COLORADO SCIENTIFIC SOCIETY PROCEEDINGS

VOLUME 13
No. 5

PUBLISHED BY THE SOCIETY
DENVER, COLORADO
1933

COLORADO SCIENTIFIC SOCIETY

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Denver Public Library, Denver, Colo.

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[Presented before the Society January 28, 1933]

VEIN SYSTEMS OF THE ARRASTRE BASIN AND REGIONAL GEOLOGIC STRUCTURE IN THE SILVERTON AND TELLURIDE QUADRANGLES, COLORADO[1]

W. S. BURBANK[2]

CONTENTS

ILLUSTRATIONS

[1]Published by permission of the Director of the U. S. Geological Survey, the Colorado Geological Survey Board, and the Colorado Metal Mining Fund.
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INTRODUCTION

The special area described in this paper is in the San Juan Mountains of southwestern Colorado and comprises a portion of the south-central part of the Silverton quadrangle a few miles west of the Continental Divide and tributary to the drainage system of the Animas River. The results published herein present a summary of progress in the detailed geologic study of Silverton and vicinity where recent successful mining developments have demonstrated that an adequate appreciation of geologic structure would be particularly helpful in ore hunting. The work has been conducted by the United States Geological Survey in cooperation with the State of Colorado and the Colorado Metal Mining Fund. This paper is based in part on 7 weeks of field work in the autumn of 1932, when the writer was assisted by C. Douglass Hier, and in part on several previous seasons that had been spent in mapping portions of the northwestern part of the Silverton quadrangle and the northeastern part of the Telluride quadrangle. A small amount of time was devoted to general reconnaissance throughout the western San Juan region.

Acknowledgment is due especially to the author's colleagues in the Colorado work, Messrs. E. B. Eckel and E. N. Goddard, for their assistance during these other field seasons, and to Mr. T. S. Lovering for valuable suggestions in the presentation of the structural problems. The writer wishes also to acknowledge the cooperation of the officials and engineering staff of the Shenandoah-Dives Mining Co., and access to maps and other data furnished both by this company and the western mining department of the American Smelting & Refining Co.

The writer has been greatly aided by the reports on the geology of the Silverton quadrangle by Cross and others[3] and on the economic geology of the Silverton quadrangle by Ransome.[4] These reports have provided the foundation for the recent more detailed work.

[3]Cross, Whitman; Howe, Ernest; and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Silverton folio (No. 120), 1905.

[4]Ransome, F. L., A report on the economic geology of the Silverton quadrangle, Colorado: U. S. Geol. Survey Bull. 182, 1901.

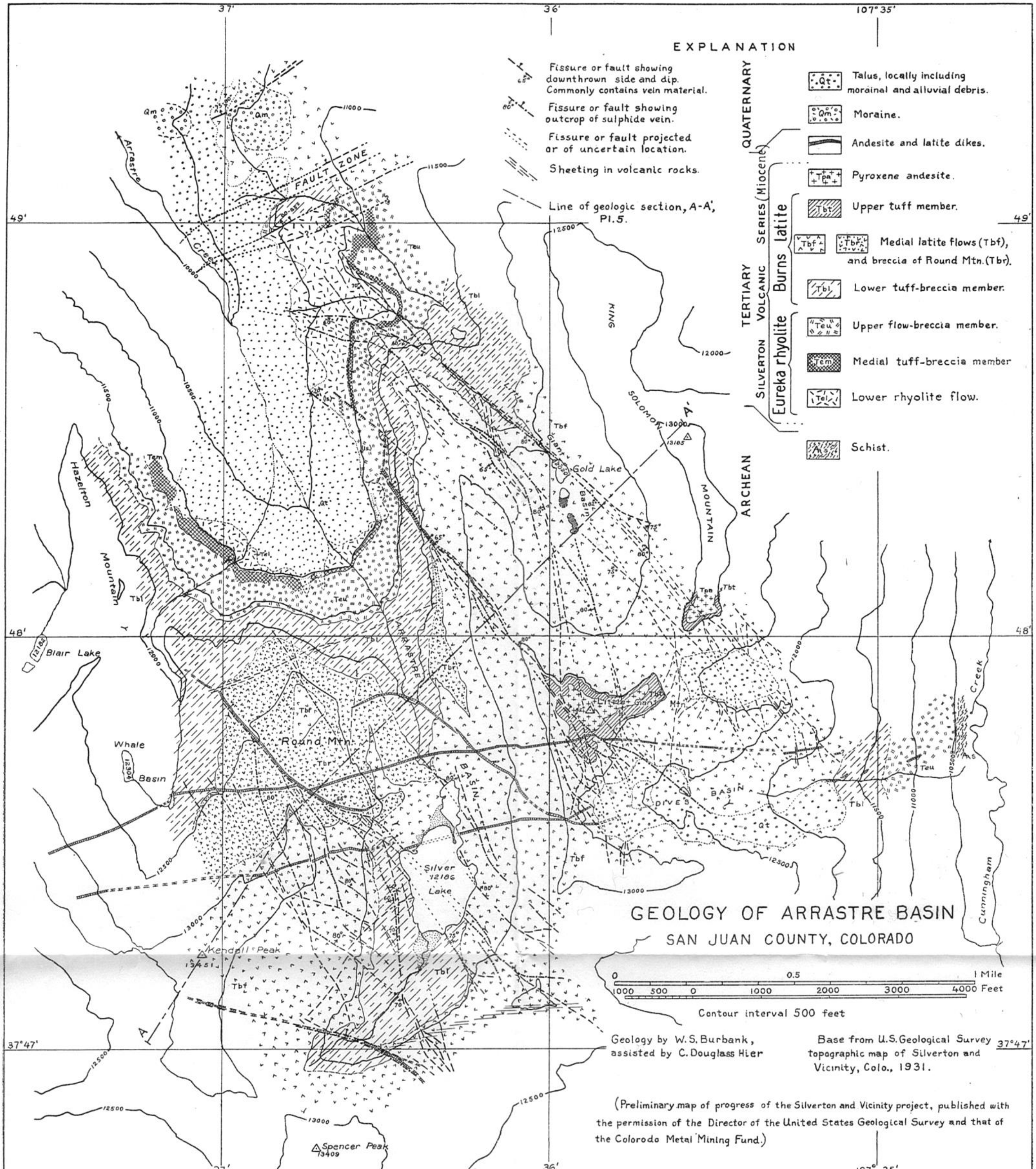


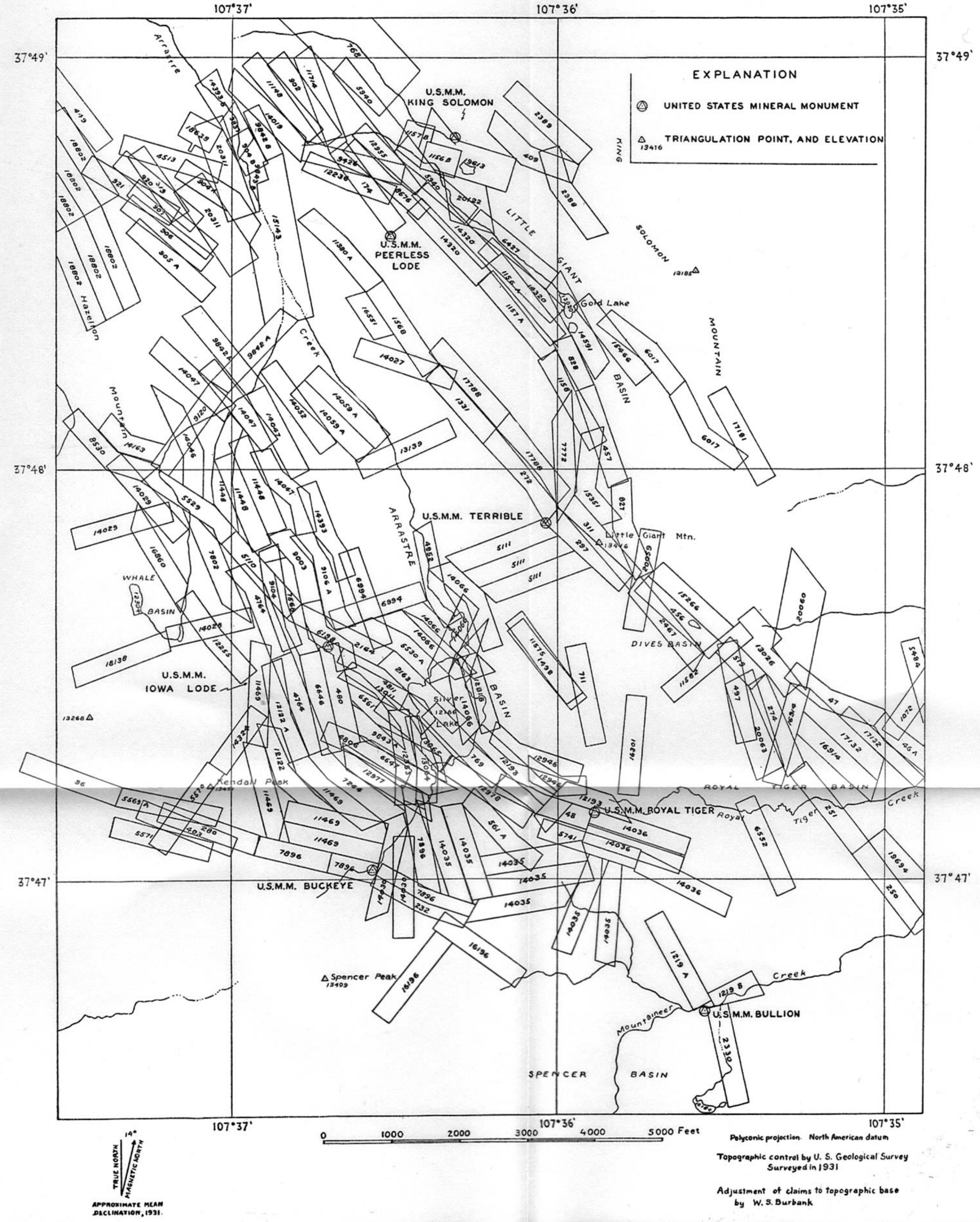
PLATE I. Geology of Arrastre Basin, San Juan County, Colorado.

Both during field studies in the San Juan region as a whole and during those in the Arrastre Basin area it became apparent that a clear understanding of local conditions of mineralization and structure necessitated a broad perspective view of the major structural features of the Silverton and Telluride region. Although it is not the primary intention of this paper to attempt such a review of the San Juan region, the Arrastre Basin area exhibits important key structural features that have assisted greatly in bringing together many seemingly unrelated and detached structural problems. It seems advisable, therefore, to include in this report a review of the regional structure and mineralization of the Silverton and Telluride quadrangles, and to coordinate these features with the detailed description of Arrastre Basin. The formations, geologic history, and general structure of the Animas Valley and Arrastre Basin regions are described first, and coordination of the major structural features with those of the Silverton and Telluride quadrangles is then presented, with a brief review of the regional mineralization. The final part of the paper describes in more detail the geologic features controlling mineralization in Arrastre Basin which represents one type of province or sector in what appears to be a regional unit of great extent. It is important, however, to remember that in other sectors or areas of the Silverton-Telluride region different geologic features may have controlled the localization of ore, and it is not the intention to represent the Arrastre Basin area as a type for all areas similarly situated in relation to the major structure.

The geology of the special area near Arrastre Basin described in this report is shown on plate I, and the relation of the geologic features to the groups of claims may be obtained from plate II, a claim map of Arrastre Basin and vicinity which has been adjusted to the topographic base used. Adjustment of claims to a topographic base is necessarily approximate and cannot of course represent the exact or legal position of such claims relative to geologic features.

PLATE II

Claim map of Arrastre Basin and vicinity compiled from the records of the General Land Office and adjusted to base of topographic map of Silverton and vicinity, Colorado.



LIST OF MINING CLAIMS ON PLATE II

In Order of Patent Number

Mineral Survey No.	Name of Claim or Claims
46	Highland Mary
47	Robert Bruce
48	Royal Tiger
96	Seymour
174	Peerless
232	Buckeye
250	Lookout
251	Mountaineer
272	Terrible
274	Shenandoah
280	Bear
297	North Star
311	Yellow Jacket
403	Titusville
409	King Solomon
449	Mammoth
456	Dives
457	Potomac
480	Iowa
497	Queen
519	Shenandoah No. 3
561A	Diamond L
711	Eclipse
768	North Star Placer
769	Royal Tiger No. 1
827	Cremorne
828	General Garfield
902	Little Giant
904A	Ezra R
904B	Millsite
905A	Peacock
906	Oriental
907	Little Belle
919	Toledo
920	Tom Paine
921	Lucy
1072	Long Tom
1156A	Big Giant
1156B	Millsite
1157A	Mountain Quail
1157B	Millsite
1158	Republic
1219A	Annie
1219B	Millsite
1331	Slide
1498	Sina Loa
1568	Mayflower
2163	Gretchen
2164	Silver Lake
2330	Bullion
2388	Jura
2389	Mountain Queen
2467	North Star Fractional
4513	Gray Eagle
4764	Whale—Rochester
4806	Cabo
4811	Black Diamond
4952	Martha V. F.
5110	Round Mountain
5111	Little Shaver
	Cross Cut
	Good Fortune
5484	Highland Chief
5529	Lowville
5530A	Maxwell
5569A	Caroline
5570	Leucosticte
5571	Solstice
5741	Home Stake
5940	Silver Crown—Esmaraldo
6017	Night Bird—Wilhelm
6198	Royal
6427	Black Prince
6552	Big Pine
6561	J. W. Collins
6646	Stag
6647	Grip
6994	Silver Lake Spur
	Arabian Boy
7244	American Boy
7568	Professor Stelzner
7772	North Star Extension
7802	Lena Allen
7896	Panuco—Last Chance
	Buckeye No. 2—Dandy
8530	Nevada
8676	Emma S
9003	Rivington Street
9104	New York City
9106A	Essex Street
9120	Unity
9426	Jess
9837	Iowa Millsite
9842A	El Paso—Professor Winkler
9842B	Millsite
9843A	Dump
9843B	Dump Millsite
11148	Iron Mask
11380A	Argentine
11448	Badger—Galena—Last Chance
11469	Professor Wedding
	Professor Zeuner
	Professor Weisback
	Cairo—Algiers
11575	Lake View
11582	Spotted Pup
11714	Golden Fleece
12122	Jaffa—Smyrna
12193	Cub—Last Chance
12236	Charles Clinton
12255	J. H. R.
12353	Melville
12818	Lakeside
12946	Hillside—Exploit
12955	Black Prince Extension
12977	Elk
12978	Club
13011	White Diamond
13026	Elizabeth
13064	Lake Shore
13065	Key
13139	Galicia Boy
14019	Illinois
14027	Snow Shed
14028	Professor Richter
14029	Smuggler—Sedalia
14030	Manila—General Meritt
14035	Magnolia—Jamaica
	Naples—Kingston
	Porto Rico—Lake View
	Monte Carlo
14036	Tiger Extension No. 2
	Barbadoes—Emma
14046	Professor Newberry
14047	LaVeta—Freiberg
	Professor Chandler
	General Hallock
14052	Von Cotta
14059A	Little Forest—Cascade
14066	Jupiter—Eckley Coxe
	Professor Percy
	General Hale—General Miles
14163	Jocko
14320	Contention—Dreadnaught
	Big Giant Extension
14324	Leyner
14393A	Gold Bug
14393B	Millsite
14591	Gold Lake
15143	Adams Placer
15266	Miles Johnson
15351	Huntington
15466	McMillan
16196	Ohio Boy—Producer
16301	Trilby
16551	Mayflower No. 2
16860	Gray Eagle
16914	Oregon Ship—Hobson
17132	Oregon Ship No. 2
	Oregon Ship No. 3
17181	Poffabro
17788	Togo—Kuroki
18138	Stonewall
18638	Gray Eagle Millsite
18802	Hamilton—Montreal
	Quebec—Glasgow
	London—Dublin
19613	Eufemia
19694	Edgar
20059	Dives Fraction
20060	Cora Nelie Zoe
20063	Midget
20122	Seetee
20311	Intervention
	Gunnison

LIST OF MINING CLAIMS ON PLATE II

Alphabetical

Name of Claim or Claims	Mineral Survey No.
Adams Placer	15143
Algiers	11469
American Boy	7244
Annie	1219A
Arabian Boy	6994
Argentine	11380A
Badger	11448
Barbadoes	14036
Bear	280
Big Giant	1156A
Big Giant Extension	14320
Big Pine	6552
Black Diamond	4811
Black Prince	6427
Black Prince Extension	12955
Buckeye	232
Buckeye No. 2	7896
Bullion	2330
Cabo	4806
Cairo	11469
Caroline	5569A
Cascade	14059A
Charles Clinton	12236
Club	12978
Contention	14320
Cora Nelie Zoe	20060
Cremore	827
Cross Cut	5111
Cub	12193
Dandy	7896
Diamond L	561A
Dives	456
Dives Fraction	20059
Dreadnaught	14320
Dublin	18802
Dump	9843A
Dump Millsite	9843B
Eckley Coxe	14066
Eclipse	711
Edgar	19694
Elizabeth	13026
Elk	12977
El Paso	9842A
Emma	14036
Emma S.	8676
Esmeralda	5940
Essex Street	9106A
Eufemia	19613
Exploit	12946
Ezra R.	904A
Freiberg	14047
Galena	11448
Galicia Boy	13139
General Garfield	828
General Hale	14066
General Hallock	14047
General Meritt	14030
General Miles	14066
Glasgow	18802
Gold Bug	14393A
Gold Lake	14591
Golden Fleece	11714
Good Fortune	5111
Gray Eagle	4513
Gray Eagle	16860
Gray Eagle Millsite	18638
Gretchen	2163
Grip	6647
Gunnison	20311
Hamilton	18802
Highland Chief	5486
Highland Mary	46
Hillside	12946
Hobson	16914
Home Stake	5741
Huntington	15351
Illinois	14019
Intervention	20311
Iowa	480
Iowa Millsite	9837
Iron Mask	11148
Jocko	14163
Jaffa	12122
Jamaica	14035
Jess	9426
J. H. R.	12255
Jupiter	14066
Jura	2388
J. W. Collins	6561
Key	13065
King Solomon	409
Kingston	14035
Kuroki	17788
Lake Shore	13064
Lakeside	12818
Lake View	11575
Lake View	14035
Last Chance (See Panuco—Buskeye No. 2—Dandy	7896
Last Chance (See Badger—Galena)	11448
Last Chance (See Cub)	12193
La Veta	14047
Lena Allen	7802
Leucosticte	5570
Leyner	14324
Little Belle	907
Little Giant	902
Little Forest	14059A
Little Shaver	5111
London	18802
Long Tom	1072
Lookout	250
Lowville	5529
Lucy	921
Magnolia	14035
Mammoth	449
Manila	14030
Martha, V. F.	4952
McMillan	15466
Maxwell	5530A
Mayflower	1568
Mayflower No. 2	16551
Melville	12253
Midget	20063
Miles Johnson	15266
Millsite	904B
Millsite	1156B
Millsite	1157B
Millsite	1219B
Millsite	9842B
Millsite	14393B
Monte Carlo	14035
Montreal	18802
Mountaineer	251
Mountain Quail	1157A
Mountain Queen	2389
Naples	14035
Nevada	8530
New York City	9104
North Star	297
North Star Extension	7772
North Star Fractional	2467
North Star Placer	768
Night Bird	6017
Ohio Boy	16196
Oregon Ship	16914
Oregon Ship No. 2 Oregon Ship No. 3	17132
Oriental	906
Panuco	7896
Peacock	905A
Peerless	174
Paffabro	17181
Porto Rico	14035
Potomac	457
Producer	16196
Professor Newberry	14046
Professor Chandler	14047
Professor Percy	14066
Professor Richter	14028
Professor Stelzner	7568
Professor Wedding	11469
Porfessor Weisback	11469
Professor Winkler	9842A
Professor Zeuner	11469
Quebec	18802
Queen	497
Republic	1158
Rivington Street	9003
Robert Bruce	47
Rochester	4764
Round Mountain	5110
Royal	6198
Royal Tiger	48
Royal Tiger No. 1	769
Sedalia	14029
Seetee	20122
Seymour	96
Shenandoah	274
Shenandoah No. 3	519
Silver Crown	5940
Silver Lake	2164
Silver Lake Spur	6994
Sina Loa	1498
Slide	1331
Smuggler	14029
Smyrna	12122
Snow Shed	14027
Solstice	5571
Spotted Pup	11582
Stag	6646
Stonewall	18138
Terrible	272
Togo	17788
Toledo	919
Tom Paine	920
Tiger Extension No. 2	14036
Titusville	403
Trilby	16301
Unity	9120
Von Cotta	14052
Whale	4764
White Diamond	13011
Wilhelm	6017
Yellow Jacket	311

Geologic Formations and History

Prevolcanic Rocks

Archean schist

Dark-colored schist of Archean age is exposed in Cunningham Gulch, in the eastern part of the area shown on plate I, but only a short stretch of the contact with the overlying volcanic rocks is shown. This contact represents part of the irregular prevolcanic surface of considerable local relief and was produced by erosion at different periods. The first period preceded the deposition of the Telluride conglomerate, of early Tertiary (Oligocene?) age, and another preceded the eruption of the Eureka rhyolite, of Miocene age. The schist is a finely laminated rock composed of different-textured bands of feldspar, quartz, amphiboles, and mica, with some products of milder metamorphism, as chlorite, quartz, and epidote. The schistosity in this area strikes northeast and commonly dips steeply, but local crumpling and folding has produced zones of nearly horizontal schistosity. The structure of the schist has not been studied, but a comparison of schistosity trends with fissuring in the overlying volcanic formations suggests that the basement structure has not greatly influenced lines of late Tertiary faulting and fissuring. Ransome comes to this conclusion in his report on the economic geology of the Silverton area.[5] He states, however, "In general it is apparently true that the fissures in the Algonkian [pre-Cambrian] rocks tend to be simpler and narrower than those in the volcanic rocks of later age." Ore bodies have been found in the schist of Cunningham Gulch.

Paleozoic sedimentary rocks

There are several small bodies of Paleozoic sedimentary rocks in Cunningham Gulch at positions above the Archean schists, but none of them appear within the area mapped on plate I. In a down-faulted block above the Highland Mary mine these rocks lie in normal sequence upon the schist; they comprise the Elbert formation and Ouray limestone, of Upper Devonian age; the Leadville limestone, of Mississippian age;

[5]Ransome, F. L., op. cit., pp. 53-55.

and locally thin layers of the Molas formation, of early Pennsylvanian age. The total section is about 300 feet to 350 feet in thickness. The higher formations of the Carboniferous are not preserved, having been removed by erosion in the intervals preceding and following the deposition of the Telluride conglomerate before the Miocene volcanic eruptions. On both sides of Cunningham Gulch near the Pride of the West mine bodies of limestone are apparently engulfed in eruptions of Eureka rhyolite age. These remnants of Paleozoic rocks are only of interest as showing that pre-Eureka erosion had barely stripped these rocks from this area and that fragments of them may be locally included in the volcanic formations. They are not likely to be found within the area mapped on plate I except under the particular conditions described.

Telluride Conglomerate

The Telluride conglomerate rests upon an erosion surface of low relief, approximating a plain, which separates the rocks of prevolcanic time from those of the volcanic epoch. The conglomerate does not crop out near Arrastre Basin but is exposed at the base of the San Juan tuff throughout the Ouray and Telluride quadrangles and at a few places in the Silverton quadrangle. South of Arrastre Basin on the ridge west of Whitehead Peak the conglomerate crops out at an altitude of 12,500 feet, and also on the north side of Mountaineer Creek between the tuff and schist at altitudes between 11,500 and 12,000 feet. The conglomerate, which is of Oligocene (?) age, is of nonvolcanic character and composed entirely of pre-Tertiary or early Tertiary rocks eroded from the domelike uplift of the ancestral San Juan Mountains in late Cretaceous and early Tertiary time. Remnants of the old erosion surface occur over a large part of the area covered by the first eruption of volcanic rocks and are significant of the extent and level character of this surface.

Volcanic Formations

San Juan tuff

The San Juan tuff comprises tuffs, breccias, and conglomeratic beds that were the first accumulations of volcanic debris upon the denuded surface of the early Tertiary San Juan Mountains. The tuffs rest in some places upon the Telluride conglomerate and in others directly upon surfaces of older rocks that formed the ancient mountains. It is composed almost exclusively of fine-grained andesitic and latitic lava, and very little if any of the original San Juan tuff includes fragments of rhyolite. This lack of rhyolite assists in distinguishing the original San Juan tuff from later accumulations of debris eroded from this formation that are interbedded with rhyolite lavas of Eureka age.

The San Juan tuff is not exposed in the vicinity of the Arrastre Basin and probably does not underlie much if any of the area, as it was locally removed by pre-Eureka erosion. Cross and Howe[6] mention evidence within the Silverton quadrangle that suggests another important erosion interval that followed the deposition of the Telluride conglomerate and preceded the eruption of the San Juan tuff. The present studies south of the Animas Valley indicate, however, that certain bodies of volcanic debris mapped in the Silverton folio as San Juan tuff are in reality composed of material derived from the erosional destruction of highlands of unconsolidated San Juan tuff that lay to the south of the Arrastre Basin area. This debris is believed to have been deposited during valley-cutting intervals that followed the eruptions of San Juan tuff and preceded and accompanied eruptions of the Eureka rhyolite. The bodies of breccia in Arrastre Basin which were mapped as San Juan tuff in the Silverton folio, but of whose correct identification Cross and Howe[7] expressed uncertainty, have proved to represent beds of reworked andesitic debris interbedded in the Eureka flows. Considerable alteration in the vicinity and slides of surficial material have combined to obscure the local geologic contacts, but the tracing of this andesitic breccia horizon between flows of the Eureka rhyolite around the head of Arrastre Gulch establishes its correct age. Although the geologic relations at other places in the quadrangle suggest that the post-Telluride and pre-San Juan ero-

[6]Cross, Whitman, and Howe, Ernest, op. cit. (folio 120), p. 21.
[7]Idem, p. 17.

sion interval suggested by Cross has basis in fact, this interval is not recorded in Arrastre Basin.

A few miles south of Arrastre Basin remnants of San Juan tuff are found on slopes adjacent to Whitehead Peak and bordering the head of Cunningham Gulch. The maximum thickness of these remnants is about 1,500 feet, and it is probable that they represent highlands of San Juan tuff that stood high above the level of the rhyolite flows in Arrastre Basin during Eureka time, and provided much if not all of the andesitic debris interbedded with the rhyolites.

Silverton volcanic series

Eureka Rhyolite

Subdivisions and Character

The Eureka rhyolite is the second formation of the Silverton series but the oldest exposed near Arrastre Basin. The Picayune volcanic group, which is the lowermost division, has not been identified in this area. The eruptions of the Silverton series were separated from those of the San Juan tuff by an epoch of erosion that produced deep valleys and removed probably most of the San Juan tuff from the basement beneath Arrastre Basin. In Cunningham Gulch, southeast of the area mapped, the old erosion surface that cuts down across the San Juan tuff from a point near the head of the gulch to the Archean schist near the Green Mountain mine illustrates the local slope of one of these valley sides.

Subdivision of the Eureka rhyolite has been attempted in the present work because of the advantage of smaller stratigraphic units for mapping on a scale of 1 inch to 1,000 feet. The units adopted have been found to persist throughout the Arrastre Basin area but may be subject to further revision to conform with the stratigraphy of surrounding areas. They consist of a lower rhyolite flow, a medial tuff-breccia member, and an upper flow-breccia member, but the complexity of the Eureka eruptions makes it difficult to apply adequately descriptive names.

The lower rhyolite flow comprises a series of thick flows of rhyolite or quartz latite, probably not numbering more than three individual eruptions. These flows thin out near the head of Cunningham Gulch, but reach a total thickness of about 2,000 feet in the walls of the Animas Valley near the town of Eureka, where this member represents the type section of the Eureka rhyolite in the Silverton quadrangle. The lava flows are normally grayish to dark greenish, contain numerous small inclusions of rhyolite fragments and of foreign fine-grained andesitic rocks, and have a linear and platy flow structure that locally assists in determining their attitude and mode of emplacement. The groundmass of the lava is dense or subcrystalline in appearance but, as Cross has shown, is generally a finely crystalline mass composed partly of devitrified glass. This texture of the base accounts for a pronounced brittleness of the lavas and a resulting tendency to complex fissuring. The lava is high in silica, alkalies, and lime and low in magnesia and iron—a composition that favors the alteration of thoroughly fractured rock near veins to soft masses composed largely of sericitic minerals. Such alteration produces gouges that tend to seal fault fissures.

The general opinion based upon mining experience in the district classifies the Eureka rhyolite flows as rocks unfavorable to the occurrence of ore bodies, but such a broad generalization must be applied with caution and with due regard to local conditions. The strength and origin of fissuring and the presence of andesitic dikes along the fissured zones may largely offset the unfavorable characteristic of the wall rocks. Also their position near the base of the volcanic succession may in part account for a smaller production from this series of flows, as the greater cover would tend to decrease the size of open spaces. This decrease may offset the tendency of certain ores to contain increasing amounts of gold and copper and decreasing amounts of lead and silver at greater depths.

The characteristic occurrence of these flows near Arrastre Basin is in the bottoms of Arrastre and Cunningham Gulches just south of the Animas Valley fault zone, to the north of which they are faulted beneath the level of the Animas River. They reappear northeastward on the valley sides, reaching higher altitudes toward Eureka, until at Picayune Gulch they are down-faulted again.

The medial tuff-breccia member of the Eureka represents the beginning of an epoch characterized by erosion and transportation of land waste accompanying eruptions of rhyolite flows and breccias. Only the basal tuffs and conglomeratic beds are mapped as the medial member, and later alterations of flows, breccias, and tuffs are mapped as the upper member. The basal portion of the tuff-breccia in places contains rounded stream-worn pebbles or boulders of pre-Cambrian rocks, such as quartzite, granite, and schist. Arkosic sand and fine-grained tuffaceous sediment are found locally, and in places the entire member is composed of tuffaceous breccia possessing the characteristic appearance and composition of the San Juan tuff. Outcrops of this breccia on cliffs bordering Arrastre Gulch caused the confusion already mentioned regarding the occurrence of San Juan tuff in this area. The abundance of pre-Cambrian and andesitic fragments and the imperfect sorting and rounding of materials forming this member show that highlands south of the Arrastre Basin were the source of debris, for at no other nearby place do these older rocks crop out at positions above the level of the deposits.

The upper flow-breccia member consists of a heterogeneous assemblage of thin lava flows, breccias of andesitic and rhyolitic lavas, and fine-grained tuff beds. Many lavas are characterized by abundant angular inclusions, and some beds of Cunningham Gulch seem to be composed entirely of fragmental material that possessed the property of flowage, as in a mud flow, or contained sufficient fluid lava matrix to flow in a semimolten state. In Arrastre Gulch the basal flow of this member below the Unity tunnel of the Silver Lake mine and at the main portal of the Shenandoah-Dives mine is a grayish-white rhyolite lava, generally free of inclusions but locally with a marked flow structure, as if it had been very viscous at the time of its eruption. The irregular occurrence of this flow at this horizon, its steep, nearly overhanging sides, and a bulbous structure of the flow surface are further indications of its original viscosity. Flows of similar appearance are found locally at higher horizons in the member, but the higher flows are more characteristically reddish, purplish, or greenish, and contain many included fragments. The breccia beds are commonly composed of mixtures of rhyolite and andesite fragments in very chaotic assemblage, but some beds are composed entirely or largely of andesitic debris resembling San Juan tuff. This material presumably represents accumulations of land waste derived from the highlands of San Juan tuff that lay a few miles south, southeast, and southwest of this region. Some of the breccias may represent heavy accumulations of eruptive debris on ancient mountain slopes, which were aided in their descent as landslides or mud flows by heavy rains and local precipitation of volcanic vapors. A topographic relief of not less than 2,000 to 3,000 feet must have existed at the time of the Eureka eruptions.

Relation of productive lodes to Eureka rhyolite

The two higher members of the Eureka rhyolite are locally unfavorable to the occurrence of ore bodies, particularly where they consist chiefly of rhyolite flows, as in the section between the Last Chance and Unity tunnel levels of the Silver Lake mine. It is reported that the mineralized rock between these levels was below commercial grade within the extent of exploration, both on the New York vein and on the main Silver Lake vein. The deep workings on the New York vein lie beneath the very productive New York ore shoot, the walls of which consist of the breccia beds of Round Mountain, a local member of the Burns latite. (See plate V, C and D.) As there is no dike and very little dislocation by faulting along the New York vein fissure, either in the productive part of the lode in the Burns latite or in the nonproductive part in the Eureka rhyolite, and as the division between these parts corresponds approximately to the Eureka-Burns contact, it seems probable that the rhyolite flows formed the chief unfavorable factor that accounts for the narrowness and unproductivity of the vein at deeper levels. (See plate V.) Along the Silver Lake vein itself mineralization was irregularly distributed at both higher and lower levels, and the vein walls probably consist in part of the andesitic dike along which the faulting and fissuring were localized. Other features, such as the large dislocation by faulting along the fissure and the local trend and comparatively flat dip of the fault plane, were probably determining factors in ore localization, so that the effects of different wall rocks were minimized. Thus developments on the Silver Lake vein itself can hardly be considered a fair test of the favorability of the different formations that constitute its walls. (See pp. 191-192.)

The productive ore body underlying the Mayflower claim of the Shenandoah-Dives mine was within the rhyolite flow-breccia member of the Eureka rhyolite, and here again as in the Silver Lake vein, factors other than the physical properties of the rhyolite determined the ore localization. An andesitic dike forms locally one or both walls of this vein, and fault fissures localized by the dike controlled the distribution of open spaces later filled by ore and other vein matter (see pp. 185-191). At still other places, however, these two upper members of the Eureka rhyolite consist largely of andesitic material that differs but little from the San Juan tuff and so possesses none of the unfavorable physical and chemical properties characteristic of the rhyolite flows.

In conclusion, the upper members of the Eureka rhyolite are not invariably unfavorable wall rocks except where they are composed entirely or largely of the lava flows, and even in such places due consideration must be given to local structure, such as the presence of dikes, which increase the chances of favorable fissuring, or to such factors as the character of fault movements along fissures and the dips of fault planes which may have either favorable or unfavorable effects, depending on complex conditions unrelated to the properties of the flows themselves. The probable effects of rhyolite flows on different kinds of fissuring controlled by the local strength and origin of fissuring agencies are described more at length on pages 200-202.

Burns Latite

Subdivisions and Character

The third great volcanic formation in the Silverton series of eruptions is the Burns latite. Its rocks differ in composition and texture from those of the Eureka rhyolite and are separated from them where in contact by a well-defined erosion surface that locally truncates the underlying flows of rhyolite. It is apparent that in places a considerable thickness of Eureka lavas must have been removed by stream erosion before the deposition of the Burns breccias and tuffs. In Arrastre Basin this erosion surface was a fairly uniform plain with a moderate eastward to southeastward inclination, locally broken by benches having a relief of 100 feet, but southward and southeastward the surface rises toward the Eureka highlands, and the Burns latite of Green Mountain overlaps the rhyolite onto the San Juan tuff.

In this description and on the map the Burns rocks are divided into three groups—a lower tuff-breccia member, a latite flow member, and an upper tuff member—although it was found that these three could not be strictly separated on a basis of time equivalence or of lithologic character. The groups as adopted were chosen as the most useful divisions for mapping because of their relation to structure and ore deposits.

The lower tuff-breccia member comprises 400 to 500 feet of tuffaceous beds and breccias composed of conspicuously porphyritic latite or quartz-bearing latite, commonly greenish gray. Beds containing boulders rounded by stream action indicate the work of water in distributing and sorting a large part of this debris. Other beds are composed of immense blocks 6 to 8 feet in diameter intermingled with smaller angular fragments and a matrix of fine tuff or sand, showing that their accumulation must have been brought about in part by other agencies of volcanic origin. It may be supposed that some of the fine-grained material was deposited from the air and mingled with debris thrown down the slopes of tuff and breccia cones. These volcanic cones were partly reduced by erosion, and in the small area studied there is no indication of a source or of the distance from which the debris came. The cliffs of the gulches, viewed at a distance, clearly show the bedded nature of the breccias. The breccia structure is much obscured where altered by mineralizing agencies, so that identification is often difficult near veins in underground workings or within altered zones at the surface. Under these circumstances exposures of sufficiently large faces to show the breccia structure are necessary, and the large orthoclase phenocrysts half an inch or more in length, which characterize some of the fragmental material, are helpful indicators.

The surface of the tuff-breccia on which the medial latite flows rest is more irregular than the basal contact of the Burns latite, but there is no indication of a long interval of time or of great erosion between the two members. There are also breccias interbedded with these flows that are nearly indistinguishable from the lower breccias. The typical flows of the latite overlap one another in a most irregular manner and are notable for their two strikingly different facies of crystallization. The distribution of these flow facies and the nature of their contacts indicate that they followed one another quickly and represent only a few major eruptions of lava. These flows, however, accumulated to a thickness of about 1,200 feet. For purposes of description the two facies of solidified lava will be distinguished by the terms "massive facies" and "fluidal facies," but as actually found and as would be expected from their origin, there are complete gradations between the types.

The massive facies is a dark-gray porphyritic lava with hornblende and biotite is clearly defined crystals and locally some magnetite and pyroxene. Plagioclase crystals give the rock its conspicuous porphyritic texture and range from small lath-shaped crystals an eighth of an inch or less in length to stouter rectangular crystals a quarter of an inch or more in diameter. Large orthoclase crystals half an inch in size are less common, and quartz is rare. The groundmass has a subcrystalline or vitreous appearance and in the most massive lava imparts to the rock its brittleness, splintery fracture, and resistance to weathering and erosion. This facies commonly forms jointed and cliffy prominences in contrast to the fluidal facies.

The fluidal facies is distinguished from the massive facies by its lighter-gray or greenish color and by its flow structure, which suggests a lava that has been sheared by its own motion. In chemical composition it probably differs not at all from the massive lava, but it differs much in its crystallization and from casual inspection appears to differ in the proportions and kinds of its constituent minerals. The feldspars, though probably present in much the same proportions and composition as in the massive lava, are less conspicuous on weathered surfaces. Biotite flakes are seen when the rock is broken along its flow lines, but the hornblende, magnetite, and other dark minerals of the massive lava appear to be represented largely by chloritic products and disseminated iron oxides. The massive facies at many places is strongly magnetic, causing local variation of the magnetic needle, but the fluidal facies does not appear to affect the needle.

The structural and mineralogic differences of these two facies seem to be related to different rates of crystallization in the molten lava, which resulted in greater activity of water and gaseous constituents in the fluidal facies, whereas in the vitreous base of the more massive facies these constituents became trapped and inactive. The massive facies forms crusts on the top, sides, and bottom of the fluidal facies and locally occurs as fragments engulfed in it. At other places individual spurts of the flows may be composed entirely of a single facies, but contacts between the two facies where they represent parts of a single mass are completely gradational within distances ranging from a few feet to tens of feet. The emplacement of the main lava bodies must have been attended by complex phenomena, presumably produced by numerous offshoots or spurts given off from the body while still in motion and in a state of comparatively high viscosity. There appears to be no other explanation of the irregular, steep, and at places deformed contacts between the different facies. Earlier geologic reports on Silver Lake Basin and adjacent areas contain suggestions that certain massive rocks are sheets or irregular bodies intrusive into tuffs and other flows of the Burns formation, but several sheetlike bodies that might be regarded as intrusive show features that are recognized as criteria of lava consolidated in the open air. The most definite evidence is the presence of brecciated crusts upon the lava, altered by escaping vapors and containing irregular cavities