U.S. DEPARTMENT OF THE INTERIOR
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QUANTITATIVE ASSESSMENT OF UNDISCOVERED METALLIC MINERAL RESOURCES IN THE EAST MOJAVE NATIONAL SCENIC AREA, SOUTHERN CALIFORNIA

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Summary

This assessment augments the detailed report entitled Evaluation of Metallic Mineral Resources and their Geologic Controls in the East Mojave National Scenic Area, San Bernardino County, California, by the U.S. Geological Survey (1991). The geologic and mineral resource information together with the maps and references in that report provide the principal basis for the conclusions reached in this document. That report also includes background information regarding designation of the Scenic Area and current legislation affecting it. This evaluation of the Area's metallic mineral resources was prompted by proposals for Congressional withdrawal of the lands for inclusion within the national park or wilderness systems; if enacted, such withdrawals would affect future entry for mineral exploration and development under the current mining laws of the United States. An analysis of the effect such action could have on the future resource needs of the nation is thus an important factor in any equation that seeks to balance competing land uses.

The numbers estimated for undiscovered deposits of the types considered in this assessment (table 1) suggest that the prospects for further mineral discoveries in the East Mojave National Scenic Area are relatively poor. The current focus of the minerals industry on gold may prompt exploration interest in hot-spring gold deposits within the EMNSA, but in the parlance of mineral resources, this does not appear to be an area of world-class deposits. The region has been extensively prospected for the last hundred years, and surface exposures of known types of deposits, exploitable with present-day technology, have largely been identified; deposits possibly buried by alluvium have received less attention. The probabilities for discovery of new deposits are dependent on future technological innovation and (or) dramatic changes in world politico-economic conditions that affect commodity prices and national priorities.

Table 1. *Probabilistic estimates of numbers of undiscovered mineral deposits in the East Mojave National Scenic Area, southern California*

[Numbers in parentheses after deposit types refer to deposit types in Cox and Singer (1986)]

Deposit type (number	Estimated number of undiscovered deposits at the indicated probability levels				
	0.9	0.5	0.1	0.05	0.01
Carbonatite REE (10)	0	0	1	1	2
Tungsten veins (15a)	0	0	0	0	1
Porphyry Cu (17)	0	0	0	1	1
Cu skarn (18b)	1	2	4		
Pb-Zn skarn (18c)	0	1	2	5	7
Fe skarn (18d)	0	0	1	3	5
Polymetallic replacement (19a)	0	0	0	1	1
Low-F porphyry Mo (21b)	0	0	0	0	1
Polymetallic veins (22c)	3	8	20		
Hot-spring Au (25a)	0	1	2	3	3

Assessment procedure and results

The resource-assessment team, which met on August 29-30, 1991, in Menlo Park, California, consisted of the following individuals: Richard M. Tosdal (project chief), Ted G. Theodore (project leader), William J. Bagby, James D. Bliss, Dennis P. Cox, Carroll Ann Hodges, Robert C. Jachens, David A. John, William J. Keith, Stephen D. Ludington, David M. Miller, Robert J. Miller, Jane E. Nielson, Gary A. Nowlan, Donald A. Singer, and Howard G. Wilshire. Tom Gunther, of the U.S. Bureau of Mines, was present as an observer. Bagby, Bliss, Cox, Ludington, and Singer held primary responsibility for evaluating the information available and estimating numbers that represent probability of occurrence for undiscovered mineral deposits of specific deposit types. Industrial minerals were not included. It was determined that probabilistic estimates could justifiably be made for undiscovered deposits of the following types (Cox and Singer, 1986): carbonatite REE, tungsten vein, low-F porphyry molybdenum, porphyry copper, polymetallic replacement, polymetallic vein, copper, lead-zinc, and iron skarns, and hot-spring gold. Other deposit types that are known to occur in the East Mojave National Scenic Area (EMNSA) are described in the companion report (U.S. Geological Survey, 1991). The assessment team concluded that only the deposit types listed above were amenable to quantitative analysis. The critical constraints for the selection of deposit types are: (1) appropriate geologic environment; and (2) availability of the applicable grade and tonnage models.

The largest metal mine currently in production in the EMNSA, the Colosseum Mine, is a breccia-pipe gold deposit, a type for which no occurrence or grade and tonnage model has yet been compiled; thus, even though permissive tracts for the occurrence of additional deposits of this type have been outlined, it was not possible to produce a numerical estimate of the number of additional deposits that might be present. Furthermore, many vein deposits, termed gold-silver polymetallic veins and gold-silver, quartz-pyrite veins (U.S. Geological Survey, 1991) are found in the EMNSA for which appropriate grade and tonnage models also are not available. Some of these may be epithermal and some could be quite large (similar to the Mesquite Mining District south of the EMNSA), but undiscovered deposits of these types could not be estimated.

The first step toward this assessment of undiscovered mineral resources in the EMNSA was the delineation of tracts of land, defined by geologic, geophysical, and geochemical attributes, that are *permissive* for the occurrence of specific types of mineral deposits. In the related geologic report (U.S. Geological Survey, 1991), maps showing the tracts were drawn by consensus among those most familiar with the geology, geophysics, geochemistry, and mineral occurrences of the area. The depth limitation agreed upon was 500 m, so that permissive rocks obscured by 500 m or less of valley alluvium, for example, were included in the tracts outlined. Within those tracts, additional areas were identified that were judged to be *favorable* for the presence of a deposit type, commonly because of known mineralization or alteration. A summary diagram showing these permissive terranes is included here for reference (fig. 1).

Probabilistic estimates of the numbers of undiscovered deposits were then derived, through discussion and accord, for each deposit type for which a permissive tract had been drawn and for which grade and tonnage models are available (Cox and Singer, 1986). Table 1 summarizes our best collective estimates of the number of undiscovered deposits of a given type that exist at specific probability levels within the designated permissive tracts. (Additional commentary on each deposit type is presented in the text accompanying tables 2 through 11.) These undiscovered deposits should occur with greater frequency in the parts of permissive tracts designated favorable. The probabilistic estimates were guided by the appropriate grade and tonnage models, which have been compiled for given deposit types using worldwide data (Cox and Singer, 1986); thus, about half the undiscovered deposits should exceed the median grade and tonnage as shown by the frequency distribution curves for that deposit type. Using this information, the U.S. Bureau of Mines can prepare comprehensive economic analyses and resource-supply projections.

The basis for making quantitative estimates of the numbers of undiscovered deposits of a given type derives from the accumulated knowledge about the geologic, geophysical, and geochemical environment of the area, its exploration and production history to the extent known or inferred, and the characteristics of the deposit type worldwide. A great many variables and uncertainties are inherent in the estimating procedure, and the

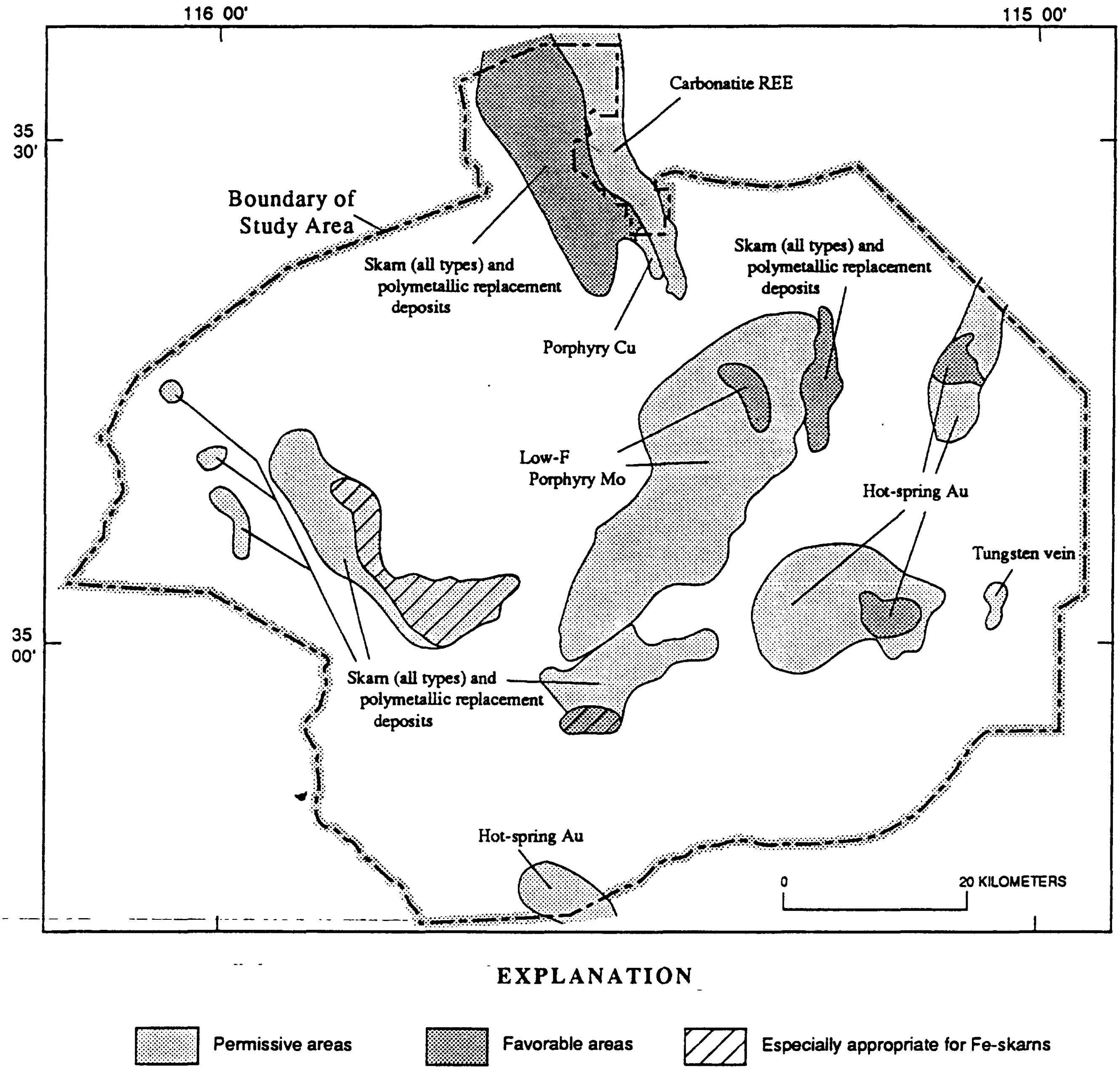

Figure 1. Favorable and permissive areas for selected mineral deposit types in the East Mojave National Scenic Area, southern California.

precision of the final numbers is dependent on both the quality of the databases and the level of experience of the assessment team. The inherent uncertainty and probabilistic nature of the assessment process is reflected in the form of the results presented in this report.

With respect to this effort in the EMNSA, the following caveats must be noted:

1. The distribution of geophysical data, although adequate to define the regional and local settings, is not detailed enough to indicate exploration targets.
2. Delineation of favorable ground by available geochemical data was hampered by the paucity of samples and by lack of adequate data for elements of interest, such as Cu, Pb, Zn, and Au.
3. Time in the field specifically devoted to mineral occurrence examination was limited to about 6 man-weeks, although information on the geologic environments was obtained from all known sources and persons. We relied to great extent on the comprehensive data gathered and compiled by the U.S. Bureau of Mines (1990).
4. The U.S. Geological Survey is not privy to all proprietary information held by mining companies that have done detailed exploration work in the area. Knowledge of company data is limited mainly to voluntary (and chance) verbal communication, including hearsay.
5. This assessment is based on our current understanding of mineral-deposit types; our knowledge is continuously subject to improvement and revision. New deposit types may be discovered and described in the future that could add new resources to those presently estimated. This assessment was made using the best tools and information available to us.

The U.S. Bureau of Mines (1990) report on the mineral occurrences of the East Mojave National Scenic Area includes an economic evaluation of the known deposits. For our purposes, some of these are considered undiscovered deposits because grade and tonnage data for them are not publicly available. Therefore these must be identified and deleted from the list of known deposits in any summary compilation, in order to avoid duplication of economic statistics.

For each of the deposit types listed below, the greatest number of deposits in the EMNSA (specifically in those tracts of land designated permissive) is estimated for which there is a 90%, 50%, 10%, 5%, and 1% chance or greater of occurring. These numbers represent the collective knowledge of 4 to 6 experts, after lengthy discussion of all known relevant factors by those familiar with the geology, geophysics, and geochemistry of the area and (or) the characteristics of the deposit type.

Each of the deposit types and its known occurrences is discussed more thoroughly in the above-referenced geologic report (U.S. Geological Survey, 1991). In the following list, the deposit type is identified by its model number (parenthesis) as assigned in Cox and Singer (1986). A complete description of the deposit type together with the grade and tonnage models that have been compiled can be found in that reference. In these models, average grades are independent of ore tonnages. The rationale and procedure for preparing a resource assessment that includes numerical estimates for specific deposit types are contained in the references by Singer and Cox (1988) and Singer (1990).

Tables showing number of deposits of given type estimated to occur within permissive areas of the EMNSA

The numbers in the tables below represent our estimates of the number of deposits that could occur within tracts (outlined on figure 1) having a geologic environment permissive for the deposit type identified. The level of confidence that the stated number of undiscovered deposits exist is indicated by the probabilities, in percent, heading each column. These estimates suggest that the East Mojave National Scenic Area is unlikely to contain significant numbers of undiscovered world-class mineral deposits of the types analyzed in this report.

To determine the possible grade and tonnage of such undiscovered deposits, one can refer to the grade and tonnage models of Cox and Singer (1986); for each probability level, half the number of deposits estimated should, on average, have grades and tonnages that are as large or larger than the median values on the appropriate grade and tonnage model curves.

These median numbers are given parenthetically in the headings for each deposit type listed below. The use of these tables is exemplified as follows: There is a 5 percent chance that one porphyry copper deposit occurs in the tract designated permissive on figure 1; such a deposit has a 50 percent chance of exceeding 140,000,000 tonnes of ore, and a 50 percent chance of having a grade of 0.54 percent Cu or higher.

Carbonatite (Model no. 10; median tonnage, 60,000,000 t; median Nb_2O_5 grade, 0.58%; 10% of the deposits have REO grades that exceed 0.35%*)

The largest producer of rare earth elements (REE) in the United States is the Mountain Pass mine, located just beyond the Scenic Area boundary, which was drawn specifically to exclude it. The same suite of rocks extends southward a short distance into the EMNSA, however, as shown on figure 1. The following table indicates our estimate that within that area a 10 percent chance exists for at least one deposit to occur, with a 50 percent chance that that one deposit will be equal to or greater than the median tonnage and grade; a 5 percent chance does not increase the odds, but there is a 1 percent chance that there are 2 or more undiscovered deposits. The grade and tonnage models are largely based on data for niobium-rich deposits that may or may not accurately reflect statistics for any undiscovered deposits in the favorable area. The data are the best available. For comparison, the Mountain Pass deposit reportedly has proven and probable ore reserves of approximately 31 million tons, based on a cut-off grade of 5 percent lanthanum oxide; Nb content of the ore is unavailable, but none is produced.

Table 2. *Estimated number of carbonatite deposits at probability levels shown*

90%	50%	10%	5%	1%
0	0	1	1	2

*All references to grade are in weight percent.

Tungsten veins (Model no. 15a; median tonnage, 560,000 t; median WO_3 grade, 0.9%)

Numerous tungsten veins exist in the EMNSA, but they are small and production has been minimal; there is little likelihood that a deposit exists comparable to those in the grade and tonnage model.

Table 3. *Estimated number of tungsten vein deposits at probability levels shown*

90%	50%	10%	5%	1%
0	0	0	0	1

Porphyry copper (Model no. 17; median tonnage, 140,000,000; median Cu grade, 0.54%)

No porphyry copper deposits are known within the EMNSA, but appropriate plutonic rocks are present; the judgement of low probability for occurrence is based in part on the lack of indication of such a deposit type despite extensive prospecting. According to our estimate, there is a low probability that one deposit occurs.

Table 4. *Estimated number of porphyry copper deposits at probability levels shown*

90%	50%	10%	5%	1%
0	0	0	1	1

Cu Skarn (Model no. 18b; median tonnage, 560,000 t; median Cu grade, 1.7%; 10% of the deposits have Ag grades that exceed 36 g/t; 10% of the deposits have Au grades that exceed 2.8 g/t)

Numerous small skarn deposits are known throughout the EMNSA; according to the table below, there is a high probability that at least one undiscovered deposit exists. Au is a common accessory metal. For comparison, the median tonnage and grade of porphyry Cu deposits, from which much of the world's present Cu production comes, are (as indicated above) 140 million tonnes and 0.54 percent Cu.

Table 5. *Estimated number of copper skarn deposits at probability levels shown*

90%	50%	10%
1	2	4

Pb-Zn skarn (Model no. 18c; median tonnage, 1,400,000 t; median Zn grade, 5.9%; median Pb grade, 2.8%; median Cu grade, 0.09%; median Ag grade, 290 g/t; 10% of the deposits have Au grades that exceed 0.46 g/t)

As in the case of copper skarns, lead-zinc skarn occurrences are fairly common in the EMNSA, but they are characteristically small. In deposits worldwide, Cu, Au, and Ag are common accessory metals.

Table 6. *Estimated numbers of Pb-Zn deposits at probability levels shown*

90%	50%	10%	5%	1%
0	1	2	5	7

Fe skarn (Model no. 18d; median tonnage, 7,200,000 t; median Fe grade, 50%)

Iron deposits are discovered relatively easily because of their magnetic signature; they appear prominently in detailed airborne magnetic surveys. Several deposits are known in the EMNSA (notably the inactive Vulcan Mine, which produced 2.6 million tons of ore), but the chances of there being large undiscovered deposits are relatively small because of extensive past exploration. Resolution of U.S. Geological Survey data available to us, however, is low, leaving open the 10 percent probability that one or more undiscovered deposits exist, although none is likely to be as large as the tonnage model indicates.

Table 7. *Estimated numbers of Fe skarn deposits at probability levels shown*

90%	50%	10%	5%	1%
0	0	1	3	5

Polymetallic replacement (Model no. 19a; median tonnage 1,800,000 t; median Pb grade, 5.2%; median Zn grade, 3.9%; median Cu grade, 0.094%; median Ag grade, 150 g/t; median Au grade, 0.19 g/t)

Several polymetallic replacement deposits are known in carbonate rocks, mainly in the western Clark Mountain Range and northern Providence Mountains. Characteristically, these deposits are small and of little consequence in the EMNSA. The data above, from Cox and Singer (1986), refer to districts, as opposed to single deposits. The numbers below indicate the probabilities for occurrence of a group of polymetallic deposits that could comprise a district having a 50 percent chance of exceeding the median tonnage and grades.

Table 8. *Estimated numbers of polymetrallic replacement deposits at probability levels shown*

90%	50%	10%	5%	1%
0	0	0	1	1

Low-F Porphyry Mo (Model no. 21b; median tonnage, 94,000,000 t; median Mo grade, 0.085%)

One large but sub-economic molybdenum deposit of this type, the Big Hunch prospect in the New York Mountains, is known to occur within the EMNSA; its average grade and tonnage are 0.025 percent Mo and 1.8 billion tonnes. The probability that one or more deposits of this type remain to be discovered is estimated at 1 percent. For comparison, grade and tonnage models for the more productive Climax-type stockwork molybdenum deposits show median numbers of 0.19 percent Mo and 200 million tonnes. The low average grade of fluorine-deficient systems has rendered them less-attractive exploration targets.

Table 9. *Estimated numbers of low-fluorine porphyry Mo deposits at probability levels shown*

90%	50%	10%	5%	1%
0	0	0	0	1

Polymetallic vein (Model no. 22c; median tonnage, 7,600 t; median Zn grade, 2.1%; median Pb grade, 9%; 10% of the deposits have Cu grades that exceed 0.89%; median Ag grade, 820 g/t; median Au grade, 0.13 g/t)

Polymetallic vein deposits are among the most common type in the world, but they are usually small and thus seldom constitute important exploration targets. Polymetallic veins generally have high concentrations of base metal minerals, but they have been exploited primarily for precious metals. There are 206 known occurrences in the EMNSA, including one significant mine, the Morning Star, for which proven reserves were reported in 1988 to include about 8 million tons of ore at a grade of 0.06 oz Au/ton (U.S. Geological Survey, 1991). The probability that additional polymetallic vein deposits exist is high, but the tonnage models (which do not apply to those with significant Au because data are inadequate) show that the median tonnage of such deposits is small.

Table 10. *Estimated numbers of polymetallic vein deposits at probability levels shown*

90%	50%	10%
3	8	20

Hot-spring Au (Model no. 25a; median tonnage, 13,000,000 t; median Ag grade, 2.9 g/t; median Au grade, 1.6 g/t {Berger and Singer, in press})

Of the several types of gold deposits that occur in volcanic rocks, hot-spring gold is the principal type currently being mined in the United States. These deposits typically are large-tonnage, low-grade deposits that are amenable to open pit mining and recovery of gold by heap leaching methods. Hot-spring gold is a major exploration target and several large deposits have been discovered in the past 10 years in the western United States. The Hart deposit, located in the eastern part of the EMNSA, is typical of this type, having 1.77 million ounces of gold reserves and potential for the discovery of additional reserves adjacent to the deposit. The probability that at least one undiscovered hot spring gold deposit exists in those Tertiary volcanic rocks labeled permissive within the EMNSA is 50%.

Table 11. *Estimated numbers of hot-spring Au deposits at probability levels shown*

90%	50%	10%	5%	1%
0	1	2	3	3

Gross In-place Value of Resources

The numbers of estimated deposits presented in tables 2-11 and summarized in table 1, combined with the grade and tonnage models, were used to calculate the gross in-place value (GIPV) of the estimated undiscovered mineral resources of the EMNSA, using the Mark3 Simulator (Drew and others, 1984; Scott and Drew, 1988). Mark3 output consists of probabilistic estimates of the amount of metal contained in the estimated undiscovered deposits. The operation of the program is discussed on pages 17 and 18 of Brew and others (1991). Table 12 shows the tonnage of metals estimated to be present in all deposit types.

Table 12A. *Mean tonnage of estimated undiscovered deposits, by type, for the East Mojave National Scenic Area, southern California*

Deposit Type	Mean no. of Deposits	tonnes REO	tonnes Nb	tonnes Cu	tonnes Au	tonnes Ag	tonnes W	tonnes Zn	tonnes Pb	tonnes Mo	tonnes Fe
Carbonatite[1]	0.34	90,200	314,000	0	0	0	0	0	0	0	0
Cu Skarn	2.25	0	0	132,000	2	19	0	0	0	0	0
W Veins	0.03	0	0	0	0	0	681	0	0	0	0
Zn-Pb Skarn	1.31	0	0	26,100	5	321	0	334,000	160,000	0	0
Mo Porphry	0.03	0	0	0	0	0	0	0	0	5,520	0
Fe Skarn	0.52	0	0	0	0	0	0	0	0	0	24,000,000[2]
Cu Porphyry	0.07	0	0	179,000	1	34	0	0	0	5,730	0
Polymetallic Replacement	0.07	0	0	753	<1	89	0	23,800	21,900	0	0
Hot-spring Au	1.08	0	0	0	52	208	0	0	0	0	0
Polymetallic Veins	9.97	0	0	1,200	3	1,040	0	58,400	82,000	0	0
total for EMNSA	--	90,200	314,000	339,000	62	1,710	681	416,000	264,000	11,200	24,000,000[2]

[1]The known deposit at Mountain Pass may not be well-represented by the models. Mountain Pass has much higher REO grades than most deposits in the model, and no columbium (Nb) is produced, whereas columbium is the most valuable commodity in most carbonatite deposits.
[2]Because of implications of aeromagnetic data for the size of undiscovered iron skarn deposits in the EMNSA, this value may be too large.

Table 12B. *Estimated tonnage of undiscovered deposits at the 0.5 probability level, by type, for the East Mojave National Scenic Area, southern California*

Deposit Type	tonnes REO	tonnes Nb	tonnes Cu	tonnes Au	tonnes Ag	tonnes W	tonnes Zn	tonnes Pb	tonnes Mo	tonnes Fe
Carbonatite	0	0	0	0	0	0	0	0	0	0
Cu Skarn	0	0	38,300	0	0	0	0	0	0	0
W Veins	0	0	0	0	0	0	0	0	0	0
Zn-Pb Skarn	0	0	0	0	14	0	67,600	22,700	0	0
Mo Porphry	0	0	0	0	0	0	0	0	0	0
Fe Skarn	0	0	0	0	0	0	0	0	0	0
Cu Porphyry	0	0	0	0	0	0	0	0	0	0
Polymetallic Replacement	0	0	0	0	0	0	0	0	0	0
Hot-spring Au	0	0	0	17	0	0	0	0	0	0
Polymetallic Veins	0	0	176	<1	363	0	24,100	46,700	0	0
total for EMNSA	0	0	71,900	27.9	890	0	168,000	134,000	0	0

GIPV represents the in-place dollar value of the resources estimated for different deposit types, and is the product of the market price of the commodity and the estimated undiscovered tonnage of the commodity. This value is different from net value, which would have to account for costs of exploration, development, mining, financing, concentrating, and refining, and would be discounted to current dollars. In fact, a large proportion of the estimated mineral deposits may not be mineable at a profit.

The prices used to calculate GIPV were primarily 5-year averages (1986-90) taken from Mineral Commodity Summaries, an annual publication of the U.S. Bureau of Mines. Table 13 gives the prices used in the calculations, in the units in which the prices are commonly reported and in U.S. dollars/tonne. The prices are not normalized to account for inflation.

Table 13. *Prices used in calculation of Gross In-place Value, GIPV*
[Prices for tungsten, copper, lead, zinc, gold, silver, molybdenum, and columbium are 5-year (1986-90) unweighted averages, calculated using data from Mineral Commodity Summaries, an annual publication of the U.S. Bureau of Mines. Price for REO is the 2-year average (1989-1990) from the same publication. Price for iron is the average price paid during 1991 for iron in all types of iron ore, FOB west coast]

Commodity	Price in $/ reported units	Price in $/tonne
[1]REO (rare-earth oxides)	$2.54/kg contained REO	2,540
[1]Tungsten (WO3)	$50.40 mtu WO_3	5,040
Copper	$1.04/lb Cu	2,293
Lead	$0.36/lb Pb	794
Zinc	$0.59/lb Zn	1,300
Gold	$403.42/oz Au	12,970,400
Silver	$5.90/oz Ag	189,680
Molybdenum	$7.43/kg Mo	7,430
Iron	$48.86/Ton contained Fe	53.86
[1]Columbium (Nb_2O_5)	$2.68/lb Nb_2O_5	5,908

[1]Rare earths, tungsten, and columbium (niobium) are priced on the basis of their oxide form; similarly, grades in the grade-tonnage models are expressed in oxide form.

Table 14 presents the calculated GIPV in two different ways, in order to highlight different aspects of the conclusions of this report. Table 14A shows the mean GIPV of the area, by deposit type, and is useful for comparing the relative GIPV contributed by those various deposit types. Table 14B shows the estimates of GIPV at a probability level of 0.5, and may be most useful for comparing the relative likelihoods that the estimated values exist.

Table 14A. *Mean GIPV of estimated undiscovered deposits, by type, for the East Mojave National Scenic Area, southern California, in millions of U.S. dollars*

Deposit Type	Mean no. of Deposits	REO	Nb	Cu	Au	Ag	W	Zn	Pb	Mo	Fe	total for deposit type
Carbonatite[1]	0.34	229	1,850	0	0	0	0	0	0	0	0	2,080
Cu Skarn	2.25	0	0	302	27	4	0	0	0	0	0	332
W Veins	0.03	0	0	0	0	0	3	0	0	0	0	3
Zn-Pb Skarn	1.31	0	0	60	60	61	0	434	127	0	0	742
Mo Porphry	0.03	0	0	0	0	0	0	0	0	41	0	41
Fe Skarn	0.52	0	0	0	0	0	0	0	0	0	1,300[2]	1,300[2]
Cu Porphyry	0.07	0	0	410	0	6	0	0	0	43	0	459
Polymetallic Replacement	0.07	0	0	2	6	17	0	31	17	0	0	72
Hot-spring Au	1.08	0	0	0	670	39	0	0	0	0	0	710
Polymetallic Veins	9.97	0	0	3	36	196	0	76	65	0	0	376
total for EMNSA		229	1,850	776	814	323	3	541	210	84	1,300[2]	6,152

[1]The known deposit at Mountain Pass may not be well-represented by the models. Mountain Pass has much higher REO grades than most deposits in the model, and no columbium (Nb) is produced, whereas columbium is the most valuable commodity in most carbonatite deposits.

[2]Because of implications of aeromagnetic data for the size of undiscovered iron skarn deposits in the EMNSA, this value may be too large.

Table 14B. *Estimated GIPV of undiscovered deposits at the 0.5 probability level, by type, for the East Mojave National Scenic Area, southern California, in millions of U.S. dollars*

Deposit Type	REO	Nb	Cu	Au	Ag	W	Zn	Pb	Mo	Fe	total for deposit type
Carbonatite	0	0	0	0	0	0	0	0	0	0	0
Cu Skarn	0	0	88	0	0	0	0	0	0	0	88
W Veins	0	0	0	0	0	0	0	0	0	0	0
Zn-Pb Skarn	0	0	0	0	3	0	88	18	0	0	108
Mo Porphry	0	0	0	0	0	0	0	0	0	0	0
Fe Skarn	0	0	0	0	0	0	0	0	0	0	0
Cu Porphyry	0	0	0	0	0	0	0	0	0	0	0
Polymetallic Replacement	0	0	0	0	0	0	0	0	0	0	0
Hot-spring Au	0	0	0	221	0	0	0	0	0	0	221
Polymetallic Veins	0	0	<1	7	69	0	31	37	0	0	145
total for EMNSA	0	0	165	362	169	0	218	107	0	0	1,020[1]

[1]Total does not agree with column sumsbecause totals are from an independent simulation that considers all deposits together.

Several distinctive differences between the two tables merit explanation. Several commodities, REO (rare-earth oxides), columbium (Nb), tungsten, molybdenum, and iron have substantial mean calculated GIPV (table 14A), even though the probability is less than 0.5 that any values exist (table 14B). The substantial means are a function of the sizes of the ore deposits in which these commodities are found. In some cases, these distributions have great variability (large standard deviations). Since the mean is calculated by dividing the number of tonnes of metal estimated by all 4,999 cycles of the Mark3 simulator by the number of cycles, a deposit type for which there is a finite probability of occurrence, no matter how small, will always generate a mean tonnage of metal.

For example, the mean GIPV for iron, in iron skarn deposits is $1,300 million (table 14A) whereas at a probability level of 0.5 (table 14B), no iron resource is indicated to exist. In fact, in the case of iron, the probability that the GIPV is as large as the mean ($1,300 million), is approximately 0.11.

Table 15 is a summary of the probabilistic estimates, at the 0.9, 0.5, and 0.1 probability levels for all commodities in the EMNSA.

Table 15.. *Probabilistic estimates of GIPV of estimated undiscovered deposits, by commodity, for the East Mojave National Scenic Area, southern California, in millions of U.S. dollars*

Commodity	0.9 probability of the following GIPV or more	0.5 probability of the following GIPV or more	0.1 probability of the following GIPV or more
REO (rare-earth oxide)	0	0	0
Columbium (Nb_2O_5)	0	0	3,240
Copper (Cu)	11	165	1,350
Gold (Au)	10	362	2,210
Silver (Ag)	27	169	833
Tungsten (WO_3)	0	0	0
Zinc (Zn)	11	218	1,530
Lead (Pb)	12	107	530
Molybdenum (Mo)	0	0	0
Iron (Fe)	0	0	1,570
total	71	1,020	11,300

The deposit types with the greatest mean GIPV (table 14A) are carbonatite REE deposits and iron skarn deposits. It is important to reiterate the uncertainty in applying the carbonatite grade and tonnage models to the EMNSA. The known deposit at Mountain Pass may not be well-represented by the models. Mountain Pass has much higher REO grades than most deposits in the model, and no columbium (Nb) is produced, whereas columbium is the most valuable commodity in most carbonatite deposits; this is reflected by the large estimated GIPV for Nb in table 14A. It is important to note that the permissive area for carbonatite REE deposits occupies a very small region, in the north-central part of the EMNSA (fig. 1).

The estimate for the probability of occurrence of one or more iron skarn deposits is 0.1. However, many iron skarn deposits are quite large, as shown by the grade and tonnage model (Cox and Singer, 1986), and, if one is present in the EMNSA, it might contain significant iron resources (tables 12, 14). Although the worldwide tonnage model for iron skarns was used for simulation, aeromagnetic data constrain the tonnage of undiscovered deposits in the EMNSA. There is virtually no chance that undetected deposits as large as those in the larger portion of the tonnage model exist; therefore the tabulated tonnage and GIPV estimates for iron are too large by at least an order of magnitude.

Tables 14 and 15 suggest that gold, especially in hot-spring gold deposits, is the resource that is most likely to occur in large amounts in the EMNSA. This is reflected in the current high level of exploration activity for this deposit type.

References

Berger and Singer, in press, Grade and tonnage model of hot-spring Au-Ag, *in* Bliss, J. D., ed., 1992, Developments in mineral deposit modeling: U.S. Geological Survey Bulletin 2004.

Brew, D. A., Drew, L. J., Schmidt, J. M., Root, D. H., and Huber, D. F., 1991, Undiscovered locatable mineral resources of the Tongass National Forest and adjacent lands, Southeastern Alaska: U.S. Geological Survey Open File Report 91-10, 370 p.

Cox, D.P., and Singer, D.A., editors, 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p.

Drew, L.J., Bliss, J.D., Bowen, R.W., Bridges, N.J, Cox, D.P, DeYoung, J.H., Houghton, J.C., Ludington, Steve, Menzie, W.D., Page, N.J, Root, D.H., and Singer, D.A., 1986, Quantitative estimation of undiscovered resources--the case study of U.S. Forest Service wilderness tracts in the Pacific Mountain System: Economic Geology, v. 81, p. 80-88.

Root, D. H. and Scott, W. A., 1988, User manual for mineral simulation program: U.S. Geological Survey Open File Report 88-15, 63 p

Singer, D.A., and Cox, D.P., 1988, Applications of mineral deposit models to resource assessments: U.S. Geological Survey Yearbook 1987, p. 55-57

Singer, D.A., 1990, Development of grade and tonnage models for different deposit types: Geological Association of Canada Special Paper (in press).

U.S. Bureau of Mines, 1991, Mineral Commodity Summaries, 196 p.

U.S. Bureau of Mines, 1990, Minerals in the East Mojave National Scenic Area, California: A minerals investigation, vol. 1: Open-File Report MLA 6-90.

U.S. Geological Survey, 1991, Evaluation of Metallic Mineral Resources and their Geologic Controls in the East Mojave National Scenic Area, San Bernardino County, California: U.S. Geological Survey Open-File Report 91-427, in press.