erage ore delivered to the concentrator carries 40 ounces of silver per ton, whereas the narrow ore seams, averaging 1.7 feet in width, usually carry 73 ounces per ton.

The mine and methods of sampling and estimating have been described in detail by Mishler and Budrow.[10]

The following notes on sampling are excerpts from this article:

In sampling development work, dilution in mining is accepted as unavoidable. Samples are cut over the full stoping width (3½ or 3 feet); if the vein is over stoping width the full vein is sampled.

Each sample across the back is divided into as many samples as there are varieties of ore and waste, and the exact width of each is noted. Where the ore is rich and easily recognized underground, it is believed that this method gives a more dependable average assay than is possible when a single sample is cut across both ore and waste.

All drifts, raises, and winzes are sampled at 5-foot intervals. The samples are cut from the backs of the drifts and from alternate sides of the raises and winzes. The backs of stopes are sampled in the same manner wherever the chute samples show that the ore is lower than milling grade.

In shrinkage stopes weekly samples are taken across the broken ore at 10-foot intervals. The width and distance from the end of the stope are recorded for each sample. The samples corresponding to the same distances are combined for the entire month and assayed. Grab samples, consisting of two double handfuls, are taken from each car of ore as it is loaded at the chute. Composites from important chutes are assayed daily. From chutes producing small tonnages and from development faces the samples are combined for periods of two or three days. The assays of chute samples are closely watched in order to maintain the grade of ore sent to the concentrator.

The following tabulation illustrates the accuracy of sampling. Odd-numbered samples were taken on one side of the drift and the even numbered on the other side. Samples were cut at 10-foot intervals.

Averages of alternate assays along Tigre vein

Level	Number of assays	Average of assays, ounces silver per ton			Error, per cent
		Odd numbers	Even numbers	Odd and even numbers	
7	428	35.4	41.4	38.4	7.8
8	368	34.4	31.9	33.1	3.6
9	288	36.0	42.3	39.2	8.0
10	232	32.0	39.7	35.9	10.6
Total	1,316	34.7	38.6	36.6	5.3

Grab sampling of cars shows an error of 9 per cent, the grab samples being high.

CRIPPLE CREEK DISTRICT, COLORADO

Jones[11] states that samples are taken by shift bosses. Streaks of ore are usually sampled together with a couple of grabs from the muck pile. Ore drawn from chutes is sampled by taking a handful from each car trammed. These grab samples will run 20 per cent higher in value than the settlement value of the ore.

[10] Mishler, R. T., and Budrow, L. R., Methods of Mining and Ore Estimation at Lucky Tiger Mine: Trans. Am. Inst. Min. and Met. Eng., vol. 72, 1925, pp. 468–483.
[11] Jones, Fred, Mining Methods of the Cripple Creek District: Trans. Am. Inst. Min. and Met. Eng., vol. 72, 1925, pp. 512–517.

JARBIDGE DISTRICT, NEVADA

Park[12] has written of the sampling practice in this district as follows:

The wall rock is investigated by means of crosscuts and by holes drilled by ordinary drifting machines using extension bits. These holes may be quickly and cheaply drilled to depths of 50 or 60 feet and the sludge samples obtained show the presence of any values equally as well as the more expensive diamond-drill hole.

Drifts driven on the vein are sampled at intervals of from 3 to 5 feet. The samples are taken with a pick and average 10 or more pounds in weight. The face is sampled in sections, usually three or more samples being taken in one cut across the width of the drift, one sample representing the main vein material and the other stringers or wall rock included in the opening. A further sample is taken of the muck removed from each round; this serves as a rough check on samples cut from the face.

In this district the gold and silver are found mainly in the native state in quartz veins in volcanic flows. The veins are generally well defined. The chief gangue minerals are quartz and adularia. The veins are generally soft and often contain streaks of clay or gouge up to 6 or 8 inches thick.

MOGOLLON DISTRICT, NEW MEXICO

The gold-silver ore occurs in veins in igneous rocks in a gangue of quartz, calcite, wall-rock fragments, and some fluorite. Argentite and auriferous pyrite are the principal valuable minerals. In high-grade ore, native silver and free gold are often observed and frequently cerargyrite and bromyrite. According to Kidder[13]—

Underground samples are taken by trammers on each shift from every development face. Later, for purposes of preparing assay plans and estimating reserves, moil samples are cut, usually at intervals of 10 feet, and in spotted or high-grade ore, at intervals of 5 feet. In winzes and raises the samples are ordinarily cut at a difference of elevation of 5 feet, but on alternate sides of the raise or winze. Backs of stopes are cut at intervals of 10 feet, but on each successive slice the samples are cut halfway between those on the previous slice.

In addition to the sampling of development faces for estimating the mineral contents of ore bodies chute samples are taken, and the tonnage drawn from each chute is estimated by the number of cars trammed. The average assay in ounces of gold and silver is calculated for each chute at the end of the month. As the ore is trammed to the mill the cars are weighed, and a grab sample is taken from the top of each car and a composite sample made for each shift. At the end of the month the calculated average of the scale samples is checked against the chute samples taken underground and against the average mill heads as determined from the ounces of gold and silver in the bullion, concentrates, and tailings (production plus tails). On account of the slightly higher assay of the fines in the ore the average mine sample and the scale sample are usually slightly higher than the mill-head sample. The yearly average, however, seldom shows a variation of more than 10 per cent compared with the mill heads and generally agrees within 3 or 4 per cent. On spotty and high-grade ore the underground car samples are very unreliable. To be used at all, lots of ore after being sampled underground should be crushed and checked in a Snider, Vezin, or other automatic sampler.

[12] Park, John Furness, Mining Methods of Jarbidge District: Trans. Am. Inst. Min. and Met. Eng., vol. 72, 1925, pp. 518–528.
[13] Kidder, S. J., Mining Methods in Mogollon District, New Mexico: Trans. Am. Inst. Min. and Met. Eng., vol. 72, 1925, pp. 529–549.

and value of the ore mined. These figures, obtained from stoped areas above and below an unstoped block of ore, are averaged, and the resulting factors are applied to the unstoped block.

LUCKY TIGER MINE, SONORA, MEXICO

Mishler and Budrow[7] have described the methods of calculating ore reserves, and the following is abstracted from their paper.

The assays, figured to stoping width are plotted on longitudinal sections and plans drawn to a scale of 1 inch = 40 feet. Ore reserves are estimated as of January 1 and July 1 each year. Backs of old stopes are surveyed and plotted on the assay maps as of those dates. If the back has not been sampled, the average assays along the levels above and below are weighted inversely to their distance from the back, and the average thus obtained is taken as the assay value of the back. If all the assays surrounding a block represent stoping width, their arithmetical average is taken as the assay of the block. The tonnage is figured by multiplying the area of the block by the stoping width and dividing by a cubic-feet-per-ton factor of 11.5. When any of the assays around the block represent more than stoping width, the excess width must be considered in figuring the average assay and tonnage.

If blocks are developed on less than four sides, it is customary to figure that ore extends 30 feet from the drifts and raises, or below the lowest level.

The full assay value of each sample is employed. The modification of high assays is warranted when the estimates are based upon only a few samples, but when several thousand samples are available, abnormally high assays will be offset by abnormally low ones.

Over a period of 14 years the estimated ore reserves have averaged 34.0 ounces of silver per ton; the ore mined during the period averaged 37.1 ounces, an error of 3.1 ounces or 8.4 per cent.

JARBIDGE DISTRICT, NEVADA

According to Park,[8] raises are put up in ore, usually about 100 feet apart. The blocks between these raises are estimated from the average assay value and cubical contents. The tonnage figure for the ore is 18 cubic feet per ton in place and 23 cubic feet broken. The estimated tonnage in a block is generally within 10 per cent of the actual amount and is always low because of dilution in mining. The estimated grade runs about 17 per cent higher than the true grade, and this factor is taken into account when reports are prepared on newly blocked-out territory.

MOGOLLON DISTRICT, NEW MEXICO

According to Kidder,[9] stope maps on a scale of 1 inch equals 10 feet show the width and value of ore where each sample was cut as well as the tonnage and value of ore broken in the stope during each month. The average grade of ore is calculated from the foot-ounces of gold and foot-ounces of silver, allowing 13 cubic feet per ton of ore in place.

The sampling of the smaller blocks of ore generally checks closely with the tonnage and grade of ore produced, but the larger blocks are rarely sufficiently developed ahead of mining to permit more than rough estimates of their probable production. As stoping proceeds

[7] Mishler, R. T., and Budrow, L. R., work cited.
[8] Park, John, work cited.
[9] Kidder, S. J., work cited.

and the width and grade are more clearly established it has been found that the monthly estimates of ore broken, when finally checked against the ore drawn, agree closely as to tonnage and grade. The ore drawn, however, commonly exceeds the estimates of tonnage, while the grade of ore drawn will be correspondingly less.

CONSOLIDATED CORTEZ MINE, CORTEZ, NEV.

At Cortez, Nev., silver ore occurs principally in fissure veins and the ore bodies are irregular in dimensions and in grade. Hezzelwood[10] states that these conditions have been responsible for evolution of the following practice:

The usual methods of blocking out the ore by measuring and sampling in making estimates of ore reserves has been found unreliable at the Cortez mine. The tendency of the ore to narrow or widen and the grade to change without apparent reason makes such methods inaccurate. A ratio between the number of feet of development work and the number of tons mined has been worked out for the operations on the lower levels which were started in 1926. This ratio furnishes a basis for estimating probable ore, particularly when development work is confined to the three known zones. This method of estimating, although not accurate, is probably as safe as any method for this form of ore deposit.

COPPER MINES

HUMBOLDT MINE, MORENCI, ARIZ.

Mosier and Sherman[11] write briefly regarding estimating practice as follows:

For the estimation of ore reserves a full knowledge of the ore deposits must be obtained. Caving stopes have reasonably regular outlines, and selective mining is therefore not practicable by this method.

Some material of a grade that will not pay to reduce must be mined, and some good ore on the boundaries must be left because its inclusion would bring in too much waste. The side boundaries, which are vertical or nearly vertical, are drawn as compromise planes to inclose as much ore as possible without too much waste.

Except for preliminary estimates, the volume of material within the stope outlines constitutes the ore reserves which are bounded by (1) the undercutting level, (2) the shrinkage side outlines, and (3) the leached gossan or a stope above as the case may be. Within these boundaries the grade of ore in place is calculated by combining assays in a rational manner.

RAY MINES, RAY, ARIZ.

The following is quoted from Thomas:[12]

In churn drilling, samples were obtained by the use of a split divider. A careful record was kept of the type of material being drilled through, the color of the sludge and the character of its various mineral constituents, the weight of material cut for each 5 feet of drilling, the size of bit, and the length and size of the casing in the hole. From the weight of the sample and the size of the bit it was possible to determine whether there was caving in the hole and to thus arrive at some conclusion as to the accuracy of each 5-foot sample. The samples were assayed locally by the iodide method, and the remainder of the pulp was sent away for determination of the copper by the electrolytic method.

[10] Hezzelwood, George W., Mining Methods and Costs at the Consolidated Cortez Silver Mine, Cortez, Nev.: Inf. Circ. 6327, Bureau of Mines, 1930, p. 4.
[11] Mosier, McHenry, and Sherman, Gerald, work cited.
[12] Thomas, Robert W., work cited.

TABLE 6.—*Typical test-hole drilling data*

Mine or district and State	Kind of rock	Type of drill [1]	Depth of holes, feet	Feet per drill-shift	Purpose of drilling	Results reported	Cost per foot: Labor	Cost per foot: Total
Burra-Burra, Tennessee	Schists, graywacke, massive sulphide.	A	Up to 150	25	Outlining ore body	Satisfactory; best on inclination+15° or over.		$0.80
Acme, Tri-State	Cherty limestone	A			Prospecting walls	Cuttings useful indicator, assays unreliable.		.64
Do	do	B	17		Testing bottoms	Reliable samples		.57
Ray, Ariz	Schist	A	Max. 90	23	Prospecting instead of raising +45°.	Satisfactory		
No. 1, Menominee range, Michigan.	Hematite and iron formation.	A			Testing walls	Good in soft ore; poor in hard chert.		
Morning, Idaho	Quartzite	A	{Ave. 46 / Max. 129}	} [2] 12	Testing vein walls	Satisfactory	$0.92	1.10
Mascot, Tenn	Dolomitic limestone	D			Sampling stope backs	do		
Cananea, Mexico	{Porphyry and hard limestone.}	A	{35 to 125 / Ave. 85}	} 18½	Flat holes to delimit ore bodies.	do		
Engels, California	Diorite	D	7.7		Cuttings from 2 or 3 stope holes daily for samples.	do		
Park-Utah, Utah	Quartzite	A	Max. 88		Prospecting 2 holes only	Unsatisfactory; steel failed		
Pilares, Mexico	Brecciated volcanics	E		5	Sampling	Satisfactory		
Teck-Hughes, Ontario	Silicified syenite and porphyry, hard.	D	5		Testing vein walls every 10 feet.	Satisfactory; assays not used in reserve estimates.		
Fierro, N. Mex	Hard magnetite and limestone.	F	20		Prospecting ahead. Assays used in grade estimates.	Very satisfactory		
Do	do	A		8.84	Prospecting	More costly, less accurate than diamond drilling.	1.217	2.821
Pecos, N. Mex	Schist and diorite	A	50 to 100		Prospecting for parallel ore bodies.	Satisfactory	1.26	1.98
Black Rock, Butte, Mont	Granite	A			Prospecting. Not now used	Holes salted by soft-ore streaks. Not reliable for grade of ore.		
Page, Idaho	Quartzite	A			Prospecting walls. Not now used.	Limited range. Slow and costly in hard rock.		
Spring Hill, Mont	Hard contact met. ore and rocks.	A	Max. 35		Exploring to contact	Unsatisfactory in hard rock		
Eagle-Picher lead, Oklahoma.[3]	Chert and limestone	A	Max. 148		Exploration	Good ore found. Valuable for negative information.		1.69
Evans-Wallower lead, Oklahoma.[3]	do	A			do	Eliminated much ground thought ore bearing.		1.00
Federal M. & S. Co., Kansas[3]	do	A	Max. 147		do	Located many new ore bodies		1.90
Canam Metals, Oklahoma[3]	do	A			do	Several ore bodies found. Cheaper than other methods.		1.70
Missouri-Kansas Zinc Corporation.	Chert and limestone	A	Max. 152		Exploration often at steep plus angles.	Very satisfactory		60-.70
New Idria, California	Shale, sandstone, serpentine	A	{Ave. 99 / Max. 228}	} 30	Exploration	do		.75
Chief Consolidated, Utah[4]	Limestone and ore	A	Max. 272	23	do	do	[5] .44	.97
Southeast Missouri[6]	Limestone	A	35 to 78	35	do	75 holes drilled; satisfactory	[7] .16	
Do	do	C	Max. 22		Testing backs, floors, and walls.	Satisfactory		
Tonopah Belmont, Nevada.[8]		A	Max. 256	34	Exploration, sampling walls	Good	([9])	
Jarbidge, Nevada[10]	Volcanics		50 to 60		Exploration	As good as diamond drills and cheaper.		
Edwards, N. Y	Zinc ore in dolomite	A	Ave. 43		Testing walls	25 per cent deducted from assays.		.99

[1] A, Heavy drifter with special independent rotation; B, piston machine on tripod; C, jack hammer with pneumatic feed; D, standard medium weight drifter; E, stopers; F, jack hammer.

[2] For holes up to 100 feet deep.

[3] Netzeband, W. F., Prospecting, with the Long-Hole Drill in the Tri-State Zinc-Lead District: Min. and Met., June, 1930, pp. 295–296.

[4] Dobbel, Chas. A., Deep-Hole Prospecting at the Chief Consolidated Mines: Trans. Am. Inst. Min. and Met. Eng., vol. 72, 1925, pp. 677–689.

[5] Year 1924.

[6] Poston, Roy H., Leyner Drill in Underground Prospecting: Eng. and Min. Jour., vol. 118, Nov. 29, 1924, pp. 856–857.

[7] Approximate.

[8] Brown, R. K., Exploratory Deep-Hole Drilling: Comp. Air Mag., April, 1926, pp. 1593–1594.

[9] Time studies made. See footnote 8.

[10] Park, John Furness, Mining Methods in Jarbidge District: Trans. Am. Inst. Min. and Met. Eng., vol. 72, 1925, pp. 518–528.

mining the average grade of large tonnages of ore in place. It can not be argued from the law of averages that improper methods or carelessness will result in compensation of errors in individual samples if a large number of samples is taken, for in that event the errors will usually be cumulative in one direction or the other rather than compensating.

Even in ores in which the valuable minerals are uniformly distributed and with the most careful sampling, samples may consistently run higher or lower than the ore. One frequent cause of this is the difference in hardness or friability between the ore and the gangue minerals. At a given property experience factors can often be determined which, when applied to the sample assays, will give a correct estimate of the grade of the ore where samples run consistently high or low.

SUMMARY OF UNDERGROUND SAMPLING PRACTICE

Table 7 summarizes data on underground sampling practice by various methods under different conditions. These data are taken from previous publications in some instances and from special communications in others. Data on accuracy of sampling are not as voluminous as desired, but such figures as are available are believed worthy of tabulation.

TABLE 7.—*Summary of underground sampling practice*

District or mine and State	Character of ore	Sampling method	Indicated accuracy of sampling
GOLD AND SILVER			
Argonaut, Calif.	Gold in quartz, fissure vein	Chute and muck samples; visual inspection	
Spring Hill, Mont.	Gold with sulphides. Contact metamorphic deposit. $6 average value.	Drill cuttings and grab samples	Not reliable as to grade or ore.
Porcupine district, Ontario:			
Mine 1	Gold in quartz and sulphides in lenses in schist	Chiefly channel samples; some grab samples; test-hole drilling.	Average of many channel samples is accurate. Drift samples 12 to 20 per cent high. All channel samples 0.3 per cent high.
Mine 2	do	Channel samples and grab samples. Average grade $9.	Erratic high assays are reduced in computations resulting in error of plus or minus 3 per cent.
Mine 3	do	Channel samples and grab samples from cars. Average grade $8.	Day-to-day grab samples are erratic. Over a year average was 4.8 per cent below mill recovery plus tailings loss.
Kirkland Lake district, Ontario:			
Teck-Hughes	Gold in quartz, some tellurides and sulphides in fault zone in syenite porphyry and lamprophyre.	Channel samples; test-hole drilling in walls of stope and sides of drifts.	The average of channel samples usually about 10 per cent less than mill recovery plus tailings loss.
Wright-Hargreaves	Similar to above veins in syenite porphyry	Pick samples; each band in face sampled separately. Grab samples.	Pick samples as accurate as channel samples and check recovery plus tailings loss plus or minus 5 per cent. Grab samples 30 to 40 per cent high.
Alaska:			
Alaska-Juneau	Gold in ramifying quartz stringers in slate and metagabbro. Average value ore $0.89. Quartz sometimes high grade.	Grab samples in development headings to determine high or low value of known ore. Moil samples.	Section 1.—Moil samples $0.499, mill heads $1.012, error −50.1 per cent. Muck samples $1.657, error +63.7 per cent. Section 2.—Moil samples $0.943, mill heads $0.997, error −5.4 per cent. Muck samples $1.577, error +58.2 per cent.
Treadwell mine	Gold with sulphides and quartz in dikes	Muck samples	Average 17 years, $2.37, mill heads $2.47; error −4 per cent.
700 mine	do	do	Average 14 years, $2.20, mill heads $2.33; error −5.6 per cent.
Mexican mine	do	do	Average 16 years, $2.88, mill heads $2.83; error +1.8 per cent.
Ready Bullion mine	do	do	Average 15 years, $2.72, mill heads $2.24; error +21.4 per cent.
Mother lode, California	Gold-quartz veins in slates and greenstone	Hand pick, 5 to 20 pound samples for sampling development headings.	
Homestake mine, South Dakota	Gold-quartz replacements in folded dolomitic beds.	Channel samples in development work. Grab samples from cars.	
Cripple Creek district, Colorado	Gold tellurides in veins in tuffs, breccias, and granite.	Grab samples from chutes. Pick samples for stoping control at Cresson mine.	Grab samples generally 20 per cent high.
Jarbidge district, Nevada	Native gold and silver; quartz veins in volcanics.	Long holes for exploration. Pick samples in development headings, and grab samples.	