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FINAL REPORT ON THE SAMPLING DESIGN FOR THE OHSMI

VOLUME 1

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The Occupational Hazard Survey of the Mining Industry (OHSMI) is a project of the National Institute for Occupational Safety and Health (NIOSH). The OHSMI was envisioned as a complement to the general industry-oriented National Occupational Hazard Surveys (NOHS I and II). The specific objective was to develop a statistical sampling strategy for selecting and surveying active mine sites.

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1. INTRODUCTION

The Occupational Hazard Survey of the Mining Industry (OHSMI) is a project of the National Institute for Occupational Safety and Health (NIOSH). The OHSMI was envisioned as a complement to the general industry-oriented National Occupational Hazard Surveys (NOHS I and II). The specific objective was to develop a statistical sampling strategy for selecting and surveying active mine sites.

JRB developed three prototype designs for the OHSMI. All three designs were intended to:

- Provide coverage of appropriate Standard Industrial Classification (SIC) codes
- Estimate the number of miners exposed to hazards
- Estimate the number of mines with hazards, and with various occupational health facilities
- Provide estimates of hazards and health facilities by SIC as well as other domains which may be determined after the survey is complete.

Prototype II was chosen because it offered NIOSH the desired geographic diversity within each MSHA SIC category and could be completed within one year. Final design specifications were determined in a series of discussions, most recently in March 1982, between JRB staff and the NIOSH Project Officer for the Mining Surveillance Strategy Options project. These specifications reflected information provided to NIOSH in two JRB reports: the Report on the OHSMI Certainty Stratum (see Appendix A) and the Evaluation of Operational Status Change in the Mining Industry (January 1982).* Several times

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*Evaluation of Operational Status Change in the Mining Industry. JRB Associates. National Institute of Occupational Safety and Health, Contract No. 210-80-0026; January 15, 1982.

since this March meeting, the Project Officer and the JRB Project Manager have discussed preliminary analyses related to the final specifications and OHSMI design options.

This report represents the Final Report of the OHSMI Sample Design. Volume 1 incorporates the current design specifications, including modifications and further details added during the informal discussions. Chapter 2 discusses the design with respect to the seven basic elements that define a survey. Chapter 3 addresses the issue of nonresponse and discusses aspects of the survey design that deal with this issue.

Volume 2 consists of several data listings related to the OHSMI, presented as Exhibits 1 through 4. Exhibit 1 is Sample Frame #6--all MSHA sites in SIC categories selected by the NIOSH Project Officer, stratified by commodity and geography. Exhibit 2 lists manually-selected first-round self-representing units (SRU's) from Sample Frame #6 by SIC and mine identification code. Sample verification forms for a sample drawn from this frame are included as Exhibit 3. The computer code for the projection algorithm subroutine constitutes Exhibit 4.

Volume 3 of this report consists of the technical documentation for the Occupational Hazard Survey of the Mining Industry.

2. OHSMI DESIGN ELEMENTS

A survey design can be defined by specifying seven basic elements: sampling frame, sample number (size), sampling units, strata, selection procedure, estimation procedure, and variance calculation. Each of these elements is discussed below.

2.1 SAMPLING FRAME

A sampling frame for a survey is a listing of all of the entities that may be selected to form the sample that will be surveyed. The OHSMI sampling frame is derived from a file of metal and nonmetal mining and milling establishments maintained by the Mine Safety and Health Administration (MSHA). The particular file that was used was the 1980 year-end version of the Address and Employment file.

The original automated file consisted of records that were distinguished by a combination of the seven-digit MSHA mine identification number (mine ID) and a code for an employer at the site represented by the mine ID. To use the file as a sampling frame, the records were modified so that each mine ID corresponded to a single record.

The record for each mine ID includes information on the operational status and the mineral commodity classification of the site. The commodity classification is a five-digit coding system that MSHA has constructed from the four-digit Standard Industrial Classification (SIC). This coding system is referred to below as the MSHA SIC codes. NIOSH has specified that the OHSMI cover mine sites that have an active operating status. Eleven metal commodities and eight nonmetal commodities were specified for inclusion in the sampling frame. Table 1 lists the specified commodities, their MSHA SIC codes, and the total number of MSHA records (mine ID's) that met the further NIOSH specification of mine types.

Table 1. Number of MSHA sites with non-office employment by commodity for five-digit SIC codes selected by NIOSH for the OHSMI.

SIC CODE	DESCRIPTION	SITES WITH MINE ONLY	SITES WITH MILL ONLY	SITES WITH MINE + MILL	OTHER SITES	TOTAL
10110	Iron Ores	16	12	20	4	52
10210	Copper Ore	30	27	15	5	77
10310	Lead/Zinc Ores	27	10	20	2	59
10440	Silver Ore	30	12	18	2	62
10510 28191	Aluminum Ore and Alumina Mills	6	13	2	-	21
10612	Cobalt	0	-	1	1	2
10614	Manganese	1	3	1	-	5
10615	Molybdenum	6	1	4	-	11
10616	Nickel	-	-	1	-	1
10940 10941	Uranium and Uranium-Vanadium Ores	142	33	20	16	211
10942	Vanadium	-	1	1	-	2
Subtotal: Metal SIC's		258	112	103	30	503

Table 1. Number of MSHA sites with non-office employment by commodity for five-digit SIC codes selected by NIOSH for the OHSMI (continued).

SIC CODE	DESCRIPTION	SITES WITH MINE ONLY	SITES WITH MILL ONLY	SITES WITH MINE + MILL	OTHER SITES	TOTAL
14530 14550 14590	Clay Group	154	58	181	1	394
14720	Barite	31	48	18	–	97
14750	Phosphate Rock	20	10	28	–	58
14920	Gypsum	25	2	40	–	67
14991	Asbestos	3	3	1	–	7
14993	Gilsonite	4	–	2	–	6
14994	Mica	4	12	7	–	23
14998	Vermiculite	2	3	3	–	8
Subtotal: Nonmetal SIC's		243	136	280	1	660

The record for a mine ID includes information on process subunits at the mine site. These subunits are categorized as shown in Table 2. For the final design, NIOSH specified that sites with both a mining subunit (codes 1 and 3-7) and a mill (code 9) be given special attention, as explained in Section 2.2.

The sampling frame in Exhibit 1 includes the entire universe of MSHA mine sites for the selected commodities, categorized by the above specifications. Because the Mining Surveillance Strategy Options project does not address hazards to office workers, MSHA data for all subunits 10 have been deleted. The listing is subdivided into the SIC-regional strata (see Section 2.4). These stratum listings are grouped according to commodity in the order listed in Table 1.

The "mine only" column of Table 1 counts all sites with a subunit code of 1 or 3 through 7, but no subunit code 9. The "mill only" column counts all sites with a subunit code 9, but no subunit with a code of 1 or 3 through 7. A site was counted as a mine+mill if it had any of codes 1 or 3 through 7 and also had a subunit 9. Any other combinations of codes or sites listing no subunits were counted as "other" in Table 1.

Before the sampling frame was used in the second-stage sampling (see Section 2.5), sites with a reported total employment of zero were deleted.

The MSHA file has been found to contain mines which apparently are clustered at the same site but have different mine IDs. The use of an alternate sampling frame was considered but rejected because (1) the MSHA ID provides the only standard point of reference for sampling the population of interest, and (2) the MSHA file contains insufficient information to identify clusters reliably. When a selected site turns out to be part of a larger operation, only the selected part should be surveyed (to preserve the unbiasedness of estimates).

Table 2. Subunit categories used in the MSHA Address and Employment file.

JRB SUBUNIT CODE	SUBUNIT CATEGORY	COMMENTS
1	Underground extraction operations	Operations for removal of ore with men working below the surface of the ground.
2	Surface operations located at underground extraction operations	Includes shops, yards, and tipple when located at the same site as underground extraction operations.
3	Surface extraction operations	Includes open pit, strip, and quarry operations. Also includes shops and yards located at the same site as surface extraction operations.
4	Auger mining	Surface extraction operations with a boring machine; category is applied only to the coal industry.
5	Culm bank or refuse site operations	Reworking of previously processed coal. Applies only to the coal industry.
6	Dredging	Extraction of underwater ore by use of a floating platform.
7	Other surface mining	Includes metal/nonmetal extraction operations other than open pit, strip, quarry, or dredging. Examples are hydraulic mining, pumping, and ditching.
8	Independent shops and yards	Shops and yards not located at the same site as extraction operations. The MSHA identification number for such operations does not include any extraction subunits.
9	Mill or preparation plant	Includes milling and subsequent processing operations. A mill may have its own identification number or the same number as an extraction operation located at or near the mill site.

2.2 SAMPLE NUMBER

The sample number is the number of sampling units that are selected to be surveyed. The NIOSH design specifications that pertain to sample number apply to the number of sampling units to be selected from each stratum.

The first specification applies to the strata formed by subdividing MSHA SIC codes according to geographic regions (see Section 2.4). To the extent allowed by the population of the stratum, the survey sample should include, for each stratum, at least three sites with mining subunits and at least three sites with milling subunits. In addition, sites with both a mining subunit and a milling subunit are preferred to sites of similar size with only a mining subunit or a milling subunit. (See Section 2.3, Sampling Units, for a discussion of measure of size.) In this report, sampling units with both types of subunits will be called mine+mill units.

The second specification is that 10 to 15 percent of the stratum should be sampled with unit probability of selection proportional to employment at the unit.

As a consequence of these specifications, the exact sample number of the survey can vary. The approximate sample number is 350, if a 15-percent probability sample is selected after selecting the sites that are self-representing (see Section 2.5).

2.3 SAMPLING UNITS

The sampling units are the individual entities that constitute the sampling frame. The selection procedure specifies how individual sampling units are to be drawn from the sampling frame to form the survey sample. For the OHSMI design, the sampling units are mine sites as defined by individually-assigned MSHA mine identification numbers.

The measure of size of a sampling unit in the OHSMI design is the annual average number of non-office employees (average employment) at the mine site. Information on average employment is reported to MSHA for each subunit at a mine site. The record for each unit in the sampling frame includes the reported average employment for each of the nine subunit categories listed in Table 2. The record also includes the sum of the subunit employment figures. This sum is the reported average employment for the mine site, and is therefore the measure of size for the mine site as a sampling unit in the OHSMI.

The sampling units that are selected for the survey sample are further designated as self-representing units (SRU's) or non-self-representing units (NSRU's), depending on the way in which they were selected. SRU's are selected with certainty; in calculating statistics or variances, data from an SRU can represent only that sampling unit (hence, self-representing). In the OHSMI design, SRU's are selected at two points as described in Section 2.4.

The sampling units that are not selected with certainty become available for probability sampling. A sampling unit that is selected at this point represents the entire stratum in calculations of statistics and variances from the survey data. Thus, the sampling units selected by a probabilistic procedure are non-self-representing.

2.4 STRATA

The primary stratification of the OHSMI sampling frame is by the commodity groups shown in Table 1. NIOSH also has specified that the sampling frame be stratified within a commodity to reflect the geographic distinctions in ore and host rock that were summarized by JRB in Appendix A, the Report on the OHSMI Certainty Stratum (hereafter, the September report). These geographic distinctions were based on telephone interviews with specialists in each commodity or mineral from the U.S. Bureau of Mines or the U.S. Geological Survey. Appendix B summarizes the information obtained through these telephone interviews. For each of the geographic regions within a commodity code, NIOSH requested that the OHSMI sample contain three sampling units with mining operations and three sampling units with milling operations. Sampling units with operations of both types are the preferred option. Mines selected to satisfy this NIOSH requirement became first-stage SRU's.

The individual cells of the sampling frame formed by the SIC-regional stratification of MSHA data for the selected commodities are shown by the rows of Table 3. In most of the commodity groups with regional subdivisions, there were sampling units in the SIC stratum that did not fall into any of the regions as defined in the September report. Within each SIC division, these sampling units were placed in a separate stratum, which is noted as the "other" stratum in Table 3 and in Exhibit 1. Since the "other" strata do not represent geographic regions, no SRU's were selected from these strata.

The third column of Table 3 gives the number of units, or sites, in each cell. Further discussion of the contents of this table is included in the following section on "Selection Procedures." In some cases, the sum of the stratum numbers for a commodity is less than the number shown in Table 1 for the total number of sites. This difference represents sites that reported subunits with zero employment.

2.5 SELECTION PROCEDURES

The selection procedures in the OHSMI design draw a survey sample in two major stages. Each stage accomplishes one of the design objectives specified by NIOSH (see Section 2.2).

The first design specification is to sample at least three mining and three milling operations for each geographic region identified in the September report. This selection should favor large-sized sampling units and mine+mill units. After reviewing the contents of the individual strata from the SIC-regional stratification, JRB decided that the overall objectives of the

Table 3. Summary of sampling strategy for OHSMI.

COMMODITY (SIC Code/s)	GEOGRAPHIC REGION	GEO. CODE	NO. OF MINES IN CELL	SELECTION OF FIRST-STAGE SELF-REPRESENTING UNITS (SRU)				FURTHER SAMPLING STRATEGY
				MINE + MILL	MINE ONLY	MILL ONLY	TOTAL	
Iron Ore (10110)	CA, UT	9	3	2	1	--	3	None
	MN, MI, WI	2	33	3	--	--	3	In-stratum
	MO	9	2	2	--	--	2	None
	TX	4	4	3	--	--	3	None*
	WY	9	2	2	--	--	2	None
	Other	0	8	--	--	--	0	In-stratum
Copper Ore (10210)	AZ	1	42	3	--	--	3	In-stratum
	MI	9	1	1	--	--	1	None
	MT	3	3	--	1	1	2	None*
	NM, NV, UT	4	17	3	--	--	3	In-stratum
	TN, ID	5	11	1	2	2	5	None*
	Other	0	3	--	--	--	0	None*
Lead/Zinc Ores (10310)	CO	1	10	2	1	--	3	None*
	ID	2	6	3	--	--	3	None*
	MO	3	10	3	--	--	3	In-stratum
	TN	4	18	--	3	3	6	In-stratum
	Other	0	15	--	--	--	0	In-stratum
Silver Ores (10440)	All	8	62	3	--	--	3	In-stratum
Aluminum Ore+ (10510, 28191)	AR	1	8	1	2	2	5	None*
	GA, AL	9	5	--	2	3	5	None
	Other	0	8	--	--	--	0	In-stratum

*Remaining sites to be included as self-representing units.

Table 3. Summary of sampling strategy for OHSMI (continued).

COMMODITY (SIC Code/s)	GEOGRAPHIC REGION	GEO. CODE	NO. OF MINES IN CELL	SELECTION OF FIRST-STAGE SELF-REPRESENTING UNITS (SRU) MINE + MILL	MINE ONLY	MILL ONLY	TOTAL	FURTHER SAMPLING STRATEGY
Cobalt (10612)	All Sites	9	2	1	--	--	1	None*
Manganese (10614)	All Sites	9	5	--	2	3	5	None
Molybdenum (10615)	CO, NM	1	7	1	2	2	5	None*
	ID	9	2	--	2	--	2	None
	UT	9	0	--	--	--	0	None
	Other	0	2	--	--	--	0	None*
Nickel (10616)	All Sites	9	1	1	--	--	1	None
Uranium+ (10940, 10941)	All Sites	8	211	3	--	--	3	In-stratum
Vanadium (10942)	AR	9	1	1	--	--	1	None
	CO	9	1	--	--	1	1	None
	ID	9	0	--	--	--	0	None
Clay Group (14530, 14550, 14590)	GA, FL, SC	1	82	3	--	--	3	In-stratum
	MO, OH, PA	2	63	3	--	--	3	In-stratum
	MS, AL	3	26	3	--	--	3	In-stratum
	TN, KY	4	31	3	--	--	3	In-stratum
	TX, NC	5	46	3	--	--	3	In-stratum
	WY, MT, SD	6	28	3	--	--	3	In-stratum
	Other	0	118	--	--	--	0	In-stratum

*Remaining sites to be included as self-representing units.

Table 3. Summary of sampling strategy for OHSMI (continued).

COMMODITY (SIC Code/s)	GEOGRAPHIC REGION	GEO. CODE	NO. OF MINES IN CELL	SELECTION OF FIRST-STAGE SELF-REPRESENTING UNITS (SRU)				FURTHER SAMPLING STRATEGY
				MINE + MILL	MINE ONLY	MILL ONLY	TOTAL	
Barite (14720)	AR, NV	1	36	3	--	--	3	In-stratum
	MT, GA, TN	2	6	3	--	--	3	None*
	Other	0	55	--	--	--	0	In-stratum
Phosphate Rock (14750)	FL	1	32	3	--	--	3	In-stratum
	ID	2	6	2	1	--	3	None*
	NC	9	1	1	--	--	1	None
	TN	4	14	2	1	1	4	In-stratum
	Other	0	5	--	--	--	0	None*
Gypsum (14920)	All Sites	8	67	3	--	--	3	In-stratum
Asbestos (14991)	AZ	9	2	--	1	1	2	None
	E CA	9	2	--	1	1	2	None
	VT	9	1	1	--	--	1	None
	W CA	9	2	--	1	1	2	None
Gilsonite (14993)	All Sites	8	6	1	2	1	4	None*
Mica (14994)	NC	1	8	3	--	--	3	None*
	Other	0	15	--	--	--	0	In-stratum
Vermiculite (14998)	MT	9	1	1	--	--	1	None
	SC	9	4	1	2	1	4	None
	TX	9	0	--	--	--	0	None
	VA	9	1	1	--	--	1	None
	Other	0	2	--	--	--	0	None*
TOTAL SAMPLING UNITS			1,163	82	27	23	132	

*Remaining sites to be included as self-representing units.

survey, including efficiency and simplicity in the design and the projection techniques, would be best served by the following first-stage procedure.

(1) In each (SIC-regional) stratum, select the three largest mine+mill units. The size of the sampling unit, discussed in Section 2.3, is the average employment.

(2) If the stratum does not contain three mine+mill units, then select the largest sampling units with a mine and the largest units with a mill until the quota of three mining operations and three mills has been filled, or until the stratum is exhausted.

(3) If the stratum has been composed of mines outside the specified geographic regions, no first-round SRU's will be selected.

The sampling units that are selected become SRU's and are removed from the strata before the second-stage sampling procedures.

The results of applying the first-stage selection procedure are shown in Table 3. Note that first-stage SRU's were not selected in the strata for "other" sampling units (see Section 2.4). In the 50 SIC-regional strata (excluding the "other" strata), 19 strata had three mine+mill units available for selection under item (1) of the procedure. In six other strata, there were two mine+mill units. Thirteen strata had one mine+mill unit. In 24 strata, the quota of three mining and three milling operations could not be filled. The 132 sampling units selected as first-stage SRU's are listed as Exhibit 2 in the separate volume of exhibits.

A number of other options for meeting this first design specification were considered and rejected in favor of the above procedure. If the selection of first-stage SRU's were not determined by a simple fixed criterion, such as "select the largest," one option would be to use probability sampling from a substratum comprising the larger sampling units. All options of this type have the following problems:

- Control of the selection to favor mine+mill units over other units would require still more stratification. Many of the strata are too small even to apply this approach.
- If the unselected large units are included in the second-stage probability sampling, their overall selection probability becomes a compound product of the probability of selection at each stage. Estimation and variance calculations for such a design would be far more complex than for the simple design proposed here. The complexity would not increase the efficiency of the design.
- If unselected large units are not included in the second-stage probability sampling, larger units would be seriously underrepresented in many strata. The rationale for sampling proportional to size at the second stage would be lost.

In addition to the alternative of using probability sampling to meet the first specification, JRB also considered variations on the fixed selection criterion. There were no strata in which the selection of the three largest mine+mill units would give an SRU that was very small, but leave a very large mine or mill unselected. Therefore, no minimum size qualification to item (1) in the procedure was needed.

The second design specification is to sample 10 to 15 percent of each stratum with probability of selection being proportional to size. In Progress Report No. 6 (February 6, 1981), JRB presented a prototype design (Prototype II) for sampling from SIC-strata with the probability of selection proportional to size.[1] After considering the merits of Prototype II, which used systematic sampling, and comparing this approach with random sampling proportional to size, the JRB staff decided in favor of systematic sampling of the Prototype II design.

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[1] Mining Surveillance Strategy Options; Progress Report Number 6. JRB Associates. National Institute for Occupational Safety and Health, Contract No. 210-80-0026, February 6, 1981; Chapter 5.

The second stage of the OHSMI selection procedure is systematic selection with replacement and with probability of selection proportional to size. Because a 15 percent sample from strata with less than seven sites would be less than one unit, strata with less than seven sites remaining for this step were removed in advance; these sites are included in the sample as SRU's. Table 4 displays the steps leading from the construction of the probability sampling strata to the determination of the sampling parameters for the systematic sampling process.

Column 1 of Table 4 lists the 23 probability sampling strata. The stratum code combines the five-digit MSHA SIC code with a sixth digit, which designates either a regionally derived-sampling stratum (digits 1 through 7); a SIC group that was not regionally stratified (digit = 8); a strata with no sites remaining for probability sampling (digit = 9); or the "other" strata in a regionally stratified commodity (digit = 0). Column 2 shows the number of sites in each of these strata; column 3 gives the stratum size, which is the sum of the sizes of the sampling units in the stratum.

Because the sampling is systematic rather than random, the selection process is applied to a fixed listing of the sampling units for each probability sampling stratum (see Section 2.4). The sampling units are listed in numerical order by mine ID. This has the benefit of providing an implicit stratification by State within a stratum, because the first two digits of the mine ID are a State code. It also provides implicit stratification by age of establishment within a State, because the remaining five digits represent a chronological numbering of the mine sites. In addition, systematic sampling provides a simple way to handle the problem of very large sites that dominate the stratum size. This procedure is explained below in the discussion of second-stage SRU's.

The sampling is performed with replacement, which means that a selected sampling unit remains available for selection (that is, it is "replaced" in the stratum after being drawn) until the sample draw for that stratum is

Table 4. Occupational hazard survey of the Mining Industry: probability sample size determination.

STRATUM CODE	# OF SITES	TOTAL # OF EMPLOYEES	SRU2 TEST INTERVAL	SAMPLE SIZE1	# OF 2ND ROUND SRU SELECTION	# OF SITES REMAINING	SAMPLE SIZE2	SAMPLE INTERVAL	RANDOM NUMBER
101100	8	59.92	19.97	3	0	8	3	19.97	0.06226071
101102	30	11353.16	2270.63	5	0	30	5	2270.63	0.39664213
102101	39	12197.08	2032.85	6	0	39	6	2032.85	0.10502889
102104	14	5799.33	1933.11	3	1	13	3	1181.69	0.98918627
103100	15	1268.75	422.92	3	0	15	3	422.92	0.47333356
103103	7	665.00	221.67	3	0	7	3	221.67	0.53644995
103104	12	545.41	181.80	3	0	12	3	181.80	0.85263219
104408	59	1123.17	124.80	9	2	57	9	90.19	0.65627848
105100	8	4457.50	1485.83	3	0	8	3	1485.83	0.12910041
109408	208	11340.35	365.82	31	3	205	31	324.21	0.79055624
145300	118	1416.67	78.70	18	3	115	18	63.66	0.87868479
145301	79	4324.75	360.40	12	0	79	12	360.40	0.05530254
145302	60	377.00	41.89	9	0	60	9	41.89	0.46976362
145303	23	440.75	146.92	3	0	23	3	146.92	0.31711927
145304	28	334.42	83.60	4	0	28	4	83.60	0.82358818
145305	43	289.92	48.32	6	0	43	6	48.32	0.04655507
145306	25	939.25	234.81	4	0	25	4	234.81	0.45097887
147200	55	1198.16	149.77	8	0	55	8	149.77	0.60188438
147201	33	579.00	115.80	5	0	33	5	115.80	0.87078220
147501	29	4338.16	1084.54	4	0	29	4	1084.54	0.23643173
147504	10	78.08	26.03	3	0	10	3	26.03	0.70801533
149208	64	973.99	97.40	10	0	64	10	97.40	0.61370838
149940	15	102.25	34.08	3	0	15	3	34.08	0.59669812
TOTAL	982	64202.07		158	9	973	158		

complete. If sampling were performed without replacement, the overall probability of selection of each selected sampling unit would be dependent on which sites were selected before it. This would result in two serious consequences. First, the overall selection probability for units in the sample unit would not be proportional to size, even though the initial probabilities assigned prior to selection were proportional to size. Second, the calculation of reasonable estimates and variances would become prohibitively difficult for a stratum sample number (the number of sampling units from the stratum in the sample) greater than two or three.

Sampling with replacement raises a difficulty that the OHSMI design overcomes by a second-stage selection of SRU's. If a few sampling units are so large relative to the rest of the stratum that they dominate the stratum size, they will have a significant probability of being selected two or more times. In systematic sampling, any sampling unit with a size greater than the sampling interval (see below) may be selected at least twice. To overcome this problem, these sampling units are identified and selected as SRU's before the probability sampling of the NSRU's. The SRU's selected at this step in the OHSMI design are called second-stage SRU's.

The procedure for selecting second-stage SRU's involves calculating a "test" sampling interval for each stratum (column 4 of Table 4). This interval is then compared with the size of the sites in the stratum. Any sites with a size greater than the test interval are selected as second-stage SRU's. In each probability sampling stratum, the planned stratum sample number (that is, the number in the sample) is 15 percent of the stratum number (column 2). The test sampling interval is the stratum size (column 3) divided by the planned stratum sample number (column 5). Column 6 of Table 4 shows the number of second-stage SRU's in each probability sampling stratum. After removal of the second-stage SRU's, the stratum size is recalculated for the NSRU's (column 7).

The sample number for the probability selection is 15 percent of the number of sites in column 2, unless this percentage would give fewer than three NSRU's in the sample for that stratum. Various calculations require at least two NSRU's. To allow for the possibility that one of the NSRU's is closed when the survey is performed, a minimum of three sites was selected in all strata containing at least three NSRU's. If a stratum had less than seven NSRU's either before or after removing the second-stage SRU's, the sample number was set equal to the number of NSRU's in the stratum and all sites in the stratum became SRU's. The stratum sample numbers resulting from these considerations are shown in column 8 of Table 4.

From the recalculated stratum size (after removal of second-stage SRU's) and the expected sample number, a new sampling interval is calculated (column 9). The stratum size is divided into ranges for each NSRU, with the range being equal to the size of the NSRU. A random number between unity and the sampling interval is generated as the starting point for the selection (column 10). The selected NSRU's are those whose ranges contain the random start number or the sum of the random start plus a multiple (between one and the stratum sample number) of the sampling interval.

Table 5 lists a complete survey sample drawn by the two-stage selection. The sample size totals 348 units, defined below by selection status:

Status	A	B	0	1	2	3
Number of Sites	132	9	49	157	1	0

Selection status A indicates a first-stage SRU. Selection status B indicates a second-stage SRU. Selection status 0 indicates the site is an SRU from a small stratum. Numerical values for the selection status represent the number of times that an NSRU was selected in the probability sampling. Thus, the one mine selected twice (MID = 2401467) represents two units in the sample.

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982.

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
100034	14530	A	TOMBIGEE LTWT AGGRE	52.75	0.00	4.00	48.75
100107	14530	1	HENRY CTY MINE	9.75	0.00	9.75	0.00
100507	10110	1	BLACKBURN MN & MLL	8.00	0.00	0.00	8.00
100650	10510	A	MOBILE ALUMINUM REFINING PLANT	672.75	0.00	0.00	672.75
101565	10510	A	BARBOUR COUNTY MINES	3.75	0.00	3.75	0.00
102214	10510	A	BARBOUR COUNTY PIT	4.00	0.00	4.00	0.00
200024	10210	A	MORENCI MINE MILL & TAILING	634.25	0.00	416.25	218.00
200112	10210	1	INSPIRATION PITS	245.75	0.00	245.75	0.00
200144	10210	1	SIERRITA MINE	747.25	0.00	747.25	0.00
200151	10210	1	SAN MANUEL MINE	1997.75	1388.25	0.00	0.00
200152	10210	1	MAGMA MINE	841.50	707.00	0.00	0.00
200157	10210	A	PIMA MINE & MILL	570.00	0.00	376.50	193.50
200305	10210	A	METCALF MINE & MILL	326.25	0.00	247.75	78.50
200842	10210	1	SAN MANUEL DIV MILL	321.50	0.00	0.00	321.50
200852	10210	1	SIERRITA MILL	1038.25	0.00	0.00	1038.25
200951	14991	A	EL DORADO MINE	13.25	13.25	0.00	0.00
200954	14991	A	JAQUAYS MILL	6.00	0.00	0.00	6.00
300069	10510	A	HURRICANE CREEK	836.75	0.00	0.00	836.75
300142	14530	1	STREAKED	4.75	0.00	1.00	3.75
300257	10510	A	BAUXITE MILL	1093.75	0.00	0.00	1093.75
300261	10510	A	QUAPAW PIT & PLT	14.00	0.00	2.00	12.00
300262	10510	A	REYNOLDS SURFACE MINE	176.00	0.00	176.00	0.00
300276	14920	1	BRIAR PITS & PLT	47.25	0.00	35.50	11.75
300470	10510	0	BERGER PLANT	24.50	0.00	0.00	24.50
300472	10510	A	ARKANSAS OPERATIONS MINE	89.00	0.00	89.00	0.00
300479	10942	A	WILSON SPGS PT & PLT	169.50	0.00	14.75	154.75
300715	10510	0	RAUCH MINE	4.50	0.00	4.50	0.00
300787	14720	A	MAGNET COVE MILL	101.00	0.00	14.50	86.50
301141	10510	0	PULASKI COUNTY PITS	3.00	0.00	3.00	0.00
301364	14998	0	PORT PLANT	20.50	0.00	0.00	20.50
301496	10210	0	MONA LISA	2.00	0.00	2.00	0.00
400551	14530	1	SHEEP SPRINGS PIT & MILL	52.00	0.00	32.25	19.75
400553	14530	1	ROCKLITE PRODUCTS CLAY PIT	27.50	0.00	0.75	26.75
401061	14991	A	CALAVERAS ASBESTOS LTD	121.75	0.00	0.00	121.75
401062	14991	A	KING CITY MILL	60.25	0.00	0.00	60.25
402490	10210	0	IRON MOUNTAIN MINES	0.67	0.00	0.00	0.00
402511	10110	A	EAGLE MOUNTAIN MINE	964.50	0.00	458.00	506.50
402547	14991	A	CALARERAS ASBESTOS LTD	84.00	0.00	84.00	0.00
402550	14991	A	JOE 5 PIT	12.00	0.00	12.00	0.00
402620	14530	1	OLANCHA MILL	7.50	0.00	.	7.50
402638	14530	1	ELKORN PIT & MILL	50.50	0.00	18.75	31.75
402866	14530	1	CALCINE 1-3 MILL	54.67	0.00	0.00	54.67
402964	14530	B	EXCEL CLAY MINE	89.25	0.00	38.00	51.25
404358	10110	A	SILVER LAKE	2.50	0.00	2.50	0.00
500354	10615	A	CLIMAX MOLYBDENUM MINE UG	1729.50	1594.50	0.00	0.00
500411	10310	0	EAGLE MINE	31.00	27.75	0.00	.
500412	10310	A	EMPERIUS	95.00	92.25	0.00	0.00
500413	10440	A	BULLDOG MTN. OPERATION	178.75	141.00	0.00	36.25
500414	10310	0	IDARADO MINE	12.00	2.00	0.00	.
500416	10440	1	RICO ARGENTINE	12.25	0.25	0.00	0.00
500417	10310	A	SUNNYSIDE MINE	162.75	100.00	0.00	47.50

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982 (continued).

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
500427	14920	1	GOODWIN QY	3.75	0.00	3.75	0.00
500495	10110	1	ARGO TUNNEL	8.00	8.00	0.00	0.00
500516	10310	A	LEADVILLE UNIT	139.25	80.25	0.00	15.25
500604	10310	0	SHERMAN MINE	76.25	68.75	0.00	0.00
500790	10615	A	HENDERSON MINE	442.75	.	0.00	442.75
501159	10940	1	ANDREW'S MINING CO	3.00	2.00	0.00	0.00
501784	10942	A	MINING & METALS DIV RIFLE MILL	29.50	0.00	0.00	29.50
501785	10940	1	MINING & METALS DIV URAVAN	210.25	0.00	0.00	210.25
502141	10940	1	PITCH PROPERTY	204.50	0.00	204.50	0.00
502255	10615	0	CLIMAX TEN MILE TUNNEL	5.00	5.00	0.00	0.00
502256	10615	A	CLIMAX OPEN PIT	459.25	0.00	459.25	0.00
502337	10615	A	CLIMAX MILL	745.00	0.00	0.00	745.00
502921	10940	1	C-LP-21	21.00	19.00	0.00	0.00
503074	10310	0	MOUNTAIN MONARCH	3.00	3.00	0.00	0.00
503103	10310	0	RISORGIMENTO	3.00	3.00	0.00	0.00
503174	10310	0	VALLEY FORGE MINE	2.50	2.50	0.00	0.00
503428	10310	0	OSCEOLA-PRIDE MINE	12.50	8.50	0.00	0.00
503574	10440	1	BUFALO BOY EXPLORATION PROJECT	6.00	6.00	0.00	0.00
800110	14530	1	HAVANA MILL	29.75	0.00	0.00	29.75
800172	14750	1	PAYNE CREEK	178.25	0.00	95.25	83.00
800177	14750	A	KINGSFORD MINE AND MILL	358.92	0.00	197.42	161.50
800178	14750	A	NORALYN MINE	461.00	0.00	242.75	218.25
800183	14750	A	SUWANNEE RIVER MINE PHOSPHATE	390.50	0.00	222.50	168.00
800189	14750	1	ROCKLAND MINE	267.00	0.00	231.00	36.00
800385	14750	1	NICHOLS MINE	118.50	0.00	72.50	46.00
800524	14530	1	GADSEN CTY MINES	44.75	0.00	44.75	0.00
800832	14750	1	LONESOME MINE AND MILL	325.75	0.00	282.00	43.75
900110	14530	A	DEEP STEP MINE & ML	294.75	0.00	99.00	195.75
900114	14530	1	OCHLOCKNEE MINE	123.50	0.00	9.75	113.75
900125	14530	A	AMSTERDAM MN & PLT	370.25	0.00	43.00	327.25
900135	14530	A	WRENS MINE	139.00	0.00	9.00	130.00
900139	14530	1	DRY BRANCH MINE	132.00	0.00	132.00	0.00
900143	14530	1	PALMER MILL	94.00	0.00	0.00	94.00
900229	14530	1	MCINTYRE MILL	31.25	0.00	0.00	31.25
900241	14994	1	HARTWELL QUARRY & MILL	23.25	0.00	12.75	10.50
900244	14720	A	PAGA MINE	47.50	0.00	17.25	30.25
900245	14720	A	BARITE MINE	42.50	0.00	8.00	34.50
900337	14530	1	MAIN PROCESSING PLANT	165.00	0.00	0.00	165.00
900359	14530	1	EDGAR PLANT	207.50	0.00	0.00	207.50
900472	14530	1	TODDVILLE PLANTS 2 & 6	232.25	0.00	0.00	232.25
900482	14530	1	DRY BRANCH MILL	343.25	0.00	0.00	343.25
900584	14530	1	HUBER MINE AND MILL	134.75	0.00	134.75	0.00
900684	10510	A	ANDERSONVILLE WORKS	19.00	0.00	0.00	19.00
900921	10510	A	DALTON PLANT	2.00	0.00	0.00	2.00
1000082	10440	A	GALENA	257.50	195.50	0.00	14.75
1000083	10310	A	BUNKER HILL MINE	493.75	407.50	0.00	35.75
1000086	10310	A	STAR MORNING	312.00	218.25	0.00	27.00
1000088	10310	A	LUCKY FRIDAY	283.75	217.00	0.00	11.25
1000089	10440	A	SUNSHINE MINE & ML	251.50	193.25	0.00	35.25
1000091	14750	0	HENRY MINE	3.00	0.00	3.00	0.00
1000093	14750	A	GAY PHOSPHATE MN	167.25	0.00	154.25	13.00

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982 (continued).

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
1000094	14750	A	CONDA MINE & MILL	212.50	0.00	157.25	55.25
1000095	14750	0	WOOLEY VALLEY	96.25	0.00	96.25	0.00
1000142	10440	1	CLAYTON GROUP	25.25	17.25	0.00	8.00
1000189	10310	0	STAR MINE =1 MAIN VEIN	4.00	4.00	0.00	0.00
1000402	10440	B	DELAMAR SILVER MINE AND MILL	172.25	0.00	108.50	63.75
1000409	10440	1	CALLADAY PROJECT	37.17	25.50	0.00	0.00
1000458	10210	A	COPPER CLIFF MINE	32.50	0.00	19.50	13.00
1000479	10440	B	COEUR MINE	139.25	109.50	0.00	10.75
1000502	10310	0	REX MILL	0.67	0.00	0.00	0.67
1000531	10615	A	THOMPSON CREEK PROJECT	8.50	8.50	0.00	0.00
1000533	10612	A	BLACKBIRD MINE	119.83	37.50	0.00	4.33
1000556	14750	A	MAYBE CANYON MINE	279.50	0.00	279.50	0.00
1001317	10310	0	GOLDBACK MINE	4.00	2.00	0.00	0.00
1001408	14750	0	HENRY PHOSPHATE MINE	77.75	0.00	77.75	0.00
1001416	10615	A	ABELLA	6.00	3.00	0.00	0.00
1001458	10210	0	COPPER CLIFF MILL	21.67	0.00	0.00	21.67
1100494	14530	1	SOUTHERN CLAY INC.	59.00	0.00	0.00	59.00
1100876	10614	A	ROSICLARE MANGANESE PLT	44.25	0.00	0.00	44.25
1102403	14530	1	ABSORBENT CLAY PRODUCTS PIT &	45.25	0.00	1.50	43.75
1200427	14920	A	UNITED STATES GYPSUM CO	86.25	31.25	0.00	12.50
1300349	14530	1	CANTEX INDUSTRIES-OTTUMWA PIT	6.75	0.00	3.00	3.75
1300434	14920	1	SPERRY MINE	53.75	26.00	0.00	8.00
1301615	14920	1	KAUFFMAN GEORGE PIT	24.50	0.00	24.50	0.00
1400218	14530	1	EXCELSIOR BRICK MFG CO INC	2.25	0.00	2.25	.
1500187	14530	A	SHEPHERDSVILLE MINE	43.00	0.00	13.50	29.50
1507011	14530	1	HICKORY CLAY MILL	13.50	0.00	0.00	13.50
1600033	14530	B	BIG RIVER INDUSTRIES, INC.	90.00	0.00	14.00	76.00
1600222	10510	1	BATON ROUGE ALUMINA	825.00	0.00	0.00	825.00
1600255	14720	1	NEW ORLEANS GRINDING PLANT -DR	43.75	0.00	0.00	43.75
1600354	10510	1	ORMET CORPORATION	306.75	0.00	0.00	306.75
1600495	14720	1	MORGAN CITY PLT	22.50	0.00	0.00	22.50
1600995	14530	1	PROPPANT PLANT	40.00	0.00	0.00	40.00
1800078	14530	1	MARYLAND CLAY PRODUCTS, INC.	57.75	0.00	1.50	56.25
2000371	10210	A	WHITE PINE COPPER DIVISION	904.25	638.00	0.00	89.75
2000372	14920	1	ALABASTER MINE AND PLANT	46.50	0.00	23.00	23.50
2000422	10110	A	TILDEN MINE OP	1243.00	0.00	409.75	833.25
2000423	10110	1	REPUBLIC OP PLANT	431.33	0.00	271.33	160.00
2001019	14920	1	KENTWOOD MINE	16.50	15.50	0.00	0.00
2100209	10110	1	PETER MITCHELL MINE	1096.75	0.00	1096.75	0.00
2100256	10110	A	ERIE MINING COMPANY	1704.50	0.00	1082.50	622.00
2100282	10110	1	MINNTAC MINE	1734.25	0.00	1734.25	0.00
2100820	10110	1	MINNTAC PLANT	1297.75	0.00	0.00	1297.75
2100831	10110	1	E W DAVIS WORKS	976.25	0.00	0.00	976.25
2100904	14530	1	BURNETT MILL	9.50	0.00	0.00	9.50
2101600	10110	A	HIBBING TACONITE COMPANY	1045.75	0.00	605.25	440.50
2200031	14530	1	CYNTHIA QUARRY & MILL	23.25	0.00	20.25	3.00
2200032	14530	A	CRENSHAW MINE & PLANT	43.25	0.00	15.25	28.00
2200035	14530	A	RIPLEY MINE & MILL	88.75	0.00	9.75	79.00
2200415	14530	1	JACKSON PLANT	130.00	0.00	0.00	130.00
2300159	14530	A	ST LOUIS PT & PLT	133.75	0.00	2.75	131.00
2300320	14530	1	CERAMO CLAY CO PIT & PLT	2.25	0.00	2.25	.

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982 (continued).

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
2300409	10310	1	FLETCHER	139.25	84.00	0.00	32.00
2300454	10110	A	PEA RIDGE MINE	271.75	117.50	0.00	114.25
2300455	10110	A	PILOT KNOB PELLET COMPANY	292.00	143.50	0.00	93.25
2300457	10310	A	BUICK MINE	479.25	329.50	0.00	149.75
2300458	10310	A	FRANK R. MILLIKEN MINE & MILL	403.50	255.75	0.00	112.25
2300494	10310	A	VIBURNUM NO 28 MINE & MILL	166.00	77.75	0.00	52.25
2300497	10310	1	INDIAN CREEK MINE	108.75	68.75	0.00	19.00
2300550	14720	1	GENERAL BARITE CO. OLD MINES P	17.75	0.00	6.75	11.00
2300567	14720	1	KINGSTON =1	62.00	0.00	9.00	53.00
2301005	14530	1	SOUTHERN CLAY PLT	17.25	0.00	0.00	17.25
2301390	10310	1	CENTRAL SERVICE	89.50	0.00	0.00	0.00
2301545	14530	1	MISSOURI MINERALS PROCESSING I	41.00	0.00	0.00	41.00
2301602	14530	A	SOUTHERN CLAY PIT & PLANT	100.00	0.00	13.50	86.50
2301650	14998	0	ST. LOUIS EXPANDING PLANT	14.50	0.00	0.00	14.50
2301756	14530	1	WESTERMAN PIT =1	2.75	0.00	2.75	0.00
2301770	10612	0	MADISON MINE	27.75	0.00	0.00	0.00
2301796	14720	1	IMCO APEX MINE	21.00	0.00	21.00	0.00
2400146	14750	0	WARM SPRINGS MINE	108.25	78.25	0.00	0.00
2400165	14998	A	ZONOLITE DIV LIBBY	168.75	0.00	49.25	119.50
2400338	10210	A	BERKELEY PIT	597.75	0.00	597.75	0.00
2400689	10210	A	WEED CONCENTRATOR	268.50	0.00	0.00	268.50
2400721	10210	0	BUTTE MINES WAREHOUSE	28.75	0.00	0.00	0.00
2401220	14720	0	MONTANA BARITE MILL	15.00	0.00	0.00	15.00
2401467	10440	2	TROY PROJECT	121.75	.	0.00	37.00
2401590	10615	0	CANNIVAN GULCH PROJECT	8.00	8.00	0.00	0.00
2600097	14920	A	FLINTKOTE GYPSUM QUARRY	106.25	0.00	17.25	89.00
2600146	10110	1	COONEY IRON MINE	6.00	0.00	6.00	0.00
2600411	14720	A	GREYSTONE MINE & MILL	80.75	0.00	38.50	42.25
2600412	14720	1	DUNPHY MILL	35.75	0.00	0.00	35.75
2601043	14530	1	AMARGOSA PIT & MILL	66.75	0.00	9.00	57.75
2601047	14720	1	MAJOR BARITE	5.50	0.00	5.50	0.00
2601390	14720	1	MOUNTAIN SPRINGS PLANT	68.50	0.00	0.00	68.50
2601451	10440	1	AMERICAN FLAT =2 MILL	69.25	0.00	16.00	53.25
2601464	14720	1	FILLIPINI STRIP	53.50	0.00	53.50	0.00
2601483	10615	0	NEVADA MOLY	585.00	0.00	498.00	87.00
2601592	14720	A	STORMY CREEK MINE	65.00	0.00	58.50	6.50
2601638	10440	1	16 TO 1 MINE	20.00	14.00	0.00	0.00
2601660	14720	1	REDHOUSE MINE	10.00	0.00	10.00	0.00
2900159	10210	A	TYRONE BRANCH	717.25	0.00	447.50	269.75
2900164	10615	A	MOLY MINE & MILL	443.75	0.00	136.25	307.50
2900399	10940	B	JACKPILE PAGUATE UNIT	487.75	0.00	487.75	0.00
2900537	10940	1	SEC 24 14N 10W	36.00	30.00	0.00	0.00
2900565	10940	1	L-BAR URANIUM OPERATIONS	100.50	.	0.00	64.50
2900591	10940	1	SEC. 25 MINE	156.25	93.00	0.00	0.00
2900708	10210	A	KENNECOTT MINERALS COMPANY,CHI	545.50	0.00	510.25	35.25
2900725	10210	1	CONTINENTAL SURFACE COMPLEX	113.25	0.00	82.25	31.00
2900751	14994	1	MICA MILL	11.25	0.00	0.00	11.25
2900762	10614	A	LUCK MINE	6.75	0.00	6.75	0.00
2900772	10940	B	BLUEWATER MILL	415.25	0.00	0.00	415.25
2900775	10940	1	MAC URANIUM MILL	207.25	0.00	0.00	207.25
2900773	10940	1	SEC 17 14N 9W	57.25	53.25	0.00	0.00

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982 (continued).

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
2901214	10940	1	JACKPILE P-10 UNDERGROUND	218.50	208.50	0.00	0.00
2901267	10615	0	QUESTA MINE	201.00	.	0.00	27.00
2901597	10940	1	MARQUEZ SHAFT	73.75	19.00	0.00	20.50
2901678	10940	1	CHURCH ROCK MILL	152.50	0.00	0.00	152.50
2901710	10940	1	WESTRANCH	9.25	7.75	0.00	0.00
2901790	10940	1	CROWNPOINT SECTION 24	100.25	.	0.00	0.00
3000593	14920	1	OAKFIELD MINE	65.50	53.25	0.00	12.25
3000644	14530	B	WILLSBORO WALLASTONITE MINE &	91.50	20.75	0.00	70.75
3001185	10310	1	BALMAT MINE NO 4 AND MILL	226.25	124.75	0.00	93.00
3100128	14530	1	COOK - STONE PITS	3.00	0.00	3.00	0.00
3100135	14530	A	AQUADALE MINE	39.00	0.00	8.00	31.00
3100136	14530	1	STALITE MILL	46.00	0.00	0.00	46.00
3100212	14750	A	LEE CREEK	543.75	0.00	359.75	184.00
3100273	14994	A	MOSS MINE & MILL	44.75	0.00	12.00	32.75
3100274	14994	A	PATTERSON MN & ML	21.50	0.00	7.00	14.50
3100375	14994	A	KAOLIN MINE	79.00	0.00	20.00	59.00
3100381	14994	0	KINGS MOUNTAIN GRINDING PLANT	9.25	0.00	0.00	9.25
3100675	14994	0	SPRUCE PINE PLANT	12.75	0.00	0.00	12.75
3101080	14994	0	BILTMORE PLANT	5.00	0.00	0.00	5.00
3101148	14994	0	DENEEN MICA MILL	37.25	0.00	0.00	37.25
3101746	14994	0	FRANKLIN PLANT	21.00	0.00	0.00	21.00
3300484	14530	1	IRONDALE	27.50	24.50	0.00	0.00
3300514	14530	1	ORRVILLE TILE COMPANY	3.75	0.00	2.75	1.00
3300565	14530	1	ROMANY PLT & PITS	7.00	0.00	0.00	7.00
3400117	14530	1	MANGUM BRICK COMPANY	22.50	0.00	1.00	21.50
3400266	14920	A	SOUTHARD MINE AND PLANT	232.75	0.00	35.00	197.75
3401132	14920	1	NORTHWEST GYPSUM PIT & PLANT	5.00	0.00	5.00	0.00
3500391	10616	A	NICKEL MOUNTAIN MINE	186.50	0.00	115.25	71.25
3502868	10210	0	IRON DYKE MINE	32.00	22.00	0.00	0.00
3600609	14530	1	DREXEL MINE & MILL	9.50	8.50	0.00	0.00
3600630	14530	A	HANLEY #4A MINE & MILL	17.50	10.75	0.00	5.25
3600657	14530	1	NARVON PLANT	14.50	0.00	0.00	14.50
3800038	14530	1	AIKEN PLANT NO. 47	24.75	0.00	2.00	22.75
3800085	14998	A	KEARNEY MILL	45.75	0.00	0.00	45.75
3800086	14998	A	LAURENS COUNTY MINE	10.75	0.00	5.00	5.75
3800206	10614	A	MANGANESE MINE OP	1.00	0.00	1.00	0.00
3800251	14998	A	SPARTANBURG COUNTY MINES	29.25	0.00	29.25	0.00
3800259	14998	A	LAURENS COUNTY MINES	9.25	0.00	9.25	0.00
3900049	14530	1	BELLE FOURCHE PLANT	96.25	0.00	0.00	96.25
3901158	14994	1	BRITE X MILL	12.50	0.00	0.00	12.50
4000168	10310	A	YOUNG MINE	143.25	139.00	0.00	0.00
4000170	10310	1	IMMEL	107.50	103.25	0.00	0.00
4000194	14530	A	HENRY COUNTY MINES AND MILL	40.00	0.00	10.50	29.50
4000195	14530	1	GLEASON MINE & ML	34.50	0.00	11.00	23.50
4000204	14530	A	SOUTHERN CLAY, INC.	76.00	0.00	4.00	72.00
4000603	10210	A	LONDON MILL	122.00	0.00	0.00	122.00
4000606	10310	A	NEW MARKET MINE	129.25	123.25	0.00	0.00
4000607	10310	1	JEFFERSON CITY ZINC UNDERGROUN	128.75	128.75	0.00	0.00
4000611	14750	A	HICKMAN COUNTY-WILLIAMSPORT	10.25	0.00	10.25	0.00
4000629	14750	A	GLOBE MILL	29.75	0.00	0.00	29.75
4000704	10210	A	CHEROKEE	124.25	124.25	0.00	0.00

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982 (continued).

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
4000706	10210	0	MINE SHOPS AND MISCELLANEOUS	70.00	0.00	0.00	0.00
4000707	10210	A	CALLOWAY MINE COPPERHILL OPN	61.00	61.00	0.00	0.00
4000708	10210	0	BOYD MINE COPPERHILL OPN	43.00	43.00	0.00	0.00
4000749	14720	A	CEDARFORK MINE AND MILL	10.75	0.00	7.00	3.75
4000864	10310	A	ELMWOOD MINE	144.75	100.75	0.00	0.00
4000866	10310	A	JEFFERSON CITY MILL	59.75	0.00	0.00	59.75
4000916	14750	1	MAURY COUNTY MINE-GODWIN	6.33	0.00	6.33	0.00
4000920	14750	A	WASHER MINE AND MILL	16.00	0.00	8.00	8.00
4001045	14530	1	HOBBS CARROLL MINE	2.75	0.00	2.75	0.00
4001695	14750	1	AMOS	6.00	0.00	6.00	0.00
4001749	10310	A	ELMWOOD MILL	29.00	0.00	0.00	29.00
4001751	10310	1	BEAVER CK MINE	29.83	23.50	0.00	0.00
4001981	10310	A	YOUNG MILL	59.75	0.00	0.00	59.75
4002039	10210	A	IRON ROASTERS	129.25	0.00	0.00	129.25
4002040	10210	0	CENTRAL SERVICES	265.50	0.00	0.00	0.00
4002074	10210	0	CHEROKEE OPEN PIT	54.00	0.00	54.00	0.00
4002339	14750	1	MOBIL THOMAS TRACT	6.25	0.00	6.25	0.00
4002513	14530	1	WEAKLEY COUNTY MINES	15.00	0.00	15.00	0.00
4002521	14720	0	A.J. SMITH MINE	3.00	0.00	3.00	0.00
4002549	14720	0	NO.1 WASH PLANT	2.67	0.00	2.67	0.00
4002630	14750	A	LITTLELOT WASHER & MINE	9.50	0.00	5.00	4.50
4002633	10210	0	RAILROAD DEPARTMENT	85.00	0.00	0.00	0.00
4100148	10614	A	C.E. MINERALS,PORT BROWNSVILLE	14.25	0.00	0.00	14.25
4100241	14530	1	MCQUEENEY PIT AND PLANT	5.50	0.00	5.50	.
4100262	14530	A	KOSSE OPERATIONS	131.75	0.00	12.00	119.75
4100263	14530	1	DRESSER MINERALS-ZAVALLA	18.75	0.00	0.00	18.75
4100298	14530	A	SOUTHERN CLAY PLANT AND PITS	115.00	0.00	43.00	72.00
4100303	14530	1	CLODINE PIT	35.00	0.00	35.00	.
4100308	14530	1	FLATONIA MINES AND PLANT	23.00	0.00	0.00	23.00
4100852	14920	1	CHERRY MOUNTAIN QUARRY	26.00	0.00	21.50	4.50
4100906	10510	1	SHERWIN PLANT	1119.00	0.00	0.00	1119.00
4100922	10110	A	SIDERITE MINE & MILL	13.50	0.00	9.75	3.75
4101643	10110	A	LONESTAR STEEL MINES AND PLANT	189.00	0.00	46.00	143.00
4101665	14720	1	BROWNSVILLE MILL	19.00	0.00	0.00	19.00
4102320	10110	0	HUDSON PIT & PLT	15.00	0.00	15.00	0.00
4102492	10940	1	CLAY WEST URANIUM PLANT	138.50	0.00	0.00	138.50
4102494	10940	1	KARNES COUNTY PITS	301.50	0.00	301.50	0.00
4102515	14720	1	GALVESTON PLANT	32.00	0.00	0.00	32.00
4102745	10940	1	BURNS RANCH URANIUM PLANT	150.00	0.00	0.00	150.00
4102764	10110	A	LA RUE PIT AND PLANT	21.25	0.00	11.00	10.25
4102777	10940	1	ZAMZOW MINE	54.50	0.00	0.00	0.00
4102978	10614	A	EL PASO MANGANESE PLANT	17.00	0.00	0.00	17.00
4200071	14530	1	CLAY MINE	19.00	0.00	2.25	16.75
4200147	10310	1	TRIXIE TINTIC DIVISION	104.25	98.25	0.00	0.00
4200149	10210	B	UTAH COPPER DIVISION MINE	2254.25	0.00	2254.25	0.00
4200164	14750	0	VERNAL MILL	28.50	0.00	0.00	28.50
4200481	10940	1	MI AMORCITA MINE	4.00	4.00	0.00	0.00
4200716	10210	1	MAGNA CONCENTRATOR	883.25	0.00	0.00	883.25
4200800	10940	1	MOAB MILL	183.00	0.00	0.00	183.00
4200842	14750	0	PHOSTON OPERATIONS	9.75	0.00	0.00	9.75
4200854	14993	A	BONANZA OPERATIONS	95.00	44.50	0.00	33.50

Table 5. Occupational Hazard Survey of the Mining Industry
Sample Draw October 30, 1982 (continued).

MINE ID	SIC CODE	SELECTION STATUS	MINE NAME	TOTAL EMPLOYMENT	SUBUNIT1 EMPLOYMENT	SUBUNIT3 EMPLOYMENT	SUBUNIT9 EMPLOYMENT
4200876	14993	A	LITTLE BONANZA MILL	13.17	.	0.00	9.50
4200946	10110	A	COMSTOCK MN & MILL	30.25	0.00	17.25	13.00
4200998	14750	0	VERNAL PIT	50.75	0.00	50.75	0.00
4201146	14993	A	BOREN MINES	38.25	21.75	0.00	0.00
4201153	10210	A	CARR FORK MINE	635.25	571.00	0.00	64.25
4201200	14993	0	BONANZA NO. 8-A	3.25	2.25	0.00	0.00
4201351	14720	1	EISENMAN CHEMICAL BARITE MILL	15.50	0.00	0.00	15.50
4201395	14993	0	U-32 SHIFT	3.00	2.00	0.00	0.00
4201422	10940	1	PROBE MINE	30.25	17.50	0.00	0.00
4201446	14993	A	HOLMES MINES	8.50	6.50	0.00	0.00
4201465	10440	1	SILVER REEF MINE	5.75	0.00	5.75	0.00
4201550	10940	1	SHOOTERING MILL	339.00	0.00	0.00	339.00
4201660	10210	1	ORE HAULAGE PLANT	389.00	0.00	0.00	389.00
4300065	14991	A	LOWELL MINE & MILL ASBESTOS	176.00	0.00	54.50	121.50
4400211	14530	1	WEBLITE	33.75	0.00	27.75	6.00
4401921	10310	1	AUSTINVILLE	255.50	180.50	0.00	19.50
4401926	14920	1	COVE MINE	38.25	38.25	0.00	0.00
4405101	14998	A	RICHARD E. SANSOM MINE AND MIL	20.00	0.00	3.67	16.33
4500783	10940	1	MIDNITE MINE	82.25	0.00	82.25	0.00
4502424	10940	A	SHERWOOD	277.75	0.00	166.50	111.25
4600148	14530	1	GLOBE MINE = 1	45.25	39.50	0.00	.
4800059	14530	1	UPTON MILL	73.25	0.00	0.00	73.25
4800070	14530	A	COLONY MILL	82.75	0.00	14.00	68.75
4800144	10110	A	SUNRISE MINE & MILL	126.25	61.25	0.00	26.75
4800145	10110	A	ATLANTIC CITY ORE OPER	497.50	0.00	141.75	355.75
4800160	14750	0	LEEFE OPERATION WYOMING	72.75	0.00	6.00	66.75
4800466	10940	A	HIGHLAND URANIUM OPERATIONS	337.50	0.00	255.50	82.00
4800490	10940	A	SHIRLEY BASIN URANIUM MINE	498.75	0.00	416.75	82.00
4800557	10940	1	LUCKY MC MINE OPERATIONS	304.75	0.00	304.75	0.00
4800559	10940	1	SPLIT ROCK MILL	133.75	0.00	0.00	133.75
4800602	14530	1	GREYBULL MILL	95.00	0.00	0.00	95.00
4800611	14530	A	STUCCO MILL	61.75	0.00	17.50	44.25
4800826	10940	B	PETROTOMICS	386.75	0.00	386.75	0.00
4800862	10940	1	WEST AREA PIT	132.75	0.00	132.75	0.00
4800888	14530	1	COLONY MINE	48.75	0.00	48.75	0.00
4801016	14530	A	LOVELL MINERS	89.58	0.00	68.58	21.00
4801051	10940	1	GOLDEN EAGLE MINE	91.00	82.25	0.00	0.00
4801099	10940	1	BEAR CREEK URANIUM MINE & MILL	215.75	0.00	169.75	46.00
4801144	10940	1	BIG EAGLE MINE	198.50	0.00	198.50	0.00
4801177	10940	1	FEDERAL AMERICAN PARTNERS OPEN	230.50	0.00	230.50	0.00
4801286	10940	1	COLLINS DRAW SOLUTION MINE	29.50	0.00	19.50	10.00

A more detailed listing of information on each site in the sample is shown in Exhibit 3. The format for this listing was specified by NIOSH as the format for the final listing of the survey sample.

2.6 ESTIMATION PROCEDURE AND VARIANCE CALCULATION

2.6.1 Basic Estimation and Variance Formulas

A major advantage of the OHSMI design is the simplicity of the estimation and variance calculation formulas. After listing the required notation below, the general formula is shown for the estimate of a characteristic of the target population. This is followed by the formulas to be used for calculating the variance of the estimate.

NOTATION

Let h denote the hth stratum

i denote the ith unit (mine) within stratum h

j equal to 1, denote a self-representing unit (SRU)

j equal to 2, denote a non-self-representing unit (NSRU)

N_{h1} denote the number of self-representing units in stratum h in the population

n_{h1} denote the number of self-representing units in stratum h in the sample (by definition of self-representing $n_{h1} = N_{h1}$)

N_{h2} denote the number of non-self-representing units in stratum h in the population

n_{h2} denote the number of non-self-representing units in stratum h in the sample

π_{hi1} denote the probability of the ith self-representing unit in stratum h being included in the sample (by definition of self-representing $\pi_{hi1} = 1$ for all (h, i, 1)

π_{hi2} denote the probability of the ith non-self-representing unit in stratum h being included in the sample

M_{hi1} denote the number of employees in the ith self-representing unit within stratum h in the population

M_{hi2} denote the number of employees in the ith non-self-representing unit within stratum h in the population

M_{h1} denote the total number of employees in the self-representing units in stratum h in the population

M_{h2} denote the total number of employees in the non-self-representing units in stratum h in the population

Y_{hij} denote the value of the characteristic "Y" for (h, i, j)

$\hat{Y}_{h1}$ denote the estimate of the population total for the self-representing units within stratum h for characteristic "Y" ($\hat{Y}_{h1}$ will equal the actual Y_{h1} since the units are self-representing)

$\hat{Y}_{h2}$ denote the estimate of the population total for the non-self-representing units within stratum h for characteristic "Y"

$\hat{Y}_h$ denote the estimate of the population total for stratum h for characteristic "Y" ($\hat{Y}_h = \hat{Y}_{h1} + \hat{Y}_{h2}$)

$\hat{Y}$ denote the estimate of the population total of characteristic "Y"

$\widehat{Var}(\hat{Y}_{h2})$ denote the estimated variance of $\hat{Y}_{h2}$

$\widehat{Var}(\hat{Y}_h)$ denote the estimated variance of $\hat{Y}_h$

$\widehat{Var}(\hat{Y})$ denote the estimated variance of $\hat{Y}$

ESTIMATION TECHNIQUES

$$\hat{Y} = \sum_{h=1}^{L} \hat{Y}_h$$

$$= \sum_{h}^{L} (\hat{Y}_{h1} + \hat{Y}_{h2})$$

$$= \sum_{h}^{L} \sum_{i}^{n_{h1}} \frac{Y_{hi1}}{\pi_{hi1}} + \sum_{h}^{L} \sum_{i}^{n_{h2}} \frac{Y_{hi2}}{\pi_{hi2}} \qquad (1)$$

where,

$$\pi_{hi1} = 1 \text{ for all } (h, i, 1)$$

$$\pi_{hi2} = n_{h2} \frac{M_{hi2}}{\sum_{i}^{N_{h2}} M_{hi2}}$$

$$= n_{h2} \frac{M_{hi2}}{M_{h2}}$$

Substituting $Z_{hi2} = \frac{M_{hi2}}{M_{h2}}$,

π_{hi2} can be written as

$$\pi_{hi2} = n_{h2} Z_{hi2}.$$

VARIANCE CALCULATIONS

The actual variance of $\hat{Y}_h$, denoted by $Var(\hat{Y}_h)$, is given by the expression

$$Var(\hat{Y}_h) = Var\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2}Z_{hi2}} \right).$$

The variance of $\hat{Y}_h$ can be estimated by the expression

$$\widehat{Var}(\hat{Y}_h) = \widehat{Var}\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{\pi_{hi2}} \right).$$

This expression is independent of the self-representing units, since these units contribute nothing to the variance of Y_h. Upon substituting $\pi_{hi2} = n_{h2}Z_{hi2}$, this expression can be estimated by the equation

$$\widehat{Var}(\hat{Y}_h) = \widehat{Var}\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2}Z_{hi2}} \right)$$

$$= \frac{\sum_{i=1}^{n_{h2}} \left(\frac{Y_{hi2}}{Z_{hi2}} - \hat{Y}_{h2}\right)^2}{n_{h2}(n_{h2} - 1)} \qquad (2)$$

where,

$$\hat{Y}_{h2} = \sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{\pi_{hi2}} = \sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2}Z_{hi2}}.$$

The variance of $\hat{Y}$ can be estimated by the expression

$$\widehat{Var}(\hat{Y}) = \sum_h \widehat{Var}(\hat{Y}_h) \tag{3}$$

where $\widehat{Var}(\hat{Y}_h)$ is obtained from equation (2).

If no responses are obtained from some mines in the sample, the summations in equations (1) and (2) are understood to include only mines from which survey data were obtained.

The variance estimators for Y_h and Y using formulas (2) and (3) are based on the assumption that the units were sampled with replacement through the procedure of random selection with probability proportional to size. In the design, the units were sampled with replacement through the procedure of systematic selection with probability proportional to size. Because units in each stratum are listed in order of mine ID (which gives an implicit stratification by State and age within State), units adjacent in the lists will tend to be similar. The resulting serial correlation tends to reduce the variances of systematic sampling estimators compared to variances of random sampling estimators.[2] Therefore, these variance formulas give conservative estimates of the variance; that is, the actual variance will be no larger than the random sampling variance.

The projection algorithms for estimates of a characteristic ($\hat{Y}$) and its variance (Var(Y)) were written as a computer-based subroutine. The code and technical documentation for this projection algorithm constitute Exhibit 4.

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[2] M. H. Hansen, W. N. Hurwitz, and W. G. Madow, Sampling Survey Methods and Theory, (New York, John Wiley and Sons, 1967), Vol. I, p. 505.

2.6.2 Use of Ratio Estimation Techniques

If the measures of size that are used for the sampling are in fact correct, then the above estimation techniques and variance calculations are adequate. Even if the size measures are not exactly correct, but the relative size measures are fairly accurate, the estimation techniques and variance calculations are still appropriate.

The evaluation of operational status changes in the mining industry showed that facilities undergo significant changes in operating status even within a year's time. This raises the possibility that the measures of size that are used to select the sample may differ significantly in both absolute number and relative size from the measures of size of sampled sites as determined during the survey. In other words, the actual number of production workers at a site may be significantly different from the employment figures taken from the MSHA Address and Employment file during the sample selection. If these changes affect both the numbers of workers at sampled sites and the ratio of workers at a site to the total employment in the stratum, the estimation techniques described above may give inaccurate estimates and variances.

One statistical technique for this problem is the use of ratio estimators. However, the estimates using ratio estimators will be biased, as explained in Cochran.[3]

The estimation formula is changed by substituting $\hat{Z}_{hi2}$ for Z_{hi2}, where

$$\hat{Z}_{hi2} = \frac{\hat{M}_{hi2}}{\hat{M}_{h2}} .$$

[3] W. Cochran, Sampling Techniques, 2d ed. (New York, John Wiley and Sons, 1963), pp. 157-162.

$\hat{M}_{hi2}$ is the new measure of size of the ith NSRU in the sample from stratum h, and $\hat{M}_{h2}$ is the new measure of size for all the NSRU's in stratum h. The values of $\hat{M}_{hi2}$ and $\hat{M}_{h2}$ may come from a source such as a more recent Address and Employment file.

Although the change in the estimation of the characteristic, $\hat{Y}$, is thus relatively simple, the use of ratio estimators greatly complicates variance calculations because $\hat{Z}_{hi2}$ is now a random variable rather than a constant of the design. As noted above, the actual variance of $\hat{Y}_h$, denoted by $Var(\hat{Y}_h)$, is given by the expression

$$Var(\hat{Y}_h) = Var\left(\sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2} Z_{hi2}} \right).$$

Since the n_{h2} draws are made independently (that is, with replacement) at each draw, any element is allowed to be selected regardless of how many times it has already been drawn. Z_{hi2} is now replaced by the random variable $\hat{Z}_{hi2}$, making $Y_{hi2}/\hat{Z}_{hi2}$ a ratio estimate. Therefore, $Var(\hat{Y}_h)$, which is given by

$$Var(\hat{Y}_h) = \frac{1}{n_h} Var\left(\frac{Y_{hi2}}{Z_{hi2}}\right),$$

has the following approximation:[4]

$$Var(\hat{Y}_h) \doteq \frac{1}{n_h} \left(\frac{E\left(\frac{Y_{hi2}}{Z_{hi2}}\right)}{E\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)} \right)^2 \left\{ \frac{Var\left(\frac{Y_{hi2}}{Z_{hi2}}\right)}{\left[E\left(\frac{Y_{hi2}}{Z_{hi2}}\right)\right]^2} + \frac{Var\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)}{\left[E\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)\right]^2} - 2\,\frac{Cov\left(\frac{Y_{hi2}}{Z_{hi2}}, \frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)}{\left[E\left(\frac{Y_{hi2}}{Z_{hi2}}\right)\right]\left[E\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)\right]} \right\} \quad (4)$$

[4] L. Kish, Survey Sampling (New York, John Wiley and Sons, 1967), p. 206.

The estimate of this variance, denoted by $\widehat{Var}(\hat{Y}_h)$, is now obtained by making the following substitutions in equation (4). Replace:

$$E\left(\frac{Y_{hi2}}{Z_{hi2}}\right) \quad \text{by} \quad \frac{1}{n_{h2}} \sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{Z_{hi2}}$$

$$E\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right) \quad \text{by} \quad \frac{1}{n_{h2}} \sum_{i=1}^{n_{h2}} \frac{\hat{Z}_{hi2}}{Z_{hi2}}$$

$$Var\left(\frac{Y_{hi2}}{Z_{hi2}}\right) \quad \text{by} \quad \widehat{Var}\left(\frac{Y_{hi2}}{Z_{hi2}}\right)$$

$$Var\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right) \quad \text{by} \quad \widehat{Var}\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)$$

$$Cov\left(\frac{Y_{hi2}}{Z_{hi2}}, \frac{\hat{Z}_{hi2}}{Z_{hi2}}\right) \quad \text{by} \quad \widehat{Cov}\left(\frac{Y_{hi2}}{Z_{hi2}}, \frac{\hat{Z}_{hi2}}{Z_{hi2}}\right).$$

In the above expressions, $\widehat{Var}(X)$ and $\widehat{Cov}(X, W)$ are the estimated variances and covariances, respectively.

Values for $\widehat{Var}\left(\frac{Y_{hi2}}{Z_{hi2}}\right)$, $\widehat{Var}\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)$, and $\widehat{Cov}\left(\frac{Y_{hi2}}{Z_{hi2}}, \frac{\hat{Z}_{hi2}}{Z_{hi2}}\right)$ can be calculated from the following equations:

$$\widehat{Var}\left(\frac{Y_{hi2}}{Z_{hi2}}\right) = \sum_{i=1}^{n_{h2}} \frac{\left(\frac{Y_{hi2}}{Z_{hi2}} - \sum_{i}^{n_{h2}} \frac{Y_{hi2}}{n_{h2} Z_{h2}}\right)^2}{n_{h2}(n_{h2} - 1)}$$

$$\widehat{\text{Var}}\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}}\right) = \sum_{i=1}^{n_{h2}} \frac{\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}} - \sum_{i}^{n_{h2}} \frac{\hat{Z}_{hi2}}{n_{h2} Z_{h2}}\right)^2}{n_{h2}(n_{h2} - 1)}$$

$$\widehat{\text{Cov}}\left(\frac{Y_{hi2}}{Z_{hi2}}, \frac{\hat{Z}_{hi2}}{Z_{hi2}}\right) = \sum_{i=1}^{n_{h2}} \frac{\left(\frac{Y_{hi2}}{Z_{hi2}} - \sum_{i=1}^{n_{h2}} \frac{Y_{hi2}}{n_{h2} Z_{hi2}}\right)\left(\frac{\hat{Z}_{hi2}}{Z_{hi2}} - \sum_{i=1}^{n_{h2}} \frac{\hat{Z}_{hi2}}{n_{h2} Z_{hi2}}\right)}{n_{h2}(n_{h2} - 1)}$$

The variance of $\hat{Y}$ can be estimated by the expression

$$\widehat{\text{Var}}(\hat{Y}) = \sum_{h} \widehat{\text{Var}}(\hat{Y}_h),$$

where $\widehat{\text{Var}}(\hat{Y}_h)$ is obtained from equation (4).

As noted above, the estimates $\hat{Y}_{h2}$, $\hat{Y}_h$, and $\hat{Y}$ are biased when Z_{hi2} is replaced by $\hat{Z}_{hi2}$. The discussion of the variance approximation for a ratio estimator shows that the variance calculations become more complex and dependent on factors that are not known until after the data are collected. For these reasons, a better approach than the use of ratio estimation corrections is to update the sampling frame with the latest available data on measure of size prior to selecting the sample. If the survey is conducted immediately after the sample is drawn, then the actual sizes are likely to be close to the sizes used in the selection. In this case, the sample estimator and variance formulas will be adequate.

3. TREATMENT OF NONRESPONSE

3.1 EFFECTS OF NONRESPONSE

When a sample survey is performed, data for some members of the sample set may not be obtained by the routine data collection procedure. This lack of data is called nonresponse. In the OHSMI, there are two likely causes of nonresponse: a mine is out of operation during the survey, or a mine operator refuses to participate.

If not properly addressed, nonresponse problems can diminish the utility of survey results by reducing the statistical quality of estimates of population parameters of interest. The quality of survey results generally is discussed in terms of bias (systematic estimation errors) and precision (random estimation errors).[1] One measure of bias is the difference between the expected value of a survey estimator (e.g., a sample average) and the population value of interest. Precision usually is measured by the standard error or the variance of an estimator.

Nonresponse can cause bias in survey results when the average value of the property of interest differs for respondents and nonrespondents. It can cause imprecision by reducing the amount of data available for estimation. In addressing the problem of nonresponse, JRB considered the impact on both the bias and precision of survey results.

3.2 BIAS

Nonresponse bias may occur when the sample mean for respondents is used to estimate a population mean, but respondents and nonrespondents in the

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[1] W. Cochran, Sampling Techniques, 2d ed. (New York, John Wiley and Sons, 1963), pp. 12-16.

population have different means. The size of nonresponse bias depends on both the rate of nonresponse (W_2) and the difference between respondent and nonrespondent means: Bias = $W_2(\bar{Y}_R - \bar{Y}_N)$.[2] For nonresponse bias to be important, a large nonresponse rate generally must be combined with a large difference in means.[3] When the nonresponse rate is low, no corrective action may be needed. The characteristics of nonrespondents should be examined, however, to look for patterns of nonresponse (e.g., concentrations in particular geographic, age, or size categories). Any patterns discovered should be reported with survey results to aid in interpretation.

If the nonresponse rate is over 10 percent, it may be necessary to take corrective action. Replacing nonrespondents with respondents usually is not an effective bias-correction procedure because the replacements resemble respondents rather than nonrespondents.[4] Several effective approaches have been developed; all are based on converting at least some of the nonrespondents to respondents through followup contacts.[5] The most common approach is to select a random subsample of nonrespondents and convince them to respond. This provides data for evaluating the extent of nonresponse bias. A weighted average of respondent and converted nonrespondent data can be used to estimate population parameters if the bias appears to be serious.[6] Hansen, Hurwitz, and Madow discuss choosing the sample of nonrespondents for followup purposes.[7]

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[2] Cochran, p. 357.

[3] L. Kish, Survey Sampling, (New York, John Wiley and Sons, 1967), p. 535.

[4] Kish, p. 549.

[5] Cochran, pp. 367-371; Kish, pp. 550-557.

[6] Cochran, pp. 367-368.

[7] M. H. Hansen, W. N. Hurwitz, and W. G. Madow, Sample Survey Methods and Theory, (New York, John Wiley and Sons, 1967), Vol. I, pp. 473-475.

Followups should only be made where nonresponse is due to refusal or temporary shutdowns (seasonal shutdowns or operating problems). Exclusion of mines that are shut down for long periods will not bias results because such mines are not in the target population. By contacting members of the initial sample by phone to identify those willing to participate and arranging for written or telephone followup to those initially unwilling, it may be possible to limit travel to one visit to each selected mine. Followups are particularly important for SRU's since they make large contributions to estimates weighted by employment (and no replacements can be built into the survey for these mines).

3.3 PRECISION

The NIOSH Project Officer directed that 10 to 15 percent of all NSRU's should be sampled in the OHSMI. There are several ways of replacing non-respondents to ensure that data are obtained from the desired proportion of NSRU's and that sufficient precision is achieved. The most widely recommended procedure is to build replacements into the initial sample by taking the anticipated response rate into account.[8] For example, if data are desired from 12 percent of the population and one expects 80 percent of the sample to respond, 15 percent of the population should be sampled (0.8 x 15 percent = 12 percent). The principal advantages of this procedure are that it requires no change in the weights used in estimation and it is simple to administer.

An alternative replacement approach is a two-stage sampling procedure, in which replacements for nonrespondents are selected after the initial sample has been selected. This alternative has the disadvantage of complicating both the sampling and estimating processes. In weighted estimation the weights for replacements are not determined simply by numbers of employees, since selection also depends on the (unknown) probability that members of the initial sample do not respond. The need to use estimated nonresponse probabilities in obtaining weighted estimates tends to cancel out gains in precision obtained by

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[8] Kish, p. 558.

replacing nonrespondents (because the estimation variance depends on the variances of the property of interest and of the estimated weights).[9]

A final replacement option is quota sampling, in which one continues to select members of each stratum until the desired numbers of respondents are obtained (or all the members of a stratum have been selected). A serious disadvantage of this approach is that it may not be possible to determine the precision of the estimates it produces.[10]

The first approach described--building replacements into the initial sample--was selected for the OHSMI because it is the simplest procedure for guarding against imprecision due to nonresponse and it provides statistics weighted by numbers of workers (as is desirable in this survey). With a 15 percent sampling rate, this approach can be expected to provide data from the desired proportion of NSRU's unless the nonresponse rate exceeds one-third. If a larger nonresponse rate were to occur, bias would become the primary concern.

It should be noted that if there are strata in which the probability of nonresponse is very high (due to regional attitudes, for example), no replacement procedure can deal effectively with the problem. In such cases, replacements will be just as unlikely to respond as members of the initial sample. Thus, localized nonresponse problems should be handled as described in Section 3.2.

3.4 SUMMARY

The standard methods for dealing with nonresponse have been described, and detailed references have been given for these methods. Briefly, the different types of nonrespondents should be handled as follows:

- Permanent closing - drop from the sample since the mine does not belong to the population of interest.

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[9] Cochran, pp. 157-158.

[10] Cochran, p. 137.

- Temporary closing - set a time limit for completion of the survey and ascertain when the mine will reopen. If it reopens during the survey period, survey it at that time. Otherwise, treat it as permanently closed for purposes of the survey.

- Refused entry - convince some refusals to reconsider so that comparisons can be made between respondents and refusals. If this is not possible, attempt to obtain exposure data on some refusals from other sources (such as MSHA) and use those data to evaluate respondent-refusal differences. Study the characteristics of those who refuse to participate to identify segments of the survey most seriously affected (if any). The important point with refused entries is to evaluate the potential effect of nonresponse bias.

One cannot set a lower limit to the percent respondents that would be acceptable; this limit depends on the reasons for nonresponse, the presence or absence of nonresponse bias, and the ability to evaluate that bias by the methods outlined above. With a 90 percent or higher response rate, it generally can be assumed that nonresponse bias is no problem. It may be no problem with lower response rates, but it is unsafe to assume so. A response rate as low as two-thirds still would yield responses from the fraction of mines desired by NIOSH (10 to 15 percent). The precision of estimates could be acceptable with an even lower response rate, depending on characteristics of the population sampled (which will not be known until the survey is conducted).

APPENDIX A
REPORT ON THE OHSMI CERTAINTY STRATUM

Prepared for

National Institute for Occupational Safety and Health
Contract No. 210-80-0026

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September 4, 1981

1. A CERTAINTY STRATUM FOR THE OCCUPATIONAL HAZARD SURVEY OF THE MINING INDUSTRY

This report presents a plan for a stratum of mine sites to be included in the Occupational Hazard Survey of the Mining Survey (OHSMI). The sites in this stratum are to be selected with certainty to ensure that characteristics of special interest to NIOSH are represented in the survey sample.

JRB proposed the use of a certainty stratum in Progress Report No. 6 (February 6, 1981) as a means to provide guaranteed representation of many of the MSHA commodity classes while retaining the benefits of two-stage cluster sampling as the basic survey design. NIOSH expressed interest in this approach in the letter response to JRB of March 2, 1981. NIOSH originally directed that the certainty stratum should represent all (or most) MSHA five-digit Standard Industrial Classification (SIC) commodity classes and provide regional representation within each commodity class. These joint requirements proved to be infeasible, as the certainty stratum would contain more sites than were planned for the entire OHSMI effort. Both the NIOSH and JRB technical staffs agreed that a certainty stratum containing 10-15 percent of the total survey sample would be appropriate. The problem was to optimize coverage of commodity classes and important regional differences within classes while remaining within this size limitation.

In mid-July, JRB suggested the following approach to designing a certainty stratum. First, the 87 MSHA SIC commodity classes would be grouped for those commodities that were expected to be similar in potential health hazards. Second, for each group with more than 10 active sites in the sampling frame, JRB would consult with a commodity specialist from the Bureau of Mines or a mineral specialist from the U.S. Geological Survey about regional differences that may be relevant to health hazards. These groups will be called the Ten-Site Groups. For each commodity group, the certainty stratum would include one site for each region identified through the consultations. If the number of sites required for the Ten-Site Groups was less than the 15-percent ceiling on the certainty stratum, additional groups would be covered.

Table 1 presents the results from this approach. For each MSHA SIC class, Table 1 shows:

- The number of sites in the sampling frame that was used in Progress Report No. 6
- The number of geographic regions that were identified by JRB consultations with specialists at the Bureau of Mines or the Geological Survey
- Comments that either describe the regions, note that geographic distinctions appeared irrelevant, or explain why the class was not included in the certainty stratum.

Section 2 of this report consists of summaries of the information used to determine the geographic regions within commodity groups.

The 87 MSHA SIC classes were reduced to 74 commodity groups, as shown by the table. Of these, eight groups have no active sites in the sampling frame and are therefore omitted. JRB omitted Bituminous Coal (12110) and the sand/gravel group (14410) on the assumption that the large number of these sites and their relative geographic homogeneity will ensure adequate representation in the random sampling. The categories for Stone Not Elsewhere Classified (14110, 14290) and Nonmetallic Minerals Not Elsewhere Classified (14990) were omitted as composite classes that would not represent a specific commodity. These sites will of course be included in the frame of the random sampling.

The Ten-Site Groups can be covered within the stratum ceiling of approximately 100 sites (15 percent of 670 sites in the full sample). In addition, JRB has added sites for commodity groups with at least seven active sites in the sampling frame. Several groups with six sites, where the group may be of particular interest to NIOSH, are also included. Of the original 87 MSHA classes, 20 classes are omitted from the proposed certainty stratum because each contains too few active sites (six or fewer).

The proposed certainty stratum contains 83 sites, which represent 12.4 percent of a total survey sample of 670 sites. We suggest that the NIOSH staff review the proposed distribution of sites and recommend improvements based on their knowledge of particular mining environments. The proposed stratum is still below the 15 percent limit, so there are options to increase the number of sites either by including more of the small commodity groups or by increasing the regional distribution within groups.

Table 1. Proposed Certainty Stratum for OHSMI By MSHA Commodity Code and Region

MSHA SIC Code	Commodity	Number of Sites in Sampling Frame	Number of Geographic Regions	Comments
10110	iron ore	87	5	1. California, Utah 2. Texas 3. Minnesota, Michigan, Wisconsin 4. Missouri 5. Wyoming
10210	copper ore	87	5	1. Arizona 2. New Mexico, Nevada, Utah 3. Tennessee, Idaho 4. Michigan 5. Montana
10310	lead/zinc	82	4	1. Missouri 2. Tennessee 3. Idaho 4. Colorado
10410	gold	263	1	Mine sites cannot be divided into geographic areas.
10440	silver	89	1	Mine sites cannot be divided into geographic areas.
10510 28191	aluminum alumina	22	2	1. Arkansas 2. Georgia, Alabama
10610	ferroalloy ores	0	0	No active sites
10611	chromite	0	0	No active sites
10612	cobalt	2	0	Too few active sites
10613	columbium-tantalum	0	0	No active sites
10614	manganese	5	0	Too few active sites
10615	molybdenum	16	3	1. Colorado, New Mexico 2. Utah 3. Idaho

(continued)

Table 1. Proposed Certainty Stratum for OHSMI
By MSHA Commodity Code and Region

MSHA SIC Code	Commodity	Number of Sites in Sampling Frame	Number of Geographic Regions	Comments
10616	nickel	1	0	Too few active sites
10617	tungsten	40	1	Similar mine types
10920	mercury	1	0	Too few active sites
10940	uranium-vanadium	35	1	Similar mine types
10941	uranium	265	1	Similar mine types
10942	vanadium	3	3	1. Arkansas 2. Idaho 3. Colorado
10990	metal ores, NEC	3	0	Too few active sites
10991	antimony	2	0	Too few active sites
10992	beryl	2	0	Too few active sites
10993	platinum group	1	0	Too few active sites
10994	rare earths	2	0	Too few active sites
10995	tin ore	1	0	Too few active sites
10996	titanium	6	3	1. Florida, New Jersey 2. New York 3. Georgia
10997	zircon	0	0	No active sites
11110	coal, anthracite	424	1	Similar mine types
12110	coal, bituminous	7,151	0	Omitted from certainty stratum
13111	oil shale	17	1	Similar mine types
14110	stone, dimension NEC	13	0	Composite category omitted from certainty stratum

(continued)

Table 1. Proposed Certainty Stratum for OHSMI By MSHA Commodity Code and Region

MSHA SIC Code	Commodity	Number of Sites in Sampling Frame	Number of Geographic Regions	Comments
14111 14230	granite (dimension) granite (crushed and broken)	341	1	Similar mine types
14112 14220 14113 14291	limestone (dimension) limestone (crushed and broken) marble (dimension) marble (crushed and broken)	2,668	1	Limestone and marble are similar mine types
14114 14292	sandstone (dimension) sandstone (crushed and broken)	299	1	Similar mine types
14115 14293	slate (dimension) slate (crushed and broken)	61	1	Similar mine types
14116 14294	traprock (dimension traprock (crushed and broken)	418	1	Similar mine types
14220	limestone (crushed and broken)	2,552	-	Included with SIC 14112 (limestone, dimension)
14230	granite (crushed and broken)	222	-	Included with SIC 14111 (granite, dimension)
14290	stone (crushed and broken) NEC	199	0	Composite category, omitted from certainty stratum
14291	marble (crushed and broken)	35	-	Included with SIC 14113 (marble, dimension)
14292	sandstone (crushed and broken)	233	-	Included with SIC 14292 (sandstone, dimension)
14293	slate (crushed and broken	20	-	Included with SIC 14115 (slate, dimension)

(continued)

Table 1. Proposed Certainty Stratum for OHSMI By MSHA Commodity Code and Region

MSHA SIC Code	Commodity	Number of Sites in Sampling Frame	Number of Geographic Regions	Comments
14294	traprock (crushed and broken)	411	-	Included with SIC 14116 (traprock, dimension)
14410	sand and gravel	7,384	0	Omitted from certainty stratum
14530 14550 14590 14596	clay (fire) clay (common) clay (ceramic and refratory) NEC common shale	796	6	1. Wyoming, Montana, South Dakota 2. Mississippi, Alabama 3. Missouri, Ohio, Pennsylvania 4. Georgia, Florida, South Carolina 5. Tennessee, Kentucky 6. Texas, North Carolina
14591	aplite	3	0	Too few active sites
14592	brucite	1	0	Too few active sites
14593	feldspar	30	1	1. North Carolina
14594	kyanite	4	2	1. Georgia 2. Virginia
14595	magnesite	3	0	Too few active sites
14596	shale (common)	140	-	Included with SIC 14530, 14550, 14590 (clays)
14720	barite	99	2	1. Arkansas and Nevada 2. Montana, Georgia, Tennessee
14730	flurospar	24	2	1. Illinois 2. Western
14740	potash, soda, and borate minerals, NEC	2	0	Too few sites
14741	boron minerals	6	1	Mine types not distinct by geography

(continued)

Table 1. Proposed Certainty Stratum for OHSMI By MSHA Commodity Code and Region

MSHA SIC Code	Commodity	Number of Sites in Sampling Frame	Number of Geographic Regions	Comments
14742	potash	10	3	1. New Mexico 2. Utah 3. California
14743	trona	0	0	Omitted from certainty stratum
14744	sodium compounds	6	2	1. Wyoming 2. California, Texas
14750	phosphate rock	68	4	1. Florida 2. North Carolina 3. Idaho 4. Tennessee
14760	salt, rock	20	1	Similar mine types
14770	sulfur	1	0	Omitted from certainty stratum
14790	chemical and fertilizer, NEC	0	0	No active sites
14791	lithium	6	0	Too few active sites
14792	pigment material	2	0	Too few active sites
14793	pyrites	4	0	Too few active sites
14794	strontium	0	0	No active sites
14920	gypsum	78	1	Similar mine types
14960	talc, soapstone pyrophylite	62	6	1. New York 2. Vermont 3. Virginia 4. Montana 5. California 6. Texas
14990	nonmetallic minerals, NEC	60	0	Omitted from certainty stratum

(continued)

Table 1. Proposed Certainty Stratum for OHSMI By MSHA Commodity Code and Region

MSHA SIC Code	Commodity	Number of Sites in Sampling Frame	Number of Geographic Regions	Comments
14991	asbestos	10	4	1. E. California 2. W. California 3. Arizona 4. Vermont
14992	gemstones	15	1	No significant geo-graphical distinctions
14993	gilsonite	6	0	Too few active sites
14994	mica	26	1	1. North Carolina
14996	perlite	22	2	1. Arizona 2. New Mexico
14997	pumice	82	1	Similar mine sites
14998	vermiculite	15	3	1. Montana 2. Virginia 3. South Carolina 4. Texas
28190	industrial chemicals, NEC	1	0	Too few active sites
28191	alumina	11	-	Included with SIC 10510 (aluminum)
28193	bromine	0	0	No active sites
28991 28992	salt (evaporated) salt (in brine)	26	1	Similar mine types
29900	leonardite	3	0	Too few active sites
32410	cement	164	1	Similar mine types
32740	lime	99	1	Similar mine types

2. INFORMATION ON GEOGRAPHIC DIFFERENCES WITHIN COMMODITY TYPES

For most of the commidity codes that were included in the certainty stratum, we contacted one or more specialists from the Bureau of Mines or the U.S. Geological Survey. The section summarizes the information we obtained from these specialists and considered when drawing the geographic divisions within a commodity group. The only commodity groups represented in the certainty stratum that were not included in this process were those for which we had adequate knowledge that the sites were geographically similar with respect to health hazards.

10110 Iron Ore

Contact Person: E.C. Peterson
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1020

California and Utah mines have similar types of host rock. Texas is a unique situation. The mines in the Mesabi Range (Minnesota, Wisconsin, and Michigan) are similar, with the exception of the Republic and Tilden Mines. Missouri mines are unique. Wyoming mines are unique (open pit).

10210 Copper ore

Contact Person: Robert Schmidt
U.S. Geological Survey
Reston, Virginia
(703) 860-7356

If 10 samples are taken, take 2-3 porphyry deposits in Arizona, 2-3 porphyry deposits in the New Mexico, Nevada and Utah area, 4 from the Tennessee and Idaho massive sulfide deposits, and one from White Pine, Michigan sedimentary deposit. Butte, Montana deposit is a special case producing an unusual porphyry.

10310 Lead, Zinc

Contact Persons: J.A. Rathjen
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1083

V.A. Cammarota
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1063

Most lead (94-96 percent) is mined in Missouri. Some lead is mined in Idaho. Smaller amounts of lead are mined in polymetallic ores in Colorado, Vermont, and Nevada. These deposits contain silver, zinc, cadmium, copper, and antimony. The zinc oxide deposit near Odgensburg, New Jersey, is unique but may be inactive. Complex polymetallic mines containing lead, zinc, silver, copper, and gold are located in Kellogg, Idaho or Leadville, Colorado. Copperhill, Tennessee has a zinc-copper mine.

10410 Gold

Contact Person: J.M. Lucas
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1070

In the U.S., about 60 percent of domestic production comes from gold ores, the remainder is a byproduct of copper and other base metal production. Three mines accounted for 64 percent, and 25 mines accounted for about 97 percent of domestic output in 1979. About 88 percent came from South Dakota, Nevada, Utah, and Arizona. The leading producer is Homestake Mining, which provides more than one-fourth of domestic output from their South Dakota mine. Kennecott's gold (Arizona) is a byproduct of extensive copper mining. Third largest producer is the open pit mine in north-central Nevada. Gold deposits are found in many kinds of rock. There really is no way to separate them by geographic areas.

10440 Silver

Contact Person: H.J. Drake
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1054

Deposits are too varied to separate into distinct geographic areas.

10510, 28191 Aluminum, Alumina

Contact Person: Sam Patterson
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

The Arkansas mines contain higher grade bauxite and are used to produce aluminum. Georgia and Alabama mines consist of a low quality bauxite used to make refractories.

10615 Molybdenum

Contact Person: J.T. Kummer
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1021

Almost all molybdenum is recovered from low-grade deposits of the mineral molybdenite (MoS_2). Climax Molybdenum Company is the world's leading producing firm. They account for 70 percent of domestic output. The Climax and Henderson mines in Colorado and the Questa mine in New Mexico are the same because they are hydrothermal molybdenum stockwork deposits. Small quantities of molybdenite are widely distributed in lime-silicate deposits along the contacts between granitic intrusive rocks and lime-rick sedimentary rocks. Only domestic production from this type of mineralization has been a byproduct from the Pine Creek tungsten deposit in California.

10617 Tungsten

Contact Person: P.T. Stafford
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1020

Major producers are Union Carbide's Pine Creek, California mine; Emerson Site in Nevada; Teledyne's Medra Site in California; and National Resources development in Nevada. All are similar mine types.

10940 Uranium-Vanadium

Contact Person: F. Schottman
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1015

The Atlas Corporation at Moab, Utah and Cotter Corporation at Rifle, Colorado process uranium-vanadium ores from the Colorado Plateau. Colorado mines are underground; Wyoming mines are open pit. Utah and Colorado mines are in the Colorado Plateau. They differ from the Wyoming deposit which is a vanadiferous phosphatic shale.

10941 Uranium

Contact Person: W.S. Kirk
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1085

Most mines that mine uranium are located in the Colorado Plateau in sandstone deposits. No real major differences exist in mine types.

10942 Vanadium

Contact Person: F. Schottman
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1015

Vanadium is usually produced as a byproduct or coproduct of another element, such as uranium or phosphorus. Union Carbide Corporation mines vanadium ore at Hot Springs, Arkansas. At Soda Springs, Idaho, the Kerr-McGee Corporation recovers vanadium oxide from ferrophosphorus, a byproduct of elemental phosphorus produced from phosphate rock mined in Idaho. Union Carbide Corporation is the principal producer and consumer of vanadium oxide. Pioneer Uravan is building a new mill near Slick Rock, Colorado. It is expected to process 1,000 tons per day of uranium-vanadium ores from the Colorado Plateau when completed in 1981. There are three distinct areas for vanadium site distributions: Arkansas, Colorado (sandstone), and Idaho (phosphate).

10996 Titanium

Contact Person: L.E. Lynd
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1073

Mines in Florida and New Jersey are similar deposits of leptynite in old sandstone. A second region is New York, while Georgia deposits represent a third type.

11110 Coal, Anthracite

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

13111 Oil Shale

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

14111, 14230 Granite, dimension, and crushed and broken

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

Most deposits are generally similar. However, differences occur in grain size, texture, amount of grinding and polishing, and wet versus dry grinding. The contact person suggests taking random samples of all sites.

14112, 14220, 14113, 14291 Limestone (dimension and crushed,
Marble (dimension and crushed)

Contact Person: Richard Singleton
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1194

Since limestone and marble are chemically similar, their mines are similar. However lime or cement are manufacturing, not mining, processes. (JRB has included one site each for lime and cement in the certainty stratum to represent these processes.)

14114, 14292 Sandstone

Contact Person: G.W. Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

R.H. Singleton
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1194

Sites are generally very similar. The sandstone mined is usually brownstone. The chemistry of various sandstones is nearly identical and all sandstones are quarried.

14293, 14115 Slate, dimension and crushed

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

Sites are generally similar. Random sampling of the sites is recommended. Dry grinding produces much more dust than wet grinding.

14116, 14294 Traprock, dimension and crushed

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

Traprock is essentially made of diabase. Most deposits are generally similar. However there are differences in grain size, amount of grinding and polishing, and wet versus dry grinding. Most traprock is crushed for construction purposes. Construction personnel are not concerned about what the type of rock is. They categorize stone types very loosely. (Traprock and granite work areas do not overlap.)

14530, 14550, 14590, 14596 Fire clay, Common Clay, Ceramic Refractory Clay, Common Shale

Contact Person: S.G. Ampian
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1180

The Bureau of Mines classifies their clays into 6 different types as opposed to the four commodity types used by MSHA. Bentonite mines are similar in Wyoming, Montana, and South Dakota. Bentonite mines in Mississippi and Alabama are a different type of bentonite than the Wyoming clays. Fire clay mines are located in Missouri, Ohio, and Pennsylvania. Fullers earth is mined in Georgia and Florida. Kaoline is mined in Georgia and South Carolina. Ball Clay is mined in Tennessee and Kentucky. Common clay and shale is mined in Texas and North Carolina.

14593 Feldspar

Contact Person: Frank G. Lesure
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

Approximately one-half of production is in the Spruce Pine district, North Carolina. Feldspar is mined with micas and halloysite. There are two types of deposits and both are found in the Spruce Pine district. One type is muscovite in weathered host rock granodiorite. The second type deposit is a mixture of unweathered albite, microclines, clays, fledspar, muscovite, and quartz. This type is ground and treated by flotation. Sample Spruce Pine district for Feldspar and micas at the same time. The mine is an open pit. The minerals are very finely ground at the mill and the operation is very dusty.

14594 Kyanite

Contact Person: Frank G. Lesure
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

The only active sites are Georgia and Virginia. (JRB did not receive any information on geographic differences relevant to health effects.)

14720 Barite

Contact Person: D.E. Morse
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

There are two types of deposits, both open pit. Bedded deposits are strip-mined in Nevada. Folded lower grade beds are in Arkansas. Residual deposits are located in Missouri, Georgia, and Tennessee.

14730 Fluorospar

Contact Person: D.E. Morse
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

The contact person advised sampling Illinois mines as one type of ore, western ores as another type.

14741 Boron Minerals

Contact Person: P.A. Lyday
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

The ore is very different in mines of one geographic area. The Trona, California district is a brine deposit. In Death Valley, California, the underground ore is approximately 23-25 percent B_2O_3.

14742 Potash

Contact Person: J.P. Searls
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1190

The deposit near Carlsbad, New Mexico has 7 underground sites. Two sites produce $KMgSO_4$ and KCl. The other five sites produce KCl only. One site in Utah is a solution mine which dissolves KCl with water, then recrystallizes it. A Great Salt Lake, Utah iste uses the solar evaporation method to produce K_2SO_4. The Utah (Bonneville) salt flats deposit has trenches that collect brine and evaporate into K_2SO_4. California produces KCl, K_2SO_4, and three other items from brines that are 600 feet underground.

14744 Sodium Compounds

Contact Person: D.S. Kostick
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

Sodium carbonate (soda ash) is mined from five Wyoming mines; one is under construction. In California, sodium carbonate is mined by pumping subterranean brine to the surface. Sodium sulfate is mined from subterranean brines in California and Texas. These salts can also be produced synthetically. (JRB did not receive any information regarding geographic differences related to health effects.)

14750 Phosphate

Contact Person: W.F. Stowasser
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1190

All phosphate is mined wet using dredges and draglines. There are very few problems with dusts. In North Carolina there is one underwater mine. Montana has one small underground mine. Tennessee has a number of small mines that may be underground. Polk and Hilsboro counties in Florida have 20-30 surface mines. Idaho has 5-6 mines, which are probably dry and different from Florida. The contact person suggests sampling Florida, North Carolina, Idaho, and possibly Tennessee.

14760 Salt, rock

Contact Person: D.S. Kostick
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

Most sites are similar.

14920 Gypsum

Contact Person: J.W. Pressler
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1206

Since gypsum mines conform to commercial plaster specifications, the various mine sites are similar. Commercial plaster specifications are 85 percent hydrated calcium, 0.05 percent alkalies, <1.5-2.0 percent clays, <2.0 percent anhydrite (Sodium, potassium, etc.), and the rest silica

14960 Talc, Soapstone, Pyrophyllite

Contact Person: C. Ervin Brown
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

Most production of these minerals is from New York, Vermont, Virginia, and Montana. Soapstone and pyrophyllite are mined at different sites. Talc deposits produce a great variety of products and are selectively mined depending on the product(s) desired. In New York, St. Myers Company mines produce mainly talc from metasedimentary rock. The talc is finely ground and bagged onsite for use as a ceramic base and filler. In Vermont the main product is talc mined from ultramafic metaigneous rock. Some of the talc is ground at the mill, removed by flotation, and used as a filler. Other talc is cut as block stone. In Montana, the main product is block talc mined from metasedimentary rock. Skyler, Virginia produces soapstone as the main product from metaigneous rock. The host rock in Texas mines is metaigneous. In California one site is a metaediment deposit and the other site is a contact metamorphic deposit. The contact person suggests sites in New York, Vermont, and Montana for talc and Virginia for soapstone.

14991 Asbestos

Contact Person: R.A. Clifton
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1206

Chyrsotile is the only asbestos mine in the United States. In eastern California, there is a massive serpentine mine in Copperopolis. Western California has a mine close to Quinga and a mill near King City. Sixty percent of the asbestos in the mill has short fibers. In Globe, Arizona, a very clean mine is owned by Jaguays. A massive serpentine mine is located in Laurel, Vermont. (JRB did not receive any information regarding geographic differences related to health effects.)

14992 Gemstones

Contact Person: J.W. Pressler
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1206

In the western United States, agate, turquoise, and some opal are mined. Turquoise is mined in Nevada, New Mexico, and Arizona. Opal is mined in Nevada and Idaho. Rubies and sapphires are mained in North Carolina and Montana. Garnets are mined in Idaho, Nevada, and Maine. The total value of the mines is about $6 million and is small compared to other commodities. (JRB did not receive any information on geographic differences related to health effects.)

14994 Mica

Contact Person: Frank G. Lesure
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

Approximately one-half of mica production is in the Spruce Pine district of South Carolina. Most deposits are fiarly similar and produce scrap or flake mica.

14996 Perlite

Contact Person: Alfred L. Bush
U.S. Geological Survey
Denver, Colorado
(303) 234-2694

In northern New Mexico, Johns-Manville is the largest mine. Other mines in the area are Grefco and U.S. Perlite. Superior, Arizona also has sites. (JRB did not receive any information on geographic differences related to health effects.)

14997 Pumice

Contact Person: Alfred L. Bush
U.S. Geological Survey
Denver, Colorado
(303) 234-2694

The ore varies depending on the type of magma from which it is cooled. In some deposits basalt is the host rock, but most deposits are not basaltic. The contact person did not know of any geographic differences in the mine deposits, but suggests sampling a number of geographically separate places to get a representative sample.

14998 Vermiculite

Contact Person: Alfred L. Bush
U.S. Geological Survey
Denver, Colorado
(303) 234-2694

Approximately two-thirds of all vermiculite is produced from a very large deposit in Montana. The Montana ore is not expanded at mill, but at the site of use. Most United States' expanders process Montana ore. About one-third of all vermiculite is produced from Innery, South Carolina. Innery has about 100 or more depleted and unmined deposits. W.R. Grace is the main producer at Innery. However, smaller producers may be more cooperative. Louisa County, Virginia, ore may be different from South Carolina deposits. Sample Montana, South Carolina, a site in Yanco, Texas, and possibly Virginia.

28991, 28992 Salt, evaporated and brine

Contact Person: D.S. Kostick
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

Brine salt mines are similar. Evaporite site mines are similar in characteristics, but can be processed three different ways: vacuum pan evaporation, open pan evaporation, or solar evaporation.

32410 Cement

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

32740 Lime

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

APPENDIX B

INFORMATION ON GEOGRAPHIC DIFFERENCES WITHIN COMMODITY TYPES

For most of the commodity codes, we interviewed by telephone one or more specialists from the Bureau of Mines or the U.S. Geological Survey. This section summarizes the information we obtained from these specialists and considered when drawing the geographic divisions within a commodity group. We did not include in the interviews those commodity groups for which there was adequate knowledge that the sites were geographically similar with respect to health--Bituminous Coal (12110) and Sand and Gravel (14410).

10110 Iron Ore

Contact Person: E. C. Peterson
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1020

California and Utah mines have similar types of host rock. Texas is a unique situation. The mines in the Mesabi Range (Minnesota, Wisconsin, and Michigan) are similar, with the exception of the Republic and Tilden Mines. Missouri mines are unique. Wyoming mines are unique (open pit).

10210 Copper Ore

Contact Person: Robert Schmidt
U.S. Geological Survey
Reston, Virginia
(703) 860-7356

If 10 samples are taken, take 2-3 porphyry deposits in Arizona, 2-3 porphyry deposits in the New Mexico, Nevada, and Utah area, 4 from the Tennessee and Idaho massive sulfide deposits, and one from White Pine, Michigan sedimentary deposit. Butte, Montana deposit is a special case producing an unusual porphyry.

10310 Lead, Zinc

Contact Persons:

J. A. Rathjen
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1083

V. A. Cammarota
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1063

Most lead (94-96 percent) is mined in Missouri. Some lead is mined in Idaho. Smaller amounts of lead are mined in polymetallic ores in Colorado, Vermont, and Nevada. These deposits contain silver, zinc, cadmium, copper, and antimony. The zinc oxide deposit near Ogdensburg, New Jersey, is unique but may be inactive. Complex polymetallic mines containing lead, zinc, silver, copper, and gold are located in Kellogg, Idaho and Leadville, Colorado. Copperhill, Tennessee has a zinc-copper mine.

10410 Gold

Contact Person:

J. M. Lucas
U.S Bureau of Mines
Washington, D.C.
(202) 634-1070

In the U.S., about 60 percent of domestic production comes from gold ores; the remainder is a byproduct of copper and other base metal production. Three mines accounted for 64 percent, and 25 mines accounted for about 97 percent of domestic output in 1979. About 88 percent came from South Dakota, Nevada, Utah, and Arizona. The leading producer is Homestake Mining, which provides more than one-fourth of the domestic output from their South Dakota mine. Kennecott's gold (Arizona) is a byproduct of extensive copper mining. Third largest producer is the open pit mine in north-central Nevada. Gold deposits are found in many kinds of rock. There is really no way to separate them by geographic areas.

10440 Silver

Contact Person:

H. J. Drake
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1054

Deposits are too varied to separate into distinct geographic areas.

10510, 28191 Aluminum, Alumina

Contact Person: Sam Patterson
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

The Arkansas mines contain higher grade bauxite and are used to produce aluminum. Georgia and Alabama mines consist of a low quality bauxite used to make refractories.

10615 Molybdenum

Contact Person: J. T. Kummer
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1021

Almost all molybdenum is recovered from low-grade deposits of the mineral molybdenite (MoS_2). Climax Molybdenum Company is the world's leading producing firm. They account for 70 percent of domestic output. The Climax and Henderson mines in Colorado and the Questa mine in New Mexico are the same because they are hydrothermal molybdenum stockwork deposits. Small quantities of molybdenite are widely distributed in lime-silicate deposits along the contacts between granitic intrusive rocks and lime-rick sedimentary rocks. Only domestic production from this type of mineralization has been a byproduct from the Pine Creek tungsten deposit in California.

10617 Tungsten

Contact Person: P. T. Stafford
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1020

Major producers are Union Carbide's Pine Creek, California mine; Emerson Site in Nevada; Teledyne's Medra Site in California; and National Resources' development in Nevada. All are similar mine types.

10940 Uranium-Vanadium

Contact Person: F. Schottman
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1015

The Atlas Corporation at Moab, Utah and Cotter Corporation at Rifle, Colorado process uranium-vanadium ores from the Colorado Plateau. Colorado mines are underground; Wyoming mines are open pit. Utah and Colorado mines are in the Colorado Plateau. They differ from the Wyoming deposit which is a vanadiferous phosphatic shale.

10941 Uranium

Contact Person: W. S. Kirk
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1085

Most mines that mine uranium are located in the Colorado Plateau in sandstone deposits. No real major differences exist in mine types.

10942 Vanadium

Contact Person: F. Schottman
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1015

Vanadium is usually produced as a byproduct or coproduct of another element, such as uranium or phosphorus. Union Carbide Corporation mines vanadium ore at Hot Springs, Arkansas. At Soda Springs, Idaho, the Kerr-McGee Corporation recovers vanadium oxide from ferrophosphorus, a byproduct of elemental phosphorus produced from phosphate rock mined in Idaho. Union Carbide Corporation is the principal producer and consumer of vanadium oxide. Pioneer Uravan is building a new mill near Slick Rock, Colorado. It is expected to process 1,000 tons per day of uranium-vanadium ores from the Colorado Plateau when completed in 1981. There are three distinct areas for vanadium site distributions: Arkansas, Colorado (sandstone), and Idaho (phosphate).

10996 Titanium

Contact Person: L. E. Lynd
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1073

Mines in Florida and New Jersey are similar deposits of leptynite in old sandstone. A second region is New York, while Georgia deposits represent a third type.

11110 Coal, Anthracite

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

13111 Oil Shale

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

14111, 14230 Granite, dimension, and crushed and broken

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

Most deposits are generally similar. However, differences occur in grain size, texture, amount of grinding and polishing, and wet versus dry grinding. The contact person suggests taking random samples of all sites.

14112, 14220, 14113, 14291 Limestone (dimension and crushed), Marble (dimension and crushed)

Contact Person: Richard Singleton
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1194

Since limestone and marble are chemically similar, their mines are similar. However, lime or cement are manufacturing, not mining, processes. (JRB has included one site each for lime and cement in the certainty stratum to represent these processes.)

14114, 14292 Sandstone

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

R. H. Singleton
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1194

Sites are generally very similar. The sandstone mined is usually brownstone. The chemistry of various sandstones is nearly identical and all sandstones are quarried.

14115, 14293 Slate, dimension and crushed

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

Sites are generally similar. Random sampling of the sites is recommended. Dry grinding produces much more dust than wet grinding.

14116, 14294 Traprock, dimension and crushed

Contact Person: G. William Leo
U.S. Geological Survey
Reston, Virginia
(703) 860-6504

Traprock is essentially made of diabase. Most deposits are generally similar. However, there are differences in grain size, amount of grinding and polishing, and wet versus dry grinding. Most traprock is crushed for construction purposes. Construction personnel are not concerned about what the type of rock is. They categorize stone types very loosely. (Traprock and granite work areas do not overlap.)

14530, 14550, 14590, 14596 Fire Clay, Common Clay, Ceramic Refractory Clay, Common Shale

Contact Person: S. G. Ampian
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1180

The Bureau of Mines classifies their clays into six different types as opposed to the four commodity types used by MSHA. Bentonite mines are similar in Wyoming, Montana, and South Dakota. Bentonite mines in Mississippi and Alabama are a different type of bentonite than the Wyoming clays. Fire clay mines are located in Missouri, Ohio, and Pennsylvania. Fullers earth is mined in Georgia and Florida. Kaoline is mined in Georgia and South Carolina. Ball clay is mined in Tennessee and Kentucky. Common clay and shale are mined in Texas and North Carolina.

14593 Feldspar

Contact Person: Frank G. Lesure
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

Approximately one-half of production is in the Spruce Pine district, North Carolina. Feldspar is mined with micas and halloysite. There are two types of deposits and both are found in the Spruce Pine district. One type is muscovite in weathered host rock granodiorite. The second type deposit is a mixture of unweathered albite, microclines, clays, feldspar, muscovite, and quartz. This type is ground and treated by flotation. Sample Spruce Pine district for feldspar and micas at the same time. The mine is an open pit. The minerals are very finely ground at the mill and the operation is very dusty.

14594 Kyanite

Contact Person: Frank G. Lesure
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

The only active sites are Georgia and Virginia. (JRB did not receive any information on geographic differences relevant to health effects.)

14720 Barite

Contact Person: D. E. Morse
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

There are two types of deposits, both open pit. Bedded deposits are strip-mined in Nevada. Folded lower grade beds are in Arkansas. Residual deposits are located in Missouri, Georgia, and Tennessee.

14730 Fluorospar

Contact Person: D. E. Morse
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

The contact person advised sampling Illinois mines as one type of ore, western ores as another type.

14741 Boron Minerals

Contact Person: P. A. Lyday
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

The ore is very different in mines of one geographic area. The Trona, California district is a brine deposit. In Death Valley, California, the underground ore is approximately 23-25 percent B_2O_3.

14742 Potash

Contact Person: J. P. Searls
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1190

The deposit near Carlsbad, New Mexico has seven underground sites. Two sites produce $KMgSO_4$ and KCl. The other five sites produce KCl only. One site in Utah is a solution mine which dissolves KCl with water, then recrystallizes it. A Great Salt Lake, Utah site uses the solar evaporation method to produce K_2SO_4. The Utah (Bonneville) salt flats deposit has trenches that collect brine and evaporate into K_2SO_4. California produces KCl, K_2SO_4, and three other items from brines that are 600 feet underground.

14744 Sodium Compounds

Contact Person: D. S. Kostick
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

Sodium carbonate (soda ash) is mined from five Wyoming mines; one is under construction. In California, sodium carbonate is mined by pumping subterranean brine to the surface. Sodium sulfate is mined from subterranean brines in California and Texas. These salts can also be produced synthetically. (JRB did not receive any information regarding geographic differences related to health effects.)

14750 Phosphate

Contact Person: W. F. Stowasser
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1190

All phosphate is mined wet using dredges and draglines. There are very few problems with dusts. In North Carolina there is one underwater mine. Montana has one small underground mine. Tennessee has a number of small mines that may be underground. Polk and Hilsboro counties in Florida have 20-30 surface mines. Idaho has five or six mines, which are probably dry and different from Florida. The contact person suggests sampling Florida, North Carolina, Idaho, and possibly Tennessee.

14760 Salt, rock

Contact Person: D. S. Kostick
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

Most sites are similar.

14920 Gypsum

Contact Person: J. W. Pressler
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1206

Since gypsum mines conform to commercial plaster specifications, the various mine sites are similar. Commercial plaster specifications are 85 percent hydrated calcium, 0.05 percent alkalies, <1.5-2.0 percent clays, <2.0 percent anhydrite (sodium, potassium, etc.), and the rest silica.

14960 Talc, Soapstone, Pyrophyllite

Contact Person: C. Ervin Brown
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

Most production of these minerals is from New York, Vermont, Virginia, and Montana. Soapstone and pyrophyllite are mined at different sites. Talc deposits produce a great variety of products and are selectively mined depending on the product(s) desired. In New York, St. Myers Company mines produce mainly talc from metasedimentary rock. The talc is finely ground and bagged onsite for use as a ceramic base and filler. In Vermont the main product is talc mined from ultramafic metaigneous rock. Some of the talc is ground at the mill, removed by flotation, and used as a filler. Other talc is cut as block stone. In Montana, the main product is block talc mined from metasedimentary rock. Skyler, Virginia produces soapstone as the main product from metaigneous rock. The host rock in Texas mines is metaigneous. In California one site is a metasediment deposit and the other site is a contact metamorphic deposit. The contact person suggests sites in New York, Vermont, and Montana for talc and Virginia for soapstone.

14991 Asbestos

Contact Person: R. A. Clifton
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1206

Chrysotile is the only asbestos mined in the United States. In eastern California, there is a massive serpentine mine in Copperopolis. Western California has a mine close to Quinga and a mill near King City. Sixty percent of the asbestos in the mill has short fibers. In Globe, Arizona, a very clean mine is owned by Jaguays. A massive serpentine mine is located in Laurel, Vermont. (JRB did not receive any information regarding geographic differences related to health effects.)

14992 Gemstones

Contact Person: J. W. Pressler
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1206

In the western United States, agate, turquoise, and some opal are mined. Turquoise is mined in Nevada, New Mexico, and Arizona. Opal is mined in Nevada and Idaho. Rubies and sapphires are mined in North Carolina and Montana. Garnets are mined in Idaho, Nevada, and Maine. The total value of the mines is about $6 million and is small compared to other commodities. (JRB did not receive any information on geographic differences related to health effects.)

14994 Mica

Contact Person: Frank G. Lesure
U.S. Geological Survey
Reston, Virginia
(703) 860-6913

Approximately one-half of mica production is in the Spruce Pine district of South Carolina. Most deposits are fairly similar and produce scrap or flake mica.

14996 Perlite

Contact Person: Alfred L. Bush
U.S. Geological Survey
Denver, Colorado
(303) 234-2694

In northern New Mexico, Johns-Manville is the largest mine. Other mines in the area are Grefco and U.S. Perlite. Superior, Arizona also has sites.

(JRB did not receive any information on geographic differences related to health effects.)

14997 Pumice

Contact Person: Alfred L. Bush
U.S. Geological Survey
Denver, Colorado
(303) 234-2694

The ore varies depending on the type of magma from which it is cooled. In some deposits basalt is the host rock, but most deposits are not basaltic. The contact person did not know of any geographic differences in the mine deposits, but suggests sampling a number of geographically separate places to get a representative sample.

14998 Vermiculite

Contact Person: Alfred L. Bush
U.S. Geological Survey
Denver, Colorado
(303) 234-2694

Approximately two-thirds of all vermiculite is produced from a very large deposit in Montana. The Montana ore is not expanded at mill, but at the site of use. Most United States expanders process Montana ore. About one-third of all vermiculite is produced from Innery, South Carolina. Innery has about 100 or more depleted and unmined deposits. W. R. Grace is the main producer at Innery. However, smaller producers may be more cooperative. Louisa County, Virginia ore may be different from South Carolina deposits. Sample Montana, South Carolina, a site in Yanco, Texas, and possibly Virginia.

28991, 28992 Salt, evaporated and brine

Contact Person: D. S. Kostick
U.S. Bureau of Mines
Washington, D.C.
(202) 634-1177

Brine salt mines are similar. Evaporite site mines are similar in characteristics, but can be processed three different ways: vacuum pan evaporation, open pan evaporation, or solar evaporation.

32410 Cement

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.

32740 Lime

No specialist for this commodity was consulted by JRB on the assumption that sites were not geographically distinct.