APPLICATION OF DATA PROCESSING

TO

STRUCTURAL CONTROL OF ORE DEPOSITS

OF

THE NORTH END OF THE COLORADO MINERAL BELT,

BOULDER, JEFFERSON, GILPIN, AND CLEAR CREEK COUNTIES, COLORADO

BY

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ABSTRACT

Data processing followed by statistical studies have been used for several years in a number of different ways. This thesis demonstrates that geologic information can be reduced to coded data that can then be placed on data processing cards. It demonstrates that data so stored can be utilized to delimit geologic factors that previously had not been recognized and suggests correlations between such factors and the presence, or absence, of commercial ore deposits in a particular district.

The area chosen for this study to illustrate usefullness of this coding system embraces approximately 1,500 square miles between 45° 30' and 46° 10' north latitude and 105° 13' and 105° 50' west longitude. (Fig. 1) This includes all of the area commonly referred to the north end of the Colorado Mineral Belt, and includes a reasonably substantial area both east and west of this well-known trend.

The study has shown a number of basic features are statistically common to many of the mines in this area. Such features include common frequencies of strike, dip, direction of dip, limits of over-all mineral trends, and sharp definition to certain mineralized zones.

TABLE OF CONTENTS

ILLUSTRATIONS

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The author is indebted to the students of the Mining Department of the Colorado School of Mines who participated in the class known as Special Problems, Mining 423, in the spring and fall semesters of 1962. With their willing assistance, the coding procedure presented here was developed and tested. The statistical studies presented here were made possible by their work.

The members of the author's advisory committee--Mr. Charles O. Frush (Chairman), Dr. M. A. Klugman, and Mr. T. A. Kelly--have given considerable encouragement and assistance in the preparation of this thesis.

Mr. Curtis Wright of the Colorado School of Mines data processing unit merits special mention. His help provided the key to the development of this coding system.

INTRODUCTION

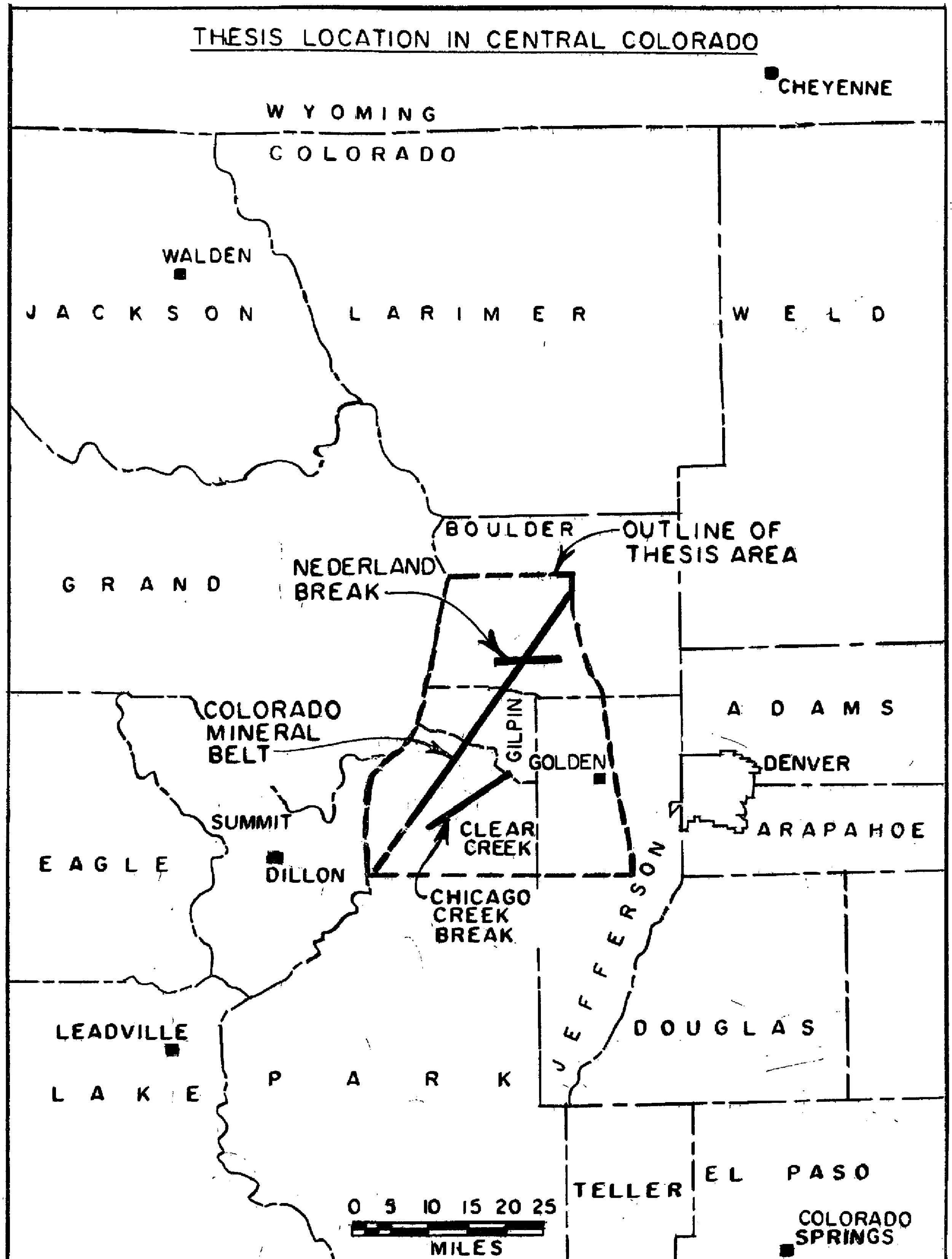
Mineral discovery by chance was at one time the most effective method available to the prospector. Time and persistance enabled these early men to look for and find many, if not all, of the significant higher grade ore deposits that at one point or another were exposed at the surface. Deposits with a blind apex were found only by chance. At that time, large low-grade deposits had little or no value because of the lack of knowledge, equipment, and transport systems necessary to permit their development.

More recently, refined exploration "tools" have been developed. These tools range from geological concepts to simple and complex geochemical and geophysical procedure. As should be expected, these methods range from the relatively cheap to the quite costly in their application. Few if any are completely definitive in themselves; positive results require further definition of the mineral occurrence by exploration drilling, open-pitting, or subsurface exploration. Apparently, then, even though some of these procedures are applicable to exploring large areas by aerial methods, resulting anomalies must be explored still further. At best this is expensive.

It has seemed reasonable to expect that history of past discoveries and known mining districts should, if used to their optimum value, shed some light on why mineral deposits occur in some areas and not in others. Such data should provide a clue to better evaluating suspected mineral trends, and if they exist, suggest others that are not expected. Better evaluation of minor mineral shows might be possible, as may a host of other currently unsuspected but important items. The problem in the past has been trying to determine which if any of the available data, or combinations of data, might give the most useful information. Prior to the development of data-processing procedures, utilization of historical data was at best very costly with completely unpredictable results.

Data processing, then, has suggested the possibility of developing another tool for mineral exploration. This tool, based in part on statistical frequency, may provide one or more reliable criteria based on history for recognizing mineral expectancy in known areas and may provide a basis for extrapolation into adjacent currently nonproductive areas. In theory, such extrapolation might be used to delimit more favorable areas for other forms of prospecting. It should be possible to establish guides for better recognition of mineral potential.

This theory of potential usefulness of data processing was tested


THESIS LOCATION IN CENTRAL COLORADO
CHEYENNE
WYOMING
COLORADO
WALDEN
JACKSON
LARIMER
WELD
BOULDER
OUTLINE OF THESIS AREA
NEDERLAND BREAK
GRAND
COLORADO MINERAL BELT
ADAMS
GILPIN
GOLDEN
DENVER
SUMMIT
CLEAR CREEK
ARAPAHOE
EAGLE
DILLON
CHICAGO CREEK BREAK
JEFFERSON
DOUGLAS
LEADVILLE
LAKE
PARK
TELLER
EL PASO
0 5 10 15 20 25
MILES
COLORADO SPRINGS

in the area known as the north end of the Colorado Mineral Belt. The total area studied (Figure 1) extends from Georgetown to Jamestown, Colorado, and from the Continental Divide to the eastern edge of the Front Range. This area embraces approximately 1,500 square miles. Reasons for choosing this area include the following:

1. The relative completeness of past prospecting.
2. The relatively large numbers of mines that were developed.
3. The range in elevation, about 6000 feet.
4. The relatively extensive coverage of this area and its mines in available literature.
5. The diversity of mineral occurrences.
6. The supposed degree of refinement of knowledge of the area.

Because of the detail necessary and extent of coverage required for such a study, the work of two classes in Data Processing in the Mining Department of the Colorado School of Mines was used in this thesis. Although much of these data were checked and a few errors were found and corrected, this author is aware that undoubtedly some errors still exist in the data used. Such errors will result from the following:

1. Incorrect interpretation of data in the preparation of original reports.
2. Incomplete data available in the preparation of the available reports.
3. Incomplete or incorrect transcription of data from published reports to the data processing cards.

4. Errors in student understanding of data available.

5. Mechanical errors in transcription.

It is felt that such errors as may exist in the data used are sufficiently few that they will not materially affect the overall results of this study.

DATA PROCESSING

Data Processing is the art of reducing many items to an orderly grouping by translating to numbers by coding for storage in a minimum space on either cards or tape. Use of this system provides rapid and simple recovery of any selected item.

Although data processing is not new, and even though the system has been applied to other phases of mining, no record was found of its application to mineral exploration requirements. This approach then required the development of a coding system that could include all data of importance. The procedure had to be selective and definitive and had to contain all items that might conceivably be of interest in exploration study.

Because such a system may be nationally useful, several of the items have been designed for equal usability in any area. Such items include the location system based on State, County, and exact location by latitude and longitude. The codes for the extent of workings, elevation of the highest workings, the mine depth, strike and dip of vein, the direction of dip, the direction and rake of the ore shoot, the trend of the major faulting, the materials mined, the major value ore, the value of ore produced, and the code for estimated ore reserves are all inclusive and should be applicable to any mining property anywhere on this continent.

Others of the codes as presented here, particularly Code I identifying the host rock, will be subject to the diverse views of many petrographers and will be exceedingly difficult to finalize. Code W, identifying gangue minerals, is subject to the same problems. Because often more than one host rock is present in each mine, it also is necessary either to allow for this situation, or to recognize that each separate set of such items must be treated individually or on a separate card.

The bibliography code as presented is thought to be sufficiently comprehensive and leaves sufficient room for expansion to permit identification of most reference works that might be used in mineral studies in Colorado. This system, however, does not allow for identifying publications of other states, and would either have to be revised to the requirements of other areas if it is to be used in other states, or would be subject to major revision if it is to be used on a national basis. Although data processing for library use is being developed, the current systems require too many card columns to be useful here.

Other codes, such as those referring to deposit characteristics and relation of faulting to ore, are not satisfactory in their present form.

Although these items are important, continued study is needed to recognize all of the diverse forms that are reported and then to find a way of reducing these data to the optimum code.

The complete code as it has been developed and used for this study is included as Appendix I of this thesis.

During this study, data on more than 1000 mines were collected. Many of these mines could not be exactly located, so data cards were not prepared. Locations are known and cards have been prepared for 488 properties. Naturally, available data vary in completness from one property to another; basic data vary from quite complete to relatively sketchy; consequently, completness of data varies greatly from one code to another.

Use of Data Obtained

Once the literature search was completed and the data were coded to data process cards, all mines included in the card system were located on a base map (Plate 1). Copies of this map were then used for plotting various combinations of data that would previously have been quite difficult to obtain. Plots of combinations tested in this manner included the following:

1. Gold, silver, lead, zinc, copper, and tungsten occurrences above 9,500-foot elevation.
2. Gold, silver, lead, zinc, copper, and tungsten occurrences between 8,500 and 9,500-foot elevation.

3. Gold, silver, lead, zinc, copper, and tungsten occurrences below 8,500-foot elevation.
4. A plot of mine depths in 200-foot intervals.
5. A plot of recorded strikes and dips. A straight statistical summation of these data also was used and appears to have given more useful data than did the map. This application is described more fully later in this thesis.
6. The type of faulting was related to strike.
7. Types of intruded rocks near or associated with mineralization were studied.
8. Fluorite, calcite, barite, chalcedony, and ankerite occurrences were related to dollar value of production from the properties.
9. Reported occurrences of all metals other than gold, silver, lead, zinc, copper, and tungsten were plotted.
10. Total production, converted to 1947-1949 dollars, as available, was plotted.
11. Dollar value of production related to strike of the vein.
12. Dollar value of production related to north or south dip of vein.
13. A plot was made showing spatial relationship of sulfide, oxide, telluride, tungstate and fluorite deposits.

14. Copper deposits were associated with various intrusive rocks.
15. A plot of lead-silver properties with more than $10,000 production was ploted against the occurrence of the gangue minerals barite, rhodochrosite, calcite-ankerite, and siderite-marcasite.
16. Occurrences of gold, silver, and native gold or silver deposits.
17. A plot of the location of north or south dipping veins.
18. A plot of the host rocks of the deposits.

Evaluation of Data Combinations

As would be expected, many of the plots described above were of little or no value, partly because of insufficient data, but more probably because the particular test data had no particular significance. A number of items of varying degrees of significance were discovered, however. Before proceeding with a discussion of results obtained, it should be pointed out that these data are a summation of much, but not all, of the data obtainable. An effort was made to get a distribution of coverage over the entire area--no effort was made to obtain every last detail concerning any particular area. It also should be pointed out that trends that have become apparent were not defined by a preplanned program, but are evident because of an attempt to obtain a broad relatively complete coverage of the subject area.

THE COLORADO MINERAL BELT

Although this feature has been recognized in its broader form for many years and has been discussed in varying degrees by many authors, this study gives a rather surprising definition to this well-known feature. It can be most clearly seen from a plot of the mines only. This plot, related to mapped major fault systems is shown as Plate I.

As can be seen on this map, the mines of the mineral belt seem to diagonal across this part of Colorado. On closer examination, it is quite remarkable that so many mines over a horizontal distance of 35 miles or more, seem to mark the western limit of a productive trend. This virtually straight line, with several marked exceptions, is the western edge of the reported mineral producing area. Its direction is N 35° E. The major mineralized areas west of this line all occur in northern and western Boulder County. It seems that many of these mines in Boulder County may be related to another major, unrecognized break discussed below as the Nederland Break. The Ward area and northern Jamestown area need some other explanation.

Although strong fault systems are mapped several miles to the west (the Berthoud Pass systems) and to the east (the Ralston system), and although the proposed limit is crossed, usually at high angles, by many well-known fracture systems, particularly near is north end, no reported faults of any relative significance occur on or near parallel to this suggested major lineament (Plate I). It is possible that if structural control does exist in this position, it may always be covered and therefore unrecognized, but this seems completely unlikely.

This western border is apparently in no way related to rock types. It does not seem to be deflected or interrupted by changes from one type of host rock to another. It does not seem to be displaced by crossing of recognized faults suggesting it may be a very young feature related to basement, but older than the ore deposits that betray its presence.

A second, essentially parallel trend of mines seems to delimit the eastern edge of the mineral belt. If this suggested trend is correct and valid, this part of the Colorado Mineral Belt is a straight zone, sharply defined on the west and moderately well defined on the east. Its trend is N 35° E. The zone, approximately 4.25 miles wide, is defined by the presence of mineralization and is not delimited by recognized structural or stratigraphic features although it is strongly suggested that such features, probably in the form of faults, may exist at depth.

THE NEDERLAND BREAK

A rather sharply defined limit of mines exists along the north side of the Nederland-Cariboo mining districts. With minor exceptions, here too is an abrupt edge to mining areas; they do not taper off erratically as would reasonably be expected. This limit, which strikes N 88° E, again is uneffected by changes in rock types from metamorphic to intrusive or the presence of recognized structural features. Perhaps significantly, the major value tungsten mines of Boulder County are all within one mile south of this projected break. The major value properties are located between 1/2 and 1 1/2 miles west of and 3/8 and 1/8 miles east of the west edge of the Colorado Mineral Belt as it projects through this area. A major cross-fracture system at depth may have caused localization of these ore deposits.

As with the Colorado Mineral Belt the second limit, this time the south side, is relatively poorly defined. If it exists, and mine frequency suggests it does, the southern limit of this trend is one mile south of the north edge.

THE CHICAGO CREEK BREAK

Perhaps the most sharply defined break of the entire area studied, and again one not recognized in published papers, is the abrupt limit of mines along the north side of Chicago Creek. Mines are plentiful and continuous along the north side of this valley. Even though veins are reported and a few prospects are found south of this valley, none are of any consequence.

As in the cases described above, this break cannot be attributed to a change in rock type. Mineralization is found in both the Idaho Springs formation (metamorphic) and the Silver Plume Granite (intrusive) north of Chicago Creek, but not south of it. Both rock types are found on both sides of Chicago Creek; the stream does not follow a contact. Although the veins are recognized as occurring in faults, and other strong faults are known in the near vicinity, no major break is recognized as being along the floor of Chicago Creek Valley. Harrison and Wells (1959, p. 49, 50, 54, and 55) described two mines near the eastern end of the Chicago Creek Break. Reverse movement on faults is reported in the

Black Swan Tunnel and the Beaver Mine. Both mines are near to but north of Chicago Creek.

Although The Chicago Creek Break is very clearly defined and appears to trend N 62 1/2° E, it, unlike the two breaks previously described, does not seem to have a matching north boundary. If such a limit does exist, development of more complete data may be necessary for is definition.

Veins in the productive area north of Chicago Creek commonly strike from N 50° to N 80° E. The mapped veins south of Chicago Creek, none of which have been particularly productive, strike from north to northwesterly. This is thought to be indicative of and statistically, as indicated later in this thesis, may be the reason for the sharp change in degree of mineralization, even though the abrupt change in the fracture systems is not explained.

THE PRECAMBRIAN TREND

A second mineralized trend is apparent from a study of the location of mines plotted on (Plate I). The usually recognized Larimide Mineral Belt is obvious trending across the map. A second, less prominent and more poorly defined north-south trend is apparent along the eastern side of the area studied. This series of mines is developed on deposits of copper, uranium, and pegmatites. Most of these properties are quite minor, although one, the Schwartzwalder uranium mine, has had production of ore valued in excess of $10,000,000.00. Deposits of this group of mines are usually considered to be Precambrian in age.

STRIKE OF MINERAL DEPOSITS

In the preparation of the data processing cards, vein strike was recorded to the nearest ten degrees. Thus, a vein striking from north to N 10° E was listed in the 10° grouping on the card. Mines striking from N 10° E to N 20° E were in the 20° grouping, and so on through. This method would mean that the median of each group would probably be about 5° less than the direction from the card data, assuming normal distribution and at the same time recognizing that true normal distribution is unlikely.

The cards were sorted into strike groupings. The data resulting from the sort of 381 cards containing the information are shown in Table 1. From inspection it is apparent that most of the veins strike from N 30° E to N 90° E. The primary strike concentration is approximately N 55° E with a secondary concentration apparent in the N 75° E range. Although other directions are represented, these are the prominently productive systems.

It is interesting to compare this regional conclusion with data collected by Harrison and Wells (1956, p. 70) concerning the statistical

Table 1. Strike Frequency of Veins in Various Sub-Areas

Strike Direction	Number of Mines					
	All Mines	All Less Lamertine	Lamertine Only	Neder-land	$1,000,000 Producers	Pre-cambrian
N 0°-10° E	5	5	0	2	2	0
10°-20°	9	9	0	3	0	0
20°-30°	11	5	6	3	1	0
30°-40°	34	13	21	4	1	1
40°-50°	56	32	24	9	8	1
50°-60°	93	24	69	2	2	0
60°-70°	46	19	27	5	1	2
70°-80°	58	28	30	7	2	0
N 80°-90° E	33	20	13	6	2	2
S 80°-90° E	9	7	2	2	0	0
70°-80°	6	6	0	0	2	0
60°-70°	3	2	1	1	0	0
50°-60°	5	4	1	0	0	1
40°-50°	2	2	0	0	1	0
30°-40°	2	2	0	0	0	0
20°-30°	3	2	1	0	1	1
10°-20°	3	2	1	0	0	0
S 0°-10° E	3	3	0	0	0	1
Total Mines	381	185	196	44	23	9

evaluation of jointing systems in the Freeland-Lamartine district, a small segment of the area covered by this study. These men recorded 1680 joint directions in the area of their study and concluded these data indicated four joint sets. Arranged in order of decreasing prominence, these systems are as follows:

N 74° W (286°) Dipping 68° N

N 82° E (082°) Dipping 62° N

N 22° W (338°) Dipping 79° NE

N 56° E (056°) Dipping 63° NW

It is quite interesting to note that the least prevalent joint direction locally was the most important system in the development of ore deposits. The second most prevalent direction, N 82° E, corresponds reasonably well with the second most prevalent trend, N 75° E, of this study. The first- and third-order joint systems, determined locally, are unimportant either locally or regionally: the veins trending in these directions approach the ore deposit background frequency level.

The vein strike data, for the Freeland-Lamartine district only, revealed that most of the productive veins in this district strike N 55° E, corresponding very closely with the strike of the least prominent jointing direction. The second order grouping strikes N 75° E, comparing favorably with the second-order N 82° E joint grouping. The first- and third-order joint systems are not recognizable in the tabulation of the strike of productive deposits.

Table 1 also shows the effect of removing the Lamartine area data from the total strike data. These data show a 10° northerly shift in the most prominent strike system to N 45° E. The secondary system remains very prominent at N 75° E. This grouping shows a minor third system striking N 15° E, a strike not recognized in any of the other groupings.

From this information it must be inferred that the most frequently productive strike system tends to vary in direction from about N 45° E to N 55° E with the latter direction actually being the most prominent.

The secondary system, trending N 75° E, is the most consistent even though it apparently does not develope ore deposits quite as often as does the primary set.

The N 55° E trend above is considered by Badgley (1960, p. 4) to be one set of a Laramide orogeny joint pair. The N 75° E group would correspond to his N 80° E system, considered to be originally of Precambrian age.

DIP OF VEINS

Several items have been developed concerning the dip of the producing deposits. Of the 264 mines whose dip data are considered good enough to use, the quadrant directions of dip is as follows:

Table 2. Dip Related to Quadrants

Quadrant	Number of Occurrences	Percent of Total
NE	19	7.2
SE	34	12.9
SW	4	1.4
NW	207	78.5

With the available data and by relating the average angle of dip in 10° increments to the dip quadrant, the following are tabulated:

Table 3. Degrees of Dip Related to Quadrants

Dip in Degrees	NE Quadrant		SE Quadrant		SW Quadrant		NW Quadrant	
	No. of Mines	%	No. of Mines	%	No. of Mines	%	No. of Mines	%
20	1	5.3	0	0	1	25	1	0.5
30	1	5.3	1	2.9	0	0	8	3.8
40	0	0	1	2.9	0	0	10	4.8
50	4	21.5	6	17.7	0	0	12	5.8
60	6	31.6	3	8.9	2	50	40	19.3
70	3	15.8	7	20.6	1	25	57	27.5
80	4	21.5	14	41.2	0	0	75	36.2
90	0	0	2	5.8	0	0	4	1.9
Total	19		34		4		207	

In all quadrants most of the ore deposits dip at 60° or steeper. As the control improves, as in the northwest and southeast quadrants, it is apparent that most of the productive orebodies dip at approximately 80°, regardless of direction. If these ore deposits are formed in openings developed according to the cymoid theory described by McKinstry (1948, p. 315) that states ore deposits will be formed on the flatter portions of reverse faults and the steeper portion of normal faults, it may be inferred that relatively few commercial deposits have been formed in openings along reverse faults and that reverse faults are very infrequent. Present control is too poor to give better definition.

The steepness of the ore zones infer ore development in the open channel ways of normal faults, or the development is equally possible in cymoid openings along strike-slip faults. Again present control does not permit a conclusive statement on this point.

It would be most interesting to correlate steepness of the orebody with type of fault with depth of mine. Many mines may have bottomed at flattening of dip; if mining were continued deeper to a steepening of dip, deeper unknown ore deposits may easily exist. Again, better data control is needed.

Degree of dip of veins related to north or south dip is shown in tables 4 and 5 respectively. Here again where sufficient control is available, the 70° to 80° dip range is most important.

Table 4. Dip Frequency of Veins in Various Sub-Areas

North Dip Only

Dip North	Number of Mines					
	All Mines	All Less Lamartine	Lamartine Only	Neder-land	$1,000,000 Producers	Pre-cambrian
0°-10°	0	0	0	0	0	0
10°-20°	2	2	0	0	0	1
20°-30°	9	5	4	0	0	1
30°-40°	12	4	8	0	1	0
40°-50°	18	12	6	1	0	0
50°-60°	45	26	19	1	5	1
60°-70°	62	24	38	8	3	0
70°-80°	86	34	51	16	4	0
80°-90°	6	2	4	1	2	1
90°	19	16	3	4	1	2
Total	259	126	133	31	16	6

Table 5. Dip Frequency of Veins in Various Sub-Areas

South Dip Only

Dip South	Number of Mines					
	All Mines	All Less Lamartine	Lamartine Only	Nederland	$1,000,000 Producers	Precambrian
0°–10°	1	1	0	0	0	0
10°–20°	1	1	0	0	0	0
20°–30°	1	1	0	0	0	0
30°–40°	1	0	1	1	0	0
40°–50°	6	5	1	3	2	0
50°–60°	2	2	0	1	0	0
60°–70°	10	10	0	1	2	1
70°–80°	16	13	3	1	2	1
80°–90°	3	3	0	2	0	0
Total	41	36	5	9	6	2

MINERAL TREND VERSUS PRODUCTION VALUE

One of the more interesting plots developed is the relationship of total production value to specific mine location. The value production data are rather limited because of incomplete records or because of reluctance of mining companies to release production figures. Nevertheless, a definite trend of major production value in parallel zones appears to exist across the Idaho Springs, Central City, and Jamestown areas. In these cases, this trend, if it actually exists, would strike N 75° E and would pass as indicated on Plate I. As drawn, this trend is not restricted to the limits of any of the other trend groups. Present data suggests the N 75° E direction, an over-all trend to the higher value mines, is not related to the strike of the individual ore deposits (Table 1).

The major value mines of the Nederland-Cariboo area seem to be related in over-all trend to the Nederland Break and do not seem to be a part of the N 75° E system described above.

MINERAL TRENDS RELATED TO INDIVIDUAL VEIN STRIKES

Five major mineral trends have been described:

1. The Colorado Mineral Belt
2. The Nederland Break
3. The Chicago Creek Break
4. The Precambrian Trend
5. The Trend Related to Major Value Production

For each of these, the prevalent strike of the veins within the trend is not the same as the trend direction. This condition simply suggests that the prospector should not look for new deposits by projecting his efforts along the vein strike; exploration along the overall mineral trend may be more rewarding. These overall trends, then, with a listing of the most prominent vein-strike direction within each trend are as follows:

Table 6. Prominent Vein Directions Related to Various Trends

Feature	Belt Trend	Prominent Vein Directions		
		1st Order	2nd Order	3rd Order
Colo. Mineral Belt (All excluding Lamartine area)	N 35° E	N 45° E	N 75° E	N 15° E
Nederland Break	N 88° E	N 45° E	N 75° E	---
Chicago Creek Break (Lamartine Area)	N 62½° E	N 55° E	N 75° E	---
Precambrian Trend (The Precambrian data is very poor.)	N-S	N 85° E (?)	N 65° E (?)	---
Major Value Trend	N 75° E	N 45° E	---	---

No explanation is proferred as to why mineral deposits are prevalently en echelon along an overall trend rather than parallel to it. From the figures given above, ore deposits, at least in the area studied, obviously are so arranged. The most surprising item is the relationship between the major value trend and vein strike. The major value trend direction is the same as the second-order strike system in all other cases, but here the second-order system is not present. This condition is not unreasonable; rather it further demonstrates the en-echelon character of the veins at angle to the main mineral trend.

CONCLUSIONS

This study has shown that data available in publications can be sorted, sifted, coded, and placed in recoverable form on easily handled data-processing cards. It also has shown that in areas that have been intensely prospected and developed, over-all built-in ore controls exist that can be used for future prospecting if they are recognized. However, it should be stressed that these data are given for the area studied, not for the Colorado Mineral Belt as a whole.

If properly used, extended, and studied, such data should provide useful tools to exploration groups for determining more and less favorable prospecting areas within and near the total area studied. The information also should afford a general basis for evaluating relative potential of vein systems when only strike and dip are available. Guides determined by this study listed in their apparent order of importance were as follows:

1. The N 75° E zonation of higher value properties would seem to be the most important guide. New prospects within the known

portion of the zone, deeper prospects in abandoned mines as long as older known deposits did not bottom minerologically, or prospects on strike to the east or west should be carefully evaluated.

2. If the vein strikes in the N 45° E to N 60° E range or N 70° E to N 80° E range, odds of developing commercial reserves are much better than for veins having strikes in other directions. Northwesterly striking veins have relatively little chance of containing commercial ore reserves.
3. Veins dipping to the northwest are more likely to be productive than veins dipping in any of the other three quadrants.
4. Ore deposits are most likely to be found in veins dipping from 60° to 80°, regardless of vein strike or dip direction.

General areas that seem to warrant further academic study at the outset, are the trends indicated as the west side of the Colorado Mineral Belt, the north side of the Nederland Break, and the Chicago Creek Break. Such study may provide suggestions as to the relative merit of prospecting the currently nonproductive areas across these breaks and may suggest how and where such prospecting can best be done. The actual nature of these trends may be determined and may serve as a useful tool in this or other areas.

Many additional data sorts can be made with the present carded information. If more complete data could be obtained, other potentially usful sorts could be made. Such a study would reveal the following:

1. Because specific mineral types tend to cluster, areas for those interested in prospecting for specific metals could be defined.
2. An over-all mineral zonation with depth, as is so well known in other areas, also may exist here. Such studies may suggest mines or areas where mines have bottomed because of mineralogic change, but where further change, back to commercial deposits, could be expected at greater depth.
3. There may be some relationship among ore deposits, host rocks, and intrusives that have not yet been defined.
4. The value of known deposits should be related to type of faulting. Currently available data are incomplete, but it does suggest that this could provide a valuable prospecting tool.
5. Potentially useful statistical studies of metal assemblages could be made. For example some of the mines in the western part of the tungsten belt report vanadium occurrences. Does this have any significance, if so what does it mean? Are there other metal groupings that might be useful on a regional basis much as geochemical trace element studies are currently being used?

The data presented in this paper should serve to indicate the potential of data processing as an exploration tool. Understandably, the work to date is only a beginning for the area studied, but even so, significant items have been discovered. These items can provide the basis and inspiration for studies by other students, individuals, and companies, both in extending this current work and in applying like studies to other areas of mineral potential.

It is suggested that data from districts studied in this manner be compared for possible definition of simular characteristics. Any known mineral district could be the subject of such a study, but it is hoped that the more productive areas can be studed first. This present study may be used as a preliminary guide, but additional studies should suggest logical means of expansion.

Statistical studies, using methods in additon to those presented in this paper, have been tried, but were not considered successful. It is hoped that procedures for correlating this or like data, employing computors, may be successfully developed in the future.

APPENDIX

CODE FOR

DATA PROCESSING

OF

MINERAL DEPOSITS

CARD COLUMN	ITEM
1, 2	Punch 0 and 5 respectively for Colorado
3, 4	Punch 0 and 6 respectively for Boulder County
	Punch 0 and 9 respectively for Clear Creek County
	Punch 1 and 7 respectively for Douglas County
	Punch 2 and 3 respectively for Gilpin County
	Punch 2 and 9 respectively for Jefferson County
	Punch 4 and 6 respectively for Park County
	Punch 5 and 8 respectively for Summit County
5-10	Lat. in degrees, minutes, and seconds
11-16	Long. in degrees (last 2 digits only), minutes, and seconds
17, 18	Mining method (See Code C)
19	Extent of workings (See Code D)
20, 21, 22	Elev. highest workings in hundreds of feet
23, 24, 25	Max. depth in tens of feet
26, 27	Vein strike, clockwise from north using 10° increments

(Directions, Continued)

CARD COLUMN	ITEM
28	Vein dip in 10° increments (0° to 90°)
29	Vein-dip direction (See Code E)
30	Rake of ore shoot in 10° increments (0° to 90°)
31	Direction of rake of ore shoot (Same as Code E)
32	Deposit characteristics (See Code F)
33, 34	Type of deposit (See Code G)
35	Age of deposit (See Code H)
36, 37, 38	Host rock (See Code I)
39	Age of host rock (See Code H)
40	Type of faulting (See Code J)
41, 42	Major fault trend in 10° ranges from north in clockwise direction
43	Relation of faulting to ore (See Code K)
44	Form of nearby associated volcanics (See Code L)
45, 46, 47	Main nearby associated volcanics (See Code M)
48	Age relation of intrusives to ore (Code N)
49-53	Materials mined - elements (Code O)
54-58	Materials mined - non-elements (Code P)
59, 60, 61	Major value ore (Code Q)
62	Value of ore produced reduced to 1947-1949 base (Code R)
63	Estimated total reserve of ore of grade similar to that mined in the past (Code S)

(Directions, Continued)

CARD COLUMN	ITEM
64	Potential for further exploration (Code T)
65	Reasons for closing mine (Code U)
66, 67	Bibliography (Code V)
68, 69	Bibliography (Code V)
70, 71	Bibliography (Code V)
72, 73	Bibliography (Code V)
74, 75	Bibliography (Code V)
76, 77, 78	Gangue minerals (Code W)

CODE C

COLUMN

17	18	Mining Method
0	0	Panning
0	1	Hydraulic giants
0	2	Land dredging
0	3	Floating dredges, shallow water (-200')
0	4	Floating dredges, deep water (+200')
1	5	Hand trenching
1	6	Machine trenching
1	7	Glory-holing
1	8	Open pit
2	8	Gophering
2	9	Breasting
3	0	Room and pillar
3	1	Underhand stoping
3	2	Overhand stoping
3	3	Sublevel stoping

(Code C Continued)

Column 17	Column 18	Mining Method
4	0	
4	1	Square set
4	2	Mitchell
5	0	Resuing
5	1	Shrinkage
6	0	Sand fill
7	0	Top slicing
7	1	Sub-level caving
7	2	Block caving
8	0	Leaching
9	0	Coal stripping
9	1	Coal room and pillar
9	2	Coal-robbing pillars
9	3	Coal longwall

CODE D

Column 19	Length Underground Workings	Pit Area
12	0 - 100 ft	10 x 50 ft or less
11	100 - 500 ft	50 x 50 ft or less
0	500 - 1,000 ft	100 x 100 ft or less
1	1,000 - 5,000 ft	250 x 250 ft or less
2	5,000 - 10,000 ft	500 x 500 ft or less
3	10,000 - 25,000 ft	750 x 750 ft or less
4	25,000 - 50,000 ft	1,000 x 1,000 ft or less
5	50,000 - 100,000 ft	2,500 x 2,500 ft or less
6	100,000 - 250,000 ft	5,000 x 5,000 ft or less
7	250,000 - 500,000 ft	10,000 x 10,000 ft or less
8	500,000 - 1,000,000 ft	20,000 x 20,000 ft or less
9	1,000,000 ft plus	20,000 x 20,000 ft or more

CODE E

Column 29	Dip Direction
12	N
11	NE
0	E
1	SE
2	S
3	SW
4	W
5	NW
6	Vertical
7	Flat
8	
9	

CODE F

Column 32	Deposit Characteristics
12	Deposit restricted to particular formation
11	Ore minerals change with depth or horizontally
0	Ore minerals disappear with depth
1	Ore minerals increase with depth
2	Ore related to vein intersections
3	Ore not related to vein intersections
4	Ore improves away from vein intersections
5	Ore terminates at steepening of dip
6	Ore terminates at flattening of dip
7	Ore terminates at changes in strike
8	En echelon deposits expectable, also branch or parallel veins
9	Ore consistent along vein

CODE G

Column

33	34	Type of Deposit
0	0	Placer
0	1	
0	2	
0	3	
0	4	
0	5	Vein
2	5	Massive
2	6	Contact metamorphic
2	7	Replacement
2	8	Disseminated
2	9	Breccia pipe
3	0	Dissemination with associated breccia pipes
3	1	Disemination with associated veins
3	2	Explosion breccia
5	0	Non metallic vein

(Code G, Continued)

Column 33	Column 34	Type of Deposit
6	0	Bedded deposit
7	0	Mineralized dike or sill
7	1	Pegmatites, mineralized
7	2	Aplites, mineralized

CODE H

Column	
35	Age of Deposit
12	
11	Precambrian
0	Cambrian through Silurian
1	Devonian and Mississippian
2	Pennsylvanian and Permian
3	Early Mesozoic
4	Late Mesozoic
5	Laramide
6	Tertiary
7	Quaternary
8	
9	

CODE I

Column			
36	37	38	Host Rock
0	0	0	Igneous quartz
0	0	1	Granite
0	0	2	Granite alaskite - quartz and orthoclase only
0	0	3	Granite greisen - quartz and muscovite only
0	0	4	Graphic granite - graphic texture
0	0	5	Granite pegmatite - coarse crystals
0	0	6	Granite aplite - sugary
0	0	7	Alkali granite - abundant albite and sodic amphibole or pyroxene
0	0	8	Charnokite - orthopyroxene
0	0	9	Luxullianite - tourmaline and muscovite
0	1	0	Syenite
0	1	1	Quartz syenite - a little quartz
0	1	2	Syenite pegmatite - coarse crystals
0	1	3	Syenite aplite - sugary
0	1	4	Alkali syenite - no plagioclase
0	1	5	Pulaskite - a little nepheline
0	1	6	Nordmarkite - a little quartz
0	1	7	Larvikite - "blue" feldspar

(Code I, Continued)

Column			
36	37	38	Host Rock
0	1	8	Shonkinite - abundant ferromagnesian minerals
0	1	9	Nepheline syenite
0	2	0	Leucite syenite - psleucite
0	2	1	Sodalite syenite - sodalite
0	2	2	Foyaite - abundant feldspar
0	2	3	Malignite - abundant ferromagnesian minerals
0	2	4	Ditroite - nepheline and sodalite
0	2	5	Quartz monzonite
0	2	6	Quartz monzonite pegmatite - coarse crystals
0	2	7	Quartz monzonite aplite - sugary
0	2	8	Monzonite
0	2	9	Monzonite pegmatite - coarse crystals
0	3	0	Monzonite aplite - sugary
0	3	1	Nephelite monzonite
0	3	2	Granodiorite
0	3	3	Granodiorite pegmatite - coarse crystals
0	3	4	Granodiorite aplite - sugary
0	3	5	Quartz diorite (also called tonalite)
0	3	6	Quartz diorite pegmatite - coarse crystals
0	3	7	Quartz diroite aplite - sugary
0	3	8	Diorite

(Code I, Continued)

Column			
36	37	38	Host Rock
0	3	9	Diorite pegmatite - coarse crystals
0	4	0	Diorite aplite - sugary
0	4	1	Gabbro
0	4	2	Gabbro - clinopyroxene
0	4	3	Norite - orthopyroxene
0	4	4	Olivine gabbro - olivine
0	4	5	Troctolite - olivine and plagioclase only
0	4	6	Anorthosite - plagioclase only
0	4	7	Quartz gabbro - quartz
0	4	8	Diabase
0	4	9	Theralite (nephelite gabbro)
0	5	0	Teschenite - analcite
0	5	1	Olivine theralite - olivine
0	5	2	Peridotite - clinopyroxene and olivine
0	5	3	Harzburgite - orthopyroxene and olivine
0	5	4	Picrite - some plagioclase
0	5	5	Dunite - olivine only
0	5	6	Pyroxenite
0	5	7	Hornblendite
0	5	8	Serpentine - serpentine

(Code I, Continued)

Column			
36	37	38	Host Rock
0	5	9	Chromite - chromite only
0	6	0	Missourite - pyroxene, olivine and psleucoxene
0	6	1	Ijolite - pyroxene and nepheline
0	6	2	Fergusite - pyroxene and psleucoxene
0	6	3	Lamprophyre
0	6	4	Granite porphyry
0	6	5	Syenite porphyry
0	6	6	Nepheline syenite porphyry
0	6	7	Quartz monzonite porphyry
0	6	8	Monzonite porphyry
0	6	9	Nepheline monzonite porphyry
0	7	0	Granodiorite porphyry
0	7	1	Quartz diorite porphyry
0	7	2	Diorite porphyry
0	7	3	Gabbro porphyry
0	7	4	Dolorite
0	7	5	Lamprophyre
0	7	6	Theralite porphyry
0	7	7	Olivine gabbro porphyry
0	7	8	Pyroxenite porphyry

(Code I, Continued)

Column			
36	37	38	Host Rock
0	7	9	Hornblendite porphyry
0	8	0	Peridotite porphyry (kimberlite)
0	8	1	Rhyolite porphyry
0	8	2	Alaskite porphyry
0	8	3	Trachyte porphyry - (bostonite porphyry)
0	8	4	Phonolite porphyry
0	8	5	Quartz latite porphyry
0	8	6	Latite porphyry
0	8	7	Nephelite latite porphyry
0	8	8	Dacite porphyry
0	8	9	Andesite porphyry
0	9	0	Basalt porphyry
0	9	1	Olivine basalt porphyry
0	9	2	Plagioclase basalt porphyry
0	9	3	Augitite porphyry
0	9	4	Limburgite porphyry
0	9	5	Rhyolite
0	9	6	Trachyte
0	9	7	Phonolite

(Code I, Continued)

Column			
36	37	38	Host Rock
0	9	8	Leucite phonolite - leucite
0	9	9	Tinguaite - abundant aegirine
1	0	0	Wyomingite - leucoxene and phlogopite
1	1	1	Quartz latite (dellenite)
1	1	2	Latite
1	1	3	Trachy-andesite latite
1	1	4	Nephelite latite
1	1	5	Dacite
1	1	6	Andesite
1	1	7	Propylite - hydrothermally altered andesite
1	1	8	Basalt
1	1	9	Olivine basalt
1	2	0	Analcite basalt - analcite
1	2	1	Quartz basalt - quartz
1	2	2	Oceanite - abundant olivine
1	2	3	Augitite
1	2	4	Tephrite
1	2	5	Leucite tephrite - leucite
1	2	6	Basanite - olivine and nepheline

(Code I, Continued)

Column			
36	37	38	Host Rock
1	2	7	Leucite basanite - olivine and leucoxene
1	2	8	Limburgite
1	2	9	Nephelinite - nepheline
1	3	0	Leucitite - leucoxene
1	3	1	Melilite (uncompahgrite)
1	3	2	Olivine nephelinite (nephelite basalt)
1	3	3	Obsidian - black glass
1	3	4	Pitchstone - resinous glass
1	3	5	Vitrophyre - porphyritic glass
1	3	6	Perlite - glass with concentric fractures
1	3	7	Pumice - finely cellular
1	3	8	Scoria - coarsely cellular
1	3	9	Basalt obsidian
1	4	0	Trachylyte
1	4	1	Ash
1	4	2	Tuff
3	0	0	Slate
3	0	1	Sandy slate
3	0	2	Graywacke slate

(Code I, Continued)

Column			
36	37	38	Host Rock
3	0	3	Calcareous slate
3	0	4	Graphitic slate
3	0	5	Ferruginous slate
3	0	6	Pyritic slate
3	0	7	Schist
3	0	8	Biotite schist
3	0	9	Muscovite schist
3	1	0	Hornblende schist
3	1	1	Actinolite schist
3	1	2	Talc schist
3	1	3	Epidote schist
3	1	4	Garnet schist
3	1	5	Graphite schist
3	1	6	Chlorite schist
3	1	7	Tourmaline schist
3	1	8	Quartzose schist
3	1	9	Calcareous schist
3	2	0	Greenstone schist
3	2	1	Sericite schist

(Code I, Continued)

Column			
36	37	38	Host Rock
3	2	2	Glaucophane schist
3	2	3	Schistose rhyolite porphyry
3	2	4	Schistose basalt Porphyry
3	2	5	Amphibolites
3	2	6	Phyllites
3	2	7	Eclogite - a garnet-pyroxene rock
3	2	8	Gneiss
3	2	9	Granite gneiss
3	3	0	Syenite gneiss
3	3	1	Gabbro gneiss
3	3	2	Quartzite gneiss
3	3	3	Conglomeritic gneiss
3	3	4	Augen gneiss
3	3	5	Mylonite
3	3	6	Migmatite
3	3	7	Injection gneiss
3	3	8	Hornblende gneiss
3	3	9	Biotite gneiss
3	4	0	Chlorite gneiss

(Code I, Continued)

Column			
36	37	38	Host Rock
3	4	1	Garnet gneiss
3	4	2	Sillimanite gneiss
3	4	3	Epidote gneiss
3	4	4	Tourmaline gneiss
3	4	5	Quartzite
3	4	6	Pebbly quartzite
3	4	7	Conglomeritic quartzite
3	4	8	Slatey quartzite
3	4	9	Arkose quartzite
3	5	0	Graywacke quartzite
3	5	1	Itabirite - quartzite with specular hematite flakes
3	5	2	Schistose quartzite
3	5	3	Vaspilite
3	5	4	Taconite
3	5	5	Marble
3	5	6	Skarn
3	5	7	Graphitic marble
3	5	8	Orphicalcites - marble with serpentine
3	5	9	Tremolite marble
3	6	0	Diopside marble

(Code I, Continued)

Column 36	37	38	Host Rock
3	6	1	Phlogopite marble
3	6	2	Talcose marble
3	6	3	Garnet marble
3	6	4	Serpentinites
3	6	5	Soapstone (steatites)
3	6	6	Hornfels
3	6	7	Greisen - quartz and mica
3	6	8	Prophylite
3	6	9	Greenstones

CODE J

Column 40	Type of Fault Controlling Ore
12	Normal
11	Reverse
0	Strike-slip
1	Normal - strike-slip
2	Reverse - strike-slip
3	Vertical
4	Overthrust
5	Underthrust
6	Tear
7	Bedding plane
8	Rotational
9	

CCDE K

Column	
43	Relation of Faulting tc Ore
12	Deposit pre-faulting
11	Deposit post-faulting
0	Deposit follows major faults
1	Deposit follows minor faults
2	Deposit follows erratic faults
3	Deposit cut off by older cross faults
4	Deposit cut off by younger cross faults
5	Deposit junctions with barren fault at depth
6	Deposit terminates against barren fault above
7	No relationship to faulting
8	Barren fault terminates ore laterally
9	Vein fault zone dies out with depth

CODE L

Column	
44	Form of Nearby Associated Volcanics
12	Dike
11	Sill
0	Sheet
1	Lacolith
2	Lopolith
3	Stock
4	Batholith
5	Acrobatholith
6	Flow
7	Ash
8	
9	

CODE M

Column			
45	46	47	Main Nearby Associated Volcanics
0	0	0	Igneous quartz
0	0	1	Granite
0	0	2	Granite alaskite - quartz and orthoclase only
0	0	3	Granite greisen - quartz and muscovite only
0	0	4	Graphic granite - graphic texture
0	0	5	Granite pegmatite - course crystals
0	0	6	Granite aplite - sugary
0	0	7	Alkali granite - abundant albite and sodic amphibole or pyroxene
0	0	8	Charnokite - orthopyroxene
0	0	9	Luxullianite - tourmaline and muscovite
0	1	0	Syenite
0	1	1	Quartz syenite - a little quartz
0	1	2	Syenite pegmatite - coarse crystals
0	1	3	Syenite aplite - sugary
0	1	4	Alkali syenite - no plagioclase
0	1	5	Pulaskite - a little nepheline
0	1	6	Nordmarkite - a little quartz
0	1	7	Larvikite - "blue" feldspar

(Code M, Continued)

Column			
45	46	47	Main Nearby Associated Volcanics
0	1	8	Shonkinite - abundant ferromagnesian minerals
0	1	9	Nepheline syenite
0	2	0	Leucite syenite - psleucite
0	2	1	Sodalite syenite - sodalite
0	2	2	Foyaite - abundant feldspar
0	2	3	Malignite - abundant ferromagnesian minerals
0	2	4	Ditroite - nepheline and sodalite
0	2	5	Quartz monzonite
0	2	6	Quartz monzonite pegmatite - coarse crystals
0	2	7	Quartz monzonite aplite - sugary
0	2	8	Monzonite
0	2	9	Monzonite pegmatite - coarse crystals
0	3	0	Monzonite aplite - sugary
0	3	1	Nephelite monzonite
0	3	2	Granodiorite
0	3	3	Granodiorite pegmatite - coarse crystals
0	3	4	Granodiorite aplite - sugary
0	3	5	Quartz diorite (also call tonalite)
0	3	6	Quartz diorite pegmatite - coarse crystals

(Code M, Continued)

Column			
45	46	47	Main Nearby Associated Volcanics
0	3	7	Quartz diorite aplite - sugary
0	3	8	Diorite
0	3	9	Diorite pegmatite - coarse crystals
0	4	0	Diorite aplite - sugary
0	4	1	Gabbro
0	4	2	Gabbro - clinopyroxene
0	4	3	Norite - orthopyroxene
0	4	4	Olivine gabbro - olivine
0	4	5	Troctolite - olivine and plagioclase only
0	4	6	Anorthosite - plagioclase only
0	4	7	Quartz gabbro - quartz
0	4	8	Diabase
0	4	9	Theralite (nephelite gabbro)
0	5	0	Teschenite - analcite
0	5	1	Olivine theralite - olivine
0	5	2	Peridotite - clinopyroxene and olivine
0	5	3	Harzburgite - orthopyroxene and olivine
0	5	4	Picrite - some plagioclase
0	5	5	Dunite - olivine only

(Code M, Continued)

Column			
45	46	47	Main Nearby Associated Volcanics
0	5	6	Pyroxenite
0	5	7	Hornblendite
0	5	8	Serpentine - serpentine
0	5	9	Chromite - chromite only
0	6	0	Missourite - pyroxene, olivine and psleucoxene
0	6	1	Ijolite - pyroxene and nepheline
0	6	2	Fergusite - pyroxene and psleucoxene
0	6	3	Lamprophyre
0	6	4	Granite porphyry
0	6	5	Syenite prophyry
0	6	6	Nepheline syenite porphyry
0	6	7	Quartz monzonite porphyry
0	6	8	Monzonite porphyry
0	6	9	Nepheline monzonite porphyry
0	7	0	Granodiorite porphyry
0	7	1	Quartz diorite porphyry
0	7	2	Diorite porphyry
0	7	3	Gabbro porphyry
0	7	4	Dolorite
0	7	5	Lamprophyre

(Code M, Continued)

Column 45	46	47	Main Nearby Associated Volcanics
0	7	6	Theralite porphyry
0	7	7	Olivine gabbro porphyry
0	7	8	Pyroxenite porphyry
0	7	9	Hornblendite porphyry
0	8	0	Peridotite porphyry (kimberlite)
0	8	1	Rhyolite porphyry
0	8	2	Alaskite porphyry
0	8	3	Trachyte porphyry (bostonite porphyry)
0	8	4	Phonolite porphyry
0	8	5	Quartz latite porphyry
0	8	6	Latite porphyry
0	8	7	Nephelite latite porphyry
0	8	8	Dacite porphyry
0	8	9	Andesite porphyry
0	9	0	Basalt porphyry
0	9	1	Olivine basalt porphyry
0	9	2	Plagioclase basalt porphyry
0	9	3	Augitite porphyry
0	9	4	Limburgite porphyry
0	9	5	Rhyolite

(Code M, Continued)

Column			
45	46	47	Main Nearby Associated Volcanics
0	9	6	Trachyte
0	9	7	Phonolite
0	9	8	Leucite phonolite - leucite
0	9	9	Tinguaite - abundant aegirine
1	0	0	Wyomingite - leucoxene and phlogopite
1	1	1	Quartz latite (dellenite)
1	1	2	Latite
1	1	3	Trachy-andesite latite
1	1	4	Nephelite latite
1	1	5	Dacite
1	1	6	Andesite
1	1	7	Propylite - hydrothermally altered andesite
1	1	8	Basalt
1	1	9	Olivine basalt
1	2	0	Analcite basalt - analcite
1	2	1	Quartz basalt - quartz
1	2	2	Oceanite - abundant olivine
1	2	3	Augitite
1	2	4	Tephrite
1	2	5	Leucite tephrite - leucite

(Code M, Continued)

Column			
45	46	47	Main Nearby Associated Volcanics
1	2	6	Basanite - olivine and nepheline
1	2	7	Leucite basanite - olivine and leucoxene
1	2	8	Limburgite
1	2	9	Nephelinite - nepheline
1	3	0	Leucitite - leucoxene
1	3	1	Melilite (uncompahgrite)
1	3	2	Olivine nephelinite (nephelite basalt)
1	3	3	Obsidian - black glass
1	3	4	Pitchstone - resinous glass
1	3	5	Vitrophyre - porphyritic glass
1	3	6	Perlite - glass with concentric fractures
1	3	7	Pumice - finely cellular
1	3	8	Scoria - coarsely cellular
1	3	9	Basalt obsidian
1	4	0	Trachylyte
1	4	1	Ash
1	4	2	Tuff
1	4	3	Porphyry

CODE N

Column	
48	Age Relation of Intrusives to Ore
12	Ore in and contemporaneous with intrusive
11	Ore not in but comtemporaneous with intrusive
0	Ore later than but probably derived from intrusive
1	No intrusives associated with ore
2	Older intrusive was preferred host for ore deposition
3	Deposit part of halo zone around intrusive
4	Deposit younger than intrusive but lies between it and country rock
5	
6	
7	
8	
9	

CODE O

Materials Mined - Elements

Punch	Column 49	Column 50	Column 51
12	Aluminum	Columbium	Lithium
11	Antimony	Copper	Magnesium
0	Arsenic	Fluorine (fluorspar)	Manganese
1	Barium	Gallium	Mercury
2	Beryllium	Germanium	Molybdenum
3	Bismuth	Gold	Nickel
4	Boron	Hafnium	Nitrogen
5	Bromine	Helium	Platinum group
6	Cadmium	Indium	Radium
7	Cesium	Iodine	Rare earth metals
8	Chromium	Iron	Rhenium
9	Cobalt	Lead	Rubidium

(Code O, Continued)

Materials Mined - Elements

Punch	Column 52	Column 53
12	Scandium	Titanium
11	Selenium	Tungsten
0	Silicon	Uranium
1	Silver	Vanadium
2	Sodium	Yttrium
3	Strontium	Zinc
4	Sulfur and pyrite	Zirconium
5	Tantalum	
6	Tellurium	
7	Thallium	
8	Thorium	
9	Tin	

CODE P

Materials Mined - Non-Elements

Punch	Column 54	Column 55	Column 56
12	Abrasives	Cryolite	Lignite
11	Anthracite coal	Diamond	Limestone
0	Aplites	Diatomite	Magnesite
1	Asphalts	Dimension stone	Mica
2	Asbestose	Feldspar	Mineral filler
3	Bentonite	Garnet	Mineral pigment
4	Bituminous coal	Gem stones	Minor industrial minerals
5	Bleaching clay	Granules	Monazite
6	Chalk	Graphite	Nitrogen Compound
7	Clay	Gypsum	Oil shale
8	Corundum	Kyanite group	Perlite
9	Crushed stone	Light weight aggregate	Petroleum

(Code P, Continued)

Material Mined - Non-Elements

Punch	Column 57	Column 58
12	Phosphates	Wollastonite
11	Potash	Nepheline
0	Pumice	Shells
1	Pyrophyllite	
2	Quartz crystal	
3	Refractories	
4	Sand and gravel	
5	Slate	
6	Talc	
7	Topaz	
8	Tripoli	
9	Water	

CODE Q

Column			
59	60	61	Major Value Ore
0	0	0	Aluminum
0	0	1	Antimony
0	0	2	Arsenic
0	0	3	Barium
0	0	4	Beryllium
0	0	5	Bismuth
0	0	6	Boron
0	0	7	Bromine
0	0	8	Cadmium
0	0	9	Cesium
0	1	0	Chromium
0	1	1	Cobalt
0	1	2	Columbium
0	1	3	Copper
0	1	4	Fluorine (fluorite)
0	1	5	Gallium
0	1	6	Germanium
0	1	7	Gold

(Code Q, Continued)

Column			
59	60	61	Major Value Ore
0	1	8	Hafnium
0	1	9	Helium
0	2	0	Indium
0	2	1	Iodine
0	2	2	Iron
0	2	3	Lead
0	2	4	Lithium
0	2	5	Magnesium
0	2	6	Manganese
0	2	7	Mercury
0	2	8	Molybdenum
0	2	9	Nickel
0	3	0	Nitrogen
0	3	1	Platinum group
0	3	2	Radium
0	3	3	Rare earth metals
0	3	4	Rhenium
0	3	5	Rubidium
0	3	6	Scandium
0	3	7	Selenium

(Code Q, Continued)

Column			
59	60	61	Major Value Ore
0	3	8	Silicon
0	3	9	Silver
0	4	0	Sodium
0	4	1	Strontium
0	4	2	Sulfur and pyrite
0	4	3	Tantalum
0	4	4	Tellurium
0	4	5	Thallium
0	4	6	Thorium
0	4	7	Tin
0	4	8	Titanium
0	4	9	Tungsten
0	5	0	Uranium
0	5	1	Vanadium
0	5	2	Yttrium
0	5	3	Zinc
0	5	4	Zirconium
0	5	5	Abrasives
0	5	6	Anthracite coal
0	5	7	Aplites

(Code Q, Continued)

Column			
59	60	61	Major Value Ore
0	5	8	Asphalts
0	5	9	Asbestose
0	6	0	Bentonite
0	6	1	Bituminous coal
0	6	2	Bleaching clay
0	6	3	Chalk
0	6	4	Clay
0	6	5	Corundum
0	6	6	Crushed stone
0	6	7	Cryolite
0	6	8	Diamond
0	6	9	Diatomite
0	7	0	Dimension stone
0	7	1	Feldspar
0	7	2	Garnet
0	7	3	Gem stone
0	7	4	Granules
0	7	5	Graphite
0	7	6	Gypsum
0	7	7	Kyanite - sillmanite group

(Code Q, Continued)

Column			
59	60	61	Major Value Ore
0	7	8	Light weight aggregate
0	7	9	Lignite coal
0	8	0	Limestone
0	8	1	Magnesite
0	8	2	Mica
0	8	3	Mineral filler
0	8	4	Mineral pigment
0	8	5	Minor industrial minerals
0	8	6	Monazite
0	8	7	Nitrogen compounds
0	8	8	Oil Shale
0	8	9	Perlite
0	9	0	Petroleum
0	9	1	Phosphates
0	9	2	Potash
0	9	3	Pumice
0	9	4	Pyrophyllite
0	9	5	Quartz crystal
0	9	6	Refractories
0	9	7	Sand and gravel

(Code Q, Continued)

Column			
59	60	61	Major Value Ore
0	9	8	Slate
0	9	9	Talc
1	0	0	Topaz
1	0	1	Tripoli
1	0	2	Water
1	0	3	Wollastonite
1	0	4	Nepheline

CODE R

Column	
62	Value of Ore Produced (1947-1949 Base)
12	00 - $10,000
11	$10,000 - $50,000
0	$50,000 - $100,000
1	$100,000 - $250,000
2	$250,000 - $500,000
3	$500,000 - $1,000,000
4	$1,000,000 - $10,000,000
5	$10,000,000 - $50,000,000
6	$50,000,000 - $100,000,000
7	$100,000,000 - $250,000,000
8	$250,000,000 - $500,000,000
9	$500,000,000 - or more

CODE S

Column 63	Estimated Total Tons Reserve
12	0 - 100
11	100 - 1,000
0	1,000 - 10,000
1	10,000 - 100,000
2	100,000 - 500,000
3	500,000 - 1,000,000
4	1,000,000 - 25,000,000
5	25,000,000 - 50,000,000
6	50,000,000 - 100,000,000
7	100,000,000 - 200,000,000
8	200,000,000 - 300,000,000
9	300,000,000 - plus

CODE T

Column 64	Potential for Further Exploration
12	Mined out, additional reserves unlikely
11	Known reserves depleted, exploration warranted
0	Deeper exploration warranted
1	Horizontal ore extension of vein likely
2	Parallel veins likely
3	Limits of deposit unknown
4	Bedded deposit, limits unimportant
5	Limits of reserve known
6	Ore remains
7	
8	
9	

CODE U

Column	
65	Reasons for Closing Mine
12	All reserves mined out
11	1941 gold order
0	Drop in metal prices
1	Development of other lower-cost reserves
2	Inadequate mine openings
3	Milling or smelting processes made poor recovery
4	Excessive transportation costs
5	Inadequate financing
6	Poor management or litigation
7	Excessive mine support problems
8	Excessive water at depth
9	Excessive heat at depth

CODE V

Columns 66, 68, 70, 72 and 74	Columns 67, 69, 71, 73 and 75	Bibliography
0	0	American Geological Institute Report (AGI)
0	1	American Institute of Mining, Metallurgical, and Petroleum Engineers Transactions
0	2	American Minerologist
0	3	Colorado Geological Survey Bulletin
0	4	Colorado Scientific Society Proceedings
0	5	Consulting Engineers Reports
0	6	Data from Mining Company Files
0	7	Economic Geology
0	8	Engineering and Mining Journal
0	9	Geological Society of America Bulletin
1	0	Geological Society of America Engineering Geology Case Histories
1	1	Geological Society of America Memoirs
1	2	Geological Society of America Proceedings
1	3	Geological Society of America Special Papers
1	4	Geotimes
1	5	Journal of Geology
1	6	Mineral Industries

(Code V, Continued)

Columns 66, 68, 70, 72 and 74	Columns 67, 69, 71, 73 and 75	Bibliography
1	7	Mineral Industries Journal
1	8	Mineralogist, The
1	9	"Mines" Magazine
2	0	Mining Congress Journal
2	1	Mining Engineering
2	2	Mining Journal
2	3	Mining World
2	4	Personal visit for card preparation
2	5	Tungsten Mines of Colorado
2	6	United States Bureau of Mines Annual Report of the Director
2	7	United States Bureau of Mines Bulletins
2	8	United States Bureau of Mines Charts
2	9	United States Bureau of Mines Cooperative Publication
3	0	United States Bureau of Mines Data Books
3	1	United States Bureau of Mines Economic Paper
3	2	United States Bureau of Mines Handbook
3	3	United States Bureau of Mines Information Circular
3	4	United States Bureau of Mines Manuscript Report

(Code V, Continued)

Columns 66, 68, 70, 72 and 74	Columns 67, 69, 71, 73 and 75	Bibliography
3	5	United States Bureau of Mines Map
3	6	United States Bureau of Mines Mineral Resources
3	7	United States Bureau of Mines Minerals Yearbook
3	8	United States Bureau of Mines Miners Circulars
3	9	United States Bureau of Mines Monographs
4	0	United States Bureau of Mines Periodical Reports
4	1	United States Bureau of Mines Report of Investigations
4	2	United States Bureau of Mines Schedules
4	3	United States Bureau of Mines Technical Papers
4	4	United States Geological Survey Annual Report
4	5	United States Geological Survey Bulletin
4	6	United States Geological Survey Circualr
4	7	United States Geological Survey Coal Investigation Map
4	8	United States Geological Survey Folio
4	9	United States Geological Survey Geological Quadrangle Map
5	0	United States Geological Survey Geophysical Investigation Map
5	1	United States Geological Survey Hydrological Investigation Atlas

(Code V, Continued)

Columns 66, 68, 70, 72 and 74	Columns 67, 69, 71, 73 and 75	Bibliography
5	2	United States Geological Survey Mineral Investigation Studies Map
5	3	United States Geological Survey Mineral Investigation Reserves Map
5	4	United States Geological Survey Miscellaneous Geological Investigation Map
5	5	United States Geological Survey Monographs
5	6	United States Geological Survey Oil and Gas Investigation Map
5	7	United States Geological Survey Professional Papers
5	8	United States Geological Survey Topographic Maps
5	9	United States Geological Survey Water Supply Papers
6	0	Colorado School of Mines Graduate Thesis
6	1	Colorado School of Mines Mining Department Thesis (431)
6	2	Colorado State Bureau of Mines Reports

CODE W

Punch	Column 76	Column 77	Column 78	Column 79
	Gangue Minerals			
12	Quartz	Calcite	Barite	Tourmaline
11	Siderite	Ankerite	Tremolite	Alunite
0	Beidellite	Dickite	Zircon	Dolomite
1	Magnetite	Hematite	Polydymite	Augite
2	Apatite	Chlorite	Sillimanite	Wollastonite
3	Marcasite	Pyrite	Limonite	
4	Sericite	Kaolin	Carbonate	
5	Rhodachrocite	Chalcedony	Argillite	
6	Fluorite	Epidote	Opal	
7	Garnet	Polybasite	Allophane	
8	Arsenopyrite	Illmenite	Cimolite	
9	Manganosiderite	K-Feldspar	Adularia	

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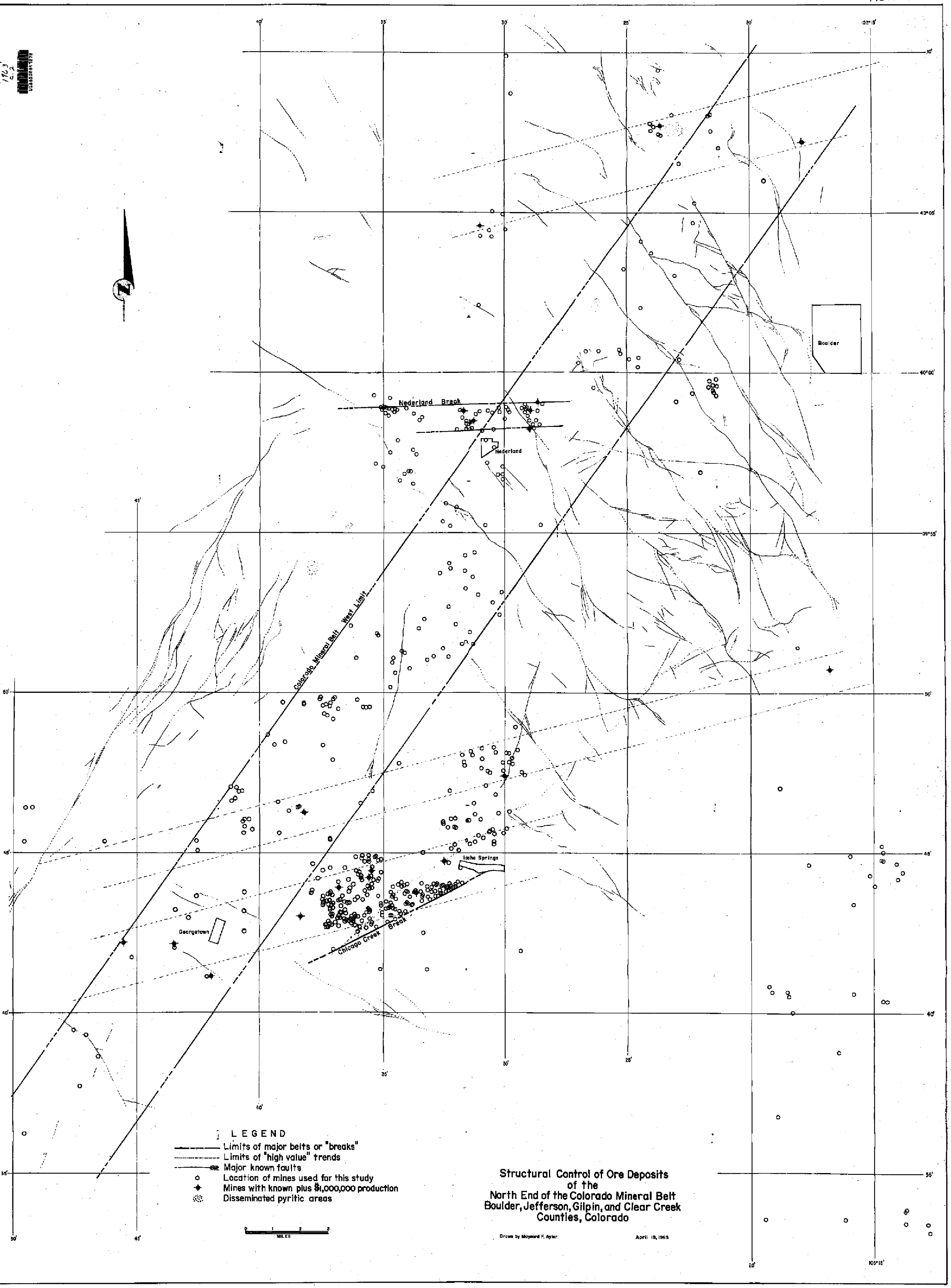
Plate 1



Nederland Break
Nederland
Boulder
Idaho Springs
Georgetown
Chicago Creek Break
Colorado Mineral Belt West Limit
LEGEND
Limits of major belts or "breaks"
Limits of "high value" trends
Major known faults
Location of mines used for this study
Mines with known plus $1,000,000 production
Disseminated pyritic areas
MILES
Structural Control of Ore Deposits
of the
North End of the Colorado Mineral Belt
Boulder, Jefferson, Gilpin, and Clear Creek
Counties, Colorado
Drawn by Maynard F. Ayler
April 19, 1965