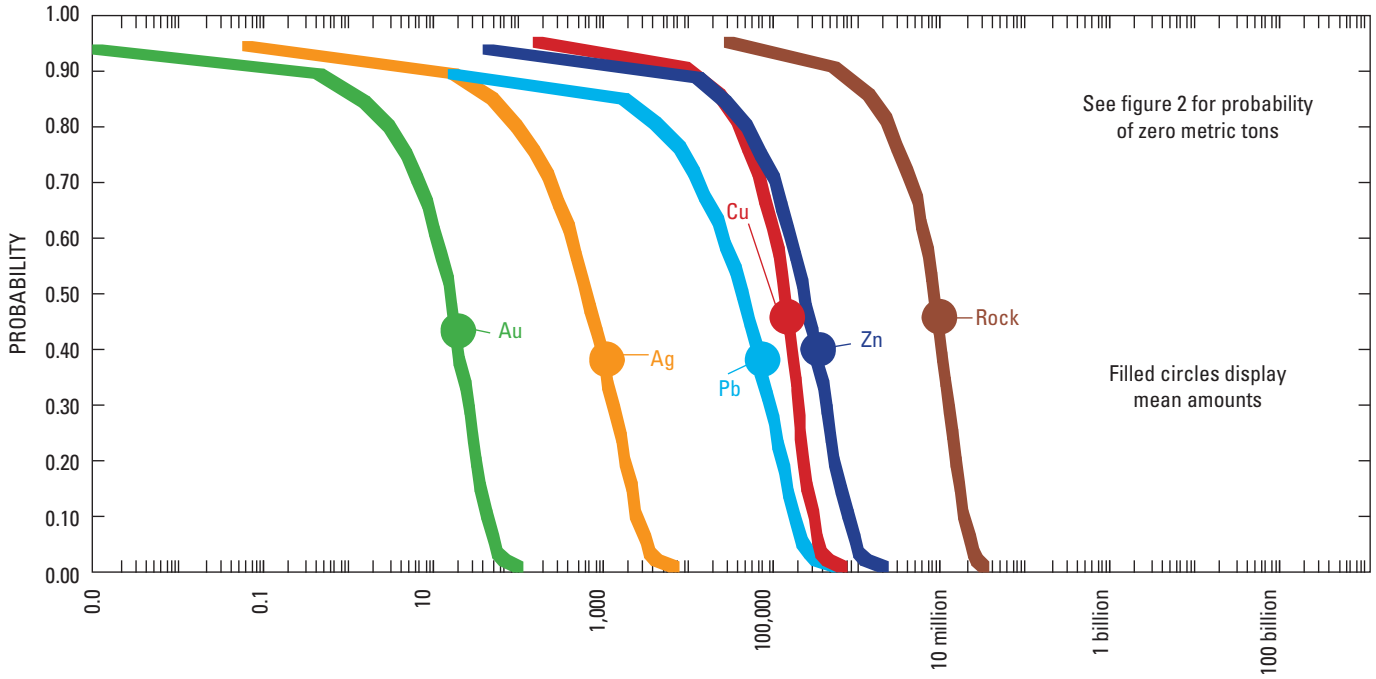

Figure 3. Graph showing cumulative distributions of contained metal and mineralized rock (in metric tons) in undiscovered kuroko massive sulfide deposits estimated in tract PC–17, California (see figs. 1 and 2). From Ludington and others (1996).

requirement that these deposits have grades and tonnages similar to the deposit model appropriate to the tract. Most models used in the national assessment were those described by Cox and Singer (1986) and Bliss (1992).

The third part of the assessment method uses a Monte Carlo simulation computer program to combine the probability distribution of the number of undiscovered deposits with the grade and tonnage datasets associated with each deposit model to obtain the probability distribution for the undiscovered metal in each tract (Root and others, 1992, 1997). For the national assessment, the resulting cumulative probability distributions represent the estimated quantities of gold, silver, copper, lead, and zinc in each tract and allow various fractals and the mean estimates to be obtained for the tracts (fig. 3).

Results of the Assessment

In the national assessment, 55 major deposit models and submodel types were used to delineate 447 permissive tracts. Quantitative estimates of undiscovered mineral resources were possible in 305 of these tracts. In addition to estimating gold, silver, copper, lead, and zinc in undiscovered mineral deposits, the national assessment (Long and others, 1998; U.S. Geological Survey National Mineral Resource Assessment Team, 2000) also estimated resources of these metals remaining in, and produced from, identified deposits, as follows:

- In undiscovered deposits minable with existing technology—18,000 metric tons (t) of gold, 460,000 t of silver, 290,000 kilotons (kt) of copper, 85,000 kt lead, and 210,000 kt of zinc.
- In identified deposits—15,000 t of gold, 160,000 t of silver, 260,000 kt of copper, 51,000 kt of lead, and 55,000 kt of zinc.
- Past production from the largest identified U.S. deposits (accounting for about 99 percent of cumulative domestic production through 1996)—12,000 t of gold, 170,000 t of silver, 91,000 kt of copper, 41,000 kt of lead, and 44,000 kt of zinc.

Some Implications

The USGS National Mineral Resource Assessment provides the first quantitative estimate of the amounts of undiscovered gold, silver, copper, lead, and zinc in the United States. The results suggest that, for conventional-type deposits of these five metals, the United States still contains about as much in undiscovered deposits as was discovered previously.

Along with providing estimates of the quantity and quality of undiscovered mineral resources, the national assessment provides a consistent, systematic database of current geologic and mineral resource information at a national scale. This database permits, at least at some minimum level, evaluation of the impact of land use decisions on the Nation's undiscovered mineral resources. Large parts of the areas delineated as permissive for occurrence of undiscovered deposits already are unavailable for future mineral exploration and development because of their use for urban, transportation, and other development and their withdrawal for wilderness, scenic areas of various kinds, national parks and monuments, wildlife refuges, endangered species protection, and so on. The national assessment database provides Federal, State, and local land management agencies information with which to estimate the potential cumulative environmental impact of possible exploration and mining activities, to evaluate the potential economic benefits of mining in comparison with other land uses, to evaluate and plan for the potential impact of mining activities on other land uses, and to appraise the fair market value of land proposed for leasing, sale, exchange, or taking. The permissive tracts delineated as part of the national assessment also permit industry to focus mineral exploration programs on the areas and regions most promising for new discoveries.

National assessments conducted on a recurring basis can provide a means to help ensure adequate mineral supplies and effective stewardship of environmental and other resources in the future. The national assessment methodology may serve as a guide for undertaking assessments at continental and global scales.

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