U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

The association of Middle Cambrian rocks and gold deposits in southwest Montana

by

Edward T. Ruppel[1]

Open-File Report 85-207

This report is preliminary and has not been reviewed or edited for conformity to U.S. Geological Survey standards or nomenclature.

[1] Federal Center, Denver, CO.

1985

CONTENTS

ILLUSTRATIONS

ABSTRACT

In the western Tobacco Root Mountains, gold-bearing quartz veins, replacement deposits, and associated placer deposits are restricted to areas where the Meagher Limestone, of Middle Cambrian age, also is present, and are further restricted to areas where the Meagher includes reefs or reef-like masses of algal carbonate rocks in its upper part. The stratigraphic relations of the Meagher Limestone, and of the underlying Middle Cambrian Wolsey Shale and Flathead Sandstone, indicate that they lap onto the edge of a fault-bounded uplifted block, the Tobacco Root Island, which is underlain by Archean crystalline metamorphic rocks. The algal reefs in the upper Meagher grew along the edges of the island. The gold deposits occur in the Meagher, in the Wolsey Shale and Flathead Sandstone, and extend downwards into the underlying crystalline metamorphic rocks where they bottom at relatively shallow depths. No gold deposits are known in sedimentary rocks above the Meagher Limestone. These relations suggest that the gold might originally have accumulated either in algal mats in the upper part of the Meagher Limestone, or in the overlying Park Shale, also of Middle Cambrian age, and that it might have been partly redistributed during diagenesis of the Park Shale, into the gold-bearing quartz veins and replacement deposits that now are found in and beneath the Meagher reefs in the western Tobacco Root Mountains.

In most other areas in southwest Montana where significant quantities of gold have been found in lode deposits or in placers, the Meagher Limestone and associated algal carbonate rocks either are present or occur nearby. Even some deposits of gold that are associated with Late Cretaceous and Tertiary granitic rocks, and clearly are of hydrothermal origin, seem likely to contain gold redistributed from underlying or nearby Middle Cambrian rocks. And some placer deposits of gold, which have no recognized source, head in areas underlain by Meagher Limestone containing reef-like deposits similar to those in the Tobacco Root Mountains. The association of gold deposits and reefs in the Meagher Limestone is so consistent as to suggest that most of the gold deposits in southwest Montana were derived from sedimentary rocks of Middle Cambrian age. If this is true, there may be other, undiscovered gold deposits in this region, either lode deposits, or fine-grained gold disseminated in Middle Cambrian sedimentary rocks, or placer deposits of gold weathered from these rocks and deposited in the gravels of present streams, or in ancient stream gravels deposited in drainages different from the present ones.

THE ASSOCIATION OF MIDDLE CAMBRIAN ROCKS AND GOLD DEPOSITS IN SOUTHWEST MONTANA

by
Edward T. Ruppel

INTRODUCTION

Cambrian sedimentary rocks in southwest Montana commonly have been thought of as broad, thin blankets of clastic and carbonate sediments deposited smoothly across the Archean crystalline basement rocks of this region. Geologic mapping in the western Tobacco Root Mountains (fig. 1.) suggests a very different depositional setting, however, because the Middle Cambrian rocks there progressively thin eastward against the shore of a pre-existing island block that was bounded by northwest- and northeast-trending faults. These faults are members of a much larger group of similar faults that have controlled the structural framework of southwest Montana, at least since Early Proterozoic time. The Tobacco Root island therefore probably was only one of many Middle Cambrian islands, in a region of orthogonal, fault-controlled block uplifts and intervening flooded structural depressions. The crystalline rocks in the cores of some islands remained exposed at least through Middle Cambrian time, because late Middle Cambrian rocks contain materials derived from crystalline rocks. Some areas may have remained as relatively high, perhaps recurrently uplifted, through much of Phanerozoic time, and some of them are uplifted now in different parts of the present mountain ranges of southwest Montana.

In the western Tobacco Root Mountains, carbonate buildups interpreted to be algal reefs occur in the Middle Cambrian Meagher Limestone where it laps onto Tobacco Root island. The lode and placer deposits of gold in this area are clustered near these reefs. The statigraphic and structural relations of Middle Cambrian rocks and the association of reefs and gold deposits are discussed in this report, and are compared with the geologic setting of some other gold deposits in southwest Montana.

Those comparisons are not yet supported by detailed geologic mapping in all of the areas discussed, however, or by widespread and systematic geochemical sampling and chemical analyses.

Several earlier reports discuss the geology and mineral deposits of different parts of the western Tobacco Root Mountains. The earliest of these is by Winchell (1914), who also discussed the mines and mineral deposits of the surrounding region. Tansley, Schafer, and Hart (1933) described the general geologic setting of the Tobacco Root Mountains, and discussed the mines and prospects in the range. Reyner (1947) and Johns (1961) described the geology and mineral deposits in part of the area. Samuelson and Schmidt (1981) discussed the structural framework of the western flank of the range north of Bear Gulch, and Schmidt and O'Neill (1982) and Schmidt and Garihan (1983) further discussed regional structural relations. Small islands of Middle Cambrian age at the north end of the Tobacco Root Mountains have been described by Robinson (1963) and Graham and Suttner (1974). Crystalline metamorphic rocks of Archean age in the Tobacco Root Mountains have been described by Reid (1957), Vitaliano and Cordua (1979) and James (1981).

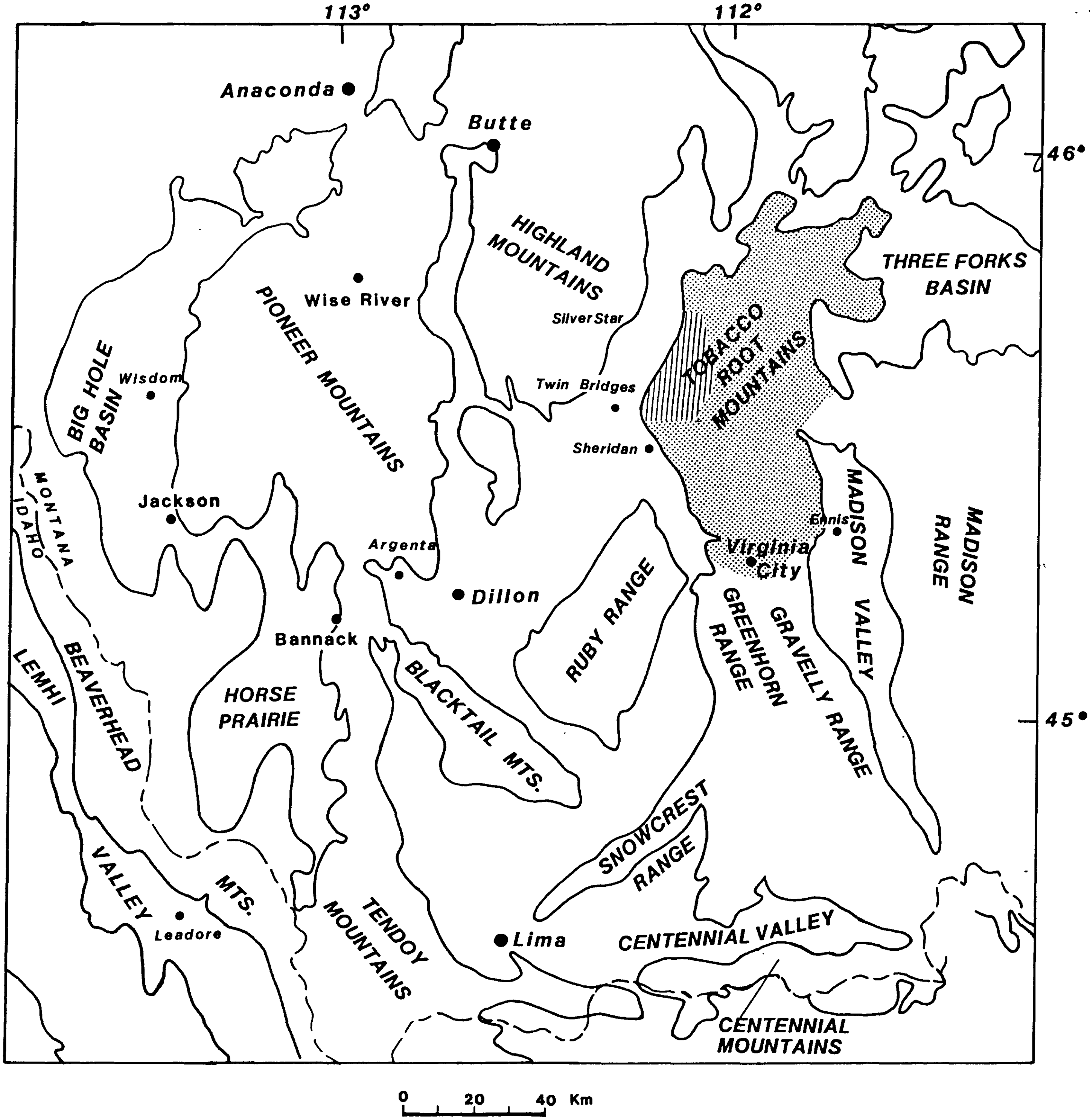


Fig. 1 Index map of southwest Montana, showing location of Tobacco Mountains

Area shown on Figs. 2,4

CAMBRIAN ROCKS EXPOSED ON THE WEST FLANK OF THE TOBACCO ROOT MOUNTAINS

The core of the Tobacco Root Mountains is underlain by crystalline metamorphic rocks of Archean age (Reid, 1957; Vitaliano and Cordua, 1979; James, 1981), which are overlain unconformably by Middle Cambrian sedimentary rocks that include the Flathead Sandstone at the base, overlain in sequence upward by the Wolsey Shale, Meagher Limestone, and Park Shale. The Park Shale is overlain by Upper Cambrian rocks of the Pilgrim Dolomite and the Snowy Range Formation.

Middle Cambrian rocks, the principal rocks considered in this report, are distributed along the full length of the west flank of the range. The best-exposed and most complete section is near Dry Georgia and Wet Georgia Gulches (fig. 2). This section, although broken by many faults, extends farther north and northeast to the head of Goodrich Gulch and the west side of Old Baldy Mountain. A similarly complete section is also present, but not as well exposed, on the south wall of the canyon of Beall Creek, at the north end of the area (fig. 2). In the area between Goodrich Gulch and Beall Creek, the Cambrian sequence is incomplete in many places, because of faulting, or because granitic sheets intrude these rocks and have strongly metamorphosed and partly destroyed them (Johns, 1961; Samuelson and Schmidt, 1981).

Flathead Sandstone

The Flathead Sandstone, composed largely of clastic detritus from the underlying Archean metamorphic rocks, changes composition and becomes thinner from the front of the range eastward. The formation crops out at the front of the range from Wet Georgia and Dry Georgia Gulches northward to near Dry Gulch (fig. 2). Farther north, from Bear Gulch to Beall Creek, it is present only farther back in the range, in poorly exposed outcrops above the crystalline metamorphic rocks.

In most places, the formation consists of yellowish gray to yellowish brown, fine- to medium-grained quartzitic sandstone, in beds 0.1-0.3 m thick, and less abundant interbeds of medium- to very coarse-grained quartzitic sandstone from 0.3-1.1 m thick. Most of the sand grains are well sorted and well rounded, and bedding surfaces commonly are thinly coated with scattered grains of coarse to very coarse sand. In some places, the lower part of the formation includes lenticular beds of quartz pebble conglomerate, from 0.1-1 m thick.

Near Dry Georgia and Wet Georgia Gulches, the quartzitic sandstones and conglomeratic rocks are underlain by finer-grained rocks that are not present elsewhere in the western Tobacco Root Mountains. These finer-grained rocks, about 20 m thick, are mainly yellowish gray to pale brown siltstone, mudstone, and shale. They include thin interbeds of argillaceous very fine-grained to fine-grained sandstone, and some thicker interbeds of quartzitic sandstone similar to the quartzitic sandstones in the upper part of the formation. The argillaceous sandstone, siltstone, and finer grained rocks mostly are thinly laminated and thinly platy to chippy or fissile. The quartzitic sandstone typically is fine-grained to very fine-grained, and is composed of well rounded and well sorted quartz grains, in beds 0.1-1.3 m thick. A few beds, however, are medium-grained and are composed of sub-rounded to sub-angular grains and of coarser, well-rounded grains of glassy quartz floating in the finer grained matrix.

EXPLANATION

- **Qf** — *Alluvial fans of Quaternary age*
- **Tt** — *Tuffaceous sandstone and siltstone of Tertiary age*
- **Tkg** — *Granitic rocks, undivided, of Tertiary or Cretaceous age*
- **Pzu** — *Sedimentary rocks of Devonian to Pennsylvanian age, undivided*
- **Ꞓu** — *Pilgrim Dolomite and Snowy Range Formation, of Late Cambrian age*
- **Ꞓm** — *Flathead Sandstone, Wolsey Shale, Meagher Limestone, and Park Shale, of Middle Cambrian age*
- **Ag** — *Crystalline metamorphic rocks of Archean age*

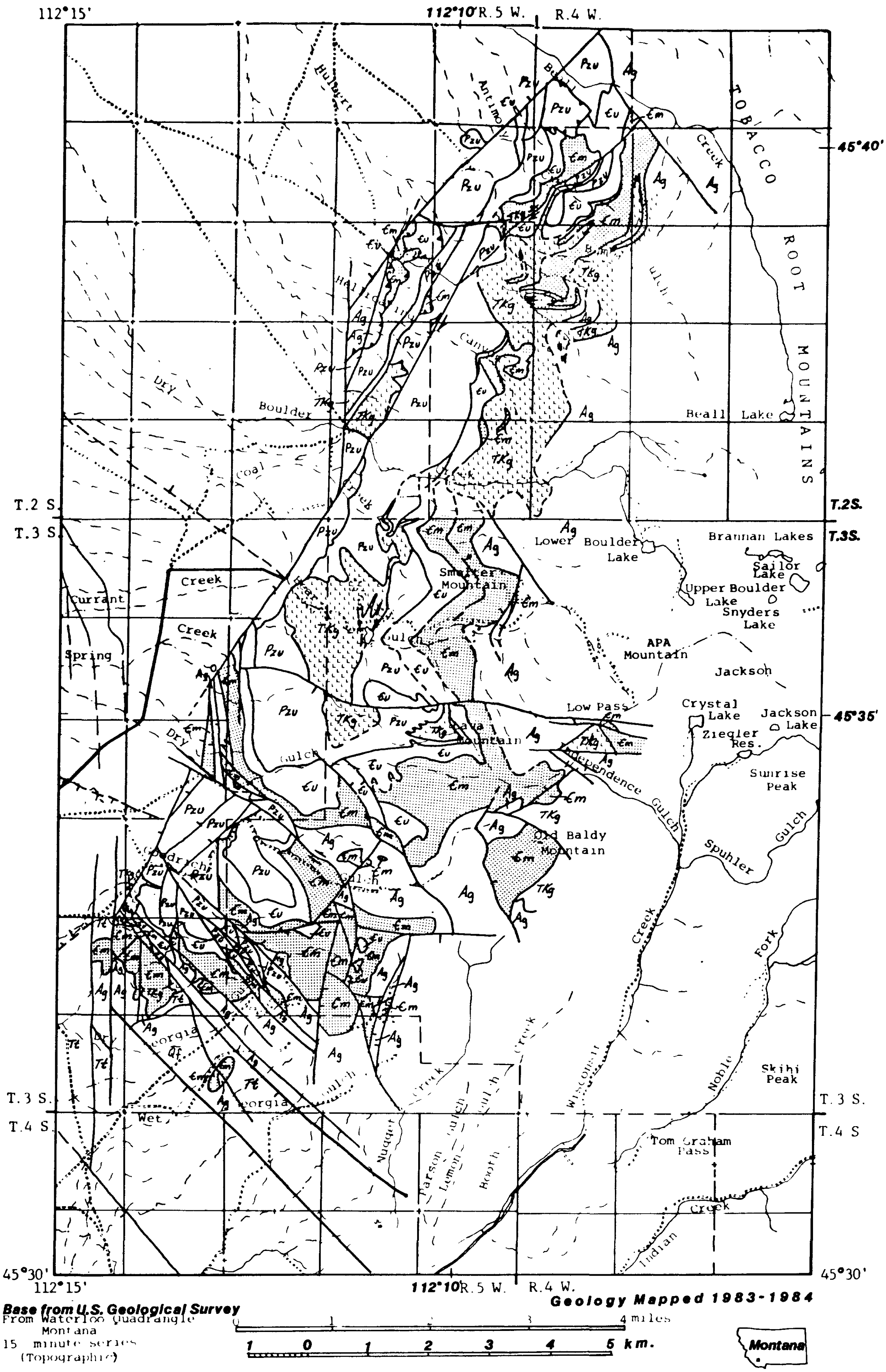
Contact dashed where concealed

Fault, bar on downthrown side, arrows show direction of lateral movement, dashed where concealed

Thrust fault, sawteeth on upper plate

Figure 2

Map showing distribution of Cambrian rocks in the western Tobacco Root Mountains



112°15'
112°10' R.5 W.
R.4 W.
45°40'
45°35'
45°30'
T.2 S.
T.3 S.
T.4 S.
TOBACCO ROOT MOUNTAINS
Beall Lake
Lower Boulder Lake
Brannan Lakes
Sailor Lake
Upper Boulder Lake
Snyders Lake
APA Mountain
Jackson
Crystal Lake
Jackson Lake
Ziegler Res.
Low Pass
Sunrise Peak
Old Baldy Mountain
Smuggler Mountain
Dependence Gulch
Spuhler Gulch
Noble Fork
Skihi Peak
Tom Graham Pass
Indian Creek
Currant Creek
Spring
Dry Boulder
Coal Creek
Wet
Parson Gulch
Lemon Gulch
Booth
Nugget
Wisconsin Creek
Geology Mapped 1983-1984
Base from U.S. Geological Survey
From Waterloo Quadrangle Montana
15 minute series (Topographic)
4 miles
1 0 1 2 3 4 5 km.
Montana

The uppermost part of the formation includes thin beds of partly glauconitic, fine-grained sandstone and interbedded mudstone that are gradational into the overlying Wolsey Shale.

In general, the formation is thickest at the range front, and thins to the east and northeast against the core of the range. The thickest section, about 43 m thick, is exposed along the lower parts of Dry Georgia and Wet Georgia Gulches. The formation thins abruptly to 0-30 m across the zone of northwest-trending faults at the front of the range near Dry Georgia Gulch, and continues to thin persistently to the northeast, to 0-10 m where it laps out against the metamorphic rocks in the core of the range. A similar pattern of eastward-thinning persists in outcrops farther north. At the mouth of Dry Gulch, the formation is about 30 m thick, and thins to 10 m or less in its easternmost outcrops in Bear Gulch. In the area from Bear Gulch to Beall Creek, it most commonly is about 3-5 m thick, but in places it is as much as 10 m thick, and in a few places it is absent.

The thick section of the formation between Dry Georgia and Wet Georgia Gulches is underlain by deeply weathered metamorphic rocks, in a zone as much as 15 m thick that grades into unweathered rocks at greater depth. The weathered zone is absent beneath the Flathead Sandstone farther east and northeast in the range, and probably was eroded during onlap of the Middle Cambrian seas, to provide the silt and mud that is present in the lower half of the formation in this area, but not elsewhere in the western Tobacco Root Mountains.

Wolsey Shale

The Wolsey Shale gradationally overlies the Flathead Sandstone, or unconformably overlies Archean crystalline metamorphic rocks where the Flathead is absent. It gradationally underlies the Meagher Limestone. Most of the formation is dark red or reddish brown to grayish red, micaceous, glauconitic siltstone and interbedded olive green fissile shale, but it also includes interbedded grayish red to yellowish gray glauconitic, argillaceous, fine-grained, platy sandstone in beds 0.3-0.5 mi thick, and thin interbeds of medium gray limestone in the upper gradational zone into the overlying Meagher Limestone. In general, the brown and red glauconitic sandstones and siltstones are most abundant in the lower half of the formation, and the upper half is olive green shale with interbedded grayish orange to yellowish gray, partly thinly laminated, partly calcareous, very fine-grained sandstone and siltstone. Near Dry Georgia Gulch, the formation includes some beds as much as 1.5 m (5 ft) thick of reddish black, chippy mudstone.

The formation is about 73 m thick in the area between Dry Georgia and Wet Georgia Gulches (Johns, 1961, p. 10), but elsewhere most commonly is only about 30 m or less thick. Like the Flathead Sandstone, it is thickest near the range front, and thins east and northeast to as little as 15 m.

Meagher Limestone

The Meagher Limestone gradationally overlies the Wolsey Shale, and conformably underlies the Park Shale; the upper contact appears to be sharp everyplace in the western Tobacco Root Mountains. Much of the formation consists of fine crystalline, medium light gray to medium gray limestone or dolomitic limestone that is irregularly mottled yellowish gray. The middle part of the formation includes beds of dolomite that commonly are medium gray to medium dark gray and not mottled. The upper part of the formation includes many beds that are mottled light gray, rather than yellowish gray, and includes carbonate buildups interpreted to be algal reefs. Most of the formation is thick bedded or massive, but some thinner beds are present throughout the formation, and the uppermost part, perhaps 15-30 m thick, is mostly thin- to medium-bedded (0.1-0.6 m), and partly is mottled pale red.

The formation is about 150 m thick between Dry Georgia and Wet Georgia Gulches, but appears to be somewhat thinner elsewhere along the range front, perhaps most commonly about 120-140 m. Like the underlying Flathead Sandstone and Wolsey Shale, it thins to the east and northeast, most commonly to about 90-110 m, but to 75 m or less in Bear Gulch.

Reefs in the upper Meagher Limestone.--The thin-bedded, mottled limestones of the upper Meagher in the western Tobacco Root Mountains surround and enclose blunt-ended, lenticular deposits of thinly laminated light gray and dark gray dolomite and associated sedimentary breccias and sub-lithographic limestone, which I interpret to be algal reef complexes. Each of the reef complexes includes some or most of the following parts (fig. 3, 4).

1) A reef base, consisting of finely brecciated or comminuted carbonate sand and interbedded or associated pelletal or oolitic limestone. In places, the reef base is irregularly channeled.

2) Light gray and dark gray calcareous algal dolomite as much as 15-20 m thick that forms the main reef body, above the reef base. Mostly commonly, the rocks in contact with the reef base are medium dark gray to dark gray, massive to thick-bedded, thinly laminated dolomite that is slightly fetid, locally cross-laminated, contains clusters of small, well-defined convex-upwards algal columns in a few places, and typically is 3-6 m thick. In most reefs, the dark gray dolomite is overlain by light gray, massive, very thinly laminated calcareous dolomite that is cross-laminated in a few places, and typically also is 3-6 m thick. But the laminated dark gray and light gray algal dolomites also occur in reverse sequence, or interbedded with each other, and in some places the dark gray rocks are absent. For example, a reef exposed near the head of Goodrich Gulch (fig. 2) consists of about 6 m of light gray, thinly laminated limy dolomite above the channeled, pelletal, lime and sand reef base, overlain successively by: about 3-4 m of medium dark gray to dark gray thinly laminated, slightly fetid limy dolomite that includes a few thin beds of yellowish gray calcareous siltstone; about 3 m of thinly laminated light gray limy dolomite; and an uppermost bed, less than 1 m thick of dark gray limy dolomite. The uppermost bed in the reef is overlain by a thin cap of yellowish-gray and gray mottled limestone.

   The lateral dimensions of the reef dolomites are uncertain because of complex faulting and limited exposures. Probably they were originally more or less oval shaped, and as much as 5 km in maximum diameter, and formed a string of small reefs along the edge of Tobacco Root Island (see p. 12).

3) Reef-front breccias, which occur along the west, or seaward side of the reef dolomites, and consist of angular blocks up to a meter across of reef dolomite, and of blocks of mottled limestone that were broken from intricately contorted beds along the reef edges. The contorted beds apparently were squeezed from beneath the reef as the reef rocks settled into the underlying lime muds. The distribution of reef-front breccias along the west edges of the reefs suggests that the breccias were formed by wave action on the seaward side of the reefs. It implies, also, that the reef dolomites stood above the sea floor and so are true reefs and not simply lenticular algal bioherms. All of the reef-front breccias now are almost entirely silicified to heavily limonite-encrusted jasperoidal breccias.

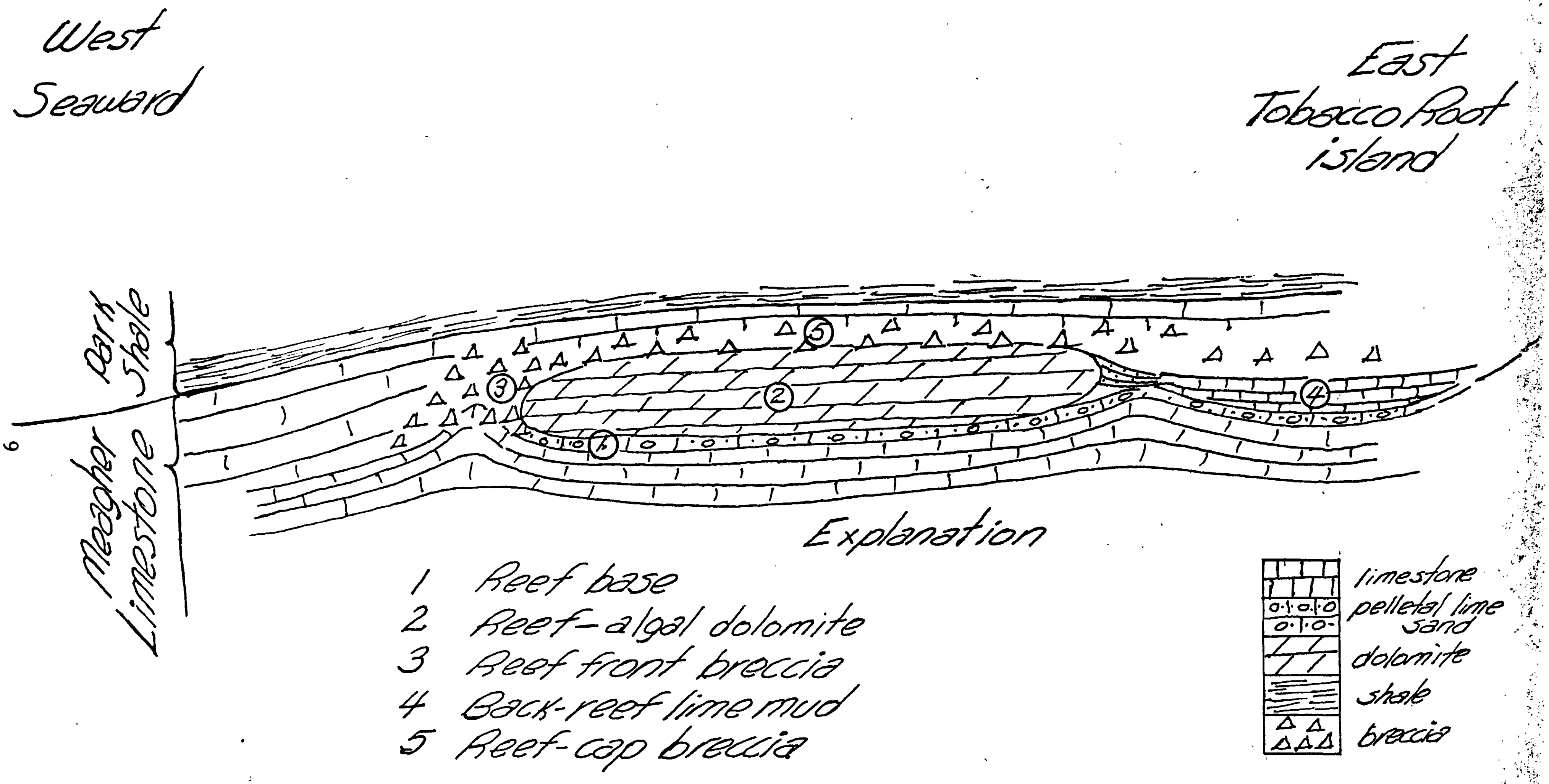
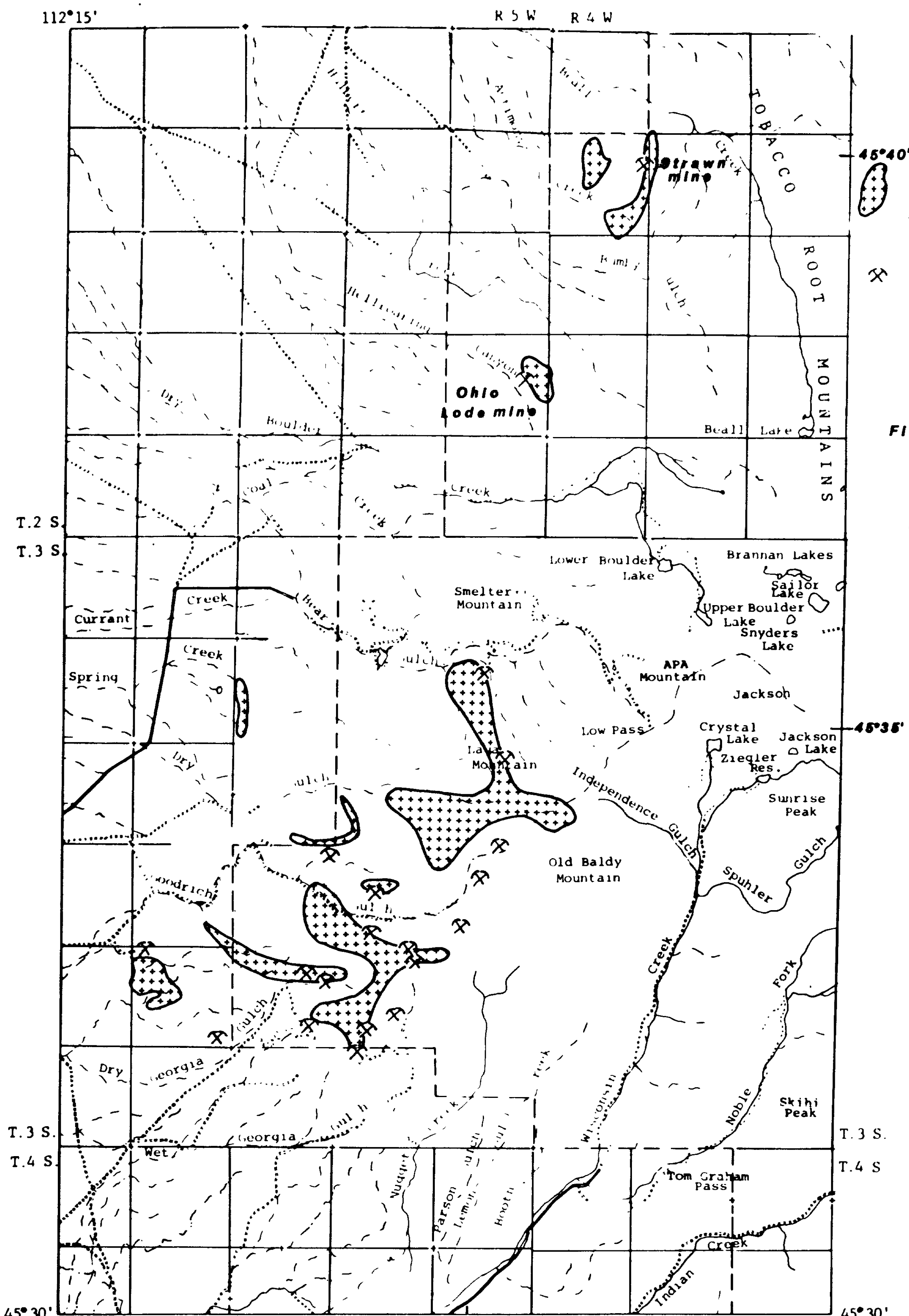


Figure 3
Composite cross-section of an idealized algal reef in the Meagher Limestone



Base From U.S. Geological Survey
From Waterloo Quadrangle
Montana
15 minute series
(Topographic)
(1:62,500)

EXPLANATION

Area of algal reefs in upper part of Meagher Limestone

Mine, prospect, or placer deposit

Figure 4 Distribution of algal reefs in the Meagher Limestone in the western Tobacco Root Mountains

4) Back-reef lime muds that consist of medium light gray, massive to thick-bedded, very fine-grained to sub-lithographic limestone as much as 15 m thick. The back-reef limestones are on the east or shoreward flank of the reefs, and are laterally gradational into the reef dolomites through a zone of cross-bedded, detrital limestone. They overlie oolitic and pelletal limestones similar to those of the reef base, and apparently occupy the same stratigraphic position as the reef dolomites. The back-reef limestones suggest that both detrital and algal carbonates accumulated as lime muds in sheltered, quiet water behind the reefs.
5) Reef-cap breccias extend across the entire reef complex, and consist of angular blocks of the underlying rocks generally somewhat smaller than those in the reef-front breccias. This breccia commonly is 5-10 m thick, but locally is as much as 15 m thick, and some thin reef dolomites are entirely brecciated. The reef-cap breccias are gradationally overlain by thin beds of yellowish-gray mottled gray limestone, typical of the marine limestones of the Meagher, that commonly are 3-6 m thick. The reef-cap breccias now are largely or entirely replaced by limonite-encrusted jasperoidal silica, like the reef-front breccias, and veins of jasperoidal silica pervasively crosscut most of the underlying reef rocks as well.

   The succession from reef dolomite to reef-cap breccia to mottled marine limestone of the Meagher suggests that the reefs finally were drowned late in the period of Meagher sedimentation, that their upper parts were brecciated by wave action as the sea deepened, and that marine limestones finally were deposited over them at the close of Meagher sedimentation. In the upper part of Goodrich Gulch, linear belts of Park Shale preserved on the upper part of the Meagher Limestone suggest either that this surface was cut by shallow channels before deposition of the shale, or that the muds were injected into fractures during diagenesis, an interpretation that seems most likely.

Park Shale

The Park Shale, the youngest Middle Cambrian formation, conformably overlies the Meagher Limestone. The contact is sharply defined, and not gradational and intertonguing as it is in places in the neighboring Ruby Range (Tysdal, 1976, p. 1-12). The formation consists mostly of pale olive or grayish green, finely micaceous fissile shale. The middle and upper part of the formation includes sparse interbeds of yellowish brown medium crystalline dolomite up to 0.5 thick, and more abundant thin interbeds of yellowish gray or grayish orange, thinly platy, fine-grained, calcareous sandstone, siltstone, and mudstone. The uppermost 3-5 m of the formation is yellowish gray platy mudstone.

The Park Shale is at most about 45 m thick (Johns, 1961, p. 11), but commonly is about 20-30 m thick. It does not seem to become significantly thinner east of the mountain front, and so it does not share the eastward-thinning pattern of the underlying sedimentary rocks.

Upper Cambrian rocks

The Park Shale is conformably overlain by the Pilgrim Dolomite, about 123 m thick, and, above the Pilgrim, the Snowy Range Formation, 0-35 m thick, both of Late Cambrian age. The thickness of the Snowy Range Formation differs from place to place as a result of erosion before Late Devonian time and the formation is absent in the Dry Georgia Gulch area, where the overlying Upper Devonian Jefferson Formation rests on deeply eroded and channeled Pilgrim Dolomite. Neither the Pilgrim nor the Snowy Range show any persistent pattern of eastward-thinning like that in Middle Cambrian rocks below the Park Shale. The absence of an eastward-thinning pattern in these formations suggests that in late Middle Cambrian and Late Cambrian time the Tobacco Root area was more deeply submerged than it was earlier in the Middle Cambrian, and that marine carbonate and clastic rocks were deposited more widely across it. The original extent of Upper Cambrian and younger sedimentary rocks is not known.

TOBACCO ROOT ISLAND

The consistent east- and northeast-thinning of Middle Cambrian rocks below the Park Shale in the western Tobacco Root Mountains indicates that these rocks were deposited on the gently sloping flanks of an uplifted region underlain by Archean crystalline metamorphic rocks. Because the present Tobacco Root Mountains are nearly surrounded by Cambrian rocks, this uplifted region seems to have been an island, the Tobacco Root island of this report. The dimensions of the island are uncertain, because the thickness and stratigraphic relations of Middle Cambrian rocks in surrounding areas are structurally complicated and not well known. Probably the island was a northwest-trending region about 40 km long and 20 km wide (fig. 5). The Flathead Sandstone and Wolsey Shale lap out against metamorphic rocks on the island flanks, and probably never extended across the top of the Tobacco Root island. The depositional relations of the Meagher Limestone are not as clear, but the eastward-thinning of the formation is evident in Bear Gulch, where it is only half as thick as at the front of the range. If this thinning rate of almost 20 m/km persisted farther east, it is unlikely that the formation extended across the island top.

The present Tobacco Root Mountains, which probably are roughly the shape of the inferred Middle Cambrian Tobacco Root island, are bounded by steep northwest-, northeast-, and east-trending frontal faults. The northwest- and northeast-trending faults that form the edge of the western Tobacco Roots (fig. 2, 5) clearly have moved relatively recently, because they break both Tertiary rocks and some Quaternary alluvial deposits. The most abrupt changes in composition and thickness in Middle Cambrian rocks take place across and along these faults, which suggests that the sediments were deposited across an irregular and rounded scarp-like front. The frontal faults seem most likely to have moved sometime before deposition of the Middle Cambrian rocks, in an episode of faulting in latest Proterozoic or Early Cambrian time, to form the Tobacco Root island, a fault-bounded block uplift. There is no clear evidence of movement along these faults during deposition of the Middle Cambrian rocks. The thickness of the Flathead Sandstone and Wolsey Shale changes erratically and abruptly from place to place along the northwest-trending fault zone between Dry Georgia and West Georgia Gulches, but these changes seem to reflect erosional irregularities rather than syndepositional faulting.

The northwest-, northeast-, and east-trending faults that formed the edges of Tobacco Root island are members of a much larger group of similarly trending faults and fault zones that are rooted in crystalline metamorphic rocks. Movment along these faults has taken place recurrently at least since the Early Proterozoic (See Vitaliano and Cordua, 1979, p. 6), and they continue, now, to control the structural fabric of southwest Montana (Ruppel, 1982). Tobacco Root island thus is only one long-lived, fault-bounded block uplift in a much larger region of orthogonal, fault-bounded uplifts that also seem likely to have stayed above transgressing Middle Cambrian seas that flooded the intervening structural troughs (Ruppel, O'Neill, and Lopez, 1983;

Explanation

↗ Interpreted thinning direction of Middle Cambrian rocks.

/ Fault or fault zone, of Early Proterozoic or older ancestry, partly recurrently active to present time.

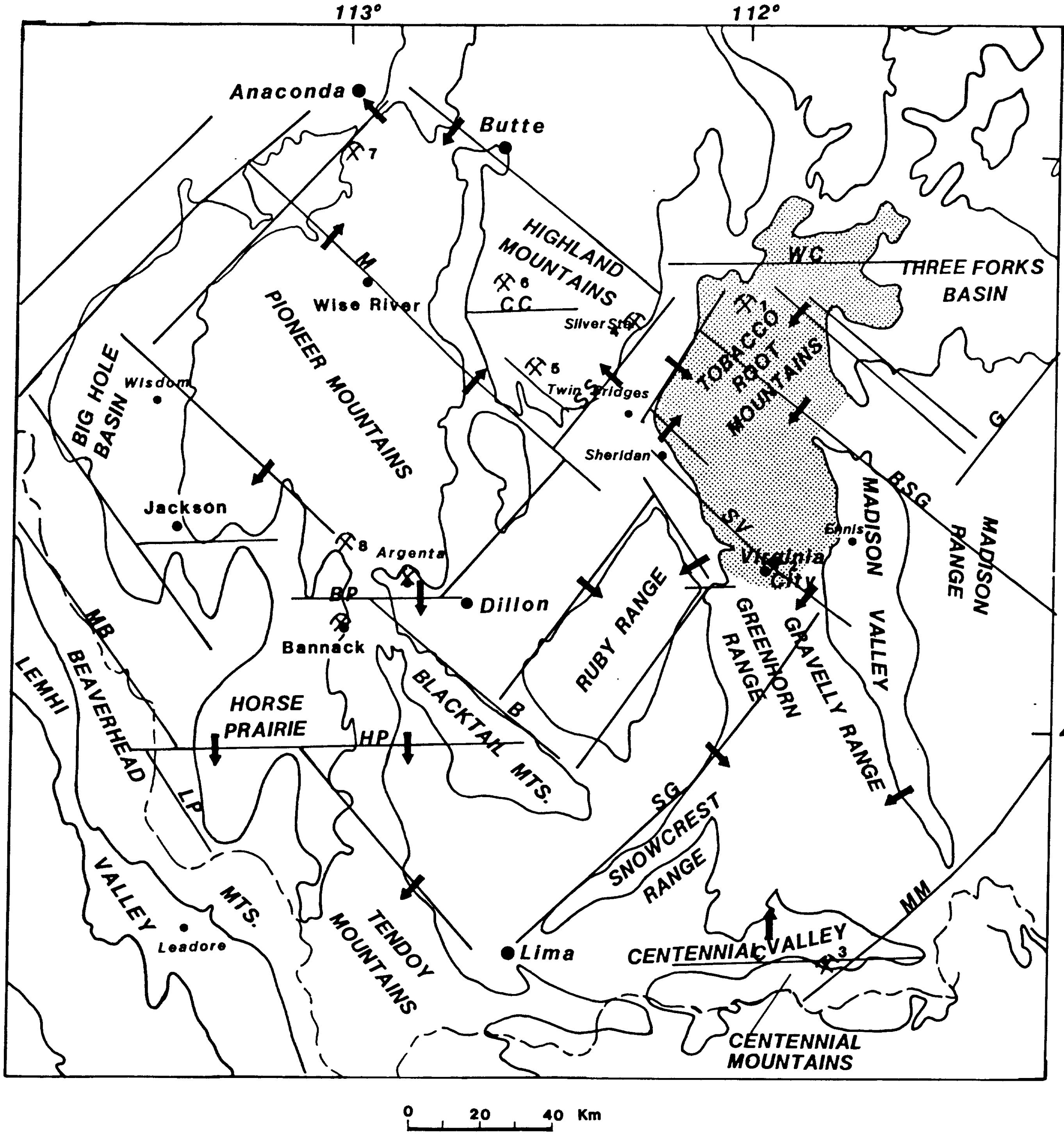
⚒ Gold mine or mining district (discussed in text)

B Blacktail
BP Badger Pass
BSG Bismark -Spanish Peaks -Gardiner
C Centennial
CC Campcreek
G Gallatin
HP Horse Prairie
LP Lemhi Pass
M McCartney
MB Miner Lake-Beaverhead Divide
MM Madison Mylonite Zone
SG Snowcrest-Greenhorn
SS Silver Star
SV Sheridan-Virginia-City
WC Willow Creek

1. Mayflower mine
2. Virginia City - Alder Gulch
3. Odell Creek
4. Silver Star
5. Rochester
6. Moose Creek-Fish Creek
7. French Creek
8. Dyce Creek-Argenta-Bannack

Figure 5

Map showing principal structural blocks in southwest Montana, the interpreted thinning directions of Middle Cambrian rocks, and location of gold deposits.


113°
112°
46°
45°
Anaconda
Butte
HIGHLAND MOUNTAINS
THREE FORKS BASIN
WC
CC
Silver Star
Wise River
PIONEER MOUNTAINS
TOBACCO ROOT MOUNTAINS
Twin Bridges
Sheridan
BIG HOLE BASIN
Wisdom
Jackson
Argenta
Dillon
BP
Bannack
RUBY RANGE
GREENHORN RANGE
GRAVELLY RANGE
MADISON VALLEY
MADISON RANGE
BSG
SV
Virginia City
Ennis
G
M
MB
BEAVERHEAD
LEMHI
HORSE PRAIRIE
HP
BLACKTAIL MTS.
B
LP
VALLEY
MTS.
Leadore
TENDOY MOUNTAINS
Lima
SG
SNOWCREST RANGE
CENTENNIAL VALLEY
MM
CENTENNIAL MOUNTAINS
0 20 40 Km

Ruppel and Lopez, 1984, pl. 1). The crystalline metamorphic rocks in the island cores seem likely, as in the Tobacco Roots, to have remained exposed at least through Middle Cambrian time as a source for the micaceous shales and feldspathic sandstones of the Park Shale (Fryxell, 1981). Some of these probable Middle Cambrian islands are shown on Figure 5, which also shows some of the known and extended major basement faults of the region.

To suggest, however, that presently uplifted mountain blocks like the Tobacco Root Mountains also were uplifts in the Proterozoic and Early and Middle Cambrian is not to suggest that they necessarily remained relatively uplifted in part or all of the intervening time. Some areas that now are depressed must once have been higher, because Archean rocks underlie Tertiary rocks and Quaternary deposits in some valley floors today and show that these areas have lost all of their covering Phanerozoic rocks. And some presently mountainous areas equally clearly must once have been relatively much lower, like the Gravelly Range, with its capping of volcanic rocks and boulder gravel of Tertiary age (Hadley, 1980, p. 86-88). The recurrent movements on the ancient faults that control the structural fabric of the region have been in different directions at different times, and the uplifts and depressions probably have differed, too (Ruppel, 1982, p. 3-7).

GOLD-BEARING QUARTZ VEINS AND RELATED GOLD DEPOSITS IN THE WESTERN TOBACCO ROOT MOUNTAINS

Gold is widespread in the western Tobacco Root Mountains in quartz veins, replacement deposits, and in small placers (fig. 2, 4). Most of the mines and prospects that explore these deposits are in the Tidal Wave mining district (Johns, 1961; Reyner, 1947), but the Ohio Lode mine and the Strawn mine are farther north in the range. The deposits of gold in quartz veins occur in crystalline metamorphic rocks, and in the overlying sedimentary rocks of Middle Cambrian age. No gold quartz veins or associated replacement deposits occur in sedimentary rocks above the Meagher Limestone.

Nearly all of the veins seem to cut both the crystalline rocks and the overlying sedimentary rocks, and the most productive parts of some veins merge into irregular, jasperoidal replacement deposits in the sedimentary rocks. The veins bottom in crystalline rocks at relatively shallow depths, all at depths of less than 185 m beneath the contact with overlying sedimentary rocks. The veins commonly strike about north to northeast, and are thin, lenticular veins that contain free gold and auriferous pyrite, sphalerite, chalcopyrite, and galena, in a gangue of quartz, jasperoidal silica, and iron oxides. Winchell (1914, p. 157) and Tansley and others (1933, p. 37) suggested that two distinct mineralogic types characterize at least some of the veins: 1) oxidized or enriched gold ore associated with auriferous pyrite, and containing minor amounts of silver and lead; and 2) chiefly silver and lead minerals with small amounts of gold.

These and other characteristics of gold-bearing lode deposits in the western Tobacco Root Mountains can be summarized very briefly. All of these deposits are in or below the Meagher Limestone, and most of them bottom at depths of 185 m or less in the underlying crystalline metamorphic rocks. All of them are in or near areas where the upper part of the Meagher Limestone includes dolomites and associated breccias that I interpret to be reef complexes that grew on the flanks of Tobacco Root island. All of them are relatively simple deposits that generally consist of free gold or gold in auriferous pyrite, and a small amount of silver, in a gangue of quartz or jasperoidal silica, with a relatively small amounts of other base-metal sulfides, also auriferous, in most deposits. Jasperoidal silica is abundant, as well, in the Meagher reefs, where it commonly almost completely replaces the reef-front and reef-cap breccias and forms multiple veins and veinlets that crosscut the reef dolomites.

The gold-bearing veins and replacement deposits in the western Tobacco Root Mountains have been interpreted to be hydrothermal deposits associated with granitic stocks, dikes, and sills of either Archean or Late Cretaceous and Tertiary age (Winchell, 1914, p. 146; Tansley and others, 1933, p. 34; Johns, 1961, p. 24-26). The granitic rocks of this region are mainly quartz monzonite and syenite, both probably related to the Tobacco Root batholith that Vitaliano and Cordua (1979, p. 5) suggest is 71-74 m.y. old. Only two small quartz monzonite masses are known in the south part of the Tidal Wave district (fig. 2), both of them on the southwest edge of the mining district, and neither of them near any known deposits of gold in quartz veins. In the central part of the district, where most of the gold veins occur, the only intrusive igneous rocks are a few thin dioritic and gabbroic dikes and sills. In the northern part of the district, north of Dry Gulch (fig. 2) a thick, bulbous quartz monzonite sill, the Bear Gulch stock of Johns (1961, p. 18), intrudes the contact between Devonian and Mississippian carbonate rocks. The sill has strongly metamorphosed the enclosing sedimentary rocks, locally to copper-bearing skarn (see Johns, 1961, p. 18, 26-27), but no associated gold-bearing quartz veins are known. In the eastern part of the district, a syenitic sill intrudes Devonian carbonate rocks on Lava Mountain, and a syenitic sheet intrudes the contact between the Flathead Sandstone and Archean metamorphic rocks on Old Baldy Mountain and at Low Pass (fig. 2). No gold deposits are known to be associated with either the Lava Mountain or Old Baldy Mountain syenitic intrusives. A short distance farther north, at the base of A.P.A. Mountain, Tansley and others (1933, p. 34-35) described gold veins apparently associated with a small monzonitic plug in Archean gneiss and schist. They interpreted this plug to be the source of most of the gold deposits in the upper part of Bear Gulch (fig. 2).

North of the Tidal Wave district from Dry Boulder Gulch to Beall Creek, a thick, irregular sheet of syenite has been intruded more or less into the contact between sedimentary rocks of Cambrian age and the older metamorphic rocks. The only known mineral deposits adjacent to the syenite sheet are in reef-like rocks in the upper part of the Meagher Limestone. They include the gold deposits at the Ohio Lode mine and the Strawn mine, and a small deposit of stibnite at the head of Antimony Creek a short distance south of the Strawn mine. At the mouth of Dry Boulder Gulch, quartz monzonite is exposed between the northeast-trending faults at the front of the range. Because of faulting, the shape of the intrusive mass is uncertain. Its upper contact is conformable with the enclosing Devonian and Mississippian sedimentary rocks, and it probably is a thick sill intruded into the contact between the Devonian and Mississippian rocks, like the Bear Gulch sill, which it compositionally resembles. No mineral deposits are known to be associated with the Dry Boulder Gulch quartz monzonite.

Because no granitic rocks are exposed in the principal area of gold deposits in the Tidal Wave district, and because he believed that the gold-bearing quartz veins occurred only in the metamorphic rocks, Winchell (1914, p. 146, 157) concluded that the gold deposits were associated with intrusive rocks of Archean age. Johns (1961, p. 18) recognized that many of the veins extended into the Cambrian sedimentary rocks, and so could not be of Archean age as Winchell had suggested; he implied that the veins were fed through faults from a deeply buried granitic intrusive. Tansley and others (1933, p. 34) interpreted the gold deposits to be of hydrothermal origin, but noted that the relation of gold-bearing quartz veins to granitic rocks was not clear, and that there was no significant alteration in the wall rocks adjacent to the veins. Considering the relative absence of gold-bearing quartz veins around the major granitic bodies in the western Tobacco Root Mountains, perhaps the most reasonable conclusion is that of Tansley and others--that the relation of gold-bearing quartz veins to granitic rocks is not clear.

Interpretation of gold deposits in the western Tobacco Root Mountains as sediment-derived precious metal deposits of Cambrian age; a working hypothesis

The consistent association of Meagher reefs and gold-bearing quartz veins and replacement deposits suggests that they are related, and that the gold deposits also are of Cambrian age. As a speculative working hypothesis, I suggest that the gold originally accumulated in Middle Cambrian algal reefs or shales, and that it was partly dissolved by siliceous and saline solutions derived from dewatering of the Park Shale during diagenesis, was carried downward by these solutions into older fractures in the underlying crystalline rocks, but only to relatively shallow depths, and was redeposited in jasperoidal quartz veins and replacement deposits.[1] This interpretation suggests that the upper part of the Park Shale formed an impermeable cap early in diagenesis of the formation, as is suggested, too, by the mudstones at the top of the formation, which differ from the fissile shales beneath (see ms. p. 15). Solutions from dewatering of muds below the impermeable cap were forced downward through the most permeable zones in the underlying rocks, the reef-front and reef-cap breccias in the Meagher, and ultimately into fractures in the metamorphic rocks at greater depth. The passage of solutions through the rocks beneath the reefs may have been through permeable beds and along bedding surfaces, and perhaps through fractures in the underlying sedimentary rocks induced by overpressuring in these small areas, or through fractures formed by recurrent small movements along ancient fractures in the metamorphic rocks. The source of the abundant silica in the jasperoidal reef breccias is interpreted to be the Park Shale. The source of sulfur in sulfide minerals is uncertain; it could have come from organic materials in the algal reefs or in the Park Shale, or from evaporites deposited on supratidal flats associated with the reefs (see Shinn, 1973). The complete brecciation of a few thin reefs suggests that some brecciation could be a result of solution and removal of evaporites, rather than of wave action alone, but there is no conclusive evidence that shows evaporites to have been associated with the Meagher reefs.

The source of the gold is similarly uncertain. The ultimate sources probably are the deeply weathered Archean crystalline rocks that are overlapped by the Middle Cambrian sediments, which were exposed on Tobacco Root island and on other, similar islands in Middle Cambrian time. The gold could have been transported from these rocks, or from gold-bearing veins that cut them, either in solution, as a colloid, or as finely particulate free gold. The widespread distribution of gold in areas of Middle Cambrian rocks elsewhere in southwest Montana (see ms. p. 21) where no crystalline rocks could have been exposed, suggests that the gold was transported in solution and precipitated and fixed in Meagher algal reefs. But finely particulate gold could also have been transported with clay particles, and deposited with mud and silt in the reefs or in the Park Shale.

---

[1] The mechanics of fluid migration from compacting shales has been summarized recently by Smith, Kyle, and Magara (1983). Transportation of silica during shale diagenesis was discussed by Wallace (1976).

If the gold deposits in quartz veins, replacements, and jasperoidal breccias in the western Tobacco Root Mountains were derived from Middle Cambrian sedimentary rocks during compaction, diagenesis, and dewatering of the Park Shale, and redeposited in and below the Meagher Limestone, these lode deposits also are of Cambrian age.

SIMILAR GOLD DEPOSITS AND RELATED PLACERS ELSEWHERE IN SOUTHWEST MONTANA

Most of the gold mines and placer deposits in southwest Montana are clustered in and around the Tobacco Root Mountains and in the Highland Mountains (fig. 5). Some of these, in the Pony and Norris areas in the north and northeast Tobacco Root Mountains, for example, are lode deposits in granitic rocks of the Tobacco Root batholith and in adjacent Archean metamorphic rocks, and seem to be closely related to the batholithic rocks (Winchell, 1914, p. 110-126; Tansley and others, 1933, p. 26-31, 51-55). Some, in the Sheridan mining area, for example, are lode deposits in Archean metamorphic rocks and may include deposits that truly are of Archean age; their origin is uncertain (Winchell, 1914, p. 132-139; Tansley and others, 1933, p. 39-45). But many others are in areas where Middle Cambrian rocks are present or nearby, and where the Meagher Limestone includes reef-like rocks similar to those in the western Tobacco Root Mountains. These deposits are briefly discussed in the following pages, along with discussions of similar deposits in other areas (fig. 5)--French Gulch (no. 7) southeast of Anaconda; Dyce Creek (no. 8), in the southwest part of the Pioneer Mountains; small placer deposits in the Gravelly Range and the Centennial Mountains (no. 3); and more speculatively, the lode and placer deposits at Bannack and in the Grasshopper Creek placer, and the mineral deposits at Argenta (no. 8). Other deposits of gold that clearly differ from the western Tobacco Root deposits are omitted here--the German Gulch (Siberia district) placer and disseminated deposit, southwest of Butte; the Golden Sunlight deposit near Whitehall; and the Chinatown placer in Horse Prairie, where the source of the placer gold is unknown.

Mayflower mine (no. 1) (Winchell, 1914, p. 99; Tansley and others, 1933, p. 31)[2].--Located in the Renova district at the north end of the Tobacco Root Mountains.

The Mayflower mine is in a gold deposit in the Meagher Limestone and underlying Wolsey Shale, Flathead Sandstone, and Proterozoic Lahood Formation, and was mined to a depth of 282 m, although no ore is known to have been produced from the deepest levels. The Meagher Limestone includes thinly laminated light gray dolomite and jasperoidal breccias in its upper part, rocks that resemble those found in the Meagher reefs in the western Tobacco Root Mountains. Although the geologic setting of the Mayflower deposit is similar to that of gold deposits in the western Tobacco Root Mountains, the gold is almost exclusively in tellurides (Winchell, 1914, p. 99), which have not been recognized in the gold ores of the Tidal Wave district.

---

[2] The number following the mine or district name refers to its location on Figure 5, and is followed by citations to the principal references that describe the mineral deposits of that area.

Virginia City and the Alder Gulch placers (no. 2) (Winchell, 1914, p. 57-61; Tansley and others, 1933, p. 45-50; Wier, 1982).—Located at the south end of the Tobacco Root Mountains, where they merge into the Greenhorn Mountains and the Gravelly Range.

The Alder Gulch placer gold commonly is thought to have come from the many gold-bearing quartz veins in Archean metamorphic rocks that are the principal rocks in the Virginia City area. The quartz veins are similar to those in Archean rocks in the western Tobacco Root Mountains, and many of them have yielded substantial amounts of gold from underground workings. Few of the quartz veins seem to persist at depth, however, and the deepest mine workings appear to be the 700 ft level in the Easton mine in Browns Gulch, a tributary to Alder Gulch. The placer deposits extend through the full length of Alder Gulch, to its head beneath a cliff of Middle Cambrian and younger sedimentary rocks (Hadley, 1969b), an area of few known gold-bearing quartz veins. In this headwaters area, erosional remnants of Flathead Sandstone suggest that the Precambrian-Paleozoic unconformity slopes gently northward, and is essentially on the rounded ridge crests of Archean rocks surrounding Virginia City, but no other erosional remnants of Paleozoic rocks are known in the area. Middle Cambrian rocks are exposed east of Virginia City, however, on the opposite sides of the Sheridan-Virginia City fault zone (fig. 5, SV), a major northwest-trending fault zone that extends from Sheridan, Mont., through Virginia City into the Madison Valley south of Ennis, Mont. (Vitaliano and Cordua, 1979). The fault zone controls the northwest-trending segment of Alder Gulch at Virginia City, and continues southeast and east from there (Hadley, 1969b). North of the fault zone, Middle Cambrian rocks, including the Meagher Limestone, dip westward toward Virginia City (Hadley, 1969b). On the crest of Ennis Hill, about 5 km east of Virginia City, the Flathead Sandstone dips 12-15^{o} west beneath the lava cap, an angle that suggests that Middle Cambrian rocks can be projected into the Virginia City area, and could be preserved beneath the lava cap at Virginia City. South of the fault zone, the upper part of the Meagher Limestone is light gray, thinly laminated dolomite and dolomitic limestone that closely resembles the algal dolomite of the western Tobacco Root Mountains. These light gray rocks include beds of limestone that contain abundant fine, well-rounded, frosted grains of quartz sand, and some beds of fine-grained, cross bedded, dolomitic or calcareous, sandstone. Here, and farther south in the Gravelly Range, the Meagher is overlain by the Upper Devonian Jefferson Dolomite, and the Park Shale and Upper Cambrian rocks are absent (Hadley, 1969a, b; 1980; Mann, 1954). Also, in this region, the Flathead Sandstone differs in thickness from place, and locally is absent (Mann, 1954, p. 6).

The structural and stratigraphic relations of Middle Cambrian rocks in the Virginia City area suggest that these rocks are in a depositional setting similar to that of Middle Cambrian rocks in the western Tobacco Root Mountains, and that the Sheridan-Virginia City fault zone was the structural edge of a Middle Cambrian island in the present region of the Gravelly Range. The western edge of the island is not known, but it may have been the ancestral, northeast-trending Snowcrest-Greenhorn fault zone (fig. 5, SG), because a more complete Cambrian sequence is present west of that fault zone (Hadley, 1980, p. 15-22). The quartz sand in the upper part of the Meagher suggests a source in crystalline metamorphic rocks exposed in the island core. The consistent absence of Upper Cambrian rocks suggests that they may never have been deposited across the Gravelly Range island.

The gold-bearing quartz veins at Virginia City seem, therefore, to occur in a structural and stratigraphic setting like that of the similar veins in the western Tobacco Root Mountains. In addition, they do not have any well defined hydrothermal source in nearby granitic rocks. I suggest that the Virginia City gold-bearing quartz veins are of Cambrian age, and are sediment-derived deposits. If so, the placer gold in Alder Gulch probably is derived from vein deposits and from the Meagher Limestone in the head of Alder Gulch and in the area around Virginia City.

This interpretation suggests, too, that the Meagher Limestone could be the source of reported, widespread fine, detrital gold in Tertiary gravel on the crest of the Gravelly Range. Placer gold also is found in the upper part of the West Fork of the Madison River at the south end of the Gravelly Range, and in most of the other creeks that drain the east side of the Gravelly Range (Lyden, 1948, p. 10, 95). These small placer deposits have no known source, but the Meagher Limestone crops out in the areas above them.

Odell Creek (no. 3) (Lyden, 1948, p. 10; Witkind, 1977, 1982).--Located on the north flank of the Centennial Mountains.

The Odell Creek placer deposit has yielded a small amount of gold from an unknown source. The deposit resembles those in creeks along the east flank of the Gravelly Range, and Odell Creek also drains a region where the Meagher Limestone is exposed. In the Centennial Range, the thickness of the Flathead Sandstone differs widely from one place to another, and the Wolsey Shale is absent. The basal part of the Meagher Limestone contains angular to rounded grains and pebbles of Archean metamorphic rocks, perhaps derived from the Middle Cambrian island inferred to have been present in the Gravelly Range region to the north.

Silver Star district (no. 4) (Winchell, 1914, p. 139-144; Sahinen, 1939, p. 34-35, 47-50).--Located on the east flank of the Highland Mountains.

The geologic relations of the gold mines in the Silver Star district are not well known. In the principal gold mines, excluding those that explore contact metamorphic deposits related to the Boulder batholith, the gold occurs in well-defined quartz veins in Archean metamorphic rocks. The mineralogy of the gold ores is much like that of the gold-bearing quartz veins in the western Tobacco Root Mountains. The Silver Star veins are near areas underlain by Middle Cambrian rocks and adjacent to a major, northeast trending fault zone at the east edge of the Highland Mountains. These few known relations suggest that the Silver Star gold deposits are similar to those in the western Tobacco Root Mountains, as does Winchells conclusion that some gold veins at Silver Star were deposited long before emplacement of the Boulder batholith (Winchell, 1914, p. 143-144).

Rochester (Rabbit) district (no. 5) (Winchell, 1914, p. 126-132; Sahinen, 1939; McClernan, 1981, p. 30-37).--Located on the south flank of the Highland Mountains.

The gold veins at Rochester are mineralogically similar to those in the western Tobacco Root Mountains, but they occur mainly in Archean crystalline metamorphic rocks and not in younger sedimentary rocks.. All of them seem to have bottomed at relatively shallow depths, perhaps most commonly at depths of less than 30 m, although the largest deposit, in the Watseca mine, was mined to a depth of about 186 m, and the Emma mine was opened to a depth of about 120 m. Many of the veins and vein zones persisted for lengths of as much as 900 m, and one, the Big Bonanza, reportedly has a strike length of more than 2,400 m, despite the shallow depths of mineralization. The veins in the Watseca mine partly are in granitic intrusive rocks related to the Boulder batholith.

No rocks of Middle Cambrian age are preserved in the Rochester basin in the central part of the Rochester district, but they do crop out about 5 km

(3 miles) farther west, along the western margin of the district. The lower part of the Meagher Limestone there includes thinly laminated limestones that probably are algal bioherms. The district is in a broad zone of northwest-trending faults of at least Early Proterozoic ancestry, that have moved recurrently almost to the present time, because some of them are marked by rounded fault scarps. The structural and stratigraphic relations of the district suggest that the Middle Cambrian rocks once extended across it. The deeply weathered, gently rolling floor of the Rochester basin probably is at or very near the Precambrian surface that was covered by the Cambrian rocks. These relations, and the characteristics of the veins in the district, suggest that the Rochester gold veins could be Cambrian in age, and similar in origin to those in the western Tobacco Root Mountains. The extension of the Watseca vein zone into much younger granitic rocks suggests hydrothermal remobilization of older vein fillings along recurrent fracture zones in the granite.

The absence of placer deposits of gold in Rochester Creek, noted by Sahinen (1939, p. 36), seems to be a result of relatively recent movement on a northeast-trending fault that extends southwest from Silver Star, across the lower parts of Rochester and Nez Perce Creeks (fig. 5, SS). The alluvium in the upper parts of these creeks, on the uplifted block west of the fault, has been almost completely eroded, and the creeks now flow in bedrock channels. The alluvium, presumably including any contained placer gold, was carried across the fault scarp, and now clogs the lower channels of Rochester and Nez Perce Creeks below the fault.

Moosetown (Moose Creek) and Fish Creek (Highland) districts (no. 6) (Winchell, 1914, p. 87-90; Sahinen, 1950, p. 37-45, 51-53).--Located on the northwest and north flanks of the Highland Mountains.

Most of the mines and prospects in these districts explore gold-bearing quartz veins and siliceous replacement deposits in the Meagher Limestone or placer deposits derived from them. The descriptions of the principal mines, like the Butte-Highlands mine in the Fish Creek district, and the Day and Harvey mine in the Moosetown district, suggest extensive metamorphism associated with the emplacement of the Boulder batholith, and widespread hydrothermal alteration accompanying mineralization. The region also is complexly folded and faulted, and the sedimentary rocks have not been studied in much detail, so that lateral changes in thickness and lithology in Middle Cambrian rocks, like those in the Tobacco Root Mountains, cannot be recognized in the published descriptions. But even though the structural and stratigraphic setting is not well known, and the gold deposits seem to be hydrothermal, the unusual abundance of gold in the Meagher Limestone here, and it relative absence in other rocks in and around the Boulder batholith in this part of the Highland Mountains, suggests that the gold was locally derived from the Meagher, and redeposited in the complex hydrothermal veins and replacement deposits of these mining districts. If so, the abundant gold in the Moosetown and Fish Creek districts might originally have been concentrated in the Meagher by the sedimentary and diagenetic processes inferred to have concentrated gold in Middle Cambrian rocks in the Tobacco Root Mountains.

French Creek (no. 7) (Lyden, 1948, p. 24-25; Noel, 1956).--Gold placers on French Creek and its tributaries Oregon Creek and California Creek, about 30 km southeast of Anaconda, Mont.; French Creek is a tributary of the Big Hole River, entering it about 17 km northwest of Wise River, Mont.

The placer deposits of gold in French Creek, Oregon Creek, and California Creek do not have any known source, and no vein deposits of gold or any other metals are known in the drainage area of these creeks. Lyden (1948, p. 24-25) suggested that the source of the gold was disseminated deposits in quartzitic rocks like those in German Gulch (Siberia district) farther east, but these rocks are not present in the French Creek drainage area. Instead, the principal rocks in the placered parts of California and Oregon Creeks are Meagher Limestone. The placer deposits head in areas where the Meagher is exposed, but apparently do not extend into the upper reaches of these creeks, where other sedimentary rocks, of Proterozoic and Late Paleozoic age, are exposed. No Meagher Limestone is exposed in the French Creek drainage area, but the placer deposits in French Creek seem to occur only in and below a segment of the gulch that originally reached northward into California Creek and now has been cut off by drainage changes.

The Meagher Limestone exposed in this area is light gray to medium dark gray dolomitic limestone and calcareous dolomite that partly is mottled lighter shades of gray, and commonly is thinly laminated. Most of these rocks are brecciated, have been strongly silicifed, and in many places are jasperoidal. The Meagher apparently overlies Middle Proterozoic rocks of the Mount Shields and Bonner Formations with angular unconformity; the Flathead Sandstone and Wolsey Shale have not been recognized, and probably either are very thin, or absent. The thickness of the Meagher is not known.

The French Creek area is in a major zone of northeast-trending faults that extend southwest into central Idaho (O'Neill, Lopez, and Desmarais, 1982; Ruppel, 1982, p. 17-19), and the rocks also are broken by other steep faults that most commonly trend about north or northwest and by flat, imbricate thrust faults. As a result, the rocks of the Meagher Limestone in the French Creek area are structurally separated from Cambrian rocks in surrounding areas, and their regional relations are unknown. They seem likely to be thinning to the northwest, because a somewhat thicker and more complete sequence of Cambrian rocks is exposed farther east, across the Continental Divide in Minnesota Gulch, but even there the Meagher is faulted and incomplete, and the Flathead Sandstone and Wolsey Shale are faulted out.

Despite the structural and stratigraphic uncertainities of this region, the Meagher Limestone here has many of the characteristics of algal reef complexes in the upper part of the Meagher in the Tobacco Root Mountains. Probably the formation was deposited in a similar setting, on the flanks of a structurally controlled Middle Cambrian island. And probably the placer deposits of gold in French Creek, California Creek, and Oregon Creek have been derived from the Meagher Limestone.

<u>Dyce Creek, the Argenta district, and the Bannack district (no's 7, 8, 9) Shenon, 1931; Lyden, 1948, p. 6-8; Geach, 1972, p. 168-170)</u>.--Located on the southwest and south margins of the Pioneer Mountains. Dyce Creek is a tributary of Grasshopper Creek, about 10 km northwest of Bannack, Mont.

The gold deposits at Dyce Creek include a few small lode deposits and a small placer deposit in the gravel of Dyce Creek below these lode deposits. The lode deposits are in the Meagher Dolomite, which here is light gray, finely crystalline dolomite, as much as 50 m thick (Zimbelman, 1982), and partly is thinly laminated, brecciated, and jasperoidal. The gold-bearing veins contain sparse free gold, some silver, and secondary lead, zinc, and copper minerals, in a gangue of quartz, jasperoidal silica, and abundant iron oxides.

At Argenta and Bannack the principal mineral deposits are lead-silver-gold- deposits in the Upper Devonian Jefferson Formation (at Argenta), and gold and silver replacement deposits in the Mississippian Madison Limestone (at Bannack). However, some mineral deposits at Argenta, including many of those that have yielded major amounts of gold, are in the Middle Proterozoic

Garnet Range Formation, or in the overlying Middle Cambrian Flathead Sandstone and Meagher Limestone. All of the mineral deposits at Argenta and Bannack are interpreted to be hydrothermal deposits related to adjacent or nearby granitic stocks.

The stratigraphic relations of Cambrian rocks in this region are poorly known because of uncertainties in the identification of some rock units of Cambrian age. At Dyce Creek, the Cambrian sequence includes all of the Middle and Upper Cambrian formations known farther east (Zimbelman, 1981; Ruppel and Lopez, 1984, p. 18-19, 28-29), although somewhat thinner. The sequence is much like the Cambrian sequence near Jackson, Mont. (Ruppel and Lopez, 1984, p.18-19, 28-29), except that the Jackson sequence is even thinner and includes only a few beds of Park Shale. At Argenta, Cambrian rocks include the Flathead Sandstone and Wolsey Shale, although these apparently are very thin or absent in some places (Myers, 1952), and an uppermost light gray, partly thinly laminated dolomite unit that originally was called the Tilden Formation (Shenon, 1931, p. 47), and subsequently was tentatively assigned to the Pilgrim(?) Dolomite (Myers, 1952) or to the Hasmark Formation (Thomas, 1978, p. 7-8).

South of Bannack, the Cambrian sequence is as abbreviated as it is at Argenta, and includes similar, but laterally more persistent lithologic units. The upper, light gray dolomite unit was tentatively assigned to the Pilgrim(?) Dolomite (Lowell, 1965), in accordance with the assignment of similar rocks to the Pilgrim(?) at Argenta (Myers, 1952).

Myers (1952) interpreted the relations of Cambrian rocks at Argenta and Bannack to be a result of Middle Cambrian faulting, uplift, and erosion, to explain the local absence of the Flathead Sandstone and Wolsey Shale, and to explain the apparent complete absence of Meagher Limestone and Park Shale beneath the light gray dolomite included in the Pilgrim(?) Dolomite. The presence of thinly-laminated, light gray dolomite in the Meagher Limestone at Dyce Creek and Jackson was not known at the time of Myer's study. These more complete exposures of Cambrian rocks suggest that the light gray dolomites at Argenta and Bannack are more appropriately included in the Meagher Limestone, or in both the Meagher and Pilgrim (as at Jackson), rather than in the Pilgrim(?) Dolomite. Also, the structural setting of this region (fig. 5, no. 8) resembles that of Tobacco Root island, with many northwest-, northeast-, and east-trending faults and fault zones, all probably of Early Proterozoic or older ancestry. I suggest that the local absence of Flathead Sandstone and Wolsey Shale at Argenta and Bannack is a result of depositional thinning and wedging out, rather than of Middle Cambrian faulting and erosion. If so, the Cambrian rocks at Argenta and near Bannack may have been deposited in a thinning wedge against an earlier uplifted island block, like the Middle Cambrian rocks in the Tobacco Root Mountains. And the unusually abundant gold at Bannack and in some mines at Argenta could therefore have come from the thinly laminated, probably algal dolomites in the Meagher Limestone, and have been redistributed in quartz veins in younger rocks by hydrothermal solutions from nearby granitic stocks of Late Cretaceous or early Tertiary age.

SUMMARY AND CONCLUSIONS

The stratigraphic and structural relations of Middle Cambrian rocks in the western Tobacco Root Mountains indicate that these rocks lap against a fault-bounded island block uplifted before Middle Cambrian time. The Flathead Sandstone and Wolsey Shale thin eastward nearly to disappearance against the island flank, and the Meagher Limestone thins by nearly a half, and includes masses of thinly laminated dolomite and accompanying breccias in its upper part that have most of the characteristics of algal reefs.

All of the gold deposits in this part of the Tobacco Root Mountains are in or below the Meagher Limestone, and all of them are in areas where algal reefs occur in the upper part of the Meagher. The close association of Meagher reefs and gold deposits implies that they are related. I suggest that the gold was derived from either the Meagher reefs or from the overlying Park Shale, and deposited in quartz veins and jasperoidal replacement deposits during compaction, dewatering, and diagenesis of the Park Shale in Cambrian time.

In most other areas in southwest Montana where gold has been found, the Meagher Limestone also is present and includes dolomites and breccias that resemble the reef-forming rocks in the Tobacco Root Mountains. The stratigraphic and structural relations of the Middle Cambrian rocks in these areas also suggest onlapping deposition onto the flanks of structurally controlled island blocks, similar to the Tobacco Root island. In some of these areas, substantial placer deposits of gold with no known source have been found, and a most likely source seems to be the disseminated gold in the Meagher Limestone.

The consistent association of gold deposits in quartz veins, jasperoidal replacement deposits, and placers, with reefs or reef-like rocks in the Meagher Limestone, suggests that other deposits like these, or of gold disseminated in the Meagher Limestone, might be found in southwest Montana and in adjacent regions where the Meagher or equivalent Middle Cambrian rocks are present. The relations known now suggest that the most favorable areas for gold deposits are those where Middle Cambrian rocks lap onto the flanks of fault-controlled island blocks, and where the Meagher Limestone includes algal reefs or reef-like bioherms. Also, the search for undiscovered placer deposits of gold might be broadened to include gravels deposited by streams now draining areas where the Meagher Limestone crops out, and to include fossil placers deposited by more ancient streams that drained these areas before the major drainage changes and drainage reversals of late Pliocene and early Pleistocene time.

References Cited

Fryxell, Jenny, 1981, Depositional environments and provenance of arkosic sandstone and conglomerate in the Park Shale, Middle Cambrian, southwestern Montana: Geological Society of America Abstracts with Programs, v. 13, no. 4, p. 197.

Geach, R. D., 1972, Mines and mineral deposits (except fuels), Beaverhead County, Montana: Montana Bureau of Mines and Geology Bulletin 85, 194 p.

Graham, S. A., and Suttner, L. J., 1974, Occurrence of Cambrian islands in southwest Montana: The Mountain Geologist, v. 11, p. 71-84.

Hadley, J. B., 1969a, Geologic map of the Cameron quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-813.

_____1969b, Geologic map of the Varney Quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-814.

_____1980, Geology of the Varney and Cameron quadrangles, Madison County, Montana: U.S. Geological Survey Bulletin 1459, 108 p.

James, H. L., 1981, Bedded Precambrian iron deposits of the Tobacco Root Mountains: U.S. Geological Survey Professional Paper 1187, 16 p.

Johns, W. M., 1961, Geology and ore deposits of the southern Tidal Wave mining district, Madison County, Montana: Montana Bureau of Mines and Geology Bulletin 24, 53 p.

Lowell, W. R., 1965, Geologic map of the Bannack-Grayling area, Beaverhead County, Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-433.

Lyden, C. J., 1948, The gold placers of Montana: Montana Bureau of Mines and Geolgy Memoir 26, 152 p.

Mann, J., 1954, Geology of part of the Gravelly Range, Montana: Yellowstone-Bighorn Research Project Contribution 190, The Yellowstone-Bighorn Research Association, Incorporated.

McClernan, H. G., 1981, The Rochester mining district, Madison County, Montana: in D. C. Lawson, comp., Directory of Montana Mining Enterprises for 1980, Montana Bureau of Mines and Geology Bulletin 115, p. 30-37.

Moore, G. T., 1956, The geology of the Mount Fleecer area, Montana: Ph. D. Thesis, Indiana University, Bloomington, Indiana.

Myers, W. B., 1952, Geology and mineral deposits of the northwest quarter Willis Quadrangle and adjacent Brown's Lake area, Beaverhead County, Montana: U.S. Geological Survey Open-File report.

Noel, J. A., 1956, The geology of the east Anaconada Range and adjacent areas; Montana: Bloomington, Indiana, Indiana University Ph. D. thesis, 74 p.

O'Neill, J. M., Lopez, D. A., and Desmarais, N. R., 1982, Recurrent movement along, and characteristics of, northeast-trending faults in part of east-central Idaho and west-central Montana: Geological Society of America Abstracts with Programs, v. 14, no. 6, p. 345.

Reid, R. R., 1957, Bedrock geology of the north end of the Tobacco Root Mountains, Madison County, Montana: Montana Bureau of Mines and Geology Memoir 36, 26 p.

Reyner, M. L., 1947, Geology of the Tidal Wave district, Madison County, Montana: Butte, Montana, Montana School of Mines Masters Thesis.

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

Ruppel, E. T., 1982, Cenozoic block uplifts in southwest Montana and east-central Idaho: U.S. Geological Survey Professional Paper 1224, 24 p.

Ruppel, E. T., and Lopez, D. A., 1984, The thrust belt in southwest Montana and east-central Idaho: U.S. Geological Survey Professional Paper 1278, 41 p.

Ruppel, E. T., O'Neill, J. M., and Lopez, D. A., 1983, Preliminary geologic map of the Dillon 1^{o} x 2^{o} quadrangle, Montana-Idaho: U.S. Geological Survey Open-file report 83-168.

Sahinen, U. M., 1939, Geology and ore deposits of the Rochester and adjacent mining districts, Madison County, Montana: Montana Bureau of Mines and Geology Memoir 19, 53 p.

______1950, Geology and ore deposits of the Highland Mountains, southwestern Montana: Montana Bureau of Mines and Geology Memoir 32, 125 p.

Samuelson, K. J., and Schmidt, C. J., 1981, Structural geology of the western Tobacco Root Mountains: in Tucker, T., ed., Southwest Montana: Montana Geological Society Field Conference and Symposium Guidebook, p. 191-199.

Schmidt, C. J., and O'Neill, J. M., 1982, Structural evolution of the southwest Montana transverse zone: in Powers, R. W., ed., The overthrust belt from Alaska to Mexico: Rocky Mountain Association of Geologists, p. 193-218.

Schmidt, C. J., and Garihan, J. M., 1983, Laramide tectonic development of the Montana Rocky Mountain foreland of southwestern Montana: in Rocky Mountain Association of Geologists Symposium, Rocky Mountain Foreland Basins and Uplifts, p. 271-294.

Shenon, P. J., 1931, Geology and ore deposits of Bannack and Argenta, Montana: Montana Bureau of Mines and Geology Bulletin 6.

Shinn, E. A., 1973, Carbonate coastal accrretion in an area of longshore transport, NE Qatar, Persian Gulf: in B. H. Purser ed., The Persian Gulf, p. 179-191, Springer-Verlag, New York.

Smith, N. G., Kyle, J. R., and Magara, K., 1983, Geophysical log documentation of fluid migration from compacting shales: a mineralization model from the Devonian strata of the Pine Point area, Canada: Economic Geology, v. 78, p. 1364-1374.

Tansley, W., Schafer, P. A., and Hart, L. H., 1933, A geological reconnaissance of the Tobacco Root Mountains, Madison County, Montana: Montana Bureau of Mines and Geology Memoir 9, 57 p.

Thomas, G. M., 1981, Structural geology of the Badger Pass area, southwest Montana: Missoula, Montana, University of Montana Masters thesis, 58 p.

Tysdal, R. G., 1976, Paleozoic and Mesozoic stratigraphy of the northern part of the Ruby Range, southwestern Montana: U.S. Geological Survey Bulletin 1405-I, 26 p.

Vitaliano, C. J., and Cordua, W. S., 1979, Geologic map of the southern Tobacco Root Mountains, Madison, County, Montana: Geological Society of America Map and Chart Series MC-31.

Wallace, C. A., 1976, Diagenetic replacement of feldspar by quartz in the Uinta Mountain Group, Utah, and its geochemical implications: Journal of Sedimentary Petrology, v. 46, p. 847-861.

Wier, K. L., 1982, Maps showing geology and outcrops of part of the Virginia City and Alder quadrangles, Madison County, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1490.

Winchell, A. N., 1914, Mining districts of the Dillon quadrangle, Montana, and adjacent areas: U.S. Geological Survey Bulletin 574, 191 p.

Witkind, I. J., 1977, Structural pattern of the Centennial Mountains, Montana-Idaho: Laramie, Wyoming, Wyoming Geological Association Guidebook, 29th Annual Field Conference, 1977, p. 531-536.

______1982, Geologic map of the Centennial Mountain Wilderness Study Area and contiguous areas, Idaho and Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1342-A.

Zimbelman, D. R., 1981, Stratigraphy of Precambrian and Cambrian sedimentary rocks, Polaris 1 SE quadrangle, Beaverhead County, Montana: Geological Society of America Abstracts with Programs, v. 13, no. 4, p. 231.