THESIS

ORIGIN OF GOLD PLACERS IN THE PIONEER DISTRICT, POWELL COUNTY, MONTANA

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY JEFFREY SCOTT LOEN, ENTITLED "ORIGIN OF GOLD PLACERS IN THE PIONEER DISTRICT, POWELL COUNTY, MONTANA", BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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ABSTRACT OF THESIS

ORIGIN OF GOLD PLACERS IN THE PIONEER DISTRICT,
POWELL COUNTY, MONTANA

This thesis presents a major reinterpretation of the genesis of gold placers in the Pioneer district, near Deer Lodge, Montana. Previous investigators considered the placers to be the result of glacial deposition and reworking of glacial drift by interglacial streams. Results of this study suggest that the oldest placers, however, occur in two Tertiary conglomerates. Placers are also present in Pleistocene glacial outwash and till, and Holocene alluvium and colluvium. Since 1862 an estimated 300,000 fine ounces of placer gold has been produced from the district, the majority of which came from the Tertiary conglomerates. Conglomerate also served as the principal source for gold in Quaternary age placers.

Piedmont slopes in the Pioneer district are underlain by three Tertiary sedimentary sequences separated by unconformities. These are from oldest to youngest: (1) the Cabbage Patch Formation (late Oligocene to early Miocene)--siltstone, mudstone, and volcanic ash deposited in rivers and lakes; (2) the Squaw Gulch beds (Middle Miocene)-siltstone, sandstone, and pebble/cobble conglomerate deposited on alluvial plains by braided streams; and

(3) the Pioneer beds (late Miocene or Pliocene (?))--matrix- and clast-supported boulder/cobble conglomerate and siltstone deposited on alluvial fans by mudflows, debris flows, and braided streams.

The apparent source of the placer gold is base- and precious-metal veins of late Cretaceous age in the northern Flint Creek Range. Gold was released from the veins during deep weathering under moist, warm climatic conditions in Oligocene and early Miocene time. Middle Miocene mountain uplift and the accompanying arid climate triggered deposition of gold-bearing gravel on mountain-front floodplains. Maximum uplift occurred during late Miocene and Pliocene (?) time when coarse gravels were deposited in alluvial fans. As uplift subsided, braided streams reworked the gold-bearing gravels, forming the richest placers. The present drainage system developed during regional stream incision in middle Pliocene to middle Pleistocene time.

Glaciers extended to the margins of the district during four major advances beginning in middle Pleistocene time. Tertiary placers were partly reconcentrated into Pleistocene glacial till and outwash, and Holocene alluvium and colluvium.

Electron microprobe analyses and assay results indicate that lode gold from veins in the northern Flint Creek Range has an average fineness range betweem 800 and 850. Veins in quartzite and slate in the roof zone of the

Royal stock contain higher-fineness gold than do veins in granodiorite of the stock. Placer gold from the Pioneer district typically contains cores averaging 830 to 870 fine and silver-depleted rims ranging from 930 to 1000 fine. The depletion of silver in the rims of the gold grains probably resulted from solution of the silver by low-temperature surface waters.

Production records indicate an average fineness for the district between 875 and 900. These higher production records reflect the influence of thick silver-depleted rims on many of the placer grains.

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Malcom E. McCallum, Michael D. Harvey, and Stephen R. Abt, of Colorado State University, served as thesis advisors. Special thanks go to Dr. McCallum for stimulating discussions and continuing encouragement.

Michael R. Waters suggested the need for a detailed study of the district after an initial study of the district by him in 1984 could not confirm many of J. T. Pardee's interpretations. Dr. Waters freely contributed data and interpretations from his investigation and also discussed geologic features in the field.

The author's wife, Kathleen E. Cohan-Loen, helped with field chores during part of the summer and drafted part of the geologic map.

Chester A. Wallace provided unpublished results of regional studies and raised many pertinent questions in the field.

Mr. and Mrs. Charles A. Brand, of Deer Lodge, Montana, generously supplied specimens of lode and placer gold from their claims and accounts of local mining history.

Ralph P. Christian gave several days of instruction on use of the electron microprobe.

Lyndel Meikle and Phyllis Richter, of the Grant-Kohrs Ranch National Historic Site in Deer Lodge, Montana, provided copies of Mr. Conrad Kohrs' records of placer gold production in the Pioneer district.

Many landowners in the area freely gave permission to work on their property.

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INTRODUCTION

The Pioneer district, near Deer Lodge, Montana, contains productive gold placers that formed in a variety of depositional environments during late Cenozoic time. The deposits occur both in Quaternary stream valleys and on the surfaces of Tertiary age alluvial fans lying hundreds of feet above the present floodplains. Since 1870 the placers have produced approximately 300,000 fine oz of gold worth an estimated $6 million (in value of metal at the time of production).

Previous studies (Lyden, 1948; Pardee, 1951) determined that the oldest gold-bearing unit in the district was glacial drift deposited during the first of three Pleistocene glaciations. The early drift was presumably reworked into fluvial placers on terraces and along valley bottoms by stream downcutting during interglacial intervals and post-glacial time. This interpretation of the origin of the placers has been widely accepted, although no detailed examination of the placers had been conducted using modern geologic concepts.

The objectives of this study are as follows: (1) to determine the genetic types and respective ages of gold placers in the Pioneer district; (2) to describe physical and compositional characteristics of the placer gold and to use these features to determine the probable lode source for the gold; and (3) to suggest new approaches to exploration for placers in the region based on reinterpretations of the origin of the placers in the Pioneer district.

Placers are the products of numerous factors, including source rock lithology, climatic fluctuations, and tectonic, geomorphic, and sedimentation histories. This thesis describes the effects of each of these factors on the formation of the placers. Detailed sedimentological data were collected during geologic mapping of the district at 1:12,000 scale. Most of the work concentrated on mining cuts, because rocks in the district are poorly exposed. Observations from many localities were combined to develop a synthesis of placer deposit types. Samples of gold collected from placers in the district were studied visually and analyzed chemically by electron microprobe. The fineness of the placer grains was compared with that of lode gold from mines in the northern Flint Creek Range and fineness calculated from yearly production records for the Pioneer district.

LOCATION AND ACCESSIBILITY

The Pioneer district is situated 15 mi northwest of Deer Lodge, the county seat of Powell County, Montana (Fig. 1). The district is a 30 sq mi area that primarily encompasses the drainage of the lower part of Gold Creek, and its tributaries, Pikes Peak Creek, Pioneer, French,

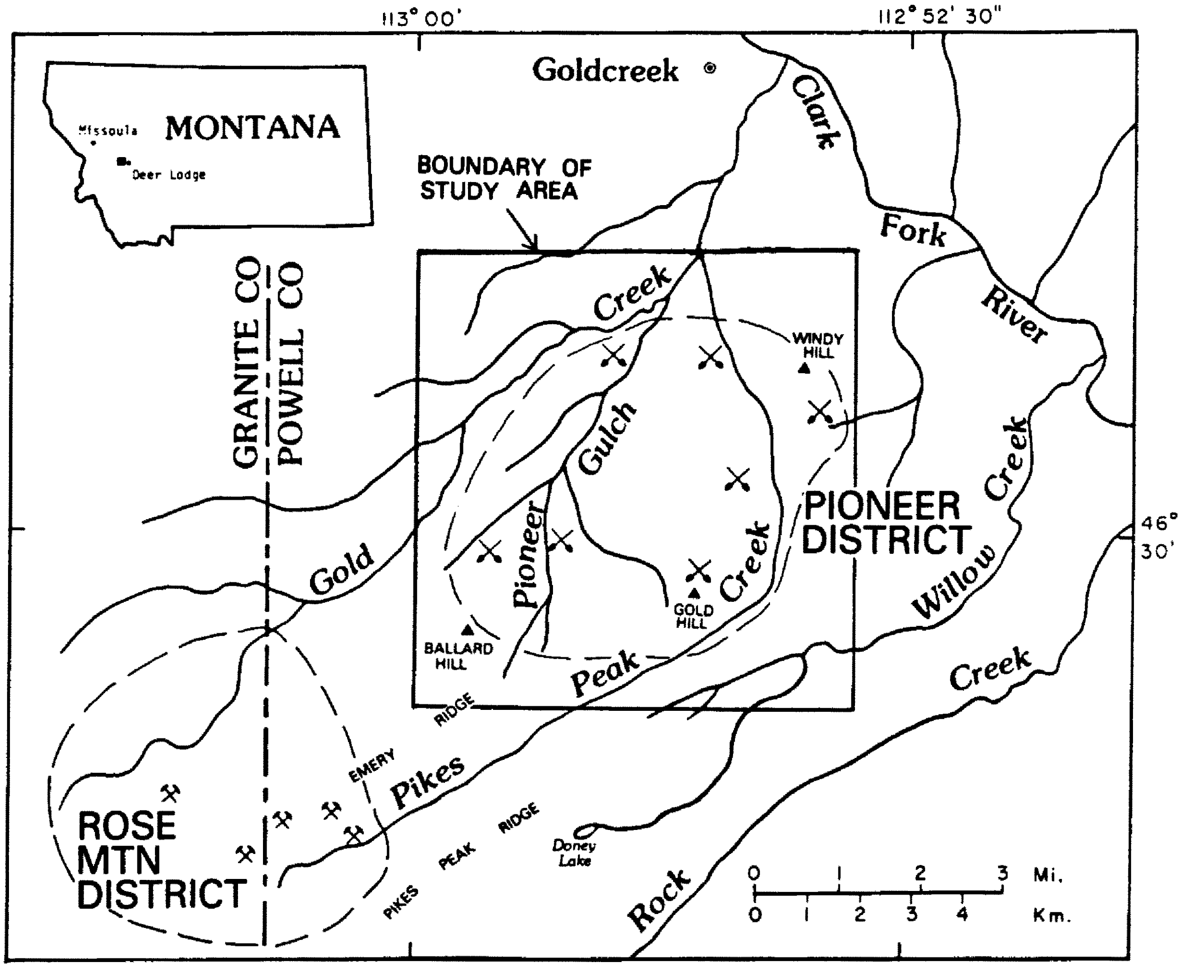


Figure 1.--Location map of the Pioneer district, Powell County, Montana, showing drainage, mining districts, and locations of principal mines.

and Squaw Gulches. Also included are parts of the drainages of Willow Creek and Independence Creek. The closest town, Goldcreek, Montana, is situated 4 mi north of the district on the south side of the Clark Fork River.

The principal access route to the Pioneer district from east or west is a gravel road leading south from Interstate 90 at the town of Goldcreek, Mont. The district may also be reached from Deer Lodge by a graded gravel road that follows the route of an old stage road. Placer mines are principally accessed by foot travel from a few jeep roads. The main placer mines in the district are located on private land.

Little remains of Yam Hill, the earliest town established in the district (in the SE 1/4, sec. 25, T. 9 N., R. 11 W.). The ghost town of Wall City is located near the confluence of Pikes Peak Creek and Gold Creek. Ruins of the town of Pioneer stand along the eastern side of Pioneer Gulch. These towns each served as the hubs of mining activity in the district at different times between 1870, when hydraulic mining began, and 1941, when operations were terminated.

TOPOGRAPHY

The main gold placers of the Pioneer district are "bench placers" located on a dissected piedmont of moderate to gentle relief along the edge of a large intermontane valley. Broad ridges form interfluves extending north and east from the mountains of the Flint Creek Range. The most important of these in terms of gold production is Gold Hill. Gold Hill is located in the W. 1/2 of sec. 36, T. 9 N., R. 11 W. (the topographic base on Plate 1 shows Gold Hill incorrectly located in the W. 1/2, sec. 26, T. 9 N., R. 11 W.).

Placers are present also in gulches cut hundreds of feet into the piedmont. Intensely glaciated valleys extend from the high peaks of the Flint Creek Range to the south edge of the district.

Elevations in the district range from a low of 4400 ft above sea level near the ghost town of Wall City where Pikes Peak Creek joins Gold Creek, to 6378 ft at the summit of Ballard Hill. The placers in the district are located between elevations of 4,500 and 5,700 ft.

DRAINAGE

The Pioneer district is situated 30 mi west of the Continental Divide, in the headwaters of the Clark Fork River. Gold Creek is a north-flowing tributary to the Clark Fork, and Pikes Peak Creek and Pioneer Creek are tributary to Gold Creek. These creeks are the only perennial streams in the area.

Gold Creek and Pikes Peak Creek head in glacial cirques of the Flint Creek Range, whereas Pioneer Gulch heads in springs along the edge of the mountain front. Gold Creek and Pikes Peak Creek consequently depend mainly on snow melt and precipitation in the mountains for their flow. Stream discharge peaks in May or June.

The scarcity of water has hampered placer-mining efforts. The extensive early mining operations of the high-level placers were made possible by water brought in by ditches from Rock Creek (4 mi south of the district), Pikes Peak Creek and Gold Creek.

CLIMATE AND VEGETATION

Intermontane valleys in the area are characterized by a semiarid climate. Temperatures are generally low and are marked by wide seasonal and daily variations. In winter, temperatures of minus 30° C are fairly common. In summer, days are as hot as 35° C, but this temperature drops very suddenly at nightfall, often reaching lows of 5° to 10° C. Average annual precipitation in the intermontane valleys is 25 to 40 cm, whereas in the higher elevations of the Flint Creek Range it is about 75 cm. Summers are typically very dry in the valleys. Most of the precipitation in the area falls as snow in the winter and rain in May and June. However, snowfall in the Flint Creek Range may occur during any month.

Wild grasses, sagebrush, weeds, and sparse juniper grow on undisturbed hills in the district. Sparse grass grows on the dry south-facing slopes, whereas shrubs and trees occupy north-facing slopes. Old placer mines are thickly covered with new growth conifers. Willows are abundant along perennial streams.

PREVIOUS STUDIES

The discovery of gold in the Pioneer district in 1852, which was reportedly also the first discovery of gold in Montana, was described by Browne (1868, p. 496-497) and Stuart (1876, p. 6). The period of greatest mining activity began in 1870. R. W. Raymond visited the district in 1871 and in 1873 described the mining operations and general features of the placer deposits.

The first comprehensive regional geological study of the area was done by Emmons and Calkins (1913). They mapped and described the rocks in much of the northern Flint Creek Range, and listed the types of lode deposits that probably served as the source of the placer gold in the Pioneer district. J. T. Pardee, who had worked with Emmons and Calkins during their study, began investigating the placers in the Pioneer district in 1916. During the summer and fall of 1916 he constructed a geologic map of the district, and formulated his hypothesis on the glacial origin of the placers. He returned to the district intermittently during the next 25 years, mainly to visit active mining operations. Pardee's report, published in 1951, has served as the principal reference on the economic geology of the district. Crawford and Starliper (1933a and b) reported on geologic influences on the origin of placer gold along Gold Creek and on the results of a microscopic study of placer gold along Gold Creek, respectively. The history of the Pioneer district and the locations of the principal placer mines were described briefly by Lyden (1948). Elliott et al. (1984) conducted a mineral resource appraisal of the Dolus Lakes area in the northern Flint Creek Range. They provided a detailed map of the area and described the types and geochemical characteristics of lode mineralization in the headwaters of the Pioneer district. Elliott et al. (in press) listed geologic features and production records for mines and prospects in mining districts throughout the Flint Creek Range.

Few specific studies of the geomorphology of the area have been conducted. The physiography and glacial geology of the Flint Creek Range was discussed by Alden (1953).

Tertiary sedimentary deposits in the intermontane basins surrounding the Flint Creek Range have been intensively studied. Earl Douglass (1901, 1903) defined two stratigraphic sequences in the Flint Creek basin, the White River beds and the Flint Creek beds. Douglass used paleontological evidence to date the deposits as Oligocene and Miocene and he correlated these beds with other sequences in the Western U.S. The paleoecology of middle Pliocene strata in the Deer Lodge Valley was reconstructed by Konizeski (1957). He concluded that the climate during Pliocene time was semiarid, similar to such conditions as exist in the valley today. Konizeski and Donohoe (1958) listed faunas in the Tertiary age strata and proposed the name "Cabbage Patch beds" for the Oligocene and Miocene age basin-fill deposits. In 1965 Konizeski reviewed the findings of the principal studies of the Tertiary strata in basins marginal to the Flint Creek Range. He suggested that low-to-moderate relief in the Flint Creek Range during early to middle Tertiary time was followed by rapid increase in relief during Pliocene time. The increase in relief corresponded to a trend from maximal precipitation to minimal precipitation between Eocene and Pliocene time. In reference to coarse Pliocene gravels in the Deer Lodge valley, Konizeski concluded, "The coarse grain size of the Tertiary deposits marginal to the Flint Creek Range apparently reflects extreme local deformation rather than high regional relief." (Konizeski, 1965, p. 17). Rasmussen (1969, 1977) conducted detailed biostratigraphic studies of the Tertiary deposits north of the Flint Creek Range. He determined that the principal middle Tertiary unit, the Cabbage Patch Formation, was deposited in one major basin (the "Clark Fork Basin") under humid and heavily vegetated conditions. Three sites of the Cabbage Patch Formation in the Pioneer district were visited by Rasmussen, and a detailed measured section of rocks along Pikes Peak Creek is included in his report (his measured section E and fossil locality KU-Mt-8; Rasmussen, 1977).

Studies of the stratigraphy, structure, and geologic history of basins surrounding the Flint Creek Range were conducted by several students from Princeton University during the late 1950's and early 1960's. Gwinn (1960) described the area north of the Flint Creek Range. Three Tertiary age units, the Barnes Creek, Flint Creek, and Cabbage Patch beds were mapped. In 1961 Gwinn published a map of the area in which the Cabbage Patch beds were defined as a mappable sequence that persists eastward from the Drummond area into the Gold Creek basin. The north-east flank of the Flint Creek Range was mapped by Mutch (1960, 1961), who distinguished three glacial advances, including one of pre-Wisconsin age. He also described a system of normal faults that may have been involved in the uplift of the Flint Creek Range in late Miocene or Pliocene time (Mutch, 1960). Csejtey (1963) studied the southeast flank of the Flint Creek Range. He described seven Tertiary units ranging in age from Eocene to Pliocene, and two Pleistocene glacial advances.

PRESENT STUDY

Field work was conducted from July 15 to August 23, 1985. This work included geologic mapping of about 20 sq mi at 1:12,000 scale, and sampling for gold and fossil specimens. The mine workings and geology were mapped on a photographic enlargement of the area, and the data were then transfered to a topographic base (Plate 1). Strat-igraphic sections of the Tertiary sedimentary rocks were measured at several localities. All numerical designations of colors are from the Rock Color Chart (Goddard et al., 1951).

Gold grains were separated from panned concentrate and quartz vein samples and analyzed by microprobe in laboratories at the U.S. Geological Survey in Denver, Colorado. Gold grains and magnetic separates of panned concentrate samples were weighed and examined by binocular microscope at Colorado State University.

British units are used throughout the report because most studies of placers have stated production figures in ounces, and volumes of material in cubic yards. Weights and lengths of gold grains were measured in metric units. For these measurements the corresponding values in British units are also listed in parentheses.

Considerable unpublished information was collected. J. T. Pardee's field notebooks (notebooks nos. 4170-A, 5550, and 5550-A, available from Field Records Office, Geologic Division, U.S. Geological Survey, Denver, Colo.) provided a valuable insight into Pardee's work. Photographs taken by Pardee were provided by the Field Records Office. J. E. Elliott, M. R. Waters, C. A. Wallace, J. P. Bradbury, and C. A. Repenning of the U.S. Geological Survey contributed unpublished data. Contributers are acknowledged where their data are mentioned in the text.

REGIONAL GEOLOGIC SETTING

The northern Flint Creek Range is underlain by sedimentary rocks that are part of the Sapphire thrust plate, which is part of one of three major zones of late Cretaceous age thrust faulting in west-central Montana (Ruppel et al., 1981). Middle Proterozoic, Paleozoic, and Mesozoic age rocks on this plate were transported a minimum of 25 to 45 mi to the east during late Cretaceous time. Late Cretaceous age plutons, including the Royal stock in the northern Flint Creek Range (Fig. 2), intruded these sedimentary rocks after thrusting ceased.

The Pioneer district is situated in the Gold Creek basin, which lies northeast of the Flint Creek Range. Tertiary age strata of the Bozeman Group in the basin represents a disjunct remnant of basin-fill strata originally deposited within a single large basin and greatly modified by later erosion and structural movements (Rasmussen, 1977). The present basin developed in response to normal faulting during late Tertiary time (Pardee, 1950).

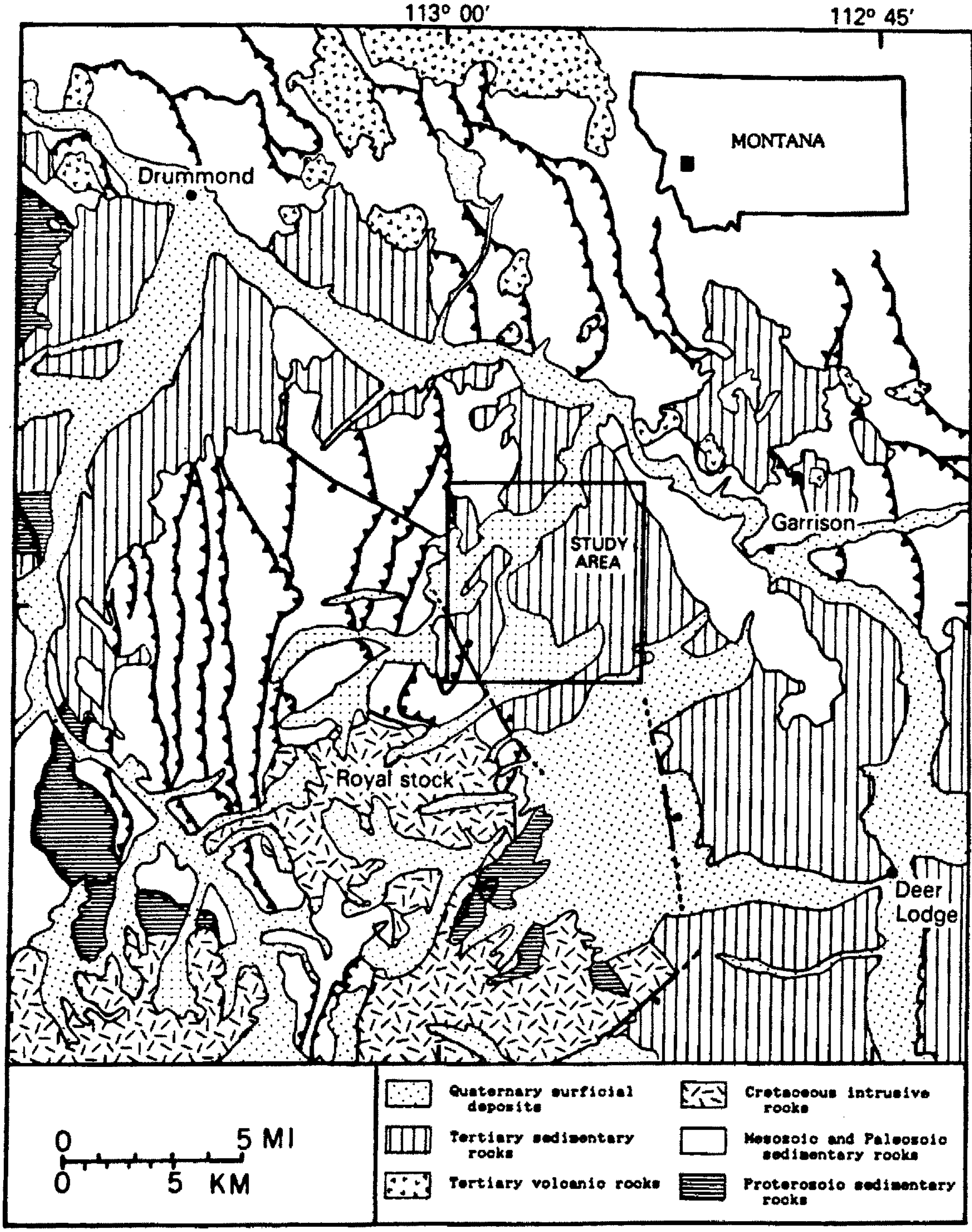


Figure 2.--Generalized geologic map of northern Flint Creek Range and vicinity (modified from C. A. Wallace, written commun., 5/85).

LITHOLOGY

The principal Paleozoic and Mesozoic sedimentary rock units in the Pioneer district (Fig. 3) have been described in detail by previous investigators (Gwinn, 1960; Mutch, 1960; Elliott et al., 1984). The Tertiary and Quaternary deposits, however, have been little studied. The map units shown on Plate 1 are described below with a strong emphasis on gold-bearing Cenozoic units. The oldest rocks are described first because the younger materials are derived from them.

PALEOZOIC SEDIMENTARY ROCKS

Paleozoic and Mesozoic rocks shown on Plate 1 are part of a thick sequence consisting of quartzites, shales, and limestones of Cretaceous through Mississippian age that underlie Emery Ridge (Fig. 1), and much of the northern Flint Creek Range. The rocks were not examined in detail during this study. The descriptions below are based on Wallace (written commun., 7/82) and Elliott et al. (1984).

Mission Canyon Formation

The Mission Canyon Formation (map unit Mmc) is the upper unit of the Mississippian age Madison Group. It consists of about 2,300 ft of richly fossiliferous, well-bedded biosparite and biosparmicrite that locally contains black chert concretions. The formation in the

AGE	UNIT	THICKNESS (Ft)
Holocene	Colluvium	0-20
	Alluvium	0-20
Pleistocene	Outwash	0-60(?)
	Till	0-200(?)
L. Mio-Plio (?)	Pioneer beds	20-30
Middle Miocene	Squaw Gulch beds	400-500
Late Oligocene-early Miocene	Cabbage Patch Formation	2,170
Eocene	Lowland Creek Volcanics	Unknown
Cretaceous	Golden Spike Formation	3,700-4,300
	Colorado Group	16,400-18,600
	Kootenai Formation	1,180
Jurassic	Ellis Formation	190-560
Permian	Phosphoria Formation	40-185
Pennsylvanian	Quadrant Formation	60-100
Mississippian	Amsden Formation	300
	Mission Canyon Formation	2,300

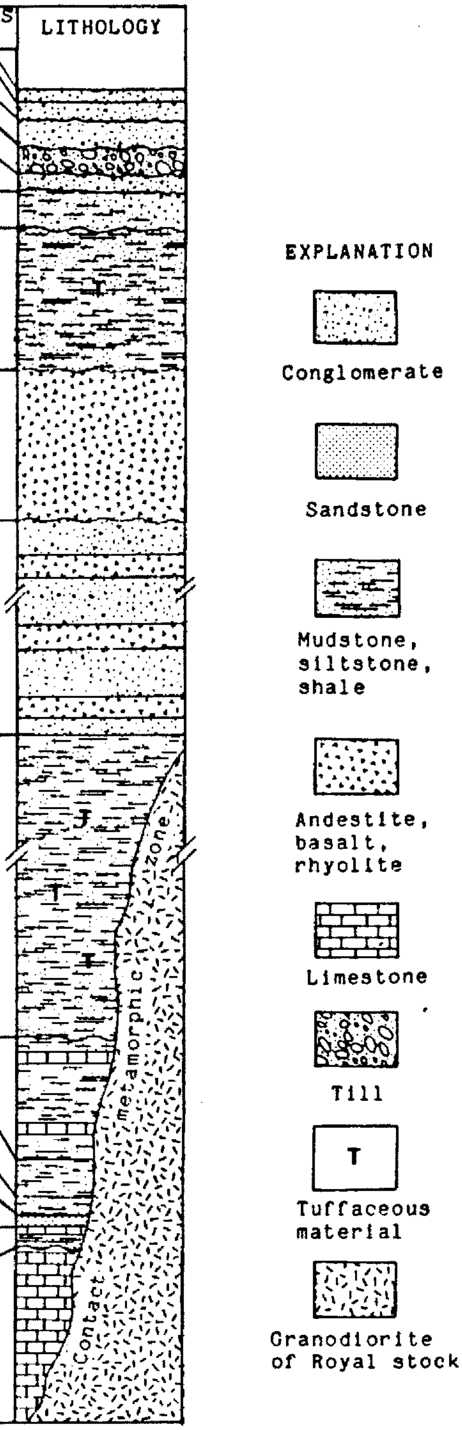


Figure 3.--Stratigraphic chart for northern Flint Creek Range (modified from Ruppel et al., 1981, Table 7).

map area contains paleokarst features including caverns and breccias.

Amsden Formation

The Amsden Formation (map unit Pa), of Pennsylvanian age, consists of about 300 ft of red silty mudstone and shale, and red siltstone interbedded with sandstone and gray limestone. The unit is present on Emery Ridge but typically is poorly exposed.

Quadrant Formation

The Pennsylvanian age Quadrant Formation (map unit Pq) is a ridge-forming angular to subangular, well-sorted, medium- to fine-grained quartzite that ranges in thickness between 60 and 100 ft. On Emery Ridge, the sequence is repeated several times because of thrusts and isoclinal folds. The repetition of beds, combined with the strong erosional resistance of the quartzite, accounts for the large percentage of Quadrant clasts in Tertiary age conglomerate in the surrounding basins.

MESOZOIC SEDIMENTARY ROCKS

Parts of a 20,000 ft section of Mesozoic sedimentary rocks outcrops locally around the periphery of the Pioneer district. The rocks are folded into large anticlines and synclines with axes that trend north. In the northern Flint Creek Range the sequence was locally intruded by the Royal stock. Mutch (1960, Plate 2) mapped Cretaceous units as underlying the Tertiary strata in the Gold Creek basin.

Cretaceous Rocks, Undivided

Three main groups of rocks are included in this unit, the Kootenai Formation (Lower Cretaceous), the Colorado Group (Middle and Upper Cretaceous), and the Golden Spike Formation (Upper Cretaceous). The Kootenai Formation includes about 1,180 ft of sandstone, siltstone, shale, and limestone. The Colorado Group consists of 16,400 to 18,600 ft of sandstone, shale, limestone, and volcaniclastic rocks. The Golden Spike Formation consists of 3,700 to 4,300 ft of interbedded volcanic and nonvolcanic rocks, principally sandstone and conglomerate.

TERTIARY SEDIMENTARY ROCKS

Three Tertiary sedimentary sequences in the Pioneer district consist of the Cabbage Patch Formation and two previously undescribed sequences that are here given informal names. Siltstone, sandstone, and conglomerate of middle Miocene age are named the "Squaw Gulch beds". Conglomerate and siltstone of late Miocene or Pliocene (?) age are named the "Pioneer beds". These strata are probably correlative with deposits of the Bozeman Group in other basins (Fig. 4).

The sequences are each bounded by unconformities (Fig. 5). The most conspicuous unconformity is of Middle Miocene age (21-17 m.y.; Rasmussen, 1973). This unconformity separates the predominantly fine-grained Cabbage Patch Formation from the coarser-grained younger units.

Figure 4.--Correlation of Tertiary sedimentary units. Solid lines between units show certain correlation; queried dashed lines between units indicate uncertain correlations. Solid lines above or below units show well-established age designations; dashed lines above or below units show approximate age designations.

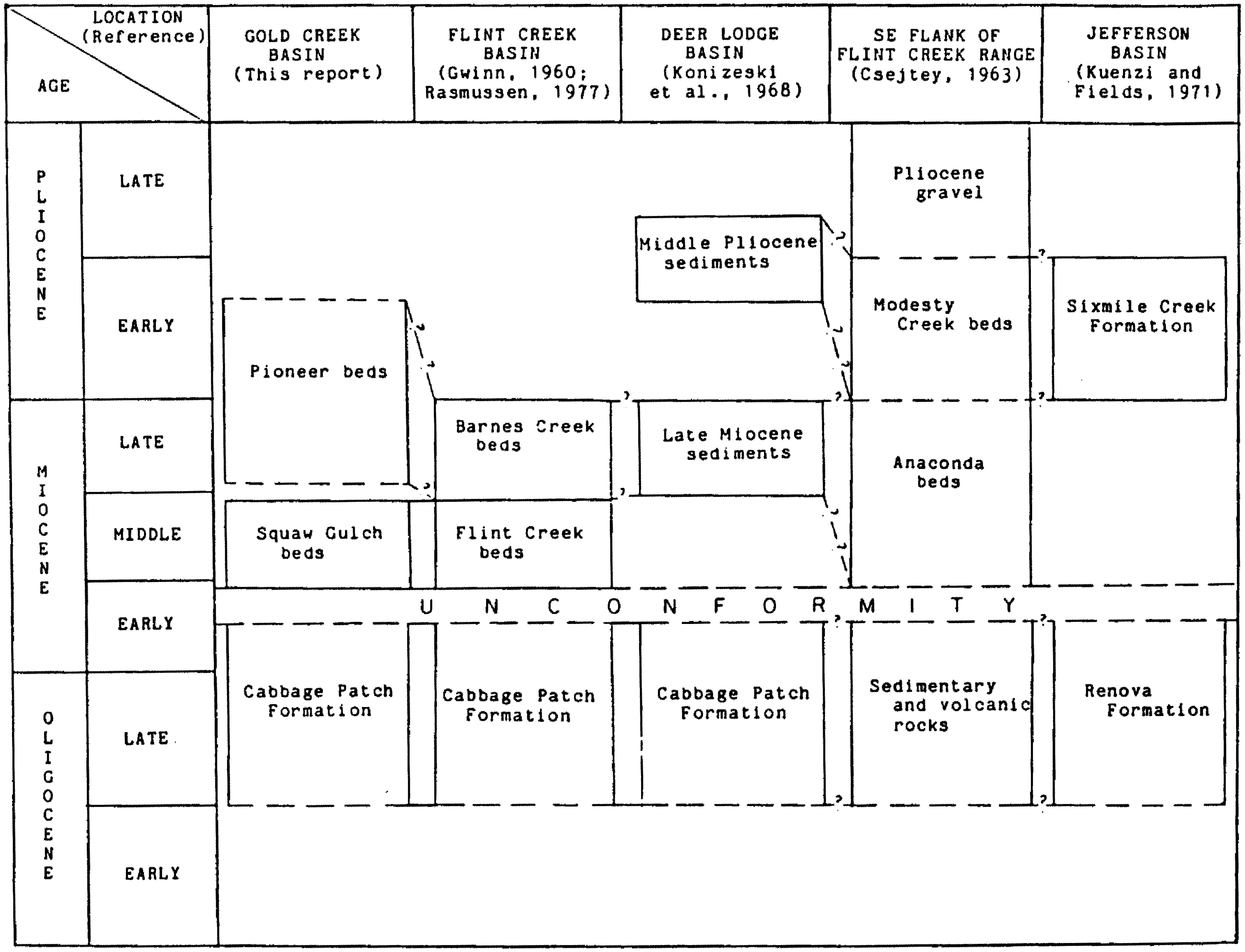
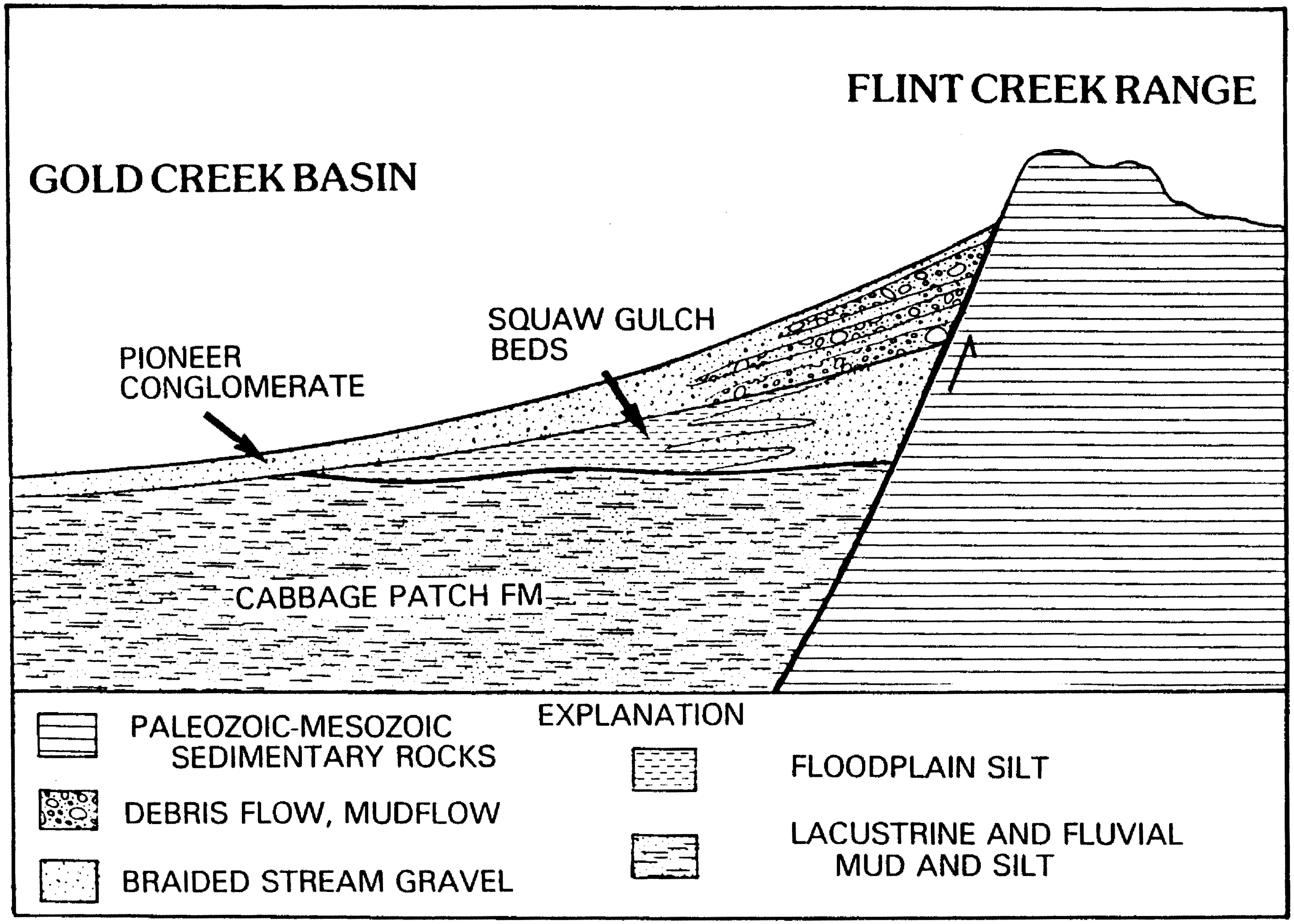

LOCATION (Reference)
AGE
GOLD CREEK BASIN (This report)
FLINT CREEK BASIN (Gwinn, 1960; Rasmussen, 1977)
DEER LODGE BASIN (Konizeski et al., 1968)
SE FLANK OF FLINT CREEK RANGE (Csejtey, 1963)
JEFFERSON BASIN (Kuenzi and Fields, 1971)
PLIOCENE
LATE
EARLY
MIOCENE
LATE
MIDDLE
EARLY
OLIGOCENE
LATE
EARLY
Pliocene gravel
Middle Pliocene sediments
Modesty Creek beds
Sixmile Creek Formation
Pioneer beds
Barnes Creek beds
Late Miocene sediments
Anaconda beds
Squaw Gulch beds
Flint Creek beds
U N C O N F O R M I T Y
Cabbage Patch Formation
Cabbage Patch Formation
Cabbage Patch Formation
Sedimentary and volcanic rocks
Renova Formation

Figure 5.--Diagrammatic cross section showing general stratigraphic relationships of Tertiary rock units along northern flank of the Flint Creek Range


FLINT CREEK RANGE
GOLD CREEK BASIN
SQUAW GULCH BEDS
PIONEER CONGLOMERATE
CABBAGE PATCH FM
EXPLANATION
PALEOZOIC-MESOZOIC SEDIMENTARY ROCKS
DEBRIS FLOW, MUDFLOW
BRAIDED STREAM GRAVEL
FLOODPLAIN SILT
LACUSTRINE AND FLUVIAL MUD AND SILT

Cabbage Patch Formation

The Cabbage Patch Formation (formerly the Cabbage Patch beds of Konizeski and Donahoe, 1958; map unit Tcp) consists of about 2,170 ft of tuffaceous mudstones and siltstones, arkosic sandstones, conglomerate, clay, marl, diatomite, and lignite. The main lithologies present are mudstone and siltstone (Table 1). The unit was previously known as "lake beds" (Pardee, 1950, 1951).

The formation is exposed in mine workings throughout the central part of the district and crops out poorly on hills in the area. It has been subdivided into lower, middle, and upper parts based on mammalian assemblages (Rasmussen, 1977, p. 107). Both the upper and lower parts of the formation are exposed in the district. Portions of the following descriptions are taken from Rasmussen's (1977) comprehensive work.

Mudstone and siltstone

Mudstone and siltstone (Fig. 6) are the most abundant lithologies present in the Cabbage Patch Formation and typically are interbedded. According to Rasmussen (1977, Table 1) these units comprise over 85% of the formation.

The mudstone and siltstone beds consist mainly of reworked volcanic ash. They typically contain sand and clay, but rarely granules and pebbles. Beds vary in thickness from about 0.4 to 4.0 in. Primary sedimentary structures are poorly developed or absent. Clays are

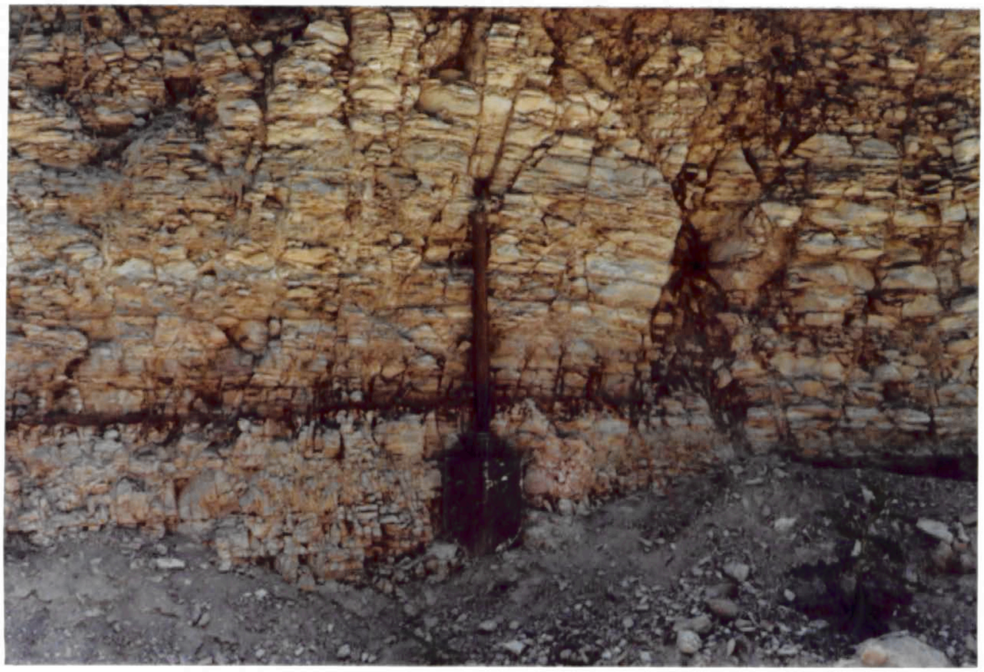


Figure 6.--Mudstone and siltstone in Cabbage Patch Formation in Pioneer Gulch. Strongly fractured character is typical of the unit. Black horizon is organic-rich layer.

Table 1.--Measured stratigraphic section, Pioneer beds and Cabbage Patch Formation. Location: Mining cut along west-sloping hill on east side of Pioneer Gulch (N 1/2, SW 1/4, sec. 13, T. 9 N., R. 11 W.).

	Thickness (feet)
Colluvium (Holocene):	
12. Soil and boulder lag, dark gray; massive, unconsolidated; clasts are angular to subrounded, mostly Quadrant quartzite with abundant percussion marks; boulder and cobbles range from 4 to 12 in. in diameter	1.9
Pioneer beds (late Miocene to Pliocene (?)):	
11. Conglomerate, white; matrix supported; pebbles, cobbles, and small boulders of quartzite, slate, and pebbles of tuffaceous mudstone and siltstone in matrix of tuffaceous silt; clasts are angular to subrounded, some oriented with long axes vertical; well consolidated, gradational contact with unit 12; forms steep face	5.9
10. Conglomerate, white; clast supported, weakly consolidated cobbles of quartzite, slate, mudstone and siltstone; rare granodiorite pebbles; sharp contact with unit 11	0.9
Total thickness of Pioneer beds	6.8
Covered interval	10.0
Cabbage Patch Formation (Late Oligocene to early Miocene):	
9. Mudstone and siltstone, white to light gray, flaggy to thinly laminated; contains abundant intact *Lymnaea* shells and ostracods	40.6
8. Siltstone with interbedded wood and leaves, dark brownish black, thinly laminated, twigs and leaves on bedding planes, gradational contact with unit 9	0.9

Table 1. (Continued)

7. Silty claystone, white, tuffaceous; micaceous; thinly laminated; contains wood and leaves gradational contact with unit 8	0.9
6. Sandstone, light gray; massive to weakly laminated; medium to coarse sand; grains are subangular, consisting of quartz, silver mica, lithic fragments, shell fragments and leaves; gradational contact with unit 7	1.6
5. Mudstone and siltstone, light olive gray; flaggy; contains abundant _Lymnaea_ shells (as much as 2 in. long) and ostracods along bedding planes; shells are fragile but intact, composed of unreplaced, chitinous material; gradational contact with unit 6	11.8
4. Mudstone and siltstone, chalky white; thinly laminated to flaggy; weakly consolidated, numerous dark brown layers of wood and leaves; _Lymnaea_ shells and fragments; gray micaceous siltite layers 1 in. thick; gradational contact with unit 5	15.8
3. Mudstone and siltstone, chalky white; weakly consolidated; massive to thinly laminated; blocky, breaks easily along bedding planes; tuffaceous, micaceous, contains wood and mollusk shells and shell fragments; grad ational contact with unit 4	14.3
2. Silty ash, light gray; weakly consolidated; massive, unlaminated, soft; contains abundant fresh muscovite; gradational contact with unit 3	1.3
1. Mudstone and siltstone, pale yellowish brown (10YR 6/2); weathers white; massive, unlaminated, well-consolidated; fine grained, micaceous, with soft resinous surface; fracture coatings of calcite; breaks into layers 0.2 to .6 in. thick; contains wood (dark brown) and rare mollusk shell fragments; sharp contact with unit 2	4.6
Total thickness of Cabbage Patch Formation	91.8
Total thickness of measured section	110.5

mostly montmorillonite with lesser amounts of detrital illite and kaolinite. The cement is dominantly carbonate.

The mudstones generally contain abundant fossils. The most abundant types found were freshwater snails, ostracods, diatoms, charophytes, and wood. The following identifications were made on specimens from the Pioneer district (J. P. Bradbury, written commun.,):

Lymnaea

Valvatidae

Candona sp. indet. due to poor preservation

Cyprid genus and specis indet. due to poor preservation

Ilocypris n. sp. (extinct form)

Fragilaria pinnata

Fragilaria brevisriata

Fragilaria construens var. venter

Fragilaria construens var. binodis

Fragilaria elliptica

Pinnularia sp.

Pinnularia elliptica

Aulacosira sp. cf. A. distans

Cymbella sp.

Amphora sp.

Gomphonema sp. cf. G. intracatum

The taxa suggest a shallow, low-energy environment dominated by ground water discharge, such as a pond-marsh complex or low energy stream. The species of Fragilaria indicate fresh water (J. P. Bradbury, written commun., 3/86). The presence of these taxa suggests a stratigraphic range for the Cabbage Patch Formation in the Pioneer district between Oligocene and lower Miocene (J. P. Bradbury, written commun., 3/86). This range is in agreement with results of previous studies in surrounding areas.

In a detailed section of 45.6 ft of mudstone and siltstone along Pikes Peak Creek in the SW 1/4 sec. 30, T. 9 N., R. 10 W., Rasmussen (1977, p. 543-545) noted abundant freshwater snails, diatoms, ostracods, fish bones, charophytes, frog bones, and plant fragments (some cattail-like). Mammal bones and teeth, root casts, land snails, bird bones and egg shells were also recognized.

Age and Correlation

The Cabbage Patch Formation ranges in age from late Oligocene to early Miocene (21 to 28 m.y. based on Arikareean land-mammals; Rasmussen, 1977, p. 133). It is probably correlative with other sequences of the Bozeman Group in western Montana that predate the middle Miocene unconformity, including the Renova Formation in the Jefferson basin (Kuenzi and Fields, 1971), the Dunbar Creek, Climbing Arrow, and Milligan Creek Formations in the Three Forks basin (Robinson, 1963), and Oligocene and Miocene volcanic and sedimentary rocks in the Deer Lodge basin (Csejtey, 1963; Konizeski, et al., 1968; Fig. 4).

Depositional Environment

Strata in the Cabbage Patch Formation are predominantly fluvial and lacustrine in origin, the fluvial strata being 4 to 5 times as abundant as lacustrine strata (Rasmussen, 1969, 1977). However, Rasmussen (1977, p. 53) noted that lacustrine sediments and lacustrine delta-fill deposits are common in the upper part of the Cabbage Patch Formation in the Gold Creek Basin. Tuffaceous mudstone and siltstone in the lower parts of the formation represent a fluviatile overbank environment.

The strata accumulated in a broad, shallow, subsiding basin (named the "Clark Fork Basin" by Rasmussen, 1977, p. 83), of which the present basins are remnants. The abundance of lacustrine strata in the Gold Creek Basin prompted Rasmussen to suggest that a large lake (named "Lake Drummond") occupied the area. The drainage was apparently toward the northwest away from the Boulder Batholith (Rasmussen, 1977, p. 88). Deltas built westward into "Lake Drummond" in the Gold Creek Basin.

The tuffaceous material is thought to be eolian volcaniclastic debris possibly derived from volcanos in the Cascade Mountains and Columbia Plateau (Rasmussen, 1977). No evidence is known for local sources of the ash. Rasmussen (1977, p. 89) suggested that avulsion was common during or directly following periods of extensive eolian ash fall deposition. The great volume of sediment deposited in overbank environments suggests a high suspended load capacity for the streams flowing through the basin.

Fossil evidence suggests the presence of freshwater lakes that were dominated by groundwater discharge. The lakes were principally through-flowing but at times ponded. Pondage of the through-flowing drainage may have been caused by volcanic flows or by blankets of volcanic ash north of Drummond (Konizeski, 1965, p. 16). Comprehensive floral and faunal lists compiled by Rasmussen (1977) also suggest a humid woodland and pondbank environment. According to Rasmussen (1977, p. 107),

> "...the climate must have been overall consistently moist as seen by the evidence for heavy vegetation, the presence of fresh-water lakes, the absence of caliche, the presence of oak and sequoia in the flora, the abundance and variety of terrestrial mollusks (including very large slugs), and the local abundance (but consistent presence) of amphibians (mainly frogs)".

Squaw Gulch Beds

The Squaw Gulch beds (map unit Ts) consist predominantly of siltstone, with lesser amounts of pebble/cobble conglomerate and sandstone (Table 2). The unit is present only along the southern margin of the Gold Creek basin. It is named after exposures in mining cuts in the headwaters of Squaw Gulch (particularly in the Squaw Gulch pit). The sequence is cut by many faults. Maximum thickness of the unit is about 500 ft.

Siltstone

Yellowish gray (5Y 7/2) to grayish orange (10YR 7/4) massive siltstone is exposed in mine workings in the central and southern parts of the map area (Fig. 7). The silt is composed mainly of poorly sorted, unoriented grains of muscovite, quartz, feldspar, and lithic fragments. It locally contains vertebrate fossils and wood.

Table 2.--Stratigraphic section of Squaw Gulch and Pioneer beds. Location of section: on steep hill on west side of Pioneer Gulch, from mine cuts in creek bottom to placer mine on Job's Point (NW 1/4, SW 1/4, sec. 27, T. 9 N., R. 11 W.).

	Thickness (feet)
Pioneer beds (Late Miocene to Pliocene (?)):	
13. Conglomerate, light brown; clast supported; polymodal; well washed; contains boulders as much as 14 in. in diameter; ungraded and weakly imbricated; moderate sorting; beds are lenticular; weakly stratified, no visible overall size trends; clasts are mostly quartzite, shale (commonly split), and granodiorite (decomposed); interbedded with sand and silt (0.4 to 1.6 in. thick); sharp scour contacts between interbeds; sequence is near horizontal (partially slumped); exposed in mining cut on Job's Point	20.1
12. Conglomerate, reddish brown; matrix supported; subangular to subround clasts of quartzite, sandstone, shale, diorite, and granodiorite; randomly oriented; clasts range to 7 ft long (ave: 1 to 3 ft)	4.1
Total thickness of Pioneer beds	24.2
Covered interval	10.0
Squaw Gulch beds (Middle Miocene):	
11. Conglomerate, light brown; clast supported; subangular to subround pebbles; clasts consist of shale, sandstone, vein quartz, quartzite	3.1
10. Siltstone, light brown; pebbly; interlayered with pebble conglomerate	5.0
9. Conglomerate, same as unit 7; gradational contact with unit 10	2.2
8. Sandy siltstone, gray; flaggy; conchoidal fracture; interbedded with medium-grained micaceous sandstone	3.1

Table 2. (Continued)

7. Conglomerate, greenish gray; clast supported; uncemented, consists of discoidal pebbles of gray and green shale in silty sand matrix ___	8.1
6. Conglomerate, reddish brown; polymodal; disoriented; clast supported; consists of pebbles as much as 1.4 in. in diameter in a matrix of small pebbles and clay; clasts are sub-round; iron stained and strongly cemented	0.3
5. Siltstone, white; flaggy to massive; unlaminated, no sedimentary structures or fossils visible; sharp contact with unit 6 ___	5.0
4. Mudstone and siltstone, greenish gray (5G 6/1) to pale pink (5RP 8/2); micaceous, massive, fragments break with conchoidal fracture; contains medium- to coarse-grained sand interbeds ___	10.2
3. Sandstone, greenish gray; very coarse sand; pebbly with clay matrix; pebbles consist of subangular shale rock chips ___	1.9
2. Mudstone and siltstone, gray; flaggy to massive bedded; micaceous, broken surfaces appear resinous ___	10.2
1. Conglomerate and siltstone, interlayered; pale yellowish brown (10YR 6/2) to dark yellowish brown (10YR 4/2); pebble/cobble conglomerate is clast supported, weakly consolidated to strongly cemented by calcium carbonate; locally iron stained; polymodal; in fine- to medium-grained sand matrix, gravel clasts are subangular to subrounded; clasts are about 80% gray shale and fine sandstone (Ellis Fm (?); 20% granodiorite and vein quartz; weakly imbricated (paleocurrent directions average N 30 E); siltstone beds are 0.4 to 4 in. thick, occurring between about 4 to 12 in. thick conglomerate lenses; locally contains leaves and wood; poorly exposed ___	174.5
Total thickness of Squaw Gulch beds ___	223.6
Total thickness of measured section ___	257.8

Figure 7.--Siltstone in Squaw Gulch beds in roadcut on west side of Main Fork of Pioneer Gulch. Siltstone contains interbedded pebble conglomerate (part of Unit 1, Table 2).

Vertebrate fossils were found in siltstone exposed in a placer mine about 1 mi east of the site of Pioneer (in the SW 1/4, NE 1/4, sec. 26, T. 9 N., R. 11 W.). The following identifications were made on specimens from this locality (C. A. Repenning, written communication, 4/15/86):

ERINACEIDAE

Close to *Brachyerix incertis* (Matthew)

HETEROMYIDAE

Cupidinimus sp.

MERYCOIDODNTIDAE

Merychyus relictus (Matthew and Cook?)

The specimen of ERINACEIDAE (long-incisored hedgehog) may represent an undescribed form because the fourth lower premolar is enlarged and simplified. The compared genus and species is known from rocks between 16 and 12 million years old. The HETEROMYIDAE fossils represent an extinct genus of the living jumping mouse (extinct form is known between 16 and 5 million years ago). The MERYCOIDODONTIDAE specimen (an oreodont) is known from deposits between 20 and 12 million years old. These mammal fossils are characteristic members of the North American Barstovian land mammal age. The beds that they came from must be between 16 and 12 million years old (middle Miocene).

The unit contains no visible freshwater invertebrate fossils, such as those that are abundant in the underlying Cabbage Patch Formation. Wood and leaves are locally present in the lower part of the sequence.

Sandstone

Poorly sorted sandstone occurs in a few exposures of the siltstone unit. The sandstone is well washed, very well size sorted, and contains abundant small-scale trough cross beds. It is weakly cemented to uncemented. Sand grains are angular to subrounded. Panned concentrates of this sandstone contain a small amount of very fine black sand, but no visible gold. The sandstone occurs in discontinuous beds that range from 2 to 20 in. in thickness.

Pebble/cobble conglomerate

Pebble/conglomerate typically consists of poorly to well-indurated, iron-stained, clast-supported gravel containing sub-rounded to well-rounded pebbles and cobbles (Fig. 8). The clasts are composed of tan quartzite and gray slate that are similar to Paleozoic and Mesozoic formations exposed on Emery Ridge. Cementation of the rock is discontinuous along strike.

This conglomerate unit is poorly exposed. On the east side of Pioneer gulch (along Kohrs and Kelly Bar, also known as "K and K Bar") it is entirely covered by as much as 30 ft of the earliest glacial till (Qt_1), except in man-made excavations. It was intensively mined for placer gold on Gold Hill and in Pioneer Gulch. In the Kohrs and Bielenburg Mine in Pioneer Gulch the "blood red gravel", as the well-cemented, iron-stained conglomerate was known, was washed from under the till using hydraulic giants. Elsewhere along K and K bar, adits were driven under the till

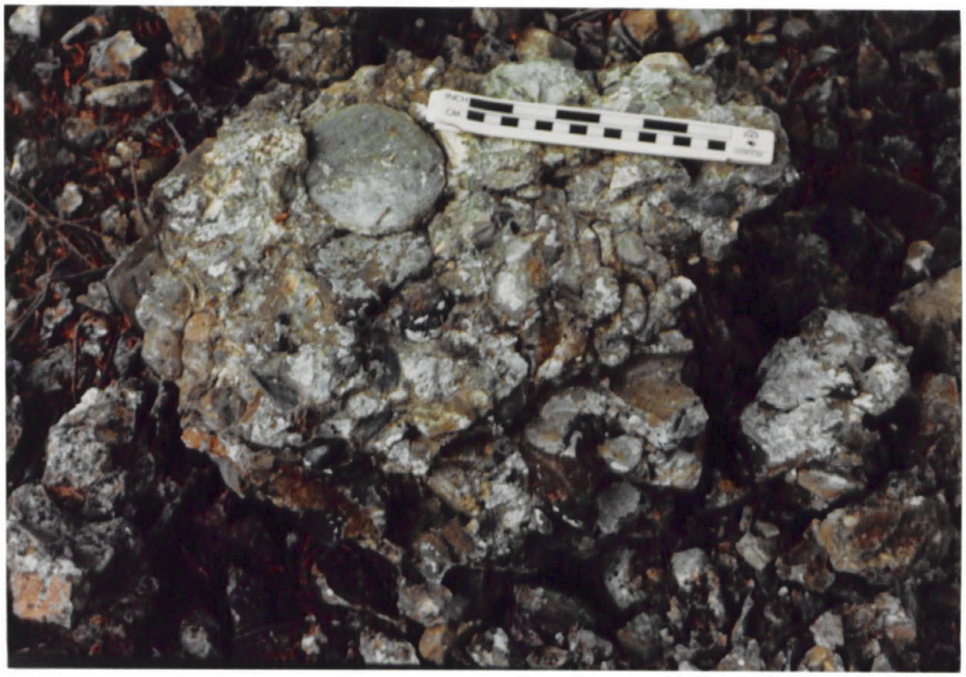


Figure 8.--Well-cemented pebble/cobble conglomerate in Squaw Gulch beds along Main Fork of Pioneer Gulch. Conglomerate underlies 5 to 30 ft of glacial till. Note well-rounded clasts.

in order to mine the conglomerate. On the west side of Pioneer Gulch, several beds of the conglomerate (as much as 8 in. thick) are exposed in mine workings.

Panned concentrates of this conglomerate contained a low proportion of magnetite (ratio of weights of non-magnetic to magnetic minerals, 150/1 to 1000/1), reflecting a lack of magnetite in the source area and(or) poor concentration of heavy minerals during deposition.

Age and Correlation

The Squaw Gulch beds are of middle Miocene age. The deposits are similar in character to the middle to late Miocene age Flint Creek beds (Douglass, 1901) in the Flint Creek basin and the Anaconda beds (Csejtey, 1963) in the southwest part of the Deer Lodge valley (Fig. 4).

Depositional Environment

The Squaw Gulch beds represent a sequence of fluvial deposits that prograded across the broad basin to the north and east during uplift in the mountains in middle Miocene time. The abundant silt probably represents floodplain deposits. The sandstone and conglomerate represent stream channels that were probably braided.

The climate at the time of deposition apparently was intermediate between the humid conditions of the Oligocene and early Miocene and the semiarid conditions of the Pliocene. Fossil evidence suggests brushy or wooded country. The presence of leaves and woody matter in the lower part of the sequence also suggests wooded country.

Pioneer beds

The Pioneer beds (map unit Tp) consist of conglomerate and siltstone that form an extensive layer throughout the Pioneer district and the northern Deer Lodge valley. The beds contain two types of boulder/cobble conglomerate that are differentiated on the basis of degree of sorting and the type of supporting media. Both matrix-supported and clast-supported types of conglomerate are interlayered with siltstone.

Matrix-supported conglomerate

This conglomerate contains unsorted gravel clasts in fine-grained matrix. Clasts are in haphazard arrangement or oriented with long axes horizontal or vertical. The conglomerate is massive. The deposits range in thickness from about 3 to 12 ft. Their geometry is apparently lobate or lenticular, with sharp contacts above and below.

The amount and composition of the matrix material varies greatly between deposits. In some deposits a few clasts are in contact with each other or they are separated by a few inches of sandy matrix, whereas in other deposits all clasts are supported by abundant silt and clay (Fig. 9). The matrix of deposits in the southern part of the district is reddish brown and clay-rich. In the northern and eastern parts of the district, the matrix material is grayish white and much tuffaceous siltstone reworked from beds in the Cabbage Patch Formation is present (Fig. 10).

Figure 9.--Matrix-supported conglomerate in Pioneer beds on Batterton Bar. Boulders and cobbles of quartzite are held in clay-rich matrix. Deposits are about 9 ft thick. Many clasts have subhorizontal orientation. Interpreted as mudflow.

Figure 10.--Matrix-supported conglomerate in Pioneer beds on Wilson Bar. Matrix and some clasts consist of reworked siltstone of Cabbage Patch Formation. Deposit is about 4.6 ft thick. Boulders are as much as 12 in. long. Overlain by soil and surficial lag.

The matrix-supported conglomerate typically contains large angular quartzite boulders. Boulders as much as 9 ft long are found on Gold Hill and Ballard Hill. Boulders as much as 6 ft long are present in deposits on Wilson Bar and Windy Hill. Two thirds to three quarters of the boulders are composed of Quadrant quartzite. Other rock types (mostly quartzite and slate from Mesozoic age formations) are present in smaller proportions. Clasts of granodiorite form less than 10% of the deposits.

Clast-supported Conglomerate

Clast-supported conglomerate consists of dense, poorly to well-sorted concentrations of pebbles, cobbles, and boulders. The conglomerate is typically well stratified and imbricated, but unsorted, unstratified deposits also occur. Imbricated clasts indicate paleoflow toward the north or northeast. The conglomerate is exposed in many mine workings throughout the district, particularly on Ballard Hill, Jobs Point, and in the area north and northeast of Gold Hill. The matrix and clast composition of the conglomerate changes markedly from south to north. On Pilgrim Bar, in the southern part of the map area, the conglomerate is brown in color and has a well-washed sand matrix containing little silt and clay. Conglomerate in the northern part of the map area, however, is light brown to white in color and contains abundant silt (Fig. 11).

Conglomerate exposed in mines on Windy Hill and between Pioneer Gulch and Pikes Peak Creek generally contains clasts

Figure 11.--Clast-supported conglomerate in Pioneer beds on Pilgrim Bar. Pioneer beds lie on siltstone of Cabbage Patch Formation.

of reworked tuffaceous siltstone in the lower sections, directly above Cabbage Patch Formation siltstone bedrock. The reworked layer fines upward and is replaced with layers of gravel consisting mainly of quartzite clasts.

Clasts in the conglomerate are angular to well rounded. They consist mainly of Quadrant quartzite, sandstone, and slate. On Ballard Hill, the clasts are angular and consist of gray slate and much calc-silicate hornfels. Granodiorite is generally rare, and where present it is strongly decomposed.

Surfaces of quartzite clasts typically show percussion marks (crescentic indentations). The marks range in size from 0.25 to 1.0 in. in diameter, and are about 0.04 in. deep (Fig. 12). In deposits several miles away from Emery Ridge, such as on Windy Hill, Woods Flat, and Wilson Bar, the marks are more abundant on the clasts and the marks are overprinted on each other. Clasts in deposits in the southern part of the district (such as on Ballard Hill and Gold Hill) show fewer marks, and the marks are present on a smaller percentage of the clasts. Klein (1963) and Lindsey (1972) consider the marks to be the result of impact during fluvial transport.

The conglomerate is typically about 20 ft thick. Individual beds generally range from 4 in. to 6 ft in thickness in most areas. Greater total thicknesses of the conglomerate may be present, but poorly exposed, on Ballard Hill. One adit on the east side of Ballard Hill (in the SE

Figure 12.--Percussion marks on quartzite boulder in tailings of Pioneer beds at Treadwater Bar. Boulder is 20 in. long.

1/4, sec. 33, T. 9 N., R. 11 W.; Plate 1) and roadcuts on the west side of the hill expose beds of coarse clast-supported conglomerate containing poorly sorted lithic fragments in a clay matrix. All deposits of the conglomerate apparently have a sheet-like geometry and typically dip north or northeast at 5° to 20°.

Siltstone

Light brown siltstone, typically composed of fine-grained tuffaceous material, is typically massive to weakly stratified and has a sharp upper contact and a gradual lower contact with conglomerate. On Pilgrim Bar the silt beds are about 1.5 to 4 ft thick and they separate beds of coarse clast-supported conglomerate (Fig. 13).

Age and Correlation

The age of the beds in the Pioneer district is not precisely known because no fossils have been found in the unit. Similar coarse, syntectonic conglomerates of late Miocene or Pliocene age have been described in many intermontane valleys of western Montana (Fig. 4). In the Flint Creek basin a similar unit, named the Barnes Creek Formation (Gwinn, 1960), is of middle to late Miocene age (Barstovian and Clarendonian), according to Fields and Rasmussen (1969). The Pioneer beds may be correlative with the Six Mile Formation, described in basins farther east (Robinson, 1967; Kuenzi and Fields, 1971), and the Modesty Creek beds (Csejtey, 1963) in the southwestern part of the Deer Lodge valley.

Figure 13.--Interstratified clast- and matrix-supported conglomerate in Pioneer beds in the Squaw Gulch pit. Large boulders are in a matrix-supported unit sandwiched between imbricated, clast-supported conglomerates. Interpreted as a stream channel (lower unit) that was covered with a debris flow (middle unit), and the debris flow was later reworked by streams (upper unit).

In the northern Deer Lodge valley, Konizeski (1957) described well-dated middle Pliocene age deposits of fine-bedded silt, and extensive lenses of cross-bedded sand and gravel. These deposits occur on the same piedmont surface as the Pioneer beds. They may, therefore, represent the distal facies of coarse conglomerate in the study area. A late Miocene to Pliocene (?) age is assigned to the Pioneer beds because similar deposits in the region have been dated as old as late Miocene and as young as middle Pliocene. It is unlikely that the deposits are of late Pliocene or Pleistocene age because the conglomerate predates the middle Pliocene to middle Pleistocene canyon cutting.

Depositional Environment

The differences in the matrix material, areal distribution, and clast size and sorting indicate that the matrix-supported conglomerate was deposited by mudflows, whereas, clast-supported conglomerate was deposited by both debris flows and braided streams. The braided streams evidently reworked some of the debris flow deposits. The siltstone probably represents sheetwash or floodplain deposits. These processes occurred on alluvial fans that formed ajacent to the Flint Creek Range during uplift of the range along normal faults in late Miocene or Pliocene time.

The clast- and matrix- supported conglomerates are closely interrelated in most exposures. In the southern part of the district, both matrix-supported and clast-supported conglomerate are interstratified (Fig. 13), and the clast-supported conglomerates show poor sorting. In the northern part of the district, well-sorted, clast-supported conglomerate predominates.

Mudflows and debris flows are typically most abundant in the proximal regions of alluvial fans and the proportion of debris- and mud-flow deposits decreases downfan. The processes of mass flow result in unsorted deposits in which clasts are randomly oriented (Pierson, 1986, p. 1066) or oriented with long axes horizontal (Bull, 1972, p. 70), as is typical of the matrix-supported conglomerate. Clast-supported conglomerate with a disoriented texture is also most common in the proximal (southern) part of the district.

Braided streams are common on the proximal and the medial parts of alluvial fans. The streams operate fairly continously, whereas the mudflows and debris flows occur infrequently (Beaty, 1974). The deposits resulting from the two processes are thus interstratified. Streams rework the upper parts of the flow deposits during the time intervals between the flows (Beaty, 1963). Braided stream channels typically have high width/depth ratios, which results in sheet-like deposits, whereas the debris and mudflows are lobate or lenticular.

Great differences in grain sizes are evident between the two types of conglomerate. The matrix-supported conglomerate typically contains boulders, but interstratified clast-supported conglomerate contains well-sorted pebbles and small cobbles. Debris flows can easily transport boulders weighing many tons (Pierson, 1986). Streams, however, are normally much more limited in their competence.

The braided stream deposits from the southern part of the district, particularly on Ballard Hill, show great textural immaturity. A great amount of matrix is retained in the clast framework, and the degree of sorting of the clasts is low. Clasts are angular. These features reflect rapid deposition by ephemeral (flashy) flow (Nemec and Steel, 1984, p. 8) in the proximal region of an alluvial fan. Well-developed clast imbrication and weak horizontal stratification distinguishes this braided alluvium from clast-supported debris flow deposits. In contrast, the texturally mature conglomerates in the central and northern part of the district reflect more channelized transport, more continuous runoff, and effective reworking in the braided stream system (Nemec and Steel, 1984, p. 8).

The climate during deposition of the Pioneer beds was probably semiarid. Bentonite, a common alteration product of volcanic ash when water is present, is ubiquitous in Oligocene and Miocene age beds, but is unknown in the Pliocene age rocks of the area (Konizeski, 1965, p. 12). Konizeski (1957) suggests that the climate during middle Pliocene time was similar to the present climate in the Deer Lodge valley, which receives little rain because of the rain shadow effect of the Flint Creek Range.

QUATERNARY SEDIMENTARY DEPOSITS

Quaternary deposits consist of till and outwash of Pleistocene age, and alluvium, colluvium, and landslide debris of Holocene age.

Glacial deposits

Glacial deposits in valleys draining the Flint Creek Range consist of a sequence of four tills, and outwash gravels related to the deposition of the last three tills. Relative weathering criteria were useful for subdivision of the glacial deposits in the area (Table 3). Criteria used include topographic form, soil development, and degree of weathering of internal clasts. Subdivision of outwash is based on height of surfaces above present streams, composition, and degree of weathering of clasts. Because tills are most abundant along or outside of the southern margin of the Pioneer district, and contain limited placer material, they were not studied in detail. The classification of glacial deposits presented herein was provided by M. R. Waters (written commun., 8/85).

Till

Three till sequences all consist primarily of poorly sorted detritus derived from granodiorite of the Royal stock. The deposits blanket the upper valleys of Pikes Peak Creek and Gold Creek, and parts of the valleys of Pioneer Gulch and French Gulch along the border of the Pioneer district. These tills appear to have roughly the same distribution in the study area valleys, although their distribution

Table 3.--Distinguishing characteristics of Pleistocene glacial deposits in the Pioneer District, Powell County, Montana (M. R. Waters, written commun., 5/85).

Glacial till			
Symbol	Preservation of morainal topography	Degree of weathering of clasts	Depth to Cca soil horizon
Qt_4	Excellent	Unweathered	4 in.
Qt_3	Good	Unweathered	1.5 ft
Qt_2	Fair	Moderately weathered	6 ft
Qt_1	Not preserved	Extremely weathered	>12 ft

Glacial outwash		
Symbol	Height of terrace remnants above stream	Characteristics of clasts
Qo_3	6 ft	Unweathered, few visible boulders
Qo_2	22 ft	Unweathered, abundant boulders
Qo_1	45 ft	Weathered, abundant boulders

in adjacent valleys is not the same. For example, the oldest till is well represented in Pioneer Gulch but was not identified in the Gold Creek valley.

The youngest till (Qt_4) consists of abundant fresh boulders in deposits displaying well-preserved morainal form with sharp ridges and many undrained depressions. The sharp-crested and steep-sided moraines are easily distinguished on topographic maps and aerial photographs.

The two intermediate tills (Qt_3 and Qt_2) have good morainal form and similar composition to that of the young till. However, soil development is greater and the tills contain a higher percentage of decomposed clasts. It is more difficult to discern the lateral and terminal moraines of these advances.

The oldest till (Qt_1) is found in valley bottoms upstream from the confluence of Pioneer Gulch and Squaw Gulch, and in Pikes Peak Creek. These deposits were identified as till from exposures in mine excavations, but otherwise they crop out poorly and show no morainal form. Surface forms primarily reflect post-depositional stream erosion, possibly by outwash streams during later glacial advances. The till consists predominantly of matrix-supported clasts of granodiorite and quartzite. The matrix is composed of sand and silt derived largely from granodiorite. Granodiorite comprises about 90% of the clasts, whereas the remaining 10% are quartzite. Clasts of granodiorite in these deposits are typically very weathered, and fall apart from a hammer blow. However, clasts are fresh where the deposits lie above the water table.

Outwash

Three ages of glacial outwash gravels are recognized in the Pioneer district. All are framework-supported channel gravels typically consisting of over 90% granodiorite clasts and less than 10% quartzite clasts. Panned concentrates of outwash characteristically contained abundant magnetite. The three outwash deposits are tentatively correlated in age with the three youngest till sequences.

The youngest outwash surface (Qo_3) occurs about 6 ft above the present stream channels and consists mainly of boulders and cobbles of fresh gray granodiorite in a sandy matrix.

In the intermediate outwash (Qo_2), large grayish-brown boulders of granodiorite are very conspicuous. In Gold Creek valley, this outwash occurs on a prominent ridge about 22 ft above the present stream channel.

The oldest outwash (Qo_1) is situated on highly eroded terraces about 45 ft above present stream channels. These terraces are preserved along lower Pikes Peak Creek and Gold Creek, and form round-topped hills of rounded cobbles and boulders of weathered granodiorite overlying mudstone and siltstone of the Cabbage Patch Formation.

Correlation of Glacial Advances

The four glacial advances described in this report can be tentatively correlated with major Pleistocene glacial stages identified elsewhere in the Rocky Mountains (Fig. 14). The youngest till displays weathering features similar to deposits that have been identified as late Wisconsin Pinedale age in other areas (e.g. in the Front Range of Colorado (Madole and Shroba, 1979)). The two intermediate tills appear similar to early Wisconsin Bull Lake deposits (Holmes and Moss, 1955). The oldest till may be of either early Wisconsin or Pre-Wisconsin age. Such correlations based mainly on weathering features may not be valid because of local differences in climate and in weathering susceptibility of the rock lithologies in the tills. No absolute dates for glacial advances in the Flint Creek Range are available. Therefore, more data are necessary before the tills in the Flint Creek Range can be dependably correlated with those in other areas.

The suggested glacial chronology is different from results of previous investigations in that no widespread early Pleistocene glaciation is identified. Emmons and Calkins (1913, p. 140), first described an early glacial drift characterized by clasts of quartzite, schist, and slate, with few granite boulders. Pardee (1951) elaborated on this observation when he established the glacial chronology for the Pioneer district. He identified early, intermediate, and late glacial drift. The early drift supposedly contained the principal gold placers in the district.

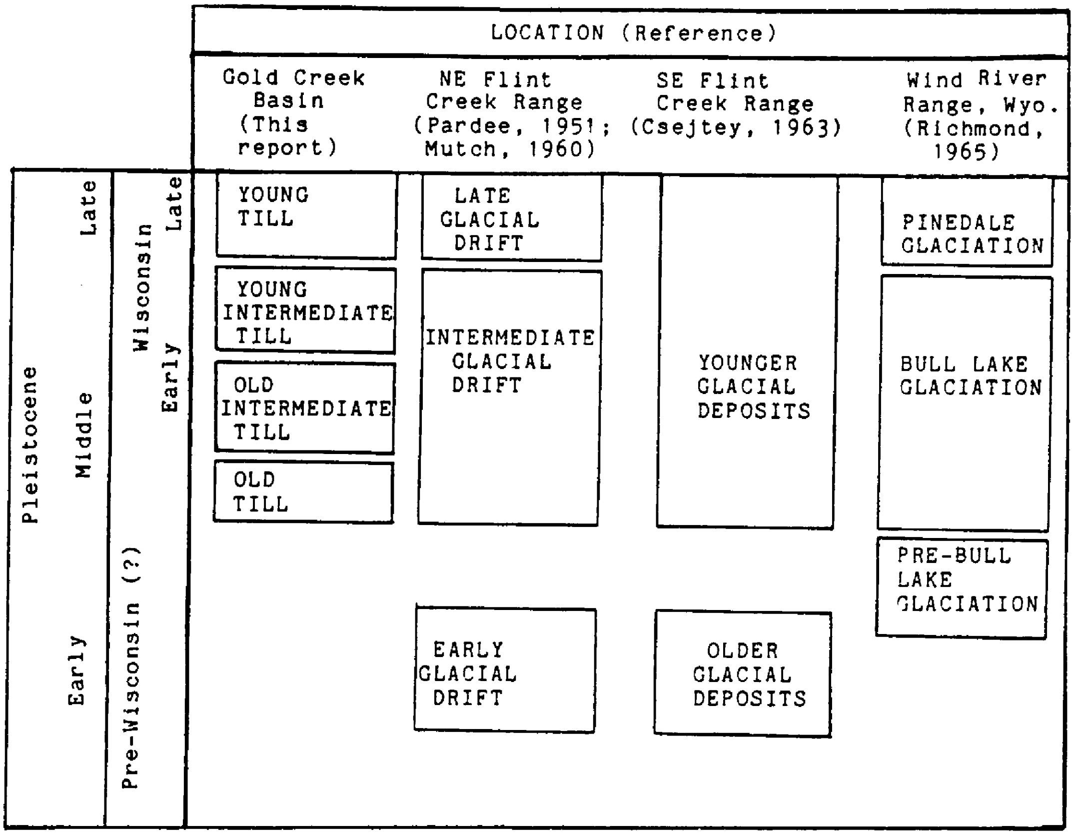


Figure 14.--Correlation of glacial sequence in the Pioneer district with sequences proposed by previous workers. Names of glacial sequences shown are those used by the reference listed above. In this report no early Pleistocene glacial deposits are recognized along the northeastern margin of the Flint Creek Range. The early Pleistocene deposits described in this area by other workers correlate with conglomerate in the Pioneer beds.

The gold-bearing early drift was thought to have been deposited by major icecaps that covered almost the entire Gold Creek basin and parts of the Deer Lodge valley during early Pleistocene time. The present drainage system presumably developed by downcutting of interglacial streams following this glaciation. Mutch (1960, Fig. 52) mapped the deposits of this early glaciation as extending to within 1.5 mi of the Clark Fork River at the mouth of Willow Creek (Fig. 1). Pardee's intermediate and late glacial drifts consisted chiefly of granitic debris deposited along the present valleys. These two drifts correlate with the four tills described herein (Fig. 14).

Alden (1953) assigned both the early and intermediate drift a pre-Wisconsin age, and the late drift a late Wisconsin age. Mutch (1960, p. 131), tentatively correlated the early drift with the pre-Wisconsin Buffalo glaciation described by Blackwelder (1915) in the Wind River Range, Wyoming, and the intermediate glaciation to the Bull Lake Glaciation. Mutch assigned the young drift to the Pinedale Glaciation.

The so-called early drift corresponds in many respects to diamictons (till-like deposits) that mantle high stream divides throughout the central and northern Rocky Mountains. Most studies completed during the early 1900's concluded that these poorly sorted deposits that contained exotic boulders were glacial in origin. The presence of these deposits on surfaces hundreds of feet above the present streams suggested that icecaps were present before the valleys were cut (Atwood and Atwood, 1948, p. 607-608). Many of these deposits, originally considered to be glacial drift, have since either been shown to be nonglacial, or their glacial origin is suspect (Meierding and Birkeland, 1980, p. 165).

Similar diamictons have been studied in detail in the Front Range of Colorado. Scott (1975) states that none of the ridgetop diamictons in Colorado are of Pleistocene age because most of the canyon cutting that isolated the deposits occurred before the Pliocene. Madole and Shroba (1979) believe that any diamictons that are more extensive than till of the Bull Lake Glaciation are probably non-glacial in origin. Meierding and Birkeland (1980, p. 167) state,

> "...there is no evidence that climatic events in the early Pleistocene were significantly more severe than they were in the late Pleistocene, and yet the inferred early Pleistocene glaciers that supposedly deposited the diamictons would have to have been two to three times as large as the late Pleistocene glaciers in order to have deposited all of the known ridgetop diamictons."

Many of the ridgetop diamictons in Colorado and Wyoming, formerly believed to be till, have since been assigned Tertiary ages (Richmond, 1965; Richmond, 1970; Madole and Shroba, 1979; Madole, 1982).

The areas where Pardee mapped "early glacial drift" such as Windy Hill, Gold Hill, and Ballard Hill, lie outside of the glacial boundary shown by the extent of Pleistocene age till units on Plate 1. The distribution of the "early glacial drift" corresponds to the late Miocene or Pliocene age Pioneer beds described in the present study. The beds locally contains till-like deposits of angular gravel supported by a silt and clay matrix, probably deposited by debris flows or mud flows. The deposits clearly pre-date the middle Pliocene to middle Pleistocene canyon cutting in the region. Correlative deposits in the Deer Lodge and Flint Creek basins have been dated by fossil evidence as late Miocene to middle Pliocene age (Konizeski, 1957, Konizeski et al. 1968, Rasmussen, 1969, 1973, 1977).

The hypothesis of glacial origin of the deposits has been supported by Pardee's observation of "striae" on some schist boulders (Pardee, 1951, p. 82-83). The presence of striated boulders could not be confirmed, however, and it is possible that such linear scratches could have been formed in other ways besides glacial transport.

No unequivocal evidence exists to support the hypothesis that large ice caps covered the Flint Creek Range and advanced far across the late Tertiary age piedmont. Evidence rather suggests that the major glaciers were all of about the same size and occupied established valleys.

Alluvium

Alluvium occupies small areas of valley bottoms along non-glaciated tributary gulches to the main stream channels. Maximum thickness is about 15 ft. Stream activity in glaciated drainages has been so minimal that little of the

Pleistocene outwash has been reworked. In non-glaciated valleys (notably Dry Gulch and the West Fork of Independence Gulch) alluvium consists of silt, sand, and gravel derived from Tertiary age siltstone and conglomerate. The alluvium ranges in character from dense framework-supported gravel layers composed of clasts ranging in size from sand to boulders, to thick beds of silt and sand. In the area between Pikes Peak Creek and Pioneer Gulch, thick beds of silt predominate. The gravels form discontinuous lenses between silt layers (Fig. 15). Some of these deposits are interlayered with colluvium. The soil development on the deposits is limited to weak A horizons generally 8 in. thick.

Colluvium

Colluvium mantles slopes throughout the Pioneer district. The colluvium occurrs as debris sheets on steep hillslopes, lag on low relief areas, and slope wash fans in small tributary gulches to main valleys.

On hillslopes, colluvium typically forms wedge-like sheets of poorly sorted, crudely stratified gravel, sand, and silt derived from Tertiary age units in the slopes above. Colluvium typically grades into alluvium in stream channels. Locally, colluvial sheets along the main stream channels were extensively mined for placer gold. The colluvium is about 25 ft in maximum thickness but is typically less than 10 ft thick. Only deposits thicker than approximately 5 ft are shown on Plate 1.

Figure 15.--Interlayered silt and gravel in Quaternary alluvium in tributary to Pioneer Gulch. Gravel consists mainly of clasts of quartzite, slate, and sandstone which have been reworked from Pioneer beds on hilltops to the east. Shovel is 27.6 in. long.

On the broad hills between the lower part of Pikes Peak Creek and Pioneer Gulch (secs. 13, 14, 23, 24, T. 9 N., R. 11 W.), colluvial lags ranging from 1.5 to 3 ft in thickness overlie siltstone of the Cabbage Patch Formation and Pioneer beds (Fig. 16). Despite the thinness of these deposits, the lag was mined for gold over a large area (mainly in Wood's Flat, W 1/2, sec. 24, T. 9 N., R. 11 W.). The lag is evidently a product of intense erosion of the Pioneer beds which formerly covered this area.

The colluvium probably ranges in age from middle Pleistocene to late Holocene but likely is primarily late Holocene in that the deposits are constantly being reworked by active slope-forming processes. Slope wash fans consisting of colluvium interbedded with alluvium overlie the youngest glacial outwash and clearly are Holocene in age.

Landslide Deposits

Landslides are present throughout the Pioneer district. The deposits were apparently formed by rotational slumping. Most are on steep hillslopes underlain by siltstone of the Cabbage Patch Formation. On the southeast side of Ballard Hill, landslide material consists of Squaw Gulch beds and glacial till. The irregular surface topography of many of the slides suggests that they are of late Holocene age. Two large slides near the center of the district correspond to the locations of major faults which were active during the Miocene and Pliocene.

Figure 16.--Surficial lag gravel on Woods Flat. Gravel overlies siltstone of Cabbage Patch Formation and ranges from 1.5 to 3 ft in thickness. Largest boulder is 3 foot-long clast of Quadrant quartzite covered with percussion marks.

STRUCTURE

Structural features in the Pioneer district include faults along the southwest edge of the Gold Creek basin, and faults and folds cutting Tertiary age sedimentary rocks within the basin. Deformation in the basin probably began before the deposition of the Cabbage Patch Formation in late Oligocene time and continued sporadically through middle Pleistocene time. The rectangular drainage pattern in many parts of the district reflects the presence of numerous faults cutting the Tertiary units. Major folds are present in the Mesozoic and Paleozoic strata surrounding the basin (Mutch, 1960; Gwinn, 1960; Elliott et al., 1984).

Gwinn (1960) suggested two periods of Tertiary normal faulting in the area, one which formed a broad depositional basin prior to deposition of the Cabbage Patch beds in late Oligocene time, and the other which uplifted the mountains relative to nearby basins in middle Miocene time. Two additional periods of faulting are suggested based on structural and stratigraphic evidence found in the Pioneer district during the present study.

The configuration of the Gold Creek basin is partly controlled by the locations of north- or northwest-trending high-angle faults (Pardee, 1950; Mutch, 1960; Konizeski et al., 1968; C. A. Wallace, written commun., 5/85). The faults separate metamorphosed Paleozoic and Mesozoic sedimentary rocks and Cretaceous intrusive rocks in the mountains from chiefly Cenozoic sedimentary rocks in the basins. Evidence for the fault at the southwest margin of the study area includes a breccia zone hundreds of feet wide occupying a linear valley parallel to the mountain front south of Ballard Hill (Plate 1). Fault breccia in this zone is developed in Quadrant quartzite. It is cemented by sparse jasperoid.

Tertiary age rocks in the Pioneer district show evidence of several stages of faulting, including abundant small-scale fractures in mudstones and siltstones, diverse bedding attitudes (dips of as much as 30°), major unconformities at stratigraphic intervals where thick sequences of rock are present in nearby areas, unlikely stratigraphic relationships, and rarely, exposed fault contacts between Tertiary units.

The 2,170 foot-thick Cabbage Patch Formation was subdivided by Rasmussen (1977, p. 107) into three units based on mammalian assemblages. The lower part of the formation is exposed at two localites in the northern portion of the Pioneer district (SE 1/4, sec. 13, T 9 N, R 11 W, and NW 1/4, sec. 14, T 9 N, R 11 W), whereas the upper part occurs along the east side of Pikes Peak Creek (SW 1/4, sec. 30, T 9 N, R 11 W), 1.8 mi southeast of the first locality (Rasmussen, 1977, p. 472, 475). The unit dips gently toward the northeast between these two sites, necessitating approximately 1,500 ft of fault offset in order to explain the exposure of the upper and lower parts of the unit at roughly the same altitude within a distance of 1.8 mi. A major northeast-trending normal fault on the west slope of Windy Hill (Plate 1) has about 460 ft of post-Pliocene displacement and movement on this fault during Miocene and Pliocene time may also account for the offset of the upper and lower units of the Cabbage Patch Formation.

A steep, north-trending fault juxtaposes siltstone of the Cabbage Patch Formation with siltstone and conglomerate of the Squaw Gulch beds just east of Gold Hill (in the NE 1/4, sec. 36, T 9 N, R 11 W). This faulted sequence is overlain by Pioneer beds that cover the Squaw Gulch beds on Gold Hill to the west. East of the fault, the Pioneer beds overly the Cabbage Patch Formation. Movement on this fault must have occurred after deposition of the Squaw Gulch beds, but before deposition of the Pioneer beds.

Stratigraphic relationships near Ballard Hill suggest other steep normal faults. Ballard Hill and the two prominent hills east of Pioneer Gulch (in secs. 25 and 26, T 9 N, R 11 W) are underlain by 300 to 500 ft of Squaw Gulch beds that are capped with Pioneer beds. Just north of this area (in secs. 22, 23, 24, T 9 N, R 11 W), Pioneer beds overlies siltstone of the Cabbage Patch Formation. This stratigraphic relationship suggests the presence of a steep east-west trending normal fault. This fault appears to connect with the north-trending fault northeast of Gold

Hill, forming one major fault block that includes Ballard Hill, Jobs Point, the hills in secs. 25 and 26, and Gold Hill. The similarity of stratigraphic relationships within this block suggests that it behaved as a reasonably coherent structural unit during late Tertiary time. Subsidiary faults offset the rocks within this block (Plate 1).

The Squaw Gulch beds were removed from areas to the north and east of this block during relative uplift of the northern and eastern blocks in late Miocene or Pliocene time. Pioneer beds were then deposited on the truncated surface. The northern block was downdropped about 300 ft after the deposition of the conglomerate. Continued faulting during Pleistocene time, combined with deep erosion and local slumping, has left isolated remnants of the conglomerate on hilltops at several levels.

The oldest Pleistocene glacial deposits in the northern Deer Lodge basin are cut by faults but the youngest deposits are undisturbed (C. A. Wallace, written commun., 5/85), indicating that significant fault movement occurred in this area between middle and late Wisconsin time.

GEOMORPHOLOGY

Landforms in the study area reflect long-active stream erosion and hillslope modification outside of the glacial margin and intense glacial erosion and deposition within the glacial margin.

STREAM EROSION

The most important period of stream erosion in the district occurred between Pliocene and middle Pleistocene time. During this time interval the main streams downcut as much as 1,000 ft along the mountain front in the southern part of the district, and 300 to 600 ft in the piedmont in the central and northern parts of the district. The downcutting of the streams during this period occurred throughout the northern Rocky Mountains.

The causes of the regional stream incision are not accurately known. According to Schumm (1981), regional stream incision is caused by tectonic activity, eustatic base level variations, and climatic change. The tectonic and climatic history of the area suggest that a combination of these influences may have been involved.

Tectonic uplift of the mountains during the late Miocene or Pliocene caused the deposition of coarse alluvial fan gravels along the flanks of the mountain ranges. A period of incision may have followed the deposition of these gravels because the sediment supply from the source areas was reduced. Konizeski (1957, p. 147) suggests that the change from aggradation to erosion in post-middle Pliocene time resulted from an increase in annual rainfall. The climate became cooler and wetter during Pleistocene time. According to Schumm (1977, p. 102), in semiarid continental interior areas, a climatic change to cooler and wetter causes erosion in the drainage systems. Conditions were thus favorable to begin downcutting in the Pliocene in response to tectonic activity and to continue the downcutting through the early to middle Pleistocene in response to climatic change.

The present steep-sided gulches that drain the northern Flint Creek Range are the result of this episode of regional downcutting. No terraces remain from this downcutting period in the Gold Creek basin because the streams either cut vertically through the soft Tertiary basin-fill deposits for a long interval of time, or the terraces were not preserved. In the map area, the principal drainage of the range during early to middle Pleistocene time was through the Gold Creek, Pioneer Gulch, and Pikes Peak Creek valleys. Later deposition of glacial till in Pioneer Gulch diverted the drainage in the eastern part of the district entirely to the Pikes Peak Creek valley.

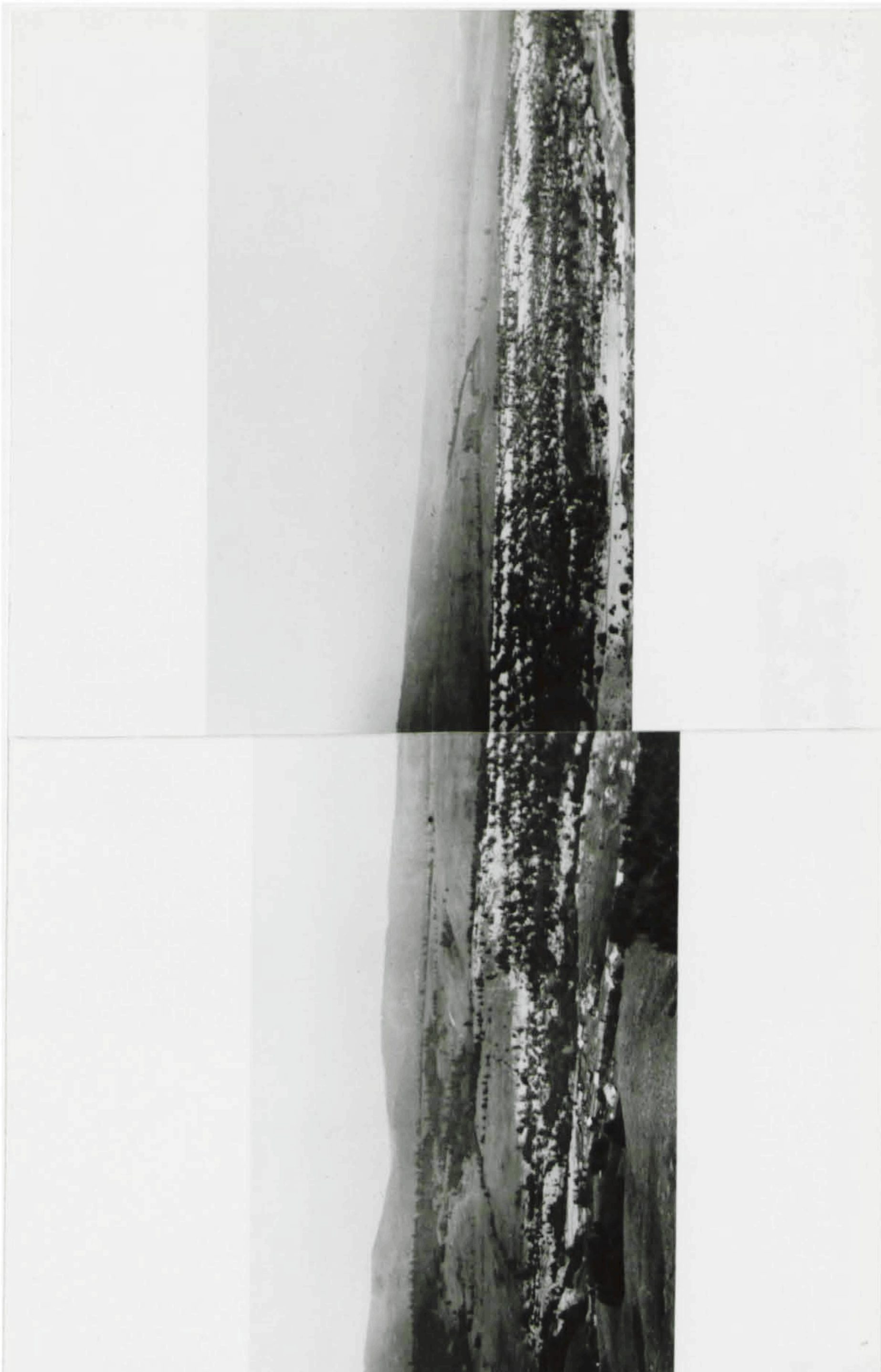
Pardee (1951) interpreted deposits in the piedmont part of the district as an alternating series of glacial drifts and fluvial terrace gravels. He constructed a longitudinal profile (Pardee, 1951, Fig. 27) in which gravels in placer mines and on the summits of hills were correlated within and between the drainage basins of Pikes Peak Creek and Pioneer Gulch. The oldest surface, recognized only on Ballard Hill and Windy Hill, was thought to represent pre-glacial gravels of late Tertiary or early Pleistocene age. Below this level lay a sequence of terraces formed by periodic downcutting by Pikes Peak Creek and Gold Creek during Pleistocene time (Pardee, 1951, p. 86). Glaciers presumably deposited the gold-rich "early drift" on the highest of these terraces. Remnants of later valley floors formed the successively lower terraces. The most noteworthy of the postulated lower terrace sequence was Pioneer Bar, a ridge that presumably had six fluvial terraces equally spaced through a vertical distance of about 200 ft. Evidence for such terraces on Pioneer Bar is unequivocal, however, because Pioneer Bar was completely mined by ground-sluicing during the 1870's and 1880's. The part of the hill that was mined now consists of several flat treads covered with piles of large boulders arranged in long rows.

The findings of the present study indicate that the early glaciers flowed down deep valleys, not across the late Tertiary piedmont. The valleys were cut before the glacial epoch, and terraces from the downcutting interval are very poorly preserved if they did form. In Pardee's (1951) stream profile, Tertiary rocks on the tops of hills are cross correlated as if they were deposited by the present stream system. The present stream system, however, did not exist when these beds were deposited.

A simpler explanation for the origin of terraces on Pioneer Bar that is consistent with the lack of well-defined terrace morphology throughout the district is that the terracing was formed by the ground sluicing operations. The miners constructed ditches at several levels to bring water from the south to the isolated, 5,000 foot-long hill. To channel the water through the workings as mining progressed, tailings were carefully piled up in long rows. Pioneer bar is now too heavily forested to view terraces. However, in 1916 J. T. Pardee photographed Pioneer bar from the hill on the east side of Pioneer Gulch (Fig. 17). Rows of tailings on several flat surfaces, and the ditches leading to some of these surfaces, are clearly visible.

The composition of the tailings lying on the surfaces ranges from 50% Quadrant quartzite, 25% other sedimentary rock types, and 25% rotten granodiorite at the top of the hill to predominantly fresh granodiorite in the present stream channels on both sides of the hill. The composition of the tailings on Pioneer Bar thus more closely resembles that of Pioneer beds (dominantly quartzite, sandstone, and slate) than Pleistocene outwash (dominantly granodiorite). The conglomerate-covered hill was perhaps weathered into a round-topped form similar to nearby Reservoir Hill by stream downcutting on both sides, and slope wash erosion.

Figure 17.--Photomosaic showing mine workings on Pioneer Bar (Photo by J. T. Pardee, 1916). White beds are mudstone and siltstone of the Cabbage Patch Formation. Flat surfaces defined by aligned tailings were interpreted as fluvial terraces by Pardee (1951). Ditches brought water in from south (left).



Based on the profile constructed by Pardee (1951, p. 76) showing six terraces just downstream from the intersection of three high-gradient streams in Pioneer Gulch, Schumm (1977, p. 230) suggested episodic erosion as a cause of placer formation at Pioneer Bar. Schumm (1977) stated, "sediments were stored and periodically reworked to produce the terraces and gold concentrations". Schumm further suggested that a convexity in the longitudinal profile reflects high sediment contribution from the three tributaries. Consequently, the site would be a likely site for channel incision, and local terrace and placer formation.

The site of intersection of the streams was a favorable site for the periodic storage and reworking of sediments because about 44,000 fine oz of gold have been recovered from outwash downstream from the site of intersection of the streams. However, well-defined terraces, as described by Pardee (1951), apparently did not form at this locality.

GLACIAL PROCESSES

Four tills and three outwash deposits were identified along the deep valleys that drain the Flint Creek Range (M. R. Waters, written commun., 8/85; Table 3). In the study area, the earliest glaciers flowed down the valleys of Gold Creek and Pioneer Gulch. Later glaciers deposited till on top of the older till. In Pioneer Gulch, the earliest glacier left large moraines that diverted later glaciers and streams down the Pikes Peak Creek valley. Locally (at Gold

Hill and Reservoir Hill), the youngest glaciers overrode the older till and crossed onto hills underlain by Tertiary sedimentary rocks.

Outwash gravels were deposited during each of the glacial advances, but only three outwash gravels could be recognized in the area. These were tentatively correlated with the three youngest tills. Small remnants of the first and second outwashes are preserved along the lower parts of Gold Creek and Pikes Peak Creek. These outwash gravels are within 50 ft of the present stream level, indicating that only a small amount of downcutting took place along this part of the valleys during the later interglacial periods. Composition of the old outwashes is similar to that of the youngest outwash (70-90% granodiorite, 10-30% quartzite, sandstone, and slate), suggesting that the proportions of granitic to sedimentary rocks available in the source area did not change appreciably during the late Pleistocene.

HILLSLOPE DEVELOPMENT

Colluvium derived from the erosion of the Tertiary valley-fill mantles most hills in the district. Hillslopes in the area have been exposed to slope-forming processes since the stream downcutting interval began in middle Pliocene time. Two types of colluvium are present, stratified sheets along steep valleys and unsorted lags on broad hills. Landslides, including rotational slumps, have also had an influence on the hillslope development of the area.

The processes that operated during hillslope evolution probably changed through time along with climatic changes and changes in the morphology of the slopes (Goudie and Bull, 1984). Slope wash has probably been the dominant slope-forming process on slopes of low to moderate relief. Landsliding has been an important process on the steepest slopes throughout the area.

Most hills in the area are underain by non-resistant and poorly vegetated Tertiary sedimentary rocks. The thickest and most widespread units are mudstone and siltstone of the Cabbage Patch Formation. The Cabbage Patch Formation is typically overlain by a caprock of Pioneer beds or colluvium derived from it. The underlying siltstone forms steep, poorly vegetated valley walls and is vulnerable to erosion by slope wash.

During storms, surface runoff transports silt and the overlying gravel clasts down the slope. Silt is moved easily, even during mild rains, whereas gravel clasts are moved principally by runoff during major storms. Runoff during rainstorms in small drainage areas is variable, and the coarsest sediments are carried only by torrential storms of low recurrence interval (Wolman and Miller, 1960). During infrequent catastrophic rainstorms, pebbles and cobbles are mobilized by overland flow and are deposited at the base of the slope. The gravel is later covered by silt transported downhill by light rainfall and creep. This process is a simple type of fluvial transport, and the resulting colluvium is crudely stratified. However, the deposits were mapped as colluvium because of their sheet-like geometry and location along hillsides.

In the central part of the district, lag gravels 1.5 to 3 ft thick cover extensive poorly vegetated low-relief areas. These lags are attributed to long-term erosion by slope wash. Some of these areas were extensively mined, indicating that the erosion concentrated placer gold that was present in the Pioneer beds. This apparently resulted from the removal of a large volume of fine-grained matrix from the conglomerate by rain splash and surface runoff.

The Cabbage Patch strata are prone to landsliding on steep slopes. Most of the slides are rotational slumps in areas along the sides of steep gulches. The landslides shown on Plate 1 all have distinct scarps at their heads and irregular topography on the landslide surfaces.

LATE CENOZOIC GEOLOGIC HISTORY

Events that occurred during middle to late Tertiary time (Table 4) had a great influence on the formation of placers in the Pioneer district. During this time the gold-bearing lodes in the present mountain sites were weathered and the gold was released and transported to the adjacent Gold Creek basin. Quaternary age events have had far less influence on the formation of gold placers.

In Eocene time, andesitic and basaltic lavas erupted and were deposited in sites that do not correspond to the present intermontane basins and may thus reflect an initial period of block faulting that formed the Clark Fork Basin. Valley-fill sediments probably also accumulated in the basin during Eocene to early Oligocene time, but these sediments were either removed by later erosion or they were covered with younger rocks.

Deposition of large volumes of valley-fill sediments began in the area north of Drummond in early Oligocene time (Rasmussen, 1977) and by late Oligocene time, sediments of the Cabbage Patch Formation were being deposited over a large area. Volcanic eruptions, possibly from the Cascade Mountains and the Columbia Plateau, spread tuffaceous material throughout the area, locally causing damming of the northwest drainage and intermittent ponding in the Flint

Table 4.--Sequence of geologic and climatic events in the Pioneer district from middle Tertiary time to present.

Time	Description of Events
Eocene	Deposition of Lowland Creek Volcanics
Eocene (?)	Formation of Clark Fork basin
Oligocene to early Miocene	Deposition of Cabbage Patch Formation. Deep weathering of lodes during period of wet, warm climate.
Middle Miocene	Uplift of mountains along extensional faults accompanied by folding of Cabbage Patch Formation. Erosion, climate became drier. Development of middle Miocene unconformity
Late Middle Miocene	Continued uplift and deposition of Squaw Gulch beds on alluvial plains adjacent to rising mountains. First placers formed.
Late Miocene (?)	Faulting of Cabbage Patch and Squaw Gulch beds. Erosion
Late Miocene to Pliocene (?)	Major period of uplift accompanied by deposition of Pioneer beds in alluvial fans. Principal placers formed.
Middle Pliocene to middle Pleistocene	Incision of modern drainage system. Faulting of Tertiary sequences. Climate becomes cooler and wetter. Royal stock exposed by erosion.
Middle to late Pleistocene	Deposition of till and outwash during four major glaciations. Erosion of non-glaciated areas.
Late Pleistocene to Recent	Continued erosion, colluvium deposition, landsliding.

Creek and Gold Creek basins. Ash and soil washed into Lake Drummond. Plants grew abundantly on the banks of the ponds and lakes, and a large number of animals, principally small mammals and amphibians, lived in these forests. Snails, ostracods, clams, and other mollusks lived in the slowly circulating shallow water in the lake. As the plants and animals died, their remains were buried under the ash, mud, and silt that became the Cabbage Patch Formation.

A period of regional erosion took place in middle Miocene time. This erosion may have been related to an increase in block-faulting in southwestern Montana. During this time the middle Tertiary basin-fill strata were folded and faulted. The outline of the present valleys was probably established by late-middle Miocene time. As the mountains rose, regional weather circulation patterns changed and the climate became drier. The dense vegetation characterisic of the early Miocene rocks died off and was replaced by brushy forest cover.

The middle Miocene uplift ended the interval of quiet water fluvial and lacustrine deposition. Beginning about 16 million years ago aggrading streams draining north from the mountains deposited silt, sand, and gravel on rising flood-plains above the dry lakebeds. This material included much clastic debris that had weathered from the sedimentary rocks exposed in the surrounding mountains. In mineralized areas the debris included placer gold derived from lodes during the preceeding period of humid climate. The first placers in the Pioneer district were deposited on piedmont slopes by streams draining northward from the northern Flint Creek Range. These placers are part of the Squaw Gulch beds.

The rocks of the Cabbage Patch Formation and the Squaw Gulch beds were faulted against each other during late Miocene (?) time. Erosion beveled off the blocks that were raised during the relative movement. At some time around late Miocene to Pliocene time the magnitude of the basin-margin faulting increased dramatically. The mountains rose more rapidly than streams could erode them, causing the deposition of much clastic debris adjacent to the fault scarps. Alluvial fans prograded into the surrounding basins. Debris flows and mudflows carried unsorted detritus containing large boulders to the proximal and medial areas of the fans. Gold liberated during the pre-middle Miocene interval of deep weathering was deposited on the alluvial plains and concentrated within the Pioneer beds. Streams continually shifted across the coalesced alluvial fans, reworking the earlier deposits.

The period of rapid uplift was short-lived. The pulse of coarse sediment deposition and the reworking of the gravels was followed by a period of deep stream incision. In middle Pliocene to middle Pleistocene time the present stream system developed, perhaps in response to an increase in stream gradient as a result of faulting followed by a change in climate to cooler and wetter conditions. Streams cut down hundreds of feet into the older Tertiary deposits. Some of the placer gold in the Tertiary gravels was probably reconcentrated into stream gravels. Fluvial terraces may have formed during this period but were destroyed by later erosion. Downcutting in the mountains exposed granodiorite of the Royal Stock. Fault movement in the Gold Creek basin during this period displaced the Pliocene alluvial plain. The Pioneer beds were consequently left on benches at several levels that tilt in different directions.

In middle Pleistocene time, glaciers developed in the mountains of the Flint Creek Range and flowed down the pre-glacial valleys to the edge of the Gold Creek Basin. The glaciers advanced four major times. The first glacier deposited a large amount of till in Pioneer Gulch, causing later glaciers and streams to flow down the Pikes Peak Creek valley. Locally, the latest glaciers overrode earlier till and covered small areas underlain by Tertiary sediments, such as at Gold Hill and Reservoir Hill. Large quantities of meltwater transported outwash gravels consisting predominantly of granodiorite detritus down the valleys during each advance. Much of the outwash was deposited in the Gold Creek valley.

The glacial activity in the mountains and foothills generally did not effect the Tertiary deposits in the Gold Creek Basin. In the basin, downcutting of streams during interglacial intervals was slight. If any significant terraces formed, they were rapidly eroded and destroyed.

At the beginning of Holocene time the climate became warmer and drier and the glaciers melted away. Streams in the area became ephemeral and their ability to transport sediment was greatly reduced except during the heaviest rains. Colluvial aprons formed along stream valleys as intermittant rain wash on hillslopes transported silt and gravel downhill from nearby outcrops of Tertiary sediments. Locally, the poorly consolidated Tertiary units slumped and landslides extended into the adjacent valleys.

ECONOMIC GEOLOGY

The Pioneer district is located in one of the richest metal-producing regions of Montana. Since mining began in 1862, the value of metal production from fifteen mining districts in the Flint Creek Range has totalled about $120 million (value of metals at time of production: Elliott et al., 1984; Elliott et al., in press). Placers in the Pioneer district were apparently derived from gold mineralization in and on the margins of the Royal stock. This area, which occupies the headwaters of Pikes Peak Creek and Gold Creek, is known as the Rose Mountain mining district (Fig. 1; Elliott et al., 1984).

LODE ORE DEPOSITS OF THE ROSE MOUNTAIN DISTRICT

Gold- and silver-bearing fissure quartz veins and mineralized shear zones occur in granodiorite of the Royal stock and in metamorphosed sedimentary rocks in the roof zone of the stock, and a few gold placers occur in Quaternary glacial deposits along Gold Creek. The value of metal produced of the Rose Mountain district is approximately $100,000, chiefly in gold and silver.

The Royal stock is a late Cretaceous (67 m.y. old; Fission-track, Baty, 1976) pluton which outcrops over about 25 sq mi in the northern Flint Creek Range. A metamorphic aureole with a maximum width of about 1 mi is developed in the middle Proterozoic to lower Cretaceous age sedimentary rocks surrounding the stock. Quartz veins associated with the Royal stock and the surrounding sedimentary rocks typically consist of clear quartz containing variable amounts of pyrite, chalcopyrite, tetrahedrite, galena, and sphalerite. The oxidized veins contain vuggy limonite, sericite, manganese stain, copper carbonates and oxides, and possibly cerussite (J. E. Elliott, written commun, 1985). Twenty-eight samples of vein and altered rock were analyzed for gold by semiquantitative spectrographic analyses (SQS) and eighteen were analyzed for gold by atomic absorption (AA; J. E. Elliott, written commun., 11/85). Gold values in rock samples analyzed by SQS range from below the limit of detection at 10 ppm (0.292 oz per st ton) to 200 ppm (5.84 oz per st ton). AA determinations for gold in the same sample sets ranged from below 0.05 ppm (.0015 oz per st ton) to 52.0 ppm (1.518 oz per st ton). Of eighteen samples analyzed by AA, the average gold value was 7.67 ppm (0.224 oz per ton). In addition to anomalies revealled by analyses of rock samples, panned concentrate samples from Pikes Peak Creek showed anomalous gold, and soil samples from along the ridge in secs. 23 and 24, T. 8 N., R. 12 W., were anomalous in silver, copper, lead, molybdenum, zinc, and other elements (Elliott et al., 1984).

Four lode mines and two placer mines with recorded production in the Rose Mountain district are described below.

The John G. Carlisle mine includes six adits that lead to about 600 ft of underground workings, and numerous surface pits (Elliott et al., 1984). Ore mineralization is confined to quartz veins in a shear zone in granodiorite (Emmons and Calkins, 1913, p. 251). Between 1897 and 1899, about $2,500 worth of gold and silver was produced.

At the Independence mine (also known as the Fourth of July mine), sulfide-bearing quartz veins averaging 0.8 ft thick occupy a shear zone in granodiorite (Elliott et al., 1984). The oxidized ore contains secondary copper minerals and native gold. One 48 lb vein sample was collected from the dump in order to obtain gold for microprobe analysis. The sample contained 221.9 mg of recoverable gold (equivalent to a grade of 0.33 oz per ton). Between 1926 and 1935, the mine produced 107 tons of ore containing 469 oz of gold, 183 oz of silver, and 62 lb of copper (McClernan, 1976, Table P-2).

The Ryan mine (also known as the Pioneer quartz mine) consists of numerous adits along 1/2" to 4" quartz veins in Paleozoic and Mesozoic sedimentary rocks. The veins contain native gold, chalcopyrite, pyrite, galena, malachite, chrysocolla, and limonite (J. T. Pardee, field notes, 8/4/16). The principal metals produced are gold, copper, silver, and lead. J. T. Pardee visited this mine on August 4, 1916, and recorded the following observations:

> "This vein reputed to have produced some phenomenally rich gold ore--... 1 lb and 8 oz of the selected rock recently shipped to Helena assay office yielded [a value of] $180 [10.2 fine oz of gold; equivalent to 13,600 oz per ton] (fineness--Au: 847.8, Ag: 140.8 ($17.61 per oz)). Several thousand dollars said to have been produced, by pounding and picking the rock by hand".

Between 1915 and 1937, the "Pioneer mine" produced 259 tons of ore containing 503 oz of gold, 202 oz of silver, and 84 lb of lead (McClernan, 1976, Table P-2). In 1936 and 1937 the Ryan mine produced 28 tons of ore containing 12 oz of gold, 73 oz of silver, and 109 lb of copper (McClernan, 1976, Table P-2).

The G. W. Tibbets mine consisits of a incline shaft sunk on an east-west vein 1 to 3 ft thick, and a crosscut adit 160 ft long that also reaches the vein. J. T. Pardee (1916 field notes) quoted Thomas McHugh, the owner of the mine, as stating that the ore assayed from $250 to $80,000 in gold per ton. Large specimens of native gold from this mine were exhibited at the 1900 World's Fair in St. Louis, Missouri. One 48 lb vein sample was collected from dumps to obtain gold for this study. The sample contained 63.3 mg of recoverable gold (equivalent to grade of 0.11 oz per ton).

The Pineau placer mine on upper Gold Creek is locally known for its production of coarse placer gold. The largest nugget weighed 27 oz (Pardee, 1951, p. 95), and mining operations in 1985 recovered nuggets as large as 7.4 oz. The deposits are in glacial till composed of granodiorite detritus overlying gravels composed principally of quartzite clasts. The gold is mainly concentrated in gravel channels lying directly on bedrock.

The Master mine is the largest of the placer mines along upper Gold Creek. The placers are apparently in the two lowest of four Pleistocene age till units, locally interbedded with well-sorted fluvial deposits. Emmons and Calkins (1913, p. 263-264) noted that the mine had produced gold valued at $35,000 (about 1,700 fine oz) between 1896 and 1913. Nuggets in excess of 10 oz have been found. The gold ranges in purity from 775 to 825 fine.

GOLD PLACERS OF THE PIONEER DISTRICT

Placers of the Pioneer district have a geologic heritage that spans about 20 million years and a cultural history dating back to 1852. Interest in these placers during the 1860's started the first of many gold rushes which resulted in the permanent settlement of the region.

History of Mining

The following historical sketch has been extracted mainly from the work of Raymond (1873), Lyden (1948), and Pardee (field notes; 1951):

The first discovery of gold in the district, which was reportedly also the first discovery of gold in Montana, was made by Francois Finlay in 1852 along Gold Creek near where the Mullan Road (an early military highway) crossed the creek. News of the discovery spread among the early traders and explorers of the region, and other parties prospected in the district in 1856 and 1858. In 1858, 1860, and 1861, groups led by Granville Stuart found promising placer ground in dry gulches tributary to Gold Creek. Stuart and others began ground sluicing in May 1862. During that summer many other gold seekers reached the district. In August 1862, however, most of the miners abandoned the Pioneer district in favor of placer deposits at Bannack, Montana. A series of gold rushes to other districts in western Montana followed the gold rush to Bannack.

The gold rush period in western Montana lasted only until the richest gravels were worked out. During the late 1860's miners returned to the Pioneer district, established ramshackle mining camps, and began large-scale systematic mining. In 1867 the Pioneer Company commenced hydraulic mining on Pioneer Gulch. The 16-mile long Rock Creek ditch, constructed in 1868 and 1869 at a cost of $125,000 by a company formed by rancher Conrad Kohrs and associates, carried 2,500 miners inches of water (6,250 cu. ft per minute) to Gold Hill. From Gold Hill the water was distributed throughout the district. In 1870 the water was sold to hundreds of miners at 25 cents per miners inch (equivalent to 25 cents for 1.5 cu ft per minute) for a total revenue of $70,000. In both 1870 and 1871 the company paid dividends of $50,000.

The first deposits to be mined in 1870 using the water from Rock Creek were on Batterton Bar, which is located between Gold Hill and Pikes Peak Creek. This deposit was rich; approximately 7000 fine oz of gold (valued at approximately $140,000) was recovered in a single season (Pardee, 1951, p. 75). By 1871 three companies on Pioneer Gulch were operating five hydraulic giants, four companies were sluicing on French Gulch, three hydraulic giants were working on Wilson Bar about 2 mi north of Pioneer, and 50 Chinese workers were recovering gold valued at about $50 per month each on small-scale operations on Pikes Peak Creek. According to Raymond (1873), about twelve men were employed in every 200 x 600 ft claim, and they worked day and night shifts. A weeks clean-up usually produced about 50 to 80 fine oz of gold (valued at $1,000 to $1,600) per claim. Raymond (1873, p. 273) estimated that in 1870 a total of approximately 230 workers (80 Whites and 150 Chinese) were employed in the placer mines of the district. By 1874 or 1875, the richer parts of the high-level placers (the "Bars") had been worked out and the miners moved to Pioneer Gulch and Ballard Hill. They mined a hill called "Pioneer Bar" for several years, using water brought by ditches from Gold Creek. More than 50,000 fine oz of gold (valued at $1 million) was washed from Pioneer Bar. Production from the mines on Ballard

Hill and French Gulch during this period is unknown, but probably was substantial. Extensive hydraulic mining continued in several parts of the district through the 1880's and 90's.

The early miners named the best-paying gravel the "quartz formation" because it consisted of pebbles, cobbles, and boulders in conglomerate composed primarily of quartzite. Raymond (1873, p. 274) stated that

> "There is this peculiarity noticeable about the gravel, that wherever it is composed of quartzite and quartzite slate it pays well, but when it is largely composed of granitic rock there is little or no gold found in it."

After 1900, dredges were used to mine glacial outwash plains in Pioneer Gulch. The first of three dredges used in the district was the steam powered "Stewart". It was operated about 1 mi below the town of Pioneer in 1905 and 1906 by an English company. The amount of gold recovered in 1905 is unknown, but from May to November, 1906 the dredge produced about 300 oz ($5,647) from 29,075 cubic yd of gravel or 19.42 cents per cu yd at $20.67 per oz (Lyden, 1948). The dredge was abandoned in 1906.

The Kohrs and Bielenberg mine, located along K and K Bar in Pioneer Gulch, was operated between 1910 and 1918. The principal workings are a large hydraulic pit known as the "1916 pit". The average rate of production from this mine was 30 to 35 oz per week (Pardee, field notes, 8/7/20). The following description of the 1916 pit is taken from Pardee (1951, p. 89):

> "The 1916 pit had an area of 4,376 square yards, from which a volume of about 30,000 cubic yards was mined with a total yield of 711 ounces of gold about 887 fine. The total value of the production was $13,033, or about 43 cents per yard mined [at $20.67 per oz]".

In 1918 the Rock Creek ditch and its reservoir were sold to an irrigation company, and the district lost its best source of water. Water from Gold Creek was used to mine deposits on the west side of Pioneer Gulch at the foot of Ballard Hill. According to mine foreman Frank Slaughtner (Pardee, field notes 8/7/20; 8/24/31), approximately 8,000 oz of gold (valued at $143,000) was produced from the pits south of the 1916 pit (about 2,200 oz ($40,000) was taken from one pit 50 x 150 ft and as much as 70 ft deep). However, the loss of the Rock Creek ditch eventually caused the period of hydraulic mining to come to an end in the Pioneer district. During the following years, the lack of water forced most miners to turn to connected-bucket dredges, dry-land dredges, and washing plants to mine the placers.

During the 1930's a small revival in placer mining took place because of the rise in value of gold from $20.67 to $35 per oz. In 1934 and 1935 the Pikes Peak Gold Mining Company operated a gasoline dragline shovel and washing plant on Pikes Peak Creek. The Orphan Boy mine, on the North Fork of Willow Creek, was briefly worked by hydraulic mining in 1935.

Between November 27, 1933 and November, 1940, the Pioneer Placer Dredging Company operated the "Mosier" dredge in Pioneer Gulch. For many years the dredge was the largest and most productive dredge in Montana. It was a 6,500 cubic yd, electric-driven "Yuba" dredge with 78 nine-cubic-foot buckets. It's capacity averaged 308 cu yd per hour as it cut a strip approximately 65 yd wide and 4 to 15 yd deep (J. T. Pardee, field notes, 8/16/35). Total production was 43,600 oz of gold and 4780 oz of silver ($1,526,190) from about 930,000 cu yd of gravel (U.S. Bureau of Mines, Minerals Yearbook; Pardee, 1951).

From January 19, 1955, to December 1957 an electric Yuba dredge with 75 three-cubic-foot buckets was operated in Reservoir Gulch by the Montana Gold and Chemical Co., of Seattle, Wash. A bulldozer and 8 hydraulic giants made up the equipment. The dredge produced 2,600 oz of gold (worth $91,100) before it was abandoned.

Few efforts have been made since 1958 to mine the placers, and little or no gold has been produced. In 1964 2 draglines, 2 crawler tractors, 2 pressure pumps for water, and a washing plant were operated along Pioneer Gulch (U.S. Bureau of Mines, Minerals Yearbook). The Orphan Boy mine, on the North Fork of Willow Creek, was prospected for a short time during the 1970's. As of August, 1985 there was no mining activity in the Pioneer district.

Production and Grade

Dollar estimates of total gold production from the Pioneer district range to as much as $20 million (Lyden, 1948). However, a figure of about $6 million (roughly 300,000 fine oz) is considered reasonable based on available data. Dependable records for the early production in the district are almost completely lacking. Partial records are available for the years 1887-1897 (L. Meikle, written commun., 10/85). In 1897 the director of the U.S. Mint estimated the value of early gold production at $4,000,000 (Pardee, 1951, p. 96). The value of production between 1904 and 1959 has been $2,052,000 (McClernan, 1976, Table P-1). The trend of placer gold production since 1880 is shown on Figure 18.

An overall grade for the district can be estimated by using the total volume of gold-bearing gravel mined. This volume was estimated by measuring individual areas of mine workings on Plate 1, and by multiplying these areas by estimates of the depth for each working (Table 5). Based on an estimate of total gold production of 300,000 fine oz the average grade of material mined in the district (not including dredge workings or production) is about 0.01 oz per cu yd or 21 cents per cu yd at $20.67 oz. This estimate is probably too low because much gold-barren material is included in the volume estimate. Since till or siltstone may form as much as three-quarters of the material processed at some large mines, the average

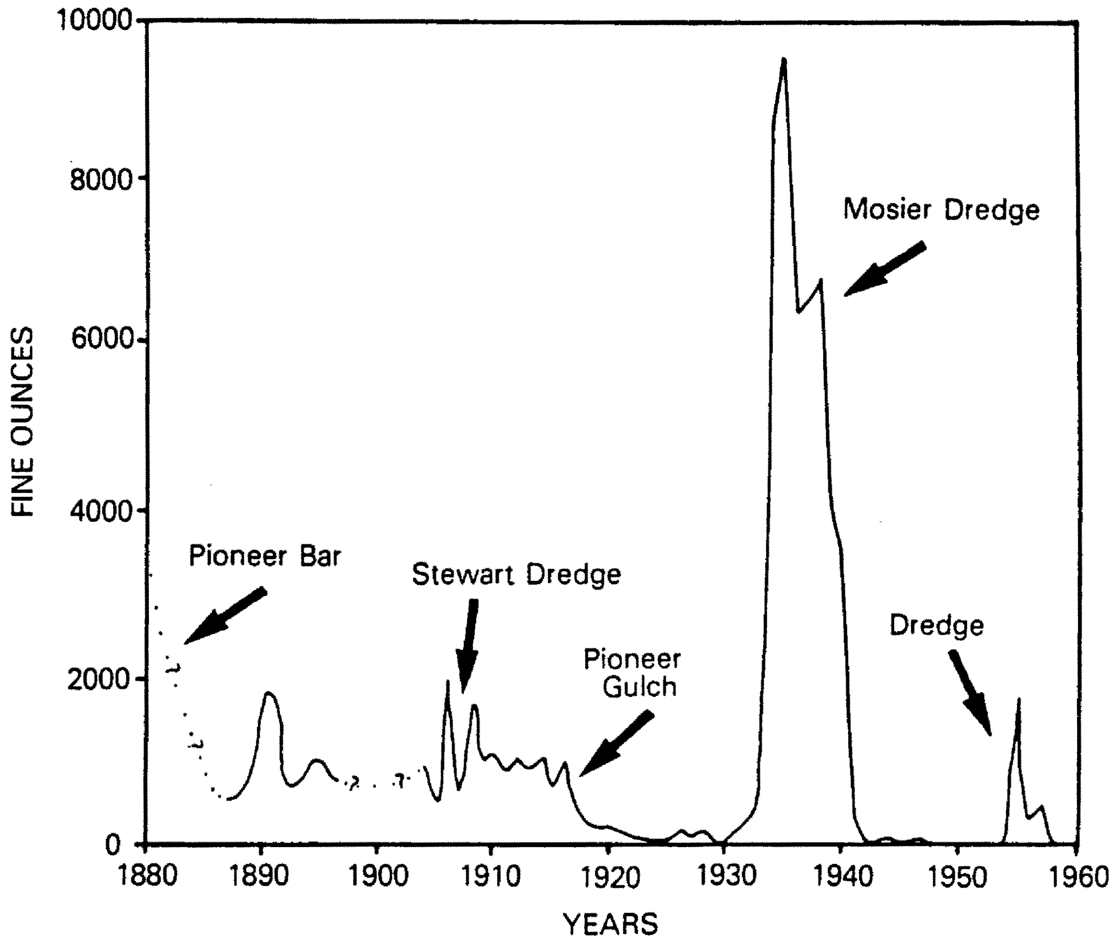


Figure 18.--Graph of placer gold production in the Pioneer district, 1880-1959. Queried dotted line indicates no data available. Production also was recorded in 1961 and between 1963 and 1967, but figures are confidential (Data compiled from L. Meikle, written commun., 10/85; U.S. Bureau of Mines, Minerals Yearbook; McClernan, 1976, Table P-1).

Table 5.--Mined areas, estimated depths and total amounts of material worked at placer mines in the Pioneer district. Areas were measured from Plate 1 and rounded to nearest 1000 sq yd. Approximate average depths of workings were estimated during examination of each site.

Location or mine name	Area (sq yd)	Estimated ave. depth (yd)	Total volume (cu yd)
Pioneer Gulch			
Middle Fork	11,000	3.0	30,000
Main Fork	862,000	5.0	4,310,000
Pioneer Gulch (Mosier dredge workings)	930,000	8.0	7,500,000
Pioneer Bar	684,000	3.5	2,394,000
Hillslope northeast of dredged area	134,000	2.0	268,000
Gulches and hill slopes east of dredged area	935,000	2.0	1,870,000
Squaw Gulch			
Squaw Gulch pit	330,000	10.0	3,300,000
Squaw Gulch	12,000	4.0	48,000
Kelly and Irvine pit	90,000	5.0	450,000
Ballard Hill			
Ballard mine	139,000	5.0	695,000
Jobs Point	46,000	5.0	230,000
French Gulch			
French Gulch	81,000	4.0	324,000
Reservoir Gulch			
Reservoir Gulch	121,000	4.0	484,000

Table 5. (Continued)

Location or mine name	Area (sq yd)	Estimated ave. depth (yd)	Total volume (cu yd)
Pikes Peak Creek			
Pikes Peak Creek	633,000	4.0	2,532,000
Batterton Bar	581,000	5.0	2,905,000
Pilgrim Bar	546,000	3.0	1,638,000
Dry Gulch	439,000	2.0	878,000
Woods Flat	346,000	0.75	259,500
Treadwater Bar	204,000	2.0	408,000
Wilson Bar	192,000	3.0	576,000
Hillslope southwest of Windy Hill	336,000	3.0	1,008,000
Undistributed	167,000	2.0	334,000
West Fork of Independence Creek			
West Fork of Indepencence Cr.	154,000	5.0	770,000
Windy Hill	126,000	2.0	252,000
Willow Creek			
Orphan Boy mine	41,000	3.0	123,000
Total ...	8,140,000	Total ...	33,587,500

gold grade of material mined in the district, excluding dredging, is probably closer to 0.02 to 0.04 oz per cu yd or 50 to 75 cents per cu yd at $20.67 per oz. The average grade of the richest mines in the district (Pioneer and Pilgrim Bars) probably ranged from 0.1 to 0.15 oz per cu yd or $2.0 to $3.0 per cu yd at $20.67 per oz. The average grade of outwash dredged in Pioneer Gulch was 0.005 oz per cu yd or 18 cents per cu yd at $35 per oz (Pardee, 1951, p. 78).

Types of Placers

The gold placers in the Pioneer district can be classified into three main types: (1) Tertiary conglomerate, (2) Pleistocene glacial deposits, and (3) Holocene alluvium and colluvium. The oldest placers served as the principal gold source for the two younger types. These types of placers, their modes of origin, ages, distribution, and, where known, gold grades, are described below.

Tertiary Conglomerate

Tertiary conglomerate is the most important deposit type in the district because it underlies about 45% of the total area of workings, including the largest and richest early mines. Gold-bearing conglomerate occurs in both the Squaw Gulch beds and the Pioneer beds. These distinctive conglomerates consist mainly of clasts of quartzite, sandstone, and slate derived from the roof zone of the Royal stock.

Pebble/cobble conglomerate--Numerous channels of pebble/cobble gravel interlayered with siltstone were deposited on alluvial plains surrounding the Flint Creek Range during initial uplift of the range in middle Miocene time. Conglomerate in the Squaw Gulch beds is present only in the southern part of the district, and exposures are poor. This conglomerate was mined in some of the largest placer workings in the district (the Squaw Gulch pit, Batterton bar, the Kohrs and Bielenburg mine). The extent, thickness, and grade of the pebble/cobble conglomerate is largely unknown because of poor exposure and lack of mine records.

Boulder/cobble conglomerate--The Pioneer beds form a hill-capping unit that outcrops throughout the Gold Creek basin. Conglomerate was deposited on alluvial fans that prograded northward from the rising Flint Creek Range. A relatively strong period of uplift caused deposition of coarse gravels on the flanks of the range by debris flows, mudflows, and braided streams. Following the uplift, braided streams reworked the gravels on a broad unconformity now represented piedmont remnants. Faulting and landsliding have greatly displaced the depositional surface of the conglomerate.

The conglomerate was mined in several high-lying areas including Ballard Hill, Pilgrim Bar, and Windy Hill. The conglomerate has been almost completely mined on the hills in the central part of the district.

The grade of this gravel is poorly known. Significant volumes of the coarse conglomerate may remain on Ballard Hill, Windy Hill, and other high hills in the area, but it is unknown if these deposits are as high grade as the deposits that were mined.

Pleistocene Glacial Deposits

Placers in glacial sediments in the district are apparently of low grade and, except for the Gold Creek valley, low volume. Many of the deposits that were previously described as gold-bearing glacial drift are reinterpreted as Tertiary conglomerate by the present study.

The glacial deposits are restricted to within the glacial margin at the southern edge of the district and to stream channels draining the margin. Glacial till and outwash did serve as placers in some parts of the district, and some of these deposits are associated with underlying Tertiary conglomerate.

Four ages of till are present in the southern part of the Pioneer district. Till was mined only rarely in this district, and where it was mined it overlies outwash and Tertiary conglomerate. Mined till consists of the oldest two of the four tills units (Qt_1, Qt_2). However, in many exposures it cannot be determined if till was the material mined or if it was simply overburden.

On K and K Bar along Pioneer Gulch, miners used hydraulic giants to wash the lower part of the oldest till. This till lay upon the "blood red gravel" of the Flint Creek beds, and possibly upon glacial outwash. These fluvial deposits are the probable sources for the gold that was mined.

Workings also are present in till on the west side of French Gulch (Plate 1). However, the deposits are too poorly exposed to determine their exact nature. Some of these alleged workings may be "wash outs" from ditches used to bring water from Gold Creek in order to mine in French Gulch.

Glacial outwash is the second most important type of placer in the district, underlying about 40% of the total mine workings. All outwash that was mined in the district was deposited in one of the following three geologic environments (Fig. 19A, B, C): (1) glacial outwash plains below terminal moraines, (2) outwash underlying ground moraine, and (3) outwash in channels marginal to major lateral moraines.

Glacial outwash in the valleys of Pioneer Gulch and Pikes Peak Creek (Fig. 19A) has been mined intensively. The outwash that was mined probably included deposits of all three known ages. The outwash in Pioneer Gulch averaged about 0.005 oz per yd or 18 cents per yd at $35 per oz (Pardee, 1951, p. 78). Crawford and Starliper (1933b) determined that 500,000 yd of dump material from outwash along Gold Creek had an average grade of about 0.086 oz per cu yd or $3.00 per yd at $35 per oz. The

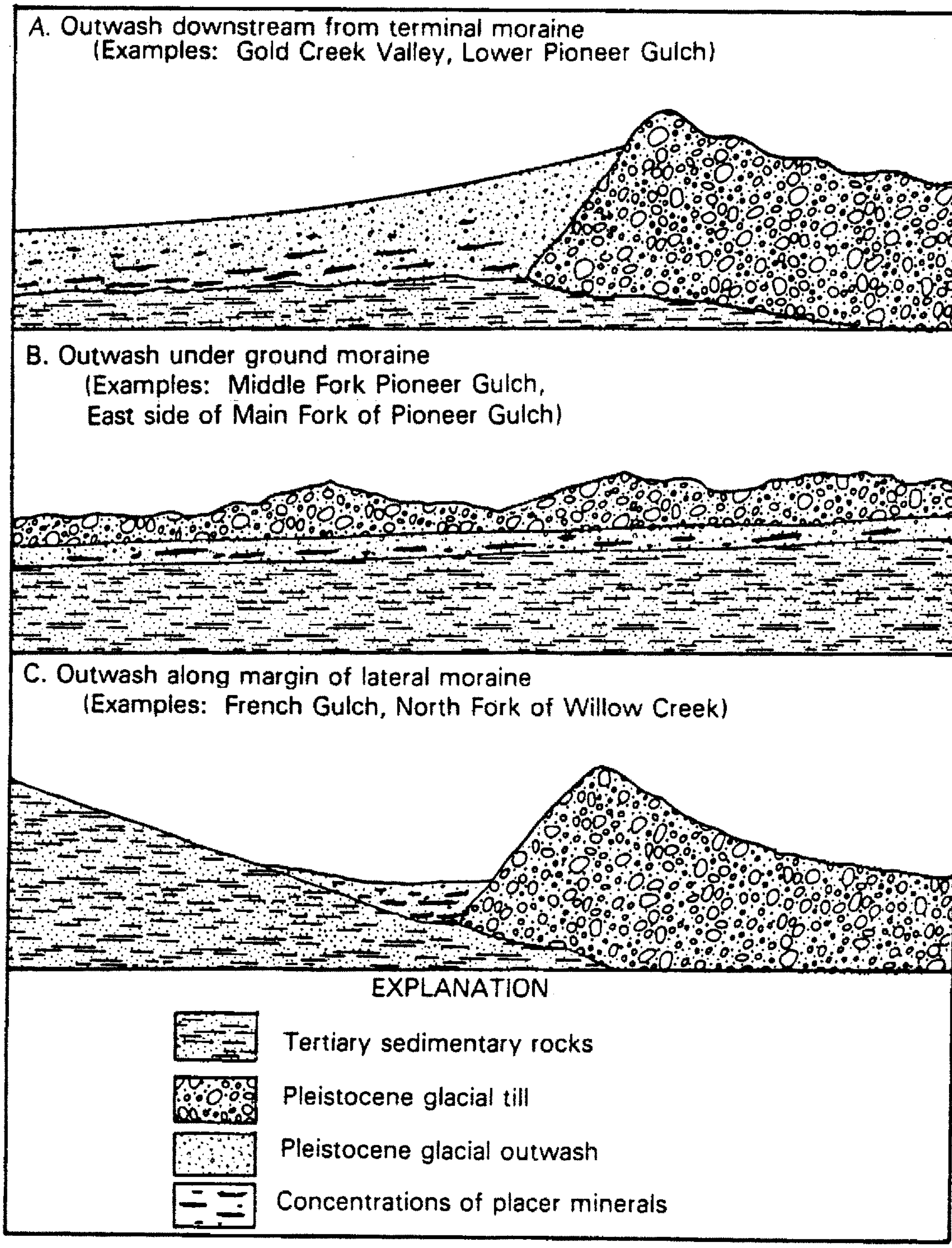


Figure. 19.--Diagrammatic cross sections illustrating placer deposit types in Pleistocene glacial outwash. Sections A and B are longitudinal; section C is transverse to flow of glacier.

only remaining high-volume outwash deposit in the district is the Gold Creek valley.

Outwash underlying Pleistocene ground moraine (Fig. 19B) has been mined at the "China diggings" along the Middle Fork of Pioneer Gulch, and possibly along the east side of the Main Fork of Pioneer Gulch.

In the southern part of the district, placers developed where glacial melt water flowed along the outside margins of Pleistocene lateral moraines (Fig. 20C). The most productive of these was French Gulch between Gold Creek and Ballard Hill. At the Orphan boy mine on Willow Creek, an analogous situation occurred. Outwash was concentrated along the outside of a lateral moraine deposited along the Pikes Peak Creek valley. In both of these cases, the deposition of thick lateral moraines against hills composed of Tertiary conglomerate and siltstones formed small valleys at the intersection point (Fig. 20C). The valleys subsequently localized runoff and glacial melt water. Although the glacial debris probably contained little gold, gold was present in the Tertiary conglomerate that the streams flowed over and reworked. Gold from these units was reconcentrated into outwash that consequently contains both granodiorite boulders from the till and quartzite clasts from both till and Tertiary deposits. The large scale of the workings in French Gulch suggest that the deposits were locally of high grade, but the abundance of boulders probably caused much difficulty.

Holocene Deposits

Alluvium and colluvium underlie about 15% of the total mine workings in the district. The processes that formed these deposits lacked the ability to transport gold from the source areas in the Flint Creek Range to the basin, thus placers formed only where a nearby pre-existing gold source was available for reconcentration (principally Tertiary conglomerate).

Alluvium was locally mined in the district; however, these deposits are small and apparently of low grade because of abundant fine-grained material. Colluvial processes strongly modified gold-bearing conglomerate in the Pioneer beds along many hills in the district. The effect of these processes was to remove light, nonresistant minerals, thereby increasing the relative content of heavy minerals, including gold. Two main types of colluvium formed in the area depending on the local relief: (1) Crudely stratified colluvial aprons along the sides of steep valleys, and (2) Lags on broad low-relief hills and slopes. The apron deposits were mined on a small scale on the east sides of both Pioneer and Pikes Peak Gulches. The gravel beds in the colluvium are generally thin, discontinuous, and poorly sorted. Lags were mined on broad areas on the hills between Pikes Peak Creek and Pioneer Gulch (in secs. 13, 24, 23, 25, and 26, T. 9 N., R. 11 W.). Much of this material may remain unworked along hills throughout the area because of the difficulty in bringing water to the sites. The grade of these colluvial deposits is unknown. However, judging from the relative scale of the mine workings, the lag deposits may be of higher grade than the apron deposits.

Descriptions of Mined Areas

The Pioneer district was separated into eight principal drainage basins (Table 5). The following descriptions summarize the principal geologic features and the types of placers present in each area:

Pioneer Gulch

The Pioneer Gulch area contains the largest proportion of placer mine workings in the district. Each placer type is present in the gulch, and, in some mines, several different types and ages of placers were mined indiscriminately.

The Middle Fork of Pioneer Gulch lies almost entirely within the Pleistocene glacial margin. The till of the second glacial advance surrounds the channel and is characterized by a gently undulating surface covered with granodiorite boulders. The only mine in this area is the "China diggings". This stretch of ground was probably mined during the 1870's or 1880's using water brought by ditches from Pikes Peak Creek. The workings consist of a single cut about 2,000 ft long and generally 6 to 12 ft deep. The cut expands to the south into an oval-shaped pit 150 ft wide, 200 ft long, and up to 20 ft deep. In the pit, at least seven adits (now caved) were driven radially from the central area into sandy outwash that underlies 3 to 5 ft of bouldery till. In addition to the adits, vertical shafts were dug through the glacial till in this area. The glacial boulders range to as much as 6 ft in length and are piled up in orderly rows between the portals of the adits. The outwash consists of unconsolidated, strongly imbricated sub-angular to subrounded pebbles and cobbles of quartzite and slate in a matrix of coarse to very coarse granodiorite sand. The abundance of quartzite and slate clasts indicates that the outwash was partially derived from Tertiary conglomerate. The outwash in this area was apparently overidden by an advancing glacier and preserved beneath the ground moraine. The production from these workings and the gold grade of the deposits are unknown.

The Main Fork of Pioneer Gulch lies upstream from the confluence of Pioneer Gulch, Squaw Gulch, and French Gulch and downstream from the terminal moraine of the second oldest glacial advance. Many large and productive placer mines along the gulch were worked continually between the early 1870's and the early 1920's. White siltstone of the Cabbage Patch Formation, now mostly covered by mine tailings, forms the floor of the gulch near its mouth. Upstream from the gulch mouth, the deposits on the east side of the gulch consist of poorly exposed Squaw Gulch beds that are overlain by 3 to 30 ft of glacial till of the oldest glacial advance. The Squaw Gulch beds also underlie the lower part of Ballard Hill on the west side of the gulch (see Table 2). The bottom of the gulch downstream from the glacial margin was almost completely mined. In the center of the gulch, remnants of glacial outwash are visible in some mine cuts. The glacial outwash in the gulch apparently consisted of several narrow channels incised into flat-lying Squaw Gulch beds near the upper end of the gulch, and into mudstone and siltstone of the Cabbage Patch Formation at the lower end.

On K and K Bar, on the east side of the gulch, the workings include many narrow cuts that followed pebble/cobble conglomerate in the Squaw Gulch beds (and possibly outwash) eastward under the till. At the head of each cut, the miners drove adits at the point where the till overburden became too thick for the pay dirt to be reached by digging downward. The well-cemented conglomerate was broken up in crude milling and sorting plants, and then fed through sluices to separate the gold.

The Kohrs and Bielenburg mine occupies the southeasternmost part of K and K Bar. In the 1916 pit, hydraulic giants were used to wash the lower part of the glacial till and underlying deposits consisting of glacial outwash (?) and Tertiary conglomerate.

Pioneer Bar forms a ridge 150 to 190 ft high, 5,000 to 5,900 ft long, and 950 ft wide, between Reservoir Gulch and Pioneer Gulch. The surface of the northernmost part of the ridge was entirely mined by ground sluicing between about 1875 and 1885 using water brought in by several ditches from Gold Creek (Fig. 17). More than 50,000 oz (over $1 million) was recovered from this deposit during this period, making Pioneer Bar the single most productive placer in the Pioneer district. The grade of the placers on Pioneer Bar can only be crudely estimated using the estimated volume shown in Table 5 and a total production of 50,000 fine oz. The average grade equals 0.021 oz per cu yd or 43 cents per yd at $20.67 per oz.

Pardee (1951, p. 90) described Pioneer Bar as a series of fluvial terraces cut by streams during interglacial intervals. As stated in the section on Geomorphology, this hypothesis cannot be confirmed. All that remains of the bar are boulders and cobbles consisting mainly of quartzite lying on flat surfaces underlain by mudstone and siltstone of the Cabbage Patch Formation.

Lower Pioneer Gulch includes the part of Pioneer Gulch below its confluence with French Gulch and Squaw Gulch, and hosts the site of the town of Pioneer. This part of the gulch is underlain by several tens of feet of glacial outwash. The underlying mudstone and siltstone of the Cabbage Patch Formation made this gulch ideal for dredging. The average grade of the outwash mined by dredging in Pioneer Gulch during the 1930's and 1940's was 0.005 oz per yd or 18 cents per yd at $35 per oz. Colluvial aprons overlie the outwash along the east side of the gulch. Parts of these aprons were mined during the early years.

Squaw Gulch

Squaw Gulch drains the west side of Gold Hill. Hydraulic pits on the Squaw Gulch side of Gold Hill are among the largest placer mines in the Pioneer district. Squaw Gulch and Pioneer beds dip away from the crest of Gold Hill on both sides, possibly indicating deformation by either folding or faulting. The principal workings in Squaw Gulch, from south to north, are the Kelly and Irvine and the Squaw Gulch pits.

The Kelly and Irvine pit is the smaller of the two pits on the west side of Gold Hill. Exposures in this mine are generally poor because of cover. Squaw Gulch beds here consist of golden brown, gray, orange, and red siltstone and fine sandstone interlayered with light brown pebble/cobble conglomerate. Siltstone forms most of the exposures in the workings. Conglomerate consists of imbricated or horizontal-lying pebbles, cobbles, and small boulders of quartzite and slate in a polymodal sand, silt, and clay matrix. The production from this mine and the grade of the gravel are unknown.

The Squaw Gulch pit contains the deepest hydraulic workings in the district (as deep as 60 ft). Historic references to the "blood red gravel" in this mine suggest that pebble/cobble conglomerate in the Squaw Gulch beds was the pay dirt. The conglomerate is interlayered with light brown, yellow, red, gray, and orange siltstone similar to that found in the Kelly and Irvine pit.

Ballard Hill

Ballard Hill is a pyramid-shaped hill lying about 1.25 mi north of Emery Ridge at the southwestern margin of the district. The north slope of the hill forms a large triangular facet that slopes northward at 10° to 15°. Ballard Hill is almost totally covered by a thick layer of gravelly colluvium, and rare exposures in roadcuts, mine cuts, and one adit (Plate 1) indicate that the hill itself may be composed of gravel. The gravel consists of clasts of slate, quartzite, and sandstone (mainly Kootenai Formation (?) sandstone and Quadrant Formation quartzite) derived from Emery Ridge, about 1.5 mi south. Angular clasts as much as 10 ft long occur near the summit of the hill, and clasts 7 ft long may be found at the northerly extension of Ballard Hill, Jobs Point.

Pardee (1951) and Gwinn (1961) mapped Ballard Hill as Cretaceous sandstone bedrock; however, no Cretaceous bedrock is exposed. These workers also mapped a deposit of "early glacial drift" on the northern flank of the hill, but this also could not be confirmed.

Ballard Hill appears to be underlain by about 350 ft or more of Squaw Gulch beds composed mainly of interbedded siltstone and conglomerate. Coarse Pioneer conglomerate caps the Squaw Gulch beds. The sequence has probably been tilted by movement along the Ballard Hill fault. Conglomerate in the Pioneer beds was mined for gold on Ballard Hill and Jobs Point.

The Ballard mine is located near the middle of the flat, north-dipping front of Ballard Hill. The area was mined using hydraulic giants and ground sluicing between the early 1870's and the middle 1890's (Pardee, field notes, 1916; L. Meikle, written commun., 10/85). The workings consist of two main channels and several smaller cuts that all run parallel to the fall line of the hill. Cuts in the Ballard mine are as much as 40 ft deep. The conglomerate is well exposed along the east side of the largest cut (NE sec. 33, T. 9 N., R. 11 W., and SE sec. 28, T. 9 N., R. 11 W.). The workings expose mottled brown, white, yellow, and gray layers of clast-supported boulder/cobble conglomerate containing abundant clay. The clasts in the conglomerate are angular to subrounded slates, quartzites, and calc-silicate hornfels. The conglomerate has a banded appearance because of staining from clasts that have been altered to clay.

The mine cuts in the Ballard mine were made into a smoothly dipping hill surface. The cuts, therefore, do not reflect the locations of pre-existing stream valleys. The Tertiary placers that underlie Ballard Hill may have a sheet-like geometry, and only a small amount of these deposits were mined in the two cuts of the Ballard mine.

Jobs Point is a spur on the north flank of Ballard Hill. It is capped by about 15 to 30 ft of coarse Pioneer beds similar to that on Ballard Hill. The mine cuts are as much as 20 ft deep, and they offer excellent exposures of the placers. Clasts in the conglomerate consist of gray slate, quartzite, pebble conglomerate (Ellis Formation (?)), and less than 10% of weathered granodiorite and diorite.

French Gulch

French Gulch lies between Ballard Hill and a large lateral moraine deposited along the east side of the Gold Creek valley. The gulch was mined by ground sluicing between the early 1870's and the middle 1890's. Outwash in the gulch was mined for a total length of about 1.2 mi. The widest and deepest workings are in the middle section of the gulch. They average about 30 to 45 ft in width and 10 to 16 ft in depth. The clasts in the outwash are roughly one quarter quartzite and slate derived from the conglomerate on Ballard Hill, and three quarters granodiorite boulders from the glacial till. Most of the clasts are cobbles and boulders ranging from 0.5 to 5 ft in diameter. The clasts were carefully piled into long rows in order to allow the water to circulate to workings farther down the gulch (Fig. 20). Total production and the grade of gravels in French Gulch is unknown.

Reservoir Gulch

Reservoir Gulch is located between Pioneer Bar and Reservoir Hill. The gravel in the gulch is glacial outwash that contains many round granodiorite boulders. The boulders average about 1 to 2 ft in length. Little placer mining was done in the upper part of the gulch,

Figure 20.--Placer mine in French Gulch. Tailings consist of granodiorite boulders derived from glacial till and quartzite derived from Tertiary conglomerate.

although many prospect pits were dug in the outwash. A small amount of ground sluicing was done in the lower part, southwest of Pioneer Bar. During the mid 1950's, a small dredge mined outwash and overlying colluvium from the mouth of Reservoir Gulch upstream for about 0.6 mi. It produced about 2,600 oz of gold (worth about $91,000).

Pikes Peak Creek

Pikes Peak Creek was named by a group of miners who came to the area from Colorado in 1862. All types of placers are present in the drainage. Tertiary conglomerate placers are the most widespread. On the hills that stand tens to hundreds of feet above the creek on the west, conglomerate and related colluvial lags were mined on a large scale using water from the Rock Creek ditch.

Batterton Bar includes a large group of hydraulic pits and ground sluice workings that extend eastward from the crest of Gold Hill. Most of the mining was done during the early 1870's using water from the Rock Creek ditch. In later years, long pipes were used to carry water from the ditch to mines farther down the hillside. Grayish orange to yellowish gray siltstone in the Squaw Gulch beds are the predominant rock type exposed in the workings. Clast- and matrix-supported Pioneer beds containing abundant red clay overlies the siltstone. The Pioneer beds consist of as much as 12 ft of poorly stratified, polymodal pebble-cobble conglomerate containing well-oriented clasts. Most of this material was left by the miners, perhaps because the high clay content made any gold present difficult to recover. The principal pay dirt apparently was in lenses of well-washed pebble/cobble conglomerate in the Squaw Gulch beds.

Pilgrim Bar is a continuation of the deposits on Batterton Bar. The area was mined mainly by ground sluicing. Clast-supported conglomerate in the Pioneer beds lie on mudstone and siltstone of the Cabbage Patch Formation in this area (the Squaw Gulch beds are not present). The conglomerate in this area contains much less clay than in the beds on Batterton Bar. It ranges in thickness from 3 to 10 ft. Quartzite clasts in the conglomerate are angular to subrounded and are typically covered by percussion marks. These conglomerate beds were among the more productive placers in the district.

According to Pardee (field notes 8/15/16, 10/20/23), total production from Pilgrim Bar was about approximately 35,000 oz of gold (about $600,000). Two miners reportedly cleaned about 4,000 oz each ($70,000) from part of the deposit. A few scattered deposits of conglomerate remain on Pilgrim Bar.

Large flat and gently-sloping areas located hundreds of feet above present stream channels were extensively mined on Treadwater Bar, Woods Flat, and Wilson Bar. The deposits were mined during the early 1870's. The placers consist mainly of clast-supported Pioneer conglomerate beds lying on mudstone and siltstone of the Cabbage Patch

Formation, and colluvial lag derived from the conglomerate (Fig. 21). The lag ranges from 1.5 to 3 ft thick and is poorly exposed. Its gold content is unknown.

Dry Gulch is a small valley that is tributary to Pikes Peak Creek between Woods Flat and Treadwater Bar. The part of the valley south of Woods Flat was mined by ground sluicing and hydraulicing during the late 1800's. Little is known about the history or production of this area. The deposits are mainly brown to pale orange siltstone in the Squaw Gulch beds that are interlayered with discontinuous pebble/cobble conglomerate beds similar to those on Gold Hill. In many cuts the siltstone is overlain by as much as 3 ft of slopewash. It is not known whether the conglomerate or the slopewash was the "pay dirt" in these mines.

The siltstone in Dry Gulch is locally overlain by coarse Pioneer conglomerate. The rocks in this area are interpreted as a large landslide that dropped the Tertiary rocks hundreds of feet relative to the rocks forming the hills to the south.

West Fork of Independence Creek

The West Fork of Independence Creek is a northeast flowing tributary to Independence Creek that empties into the Clark Fork River 3.7 mi upstream from the town of Garrison. Independence Creek is separated from lower Pikes Peak Creek by the prominent north-trending ridge of Windy Hill. Placers in the area are all related to

Figure 21.--Mine workings on Wood's Flat (photograph by J. T. Pardee, 1916). Deposits consist of a layer of colluvium ranging 1.5 to 3.0 ft thick derived from erosion of conglomerate in Pioneer beds.

Pioneer beds on Windy Hill that dip gently eastward. Placers in the headwaters of the West Fork of Independence Creek consist of boulder/cobble conglomerate in the Pioneer beds. Well-stratified sandy alluvium derived from the conglomerate was mined in the main stream channel. The grade and total production of these deposits is unknown.

Pioneer beds underly the main ridge of Windy Hill. The conglomerate consists of both matrix-supported and clast-supported beds interlayered with siltstone. Conglomerate was mined in one major oval-shaped cut on the southeast flank of Windy Hill using water brought from the Rock Creek ditch. The conglomerate consists of more than 50% Quadrant quartzite cobbles showing percussion marks and broken edges.

North Fork of Willow Creek

Willow Creek flows eastward from the Flint Creek Range south of Pikes Peak Creek. Placer mining on this creek is restricted to a single locality on the north fork of the creek, the Orphan Boy mine. The mine occupies an area 1,500 ft long and as much as 475 ft wide just below the confluence of two tributaries to the North Fork of Willow Creek. The placers consist of glacial outwash that was deposited at the intersection point between a major Pleistocene lateral moraine of the youngest glacial advance on the north and hills underlain by Tertiary conglomerate and siltstone to the south.

The outwash is composed of pebbles and cobbles of quartzite and slate and a lesser proportion of granodiorite cobbles and boulders. The gravel is weakly stratified and has a near-random fabric in which the clasts are closely interlocked. The grade of the gravel and historic production from the mine are unknown.

Gold Creek

Gold Creek was the site of the first discovery of gold in the district and the first mining. The deposits along the lower part of the creek consist mainly of small pits in glacial outwash. The site named "China Bar" near the Clark Fork River (Pardee, 1951, p. 75) was not examined. The most significant mining done along Gold Creek was at the Master and Pineau mines in the headwaters (in the Rose Mountain district in Granite County).

The Gold Creek valley, downstream from the glacial terminus, possibly represents one of the largest volume placers in the Gold Creek basin. The grade of the gravels in the outwash plain is unknown.

GEOCHEMISTRY

The physical characteristics and composition of gold from placers in the Pioneer distict and lodes in the northern Flint Creek Range were studied in order to determine similarities between the gold from the two areas. Gold samples were collected from placer deposits exposed in mines in the district, and from lode gold from veins on the dump of the Independence mine along upper Pikes Peak Creek. The composition of individual gold grains were determined by electron microprobe analysis and compared. Average fineness values were calculated from production records for comparison with the microprobe data.

SAMPLING PROCEDURE

The object of the gold sampling was to obtain as many gold samples as possible so that gold grains and mineral concentrates from several localities could be compared. Therefore, only the most promising deposits were sampled. No effort was made to calculate the gold grade of the deposits because such a study is beyond the scope of this thesis.

Vein

Forty-eight lb of oxidized quartz vein fragments was collected from mine dumps at both the Independence and G. W. Tibbets mines. Vein fragments showing visible gold or abundant iron oxides were preferentially selected. In the laboratory, the vein fragments were crushed to about 0.2 in. in a Sturtevant jaw crusher, ground to less than 0.08 in. in a roller pulverizer, and then ground to -60 mesh in a Bico disk pulverizer. The grinding produced about 4 gal of material from each of the veins. The powder was run over a Rodgers Gold Table, which separated a concentrate containing black sand and gold. Magnetite was separated using a hand magnet. The gold was concentrated by repeated close pannings and then extracted physically. Gold was present in both samples of vein.

Panned Concentrate

Twenty-nine panned concentrate samples were taken from natural exposures and mine cuts in the Pioneer district. Few of these sites were near water, so samples were put in buckets and transported to streams for panning. At each sample site, material was sieved through a 1/2 in. steel mesh screen until the material filled one 3 gal bucket. This amount of material filled three 14 in. gold pans. The material was panned until it consisted of a total of about three tablespoons of sand.

Magnetite was removed in the laboratory using a hand magnet. Final extraction of the placer gold from this separate was done in the laboratory using a gold pan and tweezers. Gold was present in 23 of the 29 samples from placers.

DESCRIPTION OF GOLD GRAINS

A total of 341 placer gold grains were obtained from the 23 samples that contained gold. Physical characteristics of the grains were examined visually and the grains from each sample were weighed and counted (Table 6).

Size

The size of placer gold in the district was estimated by measuring photographic enlargements of polished sections of 63 grains from 7 panned concentrate samples. The longest and shortest axes of each grain were measured to the nearest 10 microns (0.0000004 in.). The average maximum length of the grains is 290 microns (s= 180) and these grains range in length from 50 to 940 microns (0.001968 to 0.03701 in). A 90% confidence interval for the average maximum length of the 63 grains is between 235 and 340 microns (0.00925 to 0.01339 in.). The average minimum length of the grains is 150 microns (0.00591 in.) and the grains ranged in minimum length from 40 to 570 microns (0.00157 to 0.02244 in.). The average length/width ratio of the grains is 1.90.

Crawford and Starliper (1933b) studied placer gold in glacial outwash along Gold Creek. They stated that 50% of the placer gold is between 850 microns and 2.0 mm (.000033 to .000079 in.), and that most of the remainder is between 75 and 850 microns (.000003 to .000033 in.).

Pardee (field notes, 8/30/1921) stated that gold grains systematically decrease in size from south to north

Table 6.--Weights of placer gold grains, Pioneer district. Dashes indicate no data available. Gold weight is given in mg (weight in oz is shown in parentheses). Samples all represent 3 gal. of matrix material (screened to -1/2 in.) from gravel and conglomerate exposed in mine workings (see Plate 1 for locations of sample localities and explanation of map unit codes).

Sample No.	Location	Map Unit	Gold Weight	Number of grains	Grains per mg
L5001	Pioneer Gulch	Qo	2.7 (.000095)	15	5.56
L5002	Ballard hill	Ts	---	0	---
L5013	Wilson Bar	Tp	0.7 (.000025)	41	58.57
L5047	Pilgrim Bar	Tp	3.3 (.000116)	18	5.45
L5066a	Pilgrim Bar	Tp	6.1 (.000215)	30	4.92
L5066b	Pilgrim Bar	Tp	7.4 (.000261)	21	2.84
L5071	Pilgrim Bar	Tp	---	0	---
L5072	Pilgrim Bar	Tp	0.8 (.000028)	23	28.75
L5080	West Fork Independence Creek	Tp	4.9 (.000173)	36	7.35
L5111	E. Side Pioneer Gulch	Qal	0.2 (.000007)	2	10.00
L5118	Pioneer Gulch	Qo	0.4 (.000014)	5	12.50
L5119	Pioneer Gulch	Ts	2.3 (.000081)	9	3.91
L5121	Ballard Hill	Tp	0.2 (.000007)	1	5.0

Table 6. (Continued)

Sample No.	Location	Map Unit	Gold Weight	Number of grains	Grains per mg
L5122	Ballard Hill	Tp	0.1 (.000004)	1	10.0
L5137	Ballard mine	Tp	---	0	---
L5140	Job's Point	Tp	0.7 (.000025)	4	5.71
L5150	Main Fork, Pioneer Gulch	Ts	---	0	---
L5168	Windy Hill	Tp	47.6 (.001679)	65	1.37
L5169	Pikes Peak Creek	Qo	3.1 (.000109)	20	6.45
L5199	Orphan Boy mine	Qo	0.6 (.000021)	1	1.67
L5203	Squaw Gulch Pit	Tp	0.3 (.000011)	6	20.00
L5214	Middle Fork Pioneer Gulch	Qo	>0.1 (>.000004)	5	50.00
L5217	Main Fork, Pioneer Gulch	Ts	>0.1 (>.000004)	4	40.00
L5219	Dry Gulch	Tp	2.5 (.000088)	16	6.40
L5225	Ballard mine	Tp	0.3 (.000011)	2	6.67
L5226	Jobs Point	Tp	---	0	---
L5227	Jobs Point	Tp	0.1 (.000004)	2	20.00
L5231	Batterton Bar	Tp	---	0	---
L5236	Pikes Peak Creek	Qo	0.1 (.000004)	14	140.00

in the district. He noted that nuggets and coarse gold are confined to Ballard Hill and the upper parts of Pilgrim and Batterton Bars on Gold Hill and that medium to fine gold is found in other parts of the district. Results of the present study do not confirm this generalization. The largest average gold weight, 0.73 mg (0.00000026 oz) per grain, was from a sample containing 65 grains from Windy Hill in the northern part of the district. Four samples of gold from Pilgrim Bar (totalling 92 grains) average 0.19 mg (0.000007 oz) per grain. One explanation for the sample data may be that the processes of sediment transport during deposition of the Pioneer beds included debris flows and mudflows in which sorting of material by size or weight was minor. However, the small number of grains examined (341) probably provides an insufficient sample for dependable comparisons of the size of gold throughout the district.

Shape

The gold grains examined are typically round disks and elongate flakes. Small round nuggets also are present. Delicate, irregular forms are rare. No systematic change in the shape of the grains was observed in samples from many localities.

Internal features

The internal features of polished sections of gold grains were examined microscopically. The majority of the grains contain definite, dark, strongly pitted rims that range in thickness from about 5 to 100 microns (0.0002 to 0.0039 in.) depending on the diameter of the grain. The contact of the rims with the lighter colored cores of the grains is sharp and oriented subparallel to the grain boundaries (Fig. 22). Compositional zoning with gradual, instead of sharp, contacts between zones was not seen. Inclusions of quartz were present in some polished sections.

COMPOSITION OF GOLD

Natural gold typically occurs as an alloy of gold and silver. The fineness of gold is a measure of the proportion of gold in the gold-silver alloy expressed in parts per thousand. Gold fineness data may be used to help determine the source of placer gold because gold in lode deposits is typically within a characteristic fineness range determined by the conditions of ore formation. The cores of placer gold grains are assumed to retain this characteristic fineness. In this study, fineness values calculated from production records are compared with results of an electron microprobe study of gold from placers and one lode deposit.

Production Data

Gold fineness values for individual mines in the Pioneer district were calculated using mint returns and production records. Fineness values from these sources represent the average fineness of millions of gold grains produced during a period of many months or years.

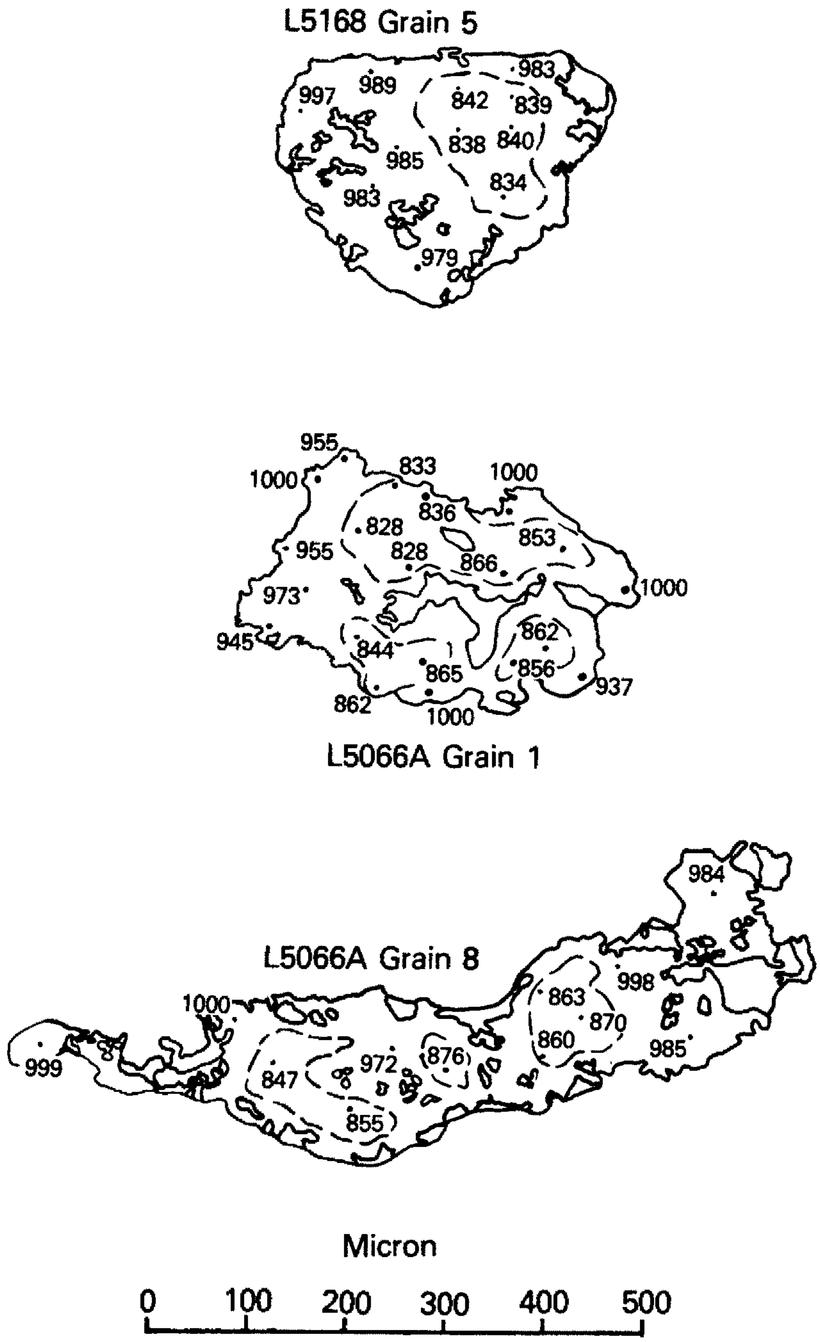


Figure 22.--Sketches of placer gold grains showing fineness of gold according to microprobe analysis. Cores of grains are outlined with dashed lines and shown with darkened pattern. Pits and cavities are outlined with solid lines.

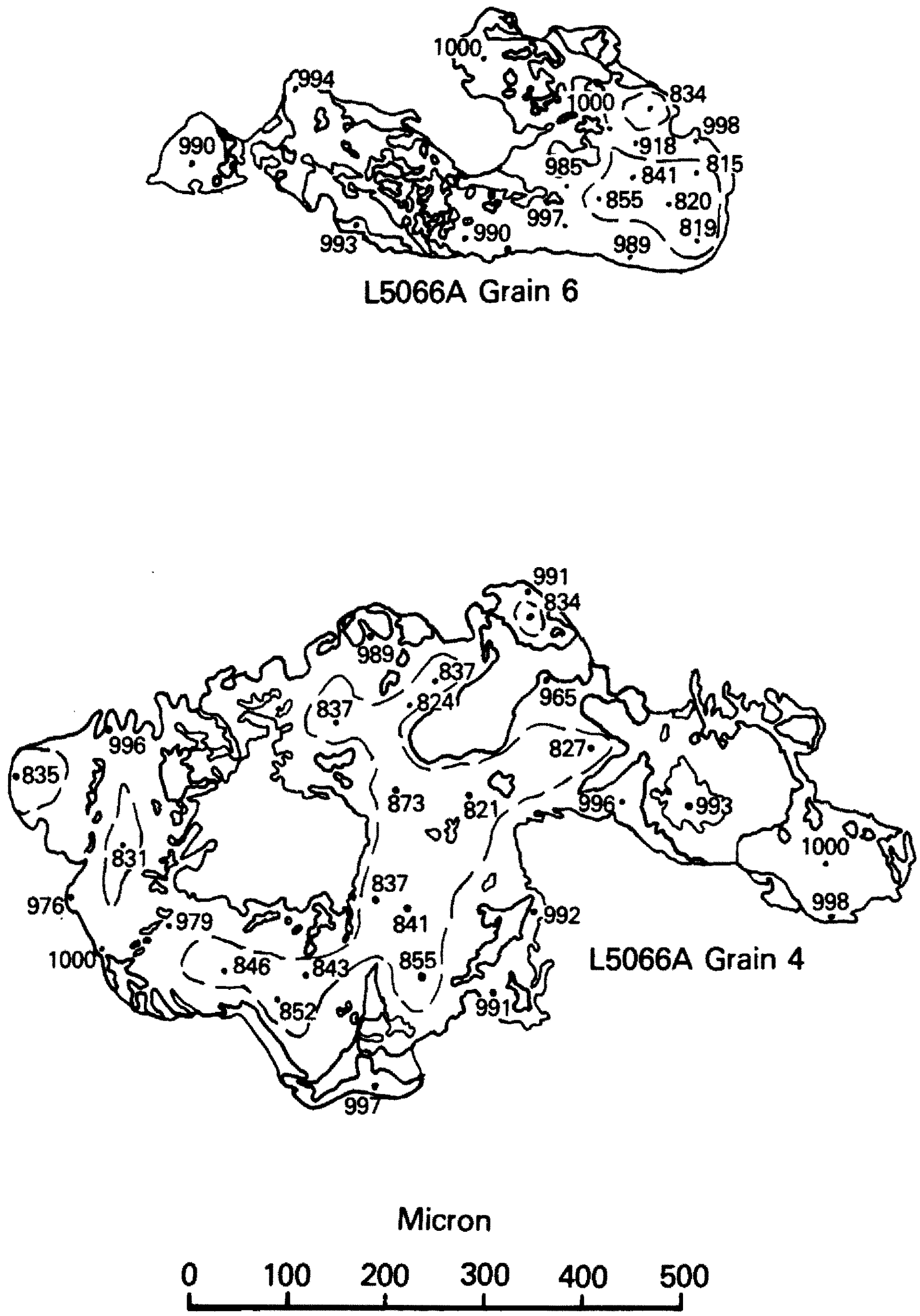


Figure 22.--(Continued)

The fineness of placer gold from the Pioneer district was known early in the district's history. Raymond (1873, p. 273) stated that the gold ran $18 to $18.75 per oz (at $20.67 per fine oz), which is equivalent to 870 to 907 fine. Records of the Larabie Bank in Deer Lodge, which handled many of the transactions between miners and the U.S. Mint (Table 7), corroborate Raymond's statement. The average fineness value in the district according to the bank records is 893.1 (std dev= 12.6). A 90% confidence interval for this average is between 888.7 and 897.5.

The average fineness of placer gold produced in the district between 1905 and 1959 is fairly restricted between an upper limit of 910 and a lower limit of 850 fine (Fig. 23). The gold produced during this period averaged 882.7 fine (std dev = 17.5). A 90% confidence interval for this average is between 876.1 and 889.3.

The 90% confidence intervals for the average fineness in the district, according to these two independent measures, partially overlap and the means are within one standard deviation of each other. The production records, therefore, indicate an average gold fineness of between about 875 and 900 for the district.

Reported figures for the fineness of lode gold in the Rose Mountain district are much lower than that of the placers in the Pioneer district. Gold from the G. W. Tibbets mine runs between 800 and 850 fine (Pardee, field notes, 8/15/16). About 10 oz of gold from the Ryan mine

Table 7.--Average fineness of gold produced from placer mines in the Pioneer District (from records of the Larabie Bank, Deer Lodge, MT as recorded in field notes of J.T. Pardee, Aug. 15, 1916). Each entry represents one shipment of placer gold received by the bank. The records date back to about 1870. The location names refer both to specific mining claims and to the names of individual miners.

Location	Fineness
Pioneer Gulch	
Pioneer Gulch	896
(H.C. #7)	894
(China Ret)	902
(China Ret)	897
Below 7,7	914
Pioneer Co.	894
Pioneer Co.	894
Thomas	895.5
Fred Meyher	900
McNish	896
McNish	895
Ballard	883
Roberts	898
Thomas	895
McDonald	904
Thomas (Oct., 1874)	897.5
McNish (Oct., 1874)	899.5
Kohrs and Bielenburg mine	890
Kohrs and Bielenburg (1916 cleanup)	893
Average	896.7
French Gulch	
French Gulch	882
Pikes Peak Creek	
Pikes Peak Creek	888
Pikes Peak Creek	882
Rodgers	876
Rodgers	873
Rodgers	881
Rodgers	878
Smith and Brady	886
Smith and Brady	888
Hogan	888
Brown and WyKoff	898
Average	883.8

Table 7. (Continued)

Location	Fineness
Independence Gulch	
Lockhard and Serial	883
Lockhard and Serial	882
Lockhard and Serial	871
Average	878.7
Ballard Hill	
Ballard mine (1874)	883
Ballard mine (1876)	882
Ballard mine (1877)	883
Average	882.7
Woods Flat	
Woods Flat	917
Woods Flat	907
Woods Flat	912
Woods Flat	901
Woods Flat	871
Average	901.6
Wilson Bar	
Wilson Bar	912
Squaw Gulch	
Squaw Gulch	914
Squaw Gulch	923
Average	918.5
Overall average of 44 records (std dev= 12.6)	893.1

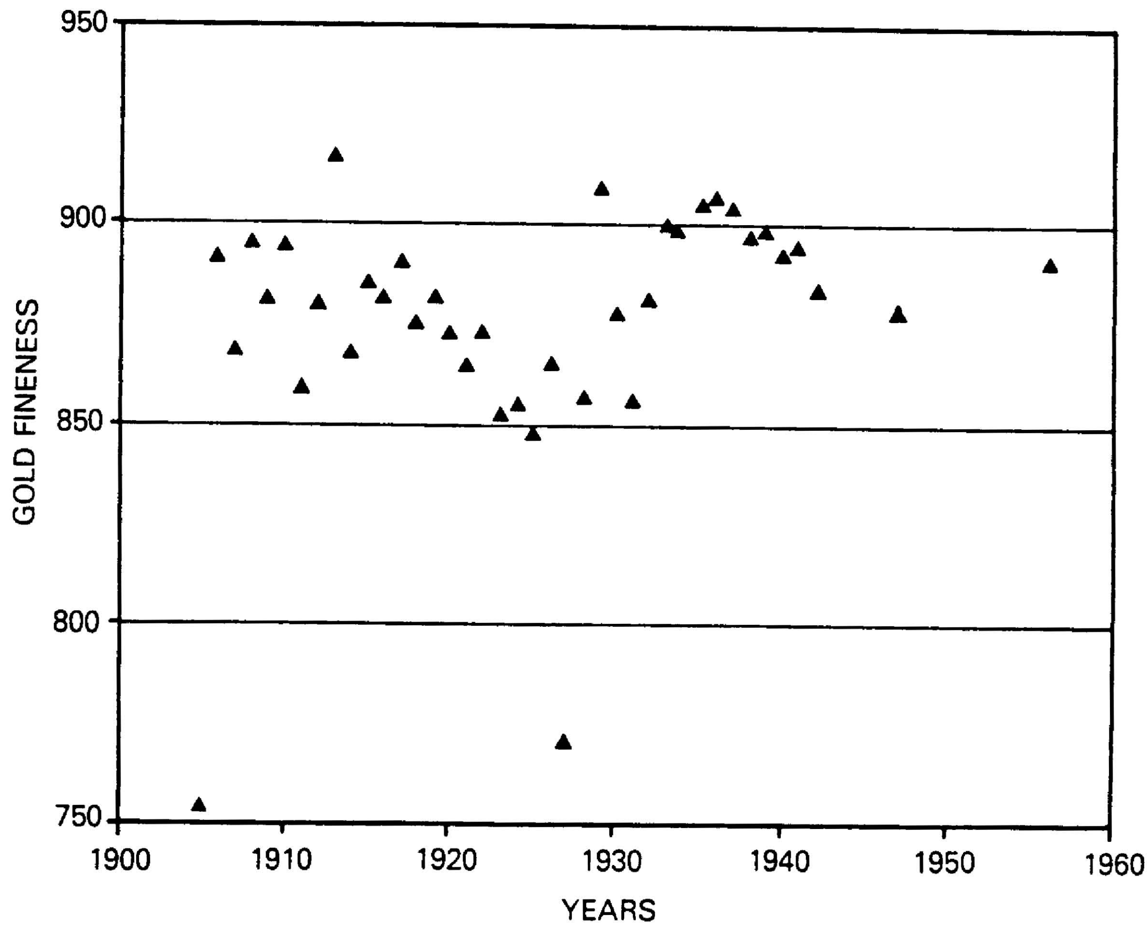


Figure 23.--Graph of fineness of gold produced from the Pioneer district, 1905-1959 (data from McClernan, 1976, Table P-1). Values below 800 fine probably reflect incomplete data.

ran 847.8 fine (Pardee, field notes, 8/4/16). These mines, like the veins that provided the placer gold to the Pioneer district, are both hosted by sedimentary rocks in the roof zone of the Royal stock.

Microprobe Study

The variations in fineness within individual gold grains from panned concentrate samples and a vein sample were quantitatively determined using an electron microprobe (sample preparation and analytical methods used are described by Desborough, 1970, p. 304-305). An electron beam with a width of less than 1 micron was directed at several points within grains. Gold and silver content was recorded in weight percent. The amount of instrumental error was within 0.3%, according to replicate analyses of standards of known composition.

Seventy-two gold grains were analyzed. Thirty-two grains were from veins at the Independence mine and 40 were from three different placers in the Pioneer district (see Appendix). A total of 379 analyses (82 vein, 297 placer) were made at different points within these grains. Because of the obvious color zoning between the rims and cores on polished sections of grains from placers, a distinction was made between compositional analyses made on the rims of grains versus analyses of cores (Fig. 24).

Gold grains from vein samples lack high-fineness rims. The maximum fineness value found was only 930, and only four out of 82 analyses (5%) were above 900 fine.

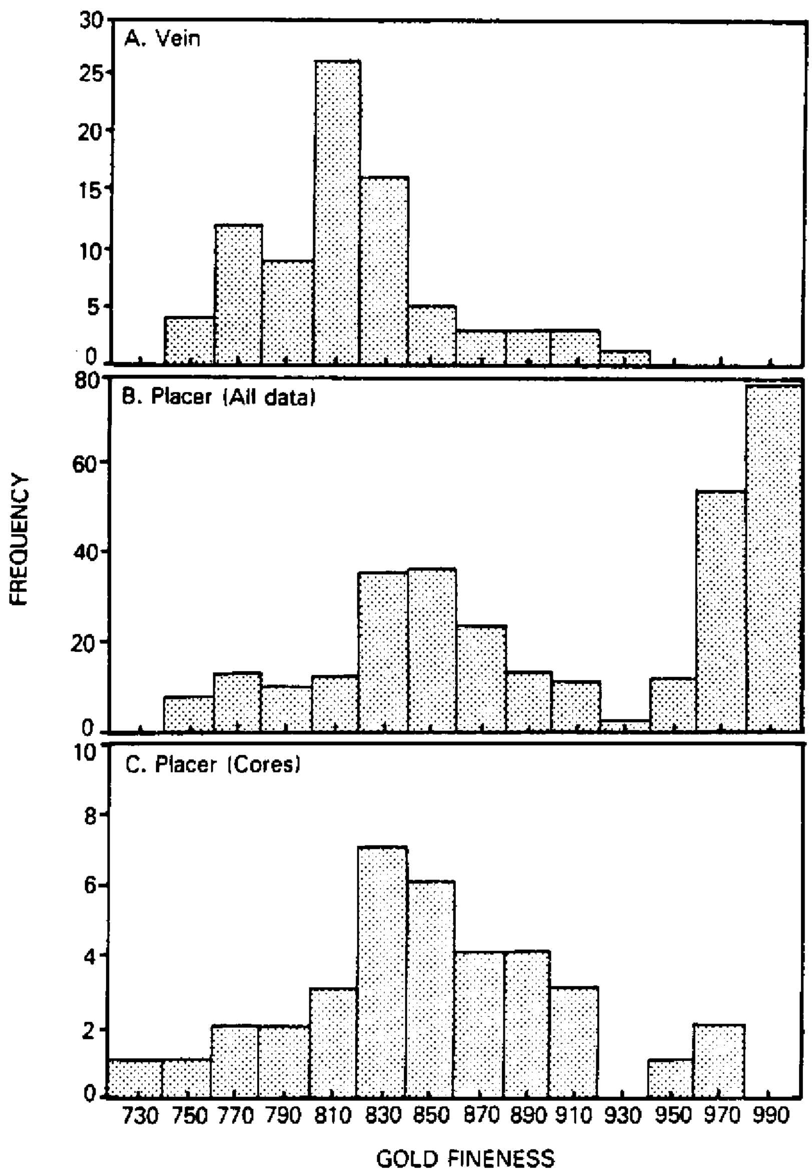


Figure 24.--Histograms of gold fineness data from microprobe analyses. The histograms represent (A) all data from 82 analyses of 32 gold grains from quartz vein, Independence Mine; (B) all data from 279 analyses of 40 gold grains from placers in the Pioneer district; and (C) averages of the core values of the 40 gold grains from placers.

Polished sections of dozens of gold grains from the Tibbets and Ryan Mines also lack visible rims. The processes that developed the rims in the placer gold grains has apparently not affected the lode gold. The fineness data for the gold from the Independence mine define a normal population with a mean of 815.5 (Fig. 24A). A 90% confidence interval for the average fineness of gold from this sample is between 805.6 and 825.4.

Sixty-five percent of the grains from placers contain cores that average 100 fineness points or more lower than the average rim values of the same grains. Because of this zoning, the plot of all data for all points on the grains appears bimodal (Fig. 24B). The rim values define a lognormal population distribution lying between 1000 and 930 fine. Fineness values from rims typically range from 980 to 1000 fine, but also range as low as 918 fine. All data for the cores of the grains define a normal distribution with a mode at about 840 (Fig. 24B). The averages of the core values of the grains range from 733 to 967, and these data form one normal population with a mean of 848.5 (Fig. 24C). A 90% confidence interval for the fineness of the cores of the placer gold grains is between 827.6 and 869.4.

DISCUSSION OF GOLD GEOCHEMISTRY

Internal Features

The rimming of the placer nuggets with gold of higher fineness may be attributed to either solution of silver from the gold/silver alloy in the rims, or by chemically precipitating shells of nearly pure gold onto placer gold grains. The sharp contacts between cores and rims in polished sections of the grains suggests that the rim was precipitated from solution. However, the areas of high-purity gold in the grains all correspond to pitted and eroded surfaces, and the grains commonly display waterworn surfaces. No crystal faces were observed on the gold grains.

Preferential solution of silver from gold grains in the stream environment is favored as the principal cause of the zoning because this process has been recognized in many gold placer districts (see Boyle, 1979, p. 336, for a review). Mann (1984) and Wilson (1984) have each documented the transport and precipitation of gold on a very localized scale in laterites and gossans. Chemical conditions in laterites and gossans are much different than the present surface conditions in western Montana, however. It is therefore unlikely that the precipitation of gold has occurred on a large scale in the Pioneer district.

Grains of placer gold from Quaternary outwash are indistinguishable from grains in Tertiary age conglomerate. Because the principal placers in outwash deposits are near large areas underlain by Tertiary conglomerate, a sizable proportion of the gold in the outwash may have been reworked from the Tertiary conglomerate.

Fineness

Fineness of gold from vein, placer, and production records were compared using 90% confidence intervals for the average fineness for each group (Fig. 25). The confidence intervals for each group are mutually exclusive. This suggests (1) the placer gold may not be derived from veins similar to those in the Independence mine, because the fineness of the cores of the placer grains are different from the fineness of the lode gold; and (2) the average fineness calculated from production records is higher than the fineness of gold from either veins or placers.

Other evidence, however, suggests that the placer gold was indeed derived from the veins in the Rose Mountain district, and that vertical zoning may explain the higher fineness of the cores of the placer gold. The abundance of quartzite and slate clasts from the Quadrant, Ellis, and possibly Kootenai Formations in the Tertiary age conglomerates is the strongest evidence that the placers were derived from mineralization in the roof zone of the Royal stock. In addition, the fineness of gold from the Ryan mine (847.8), which is hosted by sedimentary rocks in the roof zone of the stock, is essentially the same as the average for the cores of the placer gold grains (848.5).

No other sources for the placer gold are known except for the mineralization around the Royal stock. Some heavy

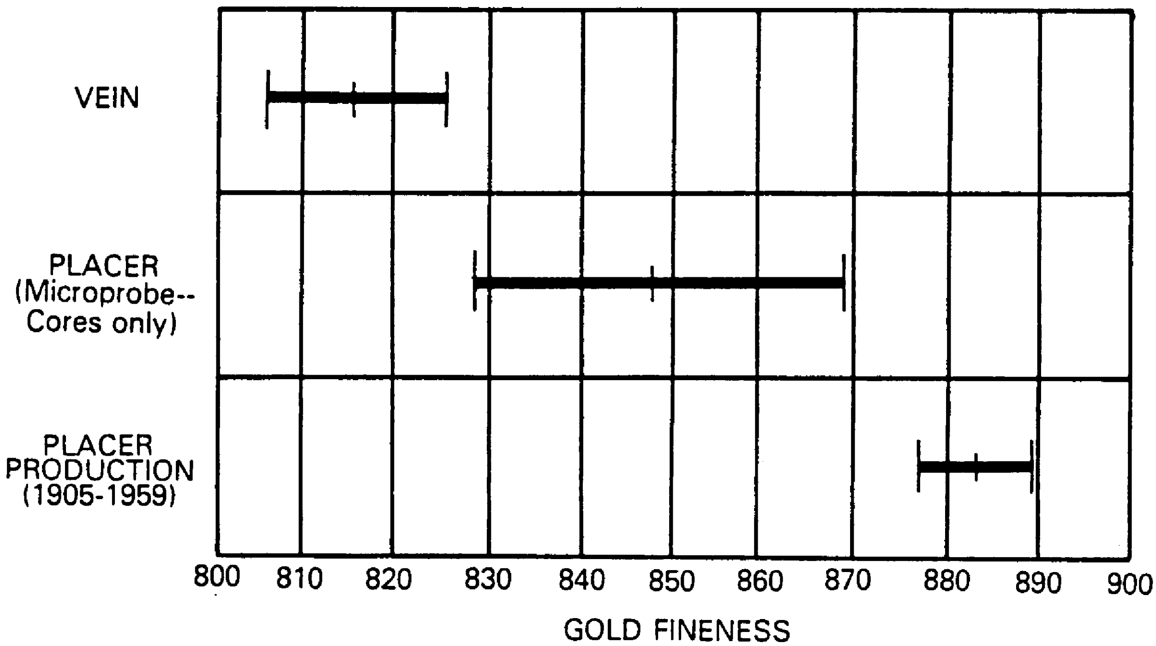


Figure 25.--Graph of 90% confidence intervals of average fineness for lode and placer gold and production records. Center mark on each interval indicates position of mean.

minerals may have been derived from the breakdown of Paleozoic and Mesozoic age sedimentary rocks in the roof zone of the stock, but these rocks contain no known gold placers and appear to be unfavorable for their occurrence. The strata contain few conglomerates, and no known gold-bearing lodes were exposed during the deposition of these beds in Paleozoic and Mesozoic time.

Possible differences in fineness between the veins hosted by granodiorite and those that provided the placer gold may result from either primary temperature zoning with increasing distance from the thermal source in the contact zone or from chemical differences between the sedimentary rocks and the granodiorite. Such variations in gold fineness with increasing distance from a thermal center are well known in other lode systems (Mertie, 1940; Jones and Fleischer, 1968; Boyle, 1979). Mertie (1940) concluded that differences in fineness between lode and placer gold are related to depth of erosion of the mother lode. Placer gold from the apical zones of lodes are of greater fineness that the deep-seated parts of the lodes not exposed to view. Vertical variations in the lode system or chemical differences between granodiorite and sedimentary rocks may thus be responsible for the differences in fineness between lode and placer grains as determined by microprobe analysis.

The discrepency between the fineness of the lode or placer grains and the fineness from production data is easily solved by considering the effect a shell of high-fineness gold has upon the average fineness of a gold grain containing a low-fineness core (Fig. 26). According to Figure 26, a gold grain containing a core between 800 and 850 fine will have an average fineness between 875 and 900 if a 1000-fine rim occupies between 18% and 50% of the grain, respectively. The placer grains in the Pioneer district are predominantly disks and flakes containing thick leached rims that easily account for this proportion (see Fig. 22).

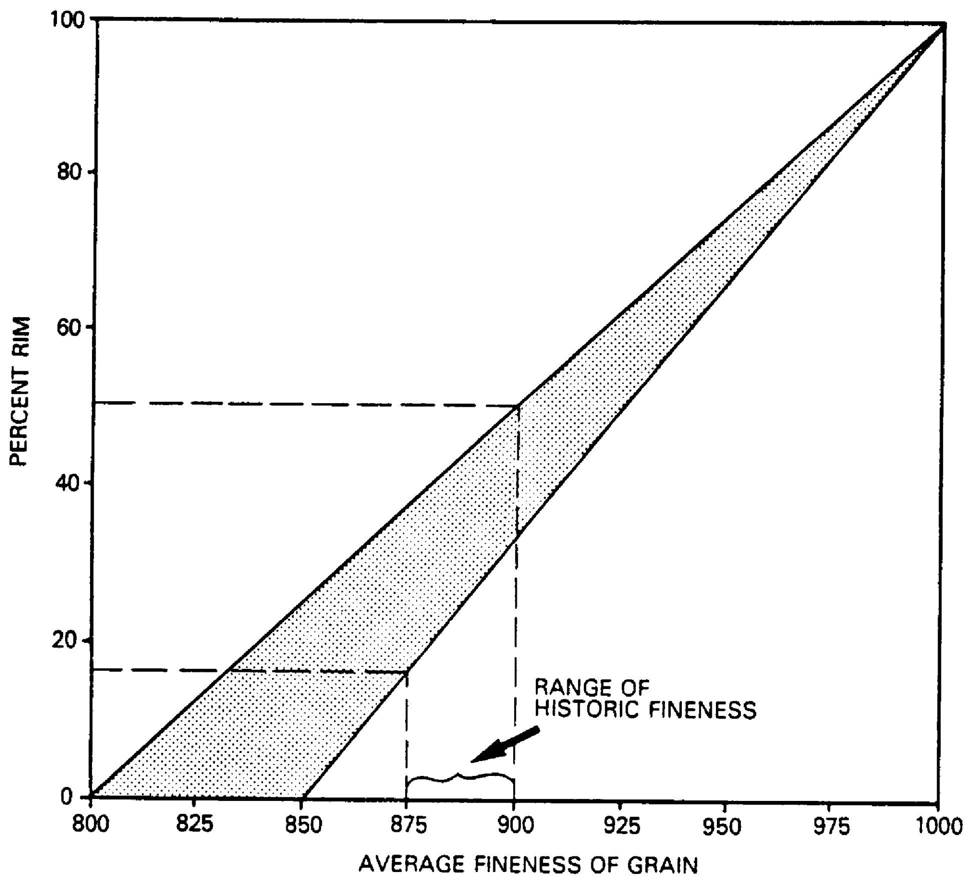


Figure 26.--Graph showing the relationship between the average fineness of a gold grain and the proportion of the grain rimmed by 1000 fine gold. Diagonal lines define field represented by gold containing cores that range from 800 to 850 fine. Dashed lines show average fineness of placer gold in the Pioneer district determined from production records.

ORIGIN OF GOLD PLACERS

The placers in the Pioneer district were derived from weathered lodes in the roof zone of the Royal stock. The formation of the primary placers resulted mainly from a favorable set of climatic, tectonic, and geomorphic conditions during middle to late Tertiary time. Secondary placers, of Quaternary age, were derived mainly from the Tertiary deposits.

Warm and moist climatic conditions during middle Teritary time probably favored deep weathering of the gold-bearing lodes in the present mountain sites. A thick surficial mantle of decomposed rock containing native gold likely resulted from this weathering.

Beginning in middle Miocene time, the region was uplifted. Uplift of the mountains caused the weather patterns to change and the climate become drier. The increase in gradient allowed streams to transport the weathered debris from the mountains to the adjacent basins. The Squaw Gulch beds represent a wedge of the weathered rock that was transported from the Flint Creek Range to the Gold Creek Basin in response to this uplift. The earliest identifiable placers in the area are pebble conglomerate in the Squaw Gulch beds.

An increase in the rate of uplift of the mountains in late Miocene or Pliocene time caused coarser material to be transported across the range-front faults between the mountains and the basins. Streams loaded with detrital material emerged from steep canyons draining the mountains and immediately deposited their loads because their flow was no longer confined. Alluvial fans prograded radially away from the Flint Creek Range. Debris flows and mudflows were triggered along valleys draining the mountain front, and some of these flows may have transported gold across the basin for several miles. Streams flowing on the fan surface reworked the earlier material and redeposited it as gravel in braided stream channels. The uplift was short-lived, resulting in the deposition of only one distinct pulse of coarse gravel represented by the Pioneer beds.

On this plain, placer gold was most effectively concentrated at a moderate distance (3 to 6 mi) from the mountain front. The material close to the mountains was deposited too rapidly to allow for significant reworking. Far from the mountains the sediments were fine grained and they contained little gold because most of it had been deposited previously. The late Tertiary plain was broken up by later faulting and associated landsliding, leaving the placers lying at several levels.

Some rich placers may have formed during the period of stream incision during middle Pliocene to middle

Pleistocene time. These placers cannot be specifically identifed, however, because they were incorporated into Pleistocene glacial deposits or destroyed by erosion and(or) mining.

As glaciers advanced down the stream valleys during middle to late Pleistocene time, they overrode both earlier outwash and Tertiary conglomerate and perhaps locally incorporated placer gold from these sources into the lower sections of glacial till. The latest glaciers appear to have transported only fresh rock debris from which little or no gold had been released by weathering.

Outwash streams may have transported some gold from the lodes to the basin during glacial periods, and the outwash also reconcentrated gold that was contained in Tertiary conglomerate.

During the Holocene, placers have formed where gold could be reconcentrated from existing placers (principally Tertiary age conglomerate) by stream flow and slope wash.

CONCLUSIONS

An integrated study of gold placers in the Pioneer district has provided a model for placer formation that is supported by several lines of geologic evidence. The model differs greatly from the results of previous studies. The main findings of the present study are as follows:

(1) The principal placers in the Pioneer district are conglomerates of middle Miocene to middle Pliocene (?) age deposited by streams on alluvial fans during uplift of the Flint Creek Range. Quaternary age placers, consisting of glacial till and outwash, and Holocene colluvium and alluvium, probably had the Tertiary conglomerate as their main gold source.

(2) The source of the placer gold is probably gold-bearing veins hosted by quartzite and slate in the eroded roof zone of the Royal stock. The eroded veins contained gold of slightly higher fineness than the deeper parts of the lodes now exposed.

(3) A long period of deep chemical weathering under warm, humid conditions preceeded the deposition of the late Tertiary conglomerates and apparently released the gold from the quartz veins in the northern Flint Creek Range.

(4) Deposits earlier described as "early glacial drift" are non-glacial deposits of Tertiary age. No evidence was found to support an extensive early Pleistocene glaciation of the piedmont surrounding the northern Flint Creek Range.

(5) The Pleistocene glaciers that developed in the northeast part of the Flint Creek Range flowed down valleys that had nearly reached their present depths.

(6) Stream downcutting and terrace formation during interglacial and post-glacial time probably did not result in the formation of significant placers, contrary to the findings of previous studies.

(7) Gold placers of Pleistocene age consist principally of three types of outwash deposits located downstream from, beneath, and lateral to major moraines, respectively. All are adjacent to gold-bearing Tertiary strata from which the gold was in part derived.

(8) Colluvial processes were responsible for forming important placer deposits from pre-existing Pioneer conglomerate beds.

(9) Placer gold grains from both the Tertiary and Quaternary deposits contain high-fineness rims separated with sharp contacts from low-fineness cores. The presence of thick leached rims on the majority of the gold grains has raised the average fineness for the district.

SUGGESTIONS FOR PLACER GOLD EXPLORATION

Tertiary conglomerate and Quaternary deposits derived directly from it represent the most important placer gold resources in the area along the northeastern margin of the Flint Creek Range. Gravels that are rich in quartzite clasts should be considered favorable for exploration because they relate to a pre-glacial period of alluvial fan sedimentation and extensive reworking of gravel on alluvial plains.

The most favorable area for the occurrence of Tertiary age placers is a band approximately 4 mi wide paralleling the northeastern margin of the Flint Creek Range, beginning approximately 2 mi from the mountain front (Fig. 27). Great volumes of Tertiary age conglomerate are present on Ballard Hill and on most other hills less than 2 mi from the mountain front; however, these proximal deposits contain abundant clay and very low proportions of heavy minerals. High-grade placers are much more likely to be present in gravels farther away from the mountains because of extensive reworking during deposition.

The distribution and gold grade of the Pioneer conglomerate is poorly known. Magnetic surveys, backhoe trenching, and/or drilling may help delineate gold-bearing channels on ridges in the area.

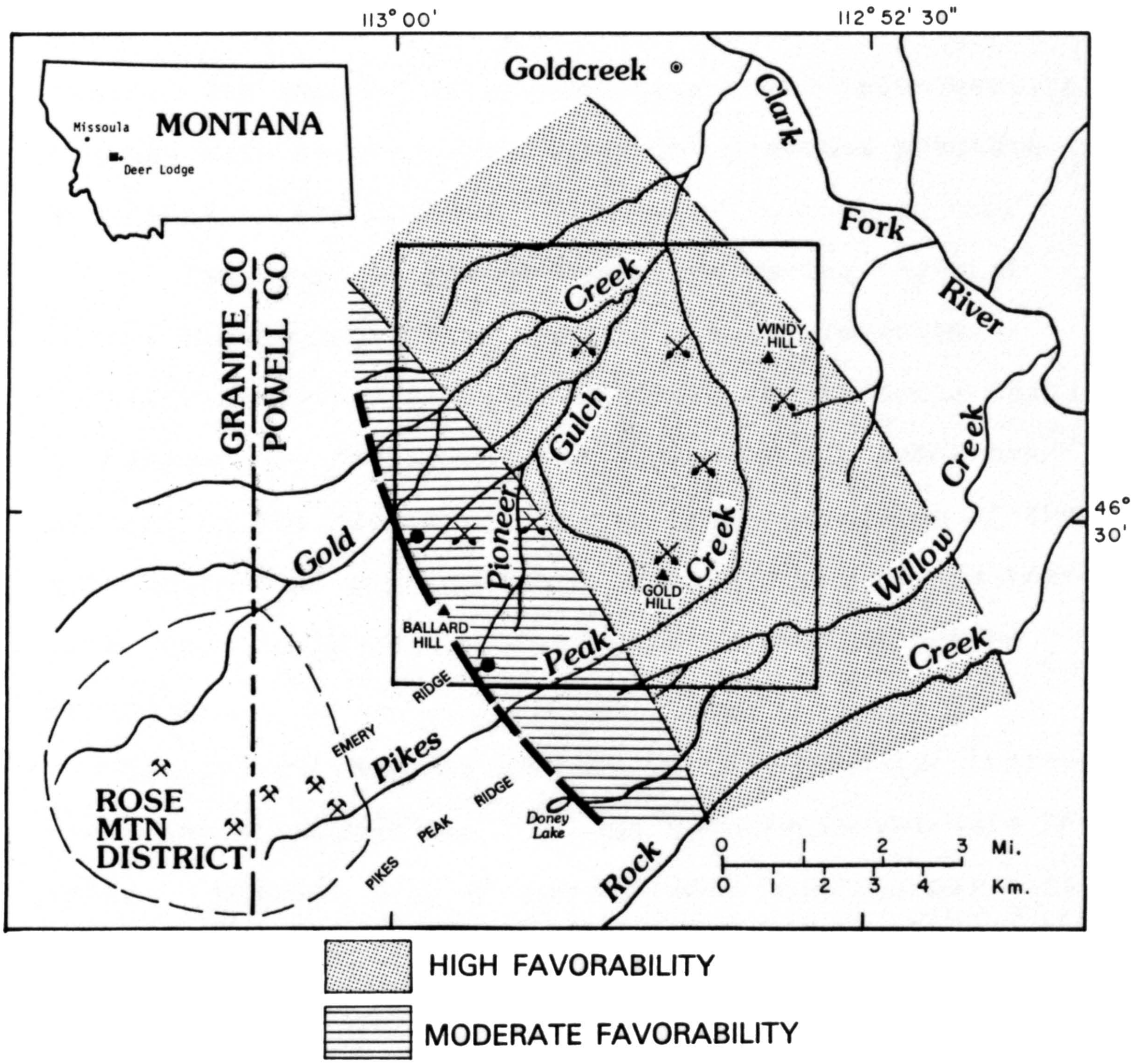


Figure 27.--Map showing favorable zones for occurrence of gold placers in Pioneer conglomerate and Squaw Gulch beds along the northeast flank of the Flint Creek Range.

Mining during the late 1800's was greatly hindered by the lack of available surface water. The Tertiary placers on high hills could be mined only where they could be reached using ditches. Certain Tertiary placers may thus remain unmined on the higher hills in the Gold Creek basin. The lack of water remains a major impediment to mining, but improved technology now provides possible solutions to the problem.

If the model of placer formation during regional middle Miocene uplift in western Montana is valid, Tertiary age placers may have formed on piedmonts adjacent to range-front faults wherever gold-bearing lodes are present in the nearby mountains. An examination of the gold content of conglomerates of late Tertiary age near other uplifts in the northern Rocky Mountains may be rewarding.

Glacial outwash may locally be of commercial interest where large volumes are present, such as in the Gold Creek valley. Glacial till of the earliest advances may contain significant amounts of placer gold incorporated from Tertiary age conglomerates and Pleistocene surficial mantle; however, the gold is poorly concentrated.

REFERENCES CITED

Alden, W. C., 1953, Physiography and glacial geology of western Montana and adjacent areas: U.S. Geological Survey Professional Paper 231, 200 p.

Atwood, W. W., and Atwood, W. W., Jr., 1948, Tertiary-Pleistocene transition at the east margin of the Rocky Mountains: Geological Society of America Bulletin, v. 59, no. 6, p. 605-608.

Baty, J. B., 1976, Fission-track age dates from three granitic plutons in the Flint Creek Range, western Montana: Northwest Geology, v. 5, p. 34-41.

Beaty, C. B., 1963, Origin of alluvial fans, White Mountains, California and Nevada: Annals of the Association of American Geographers, v. 53, p. 516-535.

________, 1974, Debris Flows, alluvial fans, and a revitalized catastrophism: Zeitschrift fur Geomorphologie, Supplementband 21, p. 39-51.

Blackwelder, Eliot, 1915, Post-Cretaceous history of the mountains of central western Wyoming: Journal of Geology, v. 23, p. 97-117, 193-217, 307-340.

Boyle, R. W., 1979, The geochemistry of gold and its deposits: Geological Survey of Canada Bulletin 280, 584 p.

Browne, J. R., 1868, Report on mineral resources of the States and Territories west of the Rocky Mountains in 1867: U.S. Government Printing Office, 674 p.

Bull, W. B., 1972, Recognition of alluvial-fans deposits in the stratigraphic record, in Rigby, J. K., and Hamblin, W. K., (eds.), Recognition of ancient sedimentary environments: Society of Economic Paleontologists and Mineralogists Special Publication No. 16, p. 63-83.

Crawford, A. L., and Starliper, Aaron, 1933a, Some physiographic and geologic features affecting the origin and concentration of placer gold along Gold Creek Montana (abst.): Proceedings of the Utah Academy of Sciences, v. 10, p. 53.

________, 1933b, A microscopic study of certain placer gold from Gold Creek Montana (abst.): Proceedings of the Utah Academy of Sciences, v. 10, p. 59.

Csejtey, Be'la, Jr., 1963, Geology of the southeast flank of the Flint Creek Range, Western Montana: Princeton, N. J., Princeton University Ph.D. dissertation, 175 p.

Desborough, G. A., 1970, Silver depletion indicated by microanalysis of gold from placer occurrences, western United States: Economic Geology, v. 65, p. 304-311.

Douglass, Earl, 1901, Fossil mammalia of the White River beds in Montana: Transactions of the American Philosophical Society, ser. 2, v. 20, p. 237-279.

________, 1903, New vertebrates from the Montana Tertiary: Annals of the Carnagie Museum, v. 2, p. 145-199.

Elliott, J. E., Waters, M. R., and Campbell, W. L., U.S. Geological Survey, and Avery, D. W., U.S. Bureau of Mines, 1984, Mineral resource potential and geologic map of the Dolus Lakes Roadless Area, Granite and Powell Counties, Montana: U.S. Geological Survey Map MF-1460-A.

Elliott, J. E., Loen, J. S., Blaskowski, M. J., and Wise, K., in press, Mines and prospects of the Butte 1° x 2° quadrangle, Montana: U.S. Geological Survey Open-File Report.

Emmons, W. H., and Calkins, F. C., 1913, Geology and ore deposits of the Philipsburg quadrangle, Montana: U.S. Geological Survey Professional Paper 78, 271 p.

Fields, R. W. and Rasmussen, D. L., 1969, Biostratigraphy and correlation of the Cabbage Patch beds, Granite and Powell counties, Montana: Geological Society of America Bulletin, v. 72, p. 1409-1414.

Goddard, E. N., et al., 1951, Rock color chart; Geological Society of America, Boulder, Colorado.

Goudie, A., and Bull, P. A., 1984, Slope process change and colluvium deposition in Swaziland: An SEM analysis: Earth Surface Processes and Landforms, v. 9, p. 289-299.

Gwinn, V. E., 1960, Cretaceous and Tertiary stratigraphy and structural geology of the Drummond area, western Montana: Princeton, N.J., Princeton University Ph. D. dissertation, 153 p.

________, 1961, Geology of the Drummond area, central-west to the Flint Creek Range: in Fields, R. W., and Shepard, Warren, (eds.), Geology of the Flint Creek Range, Montana: Billings Geological Society 16th Annual Field Conference Guidebook, p. 10-18.

Holmes, G. W., and Moss, J. H., 1955, Pleistocene geology of the southwestern Wind River Mountains: Geological Society of America Bulletin, vol. 66, p. 629-654.

Jones, R. S., and Fleischer, Michael, 1968, Gold in minerals and the composition of native gold: U.S. Geological Survey Circular 612, 17 p.

Klein, G. D., 1963, Boulder surface markings in Quaco Formation (Upper Triassic), St. Martin's, New Brunswick, Canada: Journal of Sedimentary Petrology, vol. 33, no. 1, p. 49-52.

Konizeski, R. L., 1957, Paleoecology of the middle Pliocene Deer Lodge local fauna, western Montana: Geological Society of America Bulletin, vol. 68, p. 131-150.

________, 1965, Tertiary deposits in basins marginal to the Flint Creek Range: in Fields, R. W., and Shepard, Warren, (eds.), Geology of the Flint Creek Range, Montana: Billings Geological Society 16th Annual Field Conference Guidebook, p. 10-18.

Konizeski, R. L., and Donohoe, J. C., 1958, Faunal and stratigraphic relationships of the Cabbage Patch beds, Granite County, Montana: in Guidebook, Eighth Annual Field Conference, Society of Vertebrate Paleontology, p. 45-49.

Konizeski, R. L., McMurtrey, R. G., and Brietkrietz, Alex, 1968, Geology and groundwater resources of the Deer Lodge Valley, Montana: U.S. Geological Survey Water-Supply Paper 1862, 49 p.

Kuenzi, W. D., and Fields, R. W., 1971, Tertiary stratigraphy, structure, and geologic history, Jefferson Basin, Montana: Geological Society of America Bulletin, v. 82, p. 3373-3394.

Lindsey, D. A., 1972, Sedimentary petrology and paleocurrents of the Harebell Formation, Pinyon conglomerate and associated coarse clastic deposits, northwestern Wyoming: U.S. Geological Survey Professional Paper 734-B, 68 p.

Lyden, C. J., 1948, The gold placers of Montana: Montana Bureau of Mines and Geology Memoir 26, 151 p.

Madole, R. F., 1982, Possible origins of till-like deposits near summit of the Front Range in north-central Colorado: U.S. Geological Survey Professional Paper 1243, 31 p.

Madole, R. F., and Shroba, R. R., 1979, Till sequence and soil development in the North St. Vrain drainage basin, east slope, Front Range, Colorado; in Ethridge, F. G., (ed.), Field Guide, northern Front Range and northwest Denver basin, Colorado: Rocky Mountain Section, Geological Society of America, p. 123-178.

Mann, A. W., 1984, Mobility of gold and silver in lateritic weathering profiles: some observations from Australia: Economic Geology, v. 79, p. 38-49.

McClernan, H. G., 1976, Metallic mineral deposits of Powell County, Montana: Montana Bureau of Mines and Geology Bulletin 98, 46 p.

Meierding, T. C., and Birkeland, P. W., 1980, Quaternary glaciation of Colorado: in Kent, H. C., and Porter, K. W., (eds.), Colorado Geology: Rocky Mountain Association of Geologists 1980 Symposium, p. 165-173.

Mertie, J. B., 1940, Placer gold in Alaska: Journal of the Washington Acadamey of Science, v. 30, p. 93-124.

Mutch, T. A., 1960, Geology of the northeast flank of the Flint Creek Range, Monana: Princeton, N.J., Princeton University Ph.D. dissertation, 159 p.

________, 1961, Geologic map of the northeast flank of the Flint Creek Range, western Montana: Montana Bureau of Mines and Geology Special Publication 22, scale 1:62,500.

Nemec, W., and Steel, R. J., 1984, Alluvial and coastal conglomerates: their significant features and some comments on gravelly mass-flow deposits: in Koster, E. H., and Steel, R. J., (eds.), Sedimentology of gravels and conglomerates: Canadian Society of Petroleum Geologists Memoir 10, p. 1-32.

Pardee, J. T., 1916-1940, Unpublished field notebooks nos. 4170-A, 5550, and 5550-A, available from U.S. Geological Survey, Geologic Division, Denver, Colorado.

________, 1950, Late Cenozoic block faulting in western Montana: Geological Society of America Bulletin, v. 61, no. 4, p. 359-406.

________, 1951, Gold placer deposits of the Pioneer district, Montana: U.S. Geological Survey Bulletin 978-C, p. 69-99.

Pierson, T. C., 1986, Initiation and flow behavior of the 1980 Pine Creek and Muddy River lahars, Mount St. Helens, Washington: Geological Society of America Bulletin, v. 96, p. 1056-1069.

Rasmussen, D. L., 1969, Late Cenozoic geology of the Cabbage Patch area, Granite and Powell Counties, Montana: Missoula, University of Montana M.A. thesis, 188 p.

________, 1973, Extension of the middle Tertiary unconformity into western Montana: Northwest Geology, v. 2, p. 27-35.

________, 1977, Geology and mammalian paleontology of the Oligocene-Miocene Cabbage Patch Formation, Central-western Montana: University of Kansas, Ph.D. dissertation, 775 p.

Raymond, R. W., 1873, Statistics of mines and mining in the states and territories west of the Rocky Mountains for 1871: Washington, U.S. Government Printing Office.

Richmond, G. M., 1965, Glaciation in the Rocky Mountains, in Wright, H. E., Jr., and Frey, D. G., (eds.), The Quaternary of the United States: Princeton University Press, Princeton, N. J., p. 217-230.

________, 1970, Comparison of the Quaternary stratigraphy of the Alps and Rocky Mountains: Quaternary Research, v. 1, p. 3-28.

Robinson, G. D., 1963, Geology of the Three Forks quadrangle, Montana: U.S. Geological Survey Professional Paper 370, 143 p.

________, 1967, Geologic map of the Toston quadrangle, southwestern Montana: U.S. Geological Survey Miscellaneous Geological Investigations Map I-486.

Ruppel, E. T., Wallace, C. A., Schmidt, R. G., and Lopez, D. A., 1981, Preliminary interpretation of the thrust belt in southwest and west-central Montana and east-central Idaho, in Guidebook to southwest Montana: Montana Geological Society, Field Conference and Symposium, 1981, p. 139-159.

Schumm, S. A., 1977, The fluvial system: New York, John Wiley and Sons, 338 p.

________, 1981, Evolution and response of the fluvial system, sedimentologic implications: Society of Economic Paleontologists and Mineralogists Special Publication No. 31, p. 19-29.

Scott, G. R., 1975, Cenozoic surfaces and deposits in the southern Rocky Mountains and their recognition, in Curtin, B. F., (ed.), Cenozoic history of the southern Rocky Mountains: Geological Society of America Memoir 144, p. 227-248.

Stuart, Granville, 1876, Memoirs of Montana pioneers, v. 1, Montana Historical Society.

United States Bureau of Mines, Minerals Yearbook: U.S. Government Printing Office, Washington D.C.

Wilson, A. F., 1984, Origin of quartz-free gold nuggets and supergene gold found in laterites and soils--a review and some new observations: Economic Geology, Australian Journal of Earth Sciences, v. 31, p. 303-316.

Wolman, M. G., and Miller, J. P., 1960, Magnitude and frequency of forces in geomorphic processes: Journal of Geology, v. 68, p. 54-74.

APPENDIX

Electron microprobe analyses of selected gold grains in samples of vein and placers from the Pioneer and Rose Mountain districts, Powell County, Montana. Dashes indicate data not available.

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5003	1	1	797	Core		
Lode gold from vein	1	2	824	Core		
from vein on dump	1	3	813	Core	810.0	10.8
of the Independence	1	4	820	Core		
Mine (SE of NW,	1	5	805	Core		
sec. 17, T. 8 N.,	1	6	801	Core		
R. 11 W.)						
	2	1	916	Core		
	2	2	899	Core	907.7	8.5
	2	3	908	Core		
	3	1	802	Core		
	3	2	791	Core	796.5	7.8
	4	1	761	Core	761.0	0
	5	1	861	Core		
	5	2	862	Core	854.3	12.4
	5	3	840	Core		
	6	1	797	Core		
	6	2	776	Core	786.5	14.8
	7	1	816	Core		
	7	2	833	Core	824.5	12.0
	8	1	826	Core	826.0	0
	9	1	930	Core		
	9	2	910	Core	920.0	14.1
	10	1	893	Core		
	10	2	888	Core	890.5	3.5
	11	1	826	Core		
	11	2	824	Core		
	11	3	806	Core	814.4	10.9

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5003 (Continued)	11	4	815	Core		
	11	5	801	Core		
	12	1	777	Core		
	12	2	773	Core	775.0	2.8
	13	1	759	Core		
	13	2	759	Core	761.3	4.0
	13	3	766	Core		
	14	1	819	Core		
	14	2	812	Core	815.7	3.5
	14	4	816	Core		
	15	1	841	Core		
	15	2	830	Core	835.0	5.6
	15	3	834	Core		
	16	1	804	Core		
	16	2	804	Core	806.3	4.0
	16	3	811	Core		
	17	1	758	Core		
	17	2	765	Core	761.5	4.9
	18	1	822	Core		
	18	2	816	Core	819.0	4.2
	19	1	820	Core		
	19	2	830	Core	825.0	7.1
	20	1	806	Core		
	20	2	814	Core		
	20	3	778	Core	799.0	15.5
	20	4	797	Core		
	21	1	800	Core		
	21	2	772	Core	786.0	19.8
	22	1	852	Core	852.0	0
	23	1	829	Core		
	23	2	818	Core	822.0	6.1
	23	3	819	Core		
	24	1	831	Core		
	24	2	844	Core	837.5	9.2

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5003 (Continued)	25	1	779	Core		
	25	2	792	Core	789.7	9.7
	25	3	798	Core		
	26	1	827	Core		
	26	2	800	Core	813.5	19.1
	27	1	813	Core		
	27	2	819	Core	816.0	4.2
	28	1	857	Core		
	28	2	863	Core	860.0	4.2
	29	1	764	Core		
	29	2	765	Core	764.5	0.7
	30	1	767	Core		
	30	2	742	Core	754.5	17.7
	31	1	818	Core		
	31	2	831	Core		
	31	3	816	Core	810.2	17.9
	31	4	784	Core		
	31	5	802	Core		
	32	1	824	Core		
	32	2	795	Core	805.7	7.2
	32	3	798	Core		
L5001	1	1	748	Core		
Placer gold from	1	2	759	Core		
dredge workings in	1	3	963	Rim		
Quaternary outwash	1	4	957	Rim	755.0	7.2
in Pioneer Gulch	1	5	763	Core		
Pioneer Gulch (SE	1	6	750	Core		
of NE, sec. 22,						
T. 9 N., R. 11 W.)						
	2	1	832	Core		
	2	2	998	Rim		
	2	3	849	Core		
	2	4	855	Core		
	2	5	818	Core		
	2	6	837	Core		
	2	7	832	Core		
	2	8	826	Core	834.2	11.4
	2	9	829	Core		
	2	10	986	Rim		

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5001 (Continued)	2	11	977	Rim		
	2	12	994	Rim		
	2	13	994	Rim		
	2	14	968	Rim		
	2	15	830	Core		
	3	1	786	Core		
	3	2	770	Core		
	3	3	794	Core		
	3	4	767	Core		
	3	5	993	Rim		
	3	6	968	Rim		
	3	7	821	Core	785.0	18.3
	3	8	780	Core		
	3	9	960	Rim		
	3	10	965	Rim		
	3	11	976	Rim		
	3	12	972	Rim		
	3	13	777	Core		
	3	14	980	Rim		
	4	1	971	Core		
	4	2	988	Rim	967.5	4.9
	4	3	964	Core		
	5	1	816	Core		
	5	1	816	Core	819.8	6.3
	5	2	815	Core		
	5	3	987	Rim		
	5	4	830	Core	819.8	6.3
	5	6	822	Core		
	6	1	897	Core		
	6	2	880	Core		
	6	3	896	Core		
	6	4	970	Rim	887.5	10.5
	6	5	977	Rim		
	6	6	877	Core		
	6	7	987	Rim		
	7	1	847	Core		
	7	2	847	Core		
	7	3	855	Core		
	7	4	966	Rim	849.5	3.8
	7	5	944	Rim		
	7	6	960	Rim		
	7	7	977	Rim		

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5001 (Continued)	8	1	957	Rim		
	8	2	967	Rim		
	8	3	961	Rim	849.0	0
	8	4	849	Core		
	8	5	965	Rim		
L5066A	1	1	862	Core		
(Placer gold from	1	2	856	Core		
conglomerate in	1	3	865	Core		
Pioneer beds	1	4	844	Core		
exposed in mine	1	5	828	Core		
workings on Pilgrim	1	6	853	Core		
(NE of SE, sec. 25,	1	7	1000	Rim		
T. 9 N., R. 11 W.)	1	8	937	Rim		
	1	9	1000	Rim		
	1	10	945	Rim	848.4	15.1
	1	11	1000	Rim		
	1	12	836	Core		
	1	13	1000	Rim		
	1	14	866	Core		
	1	15	833	Core		
	1	16	955	Rim		
	1	17	973	Rim		
	1	18	828	Core		
	1	19	955	Rim		
	1	20	862	Core		
	2	1	905	Core		
	2	2	900	Core		
	2	3	903	Core	904.2	3.8
	2	4	909	Core		
	3	1	994	Rim		
	3	2	1000	Rim		
	3	3	1000	Rim		
	3	4	1000	Rim	863.0	0
	3	5	863	Core		
	3	6	990	Rim		
	4	1	843	Core		
	4	2	855	Core		
	4	3	835	Core		
	4	4	831	Core		
	4	5	1000	Rim		
	4	6	827	Core		
	4	7	873	Core		
	4	8	837	Core		
	4	9	976	Rim		

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5066A (Continued)	4	10	979	Rim		
	4	11	837	Core		
	4	12	991	Rim		
	4	13	997	Rim		
	4	14	996	Rim		
	4	15	992	Rim	839.5	13.2
	4	16	821	Core		
	4	17	993	Rim		
	4	18	965	Rim		
	4	19	996	Rim		
	4	20	989	Rim		
	4	21	1000	Rim		
	4	22	998	Rim		
	4	23	834	Core		
	4	24	991	Rim		
	4	25	841	Core		
	4	27	837	Core		
	4	28	824	Core		
	4	29	852	Core		
	4	30	846	Core		
	5	1	820	Core		
	5	2	978	Rim		
	5	3	1000	Rim	820.0	0
	5	4	997	Rim		
	5	5	981	Rim		
	6	1	990	Rim		
	6	2	820	Core		
	6	3	855	Core		
	6	4	839	Core		
	6	5	990	Rim		
	6	6	994	Rim		
	6	7	1000	Rim		
	6	8	834	Core		
	6	9	815	Core	831.9	14.5
	6	10	998	Rim		
	6	11	989	Rim		
	6	12	819	Core		
	6	13	993	Rim		
	6	14	985	Rim		
	6	15	1000	Rim		
	6	16	918	Rim		
	6	17	841	Core		
	7	1	994	Rim		
	7	2	988	Rim	----	
	7	3	968	Rim		

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5066A (Continued)	8	1	870	Core		
	8	2	984	Rim		
	8	3	998	Rim		
	8	4	860	Core		
	8	5	847	Core		
	8	6	972	Rim	861.8	10.4
	8	7	855	Core		
	8	8	876	Core		
	8	9	999	Rim		
	8	10	1000	Rim		
	8	11	863	Core		
	8	12	985	Rim		
	9	1	995	Rim		
	9	2	871	Core		
	9	3	875	Core		
	9	4	979	Rim		
	9	5	864	Core	869.2	4.8
	9	6	1000	Rim		
	9	7	867	Core		
	9	8	983	Rim		
	10	1	800	Core		
	10	2	813	Core		
	10	3	788	Core	803.6	10.0
	10	4	807	Core		
	10	5	810	Core		
	11	1	890	Core		
	11	2	884	Core		
	11	3	896	Core		
	11	4	899	Core		
	11	5	900	Core	893.7	5.5
	11	6	893	Core		
	11	7	997	Rim		
	11	8	984	Rim		
	11	9	977	Rim		
	11	10	894	Core		
	12	1	1000	Rim		
	12	2	985	Rim		
	12	3	929	Core		
	12	4	971	Core	951.3	21.1
	12	5	954	Core		
	12	6	983	Rim		
	13	1	897	Core		
	13	2	883	Core		

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5066A (Continued)	13	3	867	Core	882.5	12.3
	13	4	883	Core		
	14	1	744	Core		
	14	2	746	Core		
	14	3	734	Core	733.2	25.6
	14	4	689	Core		
	14	5	753	Core		
	15	1	860	Core		
	15	2	864	Core		
	15	3	856	Core	862.2	5.6
	15	4	992	Rim		
	15	5	869	Core		
L5168	1	1	847	Core		
Placer gold from	1	2	833	Core		
from Pliocene (?)	1	3	841	Core		
conglomerate	1	4	852	Core		
exposed in mine	1	5	984	Rim		
workings on the SE	1	6	970	Rim		
shoulder of Windy	1	7	852	Core	844.2	9.0
Hill (NW of SE,	1	8	977	Rim		
sec. 19, T. 9 N.,	1	9	852	Core		
R. 10 W.)	1	10	950	Rim		
	1	11	827	Core		
	1	12	845	Core		
	1	13	955	Rim		
	1	14	849	Core		
	1	15	983	Rim		
	2	1	970	Rim		
	2	2	844	Core		
	2	3	857	Core	850.5	9.2
	2	4	991	Rim		
	3	1	978	Rim		
	3	2	845	Core		
	3	3	987	Rim		
	3	4	996	Rim	846.7	10.6
	3	5	858	Core		
	3	6	837	Core		
	4	1	978	Rim		
	4	2	981	Rim		
	4	3	771	Core		
	4	4	758	Core		
	4	5	990	Rim		

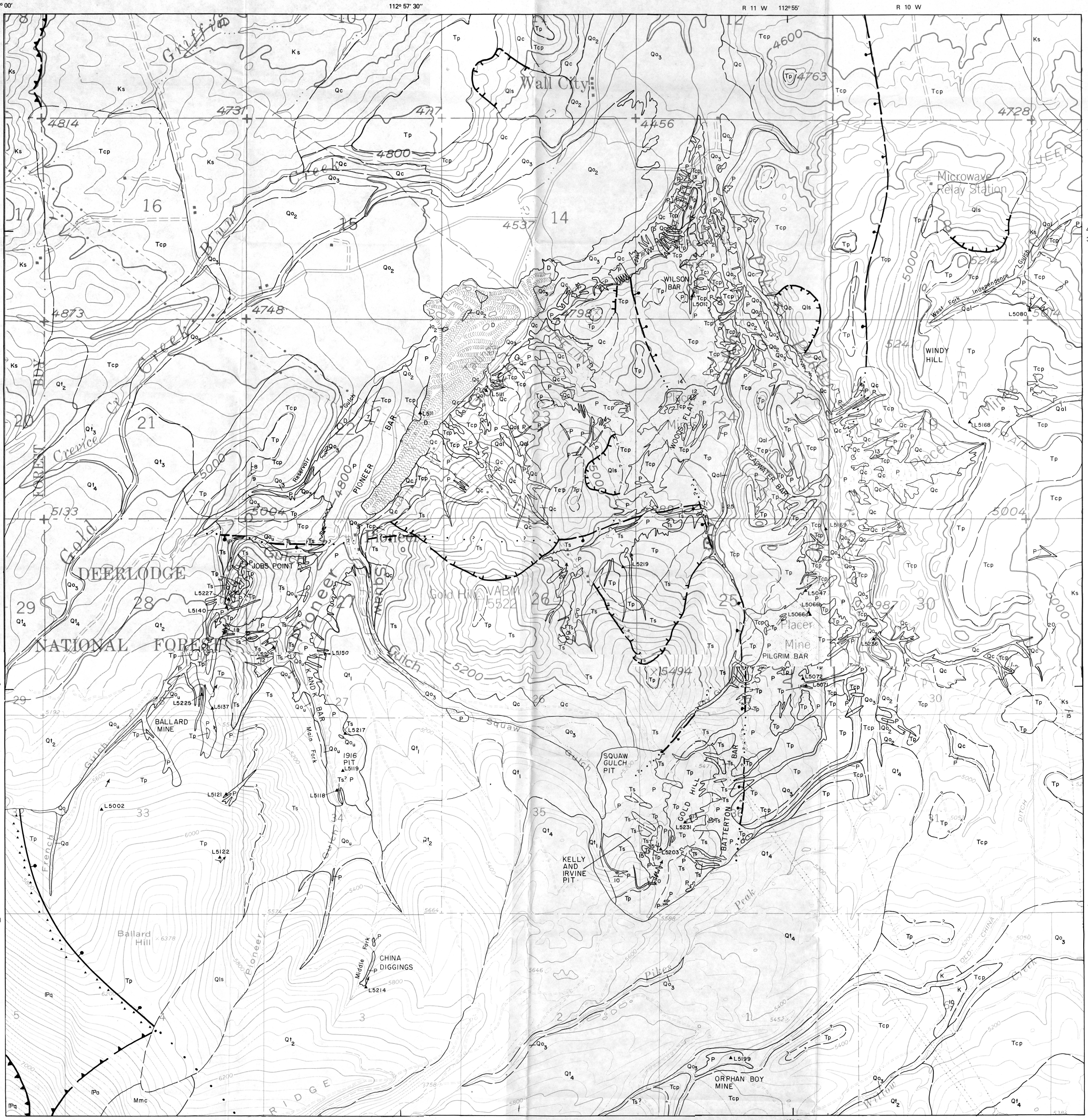
Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5168 (Continued)	4	6	760	Core		
	4	7	995	Rim	762.3	8.1
	4	8	968	Rim		
	4	9	764	Core		
	4	10	750	Core		
	4	11	960	Rim		
	4	12	985	Rim		
	4	13	771	Core		
	4	14	966	Rim		
	5	1	985	Rim		
	5	2	840	Core		
	5	3	839	Core		
	5	4	983	Rim		
	5	5	979	Rim	838.6	3.0
	5	6	834	Core		
	5	7	997	Rim		
	5	8	983	Rim		
	5	9	838	Core		
	5	10	842	Core		
	5	11	989	Rim		
	6	1	916	Core		
	6	2	975	Rim		
	6	3	986	Rim		
	6	4	901	Core	908.75	6.2
	6	5	908	Core		
	6	6	910	Core		
	6	7	978	Rim		
	7	1	915	Core		
	7	2	970	Rim	915.0	0
	8	1	869	Core		
	8	2	982	Rim		
	8	3	891	Core	880.0	15.6
	8	4	956	Rim		
	9	1	850	Core		
	9	2	861	Core		
	9	3	974	Rim		
	9	4	862	Core		
	9	5	815	Core	834.7	26.3
	9	6	813	Core		
	9	7	796	Core		
	9	8	846	Core		
	10	1	787	Core		

Appendix (Continued)

Sample (Description)	Grain No.	Point No.	Gold Fineness	Point location	Mean of Core	Std Dev
L5168 (Continued)	10	2	966	Rim		
	10	3	781	Core		
	10	4	772	Core		
	10	5	974	Rim	783.5	9.3
	10	6	975	Rim		
	10	7	794	Core		
	10	8	968	Rim		
	11	1	975	Rim		
	11	2	954	Rim	----	
	12	1	777	Core		
	12	2	773	Core	775.3	2.1
	12	3	776	Core		
	13	1	968	Core		
	13	2	968	Core	968.0	0
	13	3	970	Rim		
	14	1	870	Core		
	14	2	784	Core		
	14	3	784	Core	804.3	43.9
	14	4	779	Core		
	15	1	985	Rim		
	15	2	839	Core		
	15	3	963	Rim		
	15	4	984	Rim	849.3	9.6
	15	5	858	Core		
	15	6	989	Rim		
	15	7	851	Core		
	16	1	960	Rim		
	16	2	984	Rim		
	16	3	831	Core	820.5	14.8
	16	4	810	Core		
	17	1	973	Rim	----	
	17	2	970	Rim		

PLATE 1



Base from U.S. Geological Survey; 1:62,500, Garrison, 1952; 1:24,000, Rock Creek Lake, 1967

SCALE 1:12000

½ 0 1 MILE

.5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

N MN 19°

GEOLOGIC MAP OF THE PIONEER DISTRICT, POWELL COUNTY, MONTANA

By
Jeffrey S. Loen
1986

MONTANA

EXPLANATION

CORRELATION OF MAP UNITS

Qc, Qa, Qls		Holocene	QUATERNARY
Qt_4, Qt_3, Qt_2, Qt_1	Qo_3, Qo_2, Qo_1, Qo_u	Pleistocene	QUATERNARY
Unconformity			
Tp		Late Miocene and Pliocene (?)	TERTIARY
Unconformity			
Ts		Middle Miocene	TERTIARY
Unconformity			
Tcp		Late Oligocene and Early Miocene	TERTIARY
Unconformity			
Ks			CRETACEOUS
Unconformity			
IPq, IPa			PENNSYLVANIAN
Mmc			MISSISSIPPIAN

LIST OF MAP UNITS

Qa — ALLUVIUM (HOLOCENE)--Unconsolidated silt, sand and gravel in modern stream valleys.

Qls — LANDSLIDE DEPOSITS (HOLOCENE)--Rotational slides and slumps

Qc — COLLUVIUM (HOLOCENE)--Unconsolidated slope wash deposits

GLACIAL OUTWASH (PLEISTOCENE)--Unconsolidated glacio-fluvial gravels

Qo_3 — YOUNG OUTWASH--Forms terrace 6 ft. above present streams. Corresponds to unit Qt_4

Qo_2 — INTERMEDIATE OUTWASH--Forms terrace 20 ft. above streams. Queried where identification uncertain. Corresponds to unit Qt_3

Qo_1 — OLD OUTWASH--Forms terrace 40 ft. above stream. Probably corresponds to unit Qt_2

Qo_u — OUTWASH, UNDIVIDED--Corresponds to any or all of the above outwash deposits

GLACIAL TILL (PLEISTOCENE)--Unconsolidated, unsorted deposits of silt, sand, and boulders

Qt_4 — YOUNG TILL--Displays sharp morainal topography

Qt_3 — YOUNG INTERMEDIATE TILL--Morainal topography is well preserved but rounded

Qt_2 — OLD INTERMEDIATE TILL--Moraines have broad, smooth crests

Qt_1 — OLD TILL--Deposits display no morainal form

Tp — PIONEER BEDS (LATE MIOCENE AND PLIOCENE (?))--Interlayered clast- and matrix-supported boulder/cobble congomerate and siltstone. Where queried, contacts are in part inferred using aerial photographs

Ts — SQUAW GULCH BEDS (MIDDLE MIOCENE)--Siltstone interlayered with sandstone and pebble/cobble conglomerate

Tcp — CABBAGE PATCH FORMATION (LATE OLIGOCENE AND EARLY MIOCENE)--Interbedded tuffaceous mudstone, siltstone, sandstone, clay, diatomite, and lignite

Ks — SEDIMENTARY ROCKS, UNDIVIDED (CRETACEOUS)--Sandstone conglomerate, and limestone of the Golden Spike Formation, the Kootenai Formation, and the Colorado Group

IPq — QUADRANT FORMATION (PENNSYLVANIAN)--Thick-bedded, massive, ridge-forming quartzite

IPa — AMSDEN FORMATION (PENNSYLVANIAN)--Silty mudstone, shale, sandstone and limestone

Mmc — MISSION CANYON LIMESTONE (MISSISSIPPIAN)--Thin-bedded, fossiliferous limestone

SYMBOLS

DISTURBED SURFACE MATERIALS

P — Areas mined by ground sluicing and hydraulic mining. Includes mine tailings

D — Areas mined by dredging. Includes mine tailings

CONTACT--Dashed where approximately located or inferred; dotted where concealed. Queried where location uncertain

NORMAL FAULT--Dashed where approximately located or inferred; dotted where concealed. Bar and ball on downthrown side. Queried where location uncertain

FAULT BRECCIA

THRUST FAULT--Dashed where approximately located or inferred; dotted where concealed. Sawteeth on upper plate. Queried where location uncertain

LANDSLIDE SCARP--Dashed where approximately located or inferred. Hachures point towards landslide

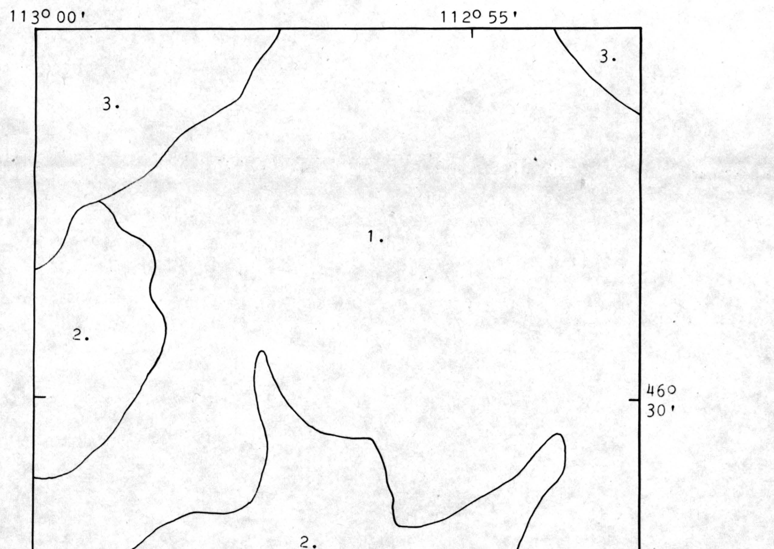
STRIKE AND DIP OF BEDS

15 Inclined

PALEOCURRENT DIRECTIONS OF IMBRICATED CLASTS IN TERTIARY CONGLOMERATE

L5168 PANNED CONCENTRATE SAMPLE LOCALITY

ADIT



Index to mapping responsibility: (1) J. S. Loen, 1985; (2) M. R. Waters, 1984-85; (3) C. A. Wallace, unpublished data; (4) Elliott et al. (1984)