DEPARTMENT OF THE INTERIOR

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PRELIMINARY GEOLOGIC MAPS, CROSS SECTIONS, AND EXPLANATION PAMPHLET FOR THE OPHIR AND MERCUR 7 1/2-MINUTE QUADRANGLES, UTAH

By

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This report and maps are preliminary and have not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION

The adjoining Ophir and Mercur quadrangles comprise the southern end of the Oquirrh Mountains in north-central Utah, and include the Ophir and Mercur mining districts and the neighboring Sunshine (South Mercur) and West Mercur mining areas. The Mercur district, closed since the 1940's, was reactivated in 1981 by the Getty Mining Company for the recovery of disseminated gold. Mining activity continues following purchase of the operation by Barrick Resources (Toronto, Canada) in 1985. Because of this recent activity and continuing U.S. Geological Survey interest in the Oquirrh Mountains, which are one of the important base and precious metal resource areas of the nation, a new more detailed evaluation of the geologic setting for ore districts within these quadrangles is reported here.

This brief report consists of two adjoining quadrangle maps and accompanying cross sections, and a phamphlet containing explanatory descriptions and correlations of the map units. The author gratefully acknowledges the assistance of T. L. Vercoutere and D. B. Vander Meulen in field mapping; Mackenzie Gordon, Jr., M. E. Taylor, W. J. Sando, K. S. Schindler, S. H. Mamay, and the late Helen Duncan for their paleontologic support; and L. D. Kornze and R. G. Blair of the Getty Mining Company in Mercur and Salt Lake City for their encouragement and spirited discussions as well as for permission and assistance in obtaining access to company-owned property. Permission for access to Homestake Mining Company property in the inactive Sunshine mining area and discussions with F. W. Baumann, Touchstone Resources, who was conducting exploration in the Sunshine area, are also gratefully acknowledged.

SUMMARY OF GEOLOGIC CHARACTERISTICS IN THE MAP AREAS

Location and setting.--The Ophir and Mercur 7 1/2-minute quadrangles, Utah, comprise the southern end of the Oquirrh Mountains, about 59 km southwest of Salt Lake City, Utah. The quadrangles include parts of Tooele and Utah Counties, and the well-known Ophir and Mercur (Camp Floyd) mining districts. The Oquirrh Mountains, which extend from the south end of the Great Salt Lake to Fivemile Pass, a distance of 55 km, is the easternmost of the block-faulted mountain ranges that comprise the Cordilleran Great Basin in Utah.

Summary sequence of geologic events

1. Deposition of miogeoclinal sediments an unknown distance to the west along the western edge of the North American craton during Paleozoic and Early Mesozoic time.

2. Movement of sedimentary sequences eastward in a series of thrust plate units during the Sevier Orogeny in late Mesozoic time, juxtaposing dissimilar parts of the basin, and folding and faulting the thrust plates as they ground to a halt in central Utah (Tooker, 1983).

3. Regional extension and faulting during the early Tertiary produced the Basin and Range structures and tilted the Oquirrh Mountains eastward.

4. Local intrusion of igneous bodies into the sedimentary sequences caused uplift and faulting during middle Tertiary time.

5. Local alteration of the wall rocks and deposition of ore minerals preferentially along faults and permeable strata by hydrothermal solutions derived from late stages of intusion activity.

6. Erosion and uplift produced extensive coarse fan deposits along the edge of the range, which were redistributed in part by Lake Bonneville during Plestocene time.

7. Moderate erosion and structural readjustment along range front faults continues in the Holocene.

Structure.--The range is formed from folded Paleozoic sedimentary strata on the upper plate of a (here unexposed) major thrust fault system, the Midas thrust, which is a part of the Sevier orogenic belt (Tooker, 1983). The upper plate of the Midas thrust was deformed into a series of broad low amplitude folds and imbricate thrust faults during the Cretaceous Sevier Orogeny. The coincidence of thrusting and folding here and elsewhere in the foreland of the Sevier thrust belt is inferred from structural relations in the Oquirrh Mountains and surrounding ranges. Distinctive stratigraphic sequences containing rocks of comparable ages, but formed in different parts of a sedimentary basin, are juxtaposed in overlying and underlying imbricate thrust plates (Tooker, 1983; and Morris, 1983). Variations of fold shapes and trends in individual thrust plates suggest that each responded to unique directional forces as they impacted on an irregular highland and adjoining lowland surfaces in central Utah. Tertiary intrusive rocks intrude the Midas thrust nappe in the vicinity of the mining district.

Two generally parallel folds, the Ophir anticline and Pole Canyon syncline, form the core of the Oquirrh Mountains in the quadrangles (cross section BB'). Rocks of the Oquirrh Group are exposed on the eastern topographically higher side of the range in the broad, slightly asymmetric eastward Pole Canyon syncline. As seen on the eastern side of Manning Canyon, the flanks of this fold are offset small amounts locally by a number of steep normal cross faults, but for the most part the syncline is through-going and trends nearly straight south-southeast. It plunges under unconsolidated sediments in the valley at the south end of the range. I believe that it is terminated by the Fivemile Pass tear fault (fig. 1), immediately south of the map area in Fivemile Pass, and is offset about 10 km to the northeast in a left-lateral sense.

The Ophir anticline forms a topographically lower and structurally more complex western part of the Oquirrh Range in the Mercur quadrangle (section B-B'). The trend of the fold, which is on the upper plate of the Manning

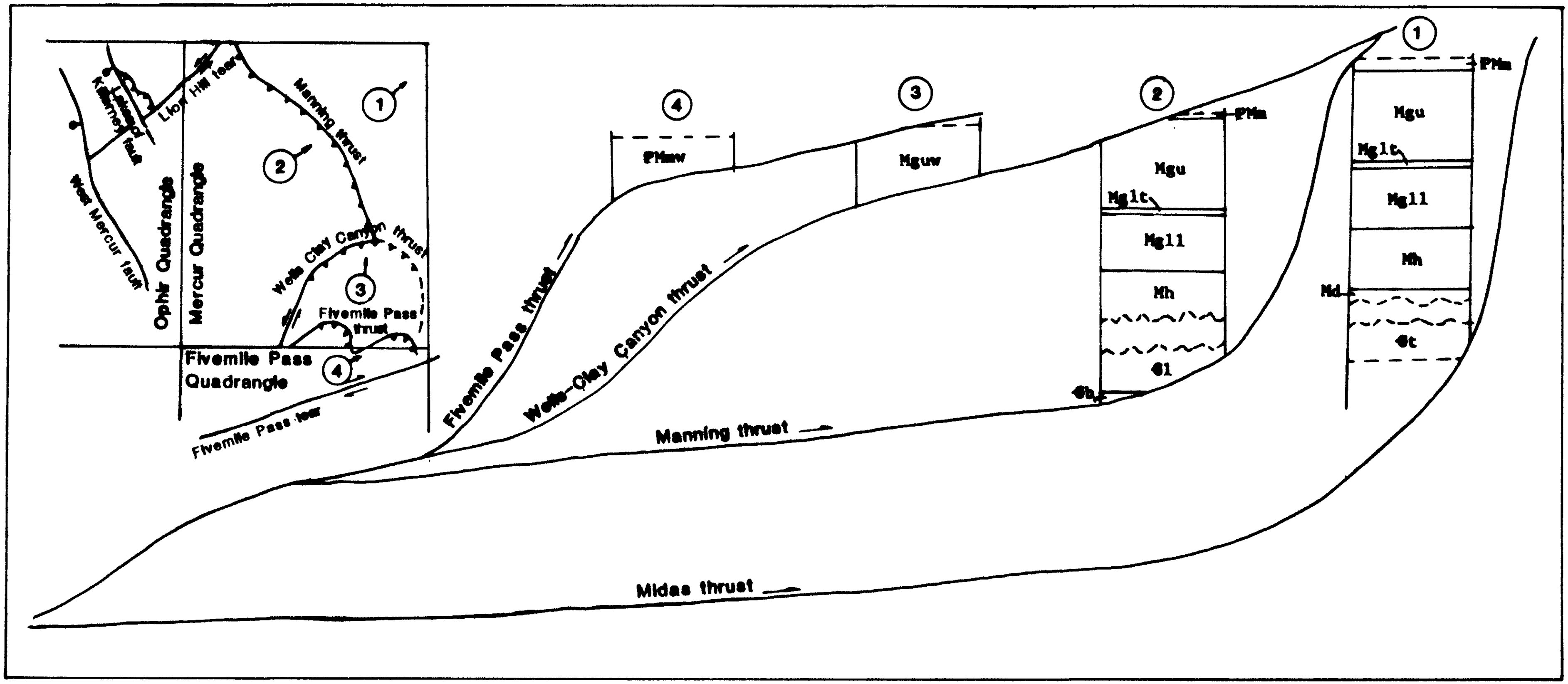


Figure 1.--Diagrammatic sketch plan and cross section showing the location, correlation, stratigraphic sequences, and imbrication of thrust faults on the upper plate of the Midas thrust fault in the Mercur and Ophir quadrangles, Utah: 1. Midas plate, Bingham sequence (Tooker and Roberts, 1970); 2. Manning plate, Bingham sequence; 3. Wells-Clay Canyon plate, transitional (Mguw) sequence; and 4. Fivemile Pass plate, transitional (PMmw) sequence. Arrow on circled plate number indicates inferred direction of plate movement.

thrust, an imbrication in the upper plate of the Midas thrust, is sinuous, generally south-southeast, as it plunges gently southward. The apparent direction of movement of the Manning-Midas thrusts here, based on the pattern of folding, was toward the east-northeast. Asymmetrical flanks of this broad fold contain minor folds and flexures; the asymmetry is caused in part by the northwest-trending Manning thrust fault, and perhaps is augmented by the intrusion of the inferred plutonic sources of the two main sill-dike intrusives in the range (section C-C'). North of Ophir Canyon and the Lion Hill tear fault termination of the Manning thrust, the Ophir anticline is a more symmetrical, narrow, high-amplitude fold. The range also becomes topographically higher, and normal cross faulting is less prominent.

The Manning thrust is exposed along the strike of Manning and Ophir (South Fork) Canyons. On the basis of stratigraphic and structural information north of Ophir Canyon, the thrust appears to be an imbrication in the Midas plate, and, I believe, has a probable displacement of a few thousand feet. Locally, east of Mercur, the Great Blue Limestone was observed to be thrust a few hundred feet eastward over the Manning Canyon Shale (Kornze, verbal common., 1983), probably along a branch of the Manning thrust. Elsewhere the thrust cuts out parts of the upper member of Great Blue Limestone and Manning Canyon Shale. While the dip of the thrust fault is steep to overturned, locally, in the pass between Manning and Ophir Canyons, the angle of dip flattens westward with depth. The Manning thrust ends in Ophir Canyon, at the mouth of the South Fork, against the Lion Hill tear fault, and presumably is terminated at its south end by the Fivemile Pass tear fault. However, just south of Manning (Site) the Manning thrust is overlain by the Wells-Clay Canyon thrust fault block (figure 1). Intraformational thrust fault branches that occur on the western side of the Ophir anticline along the range front (sections A-A' and B-B') are generally of small displacement and low angle of dip to bedding, and occur both in the lower and upper members of the Great Blue Limestone.

The Wells-Clay Canyon and Fivemile Pass thrusts at the south end of the range, moved generally northeastward, and are themselves imbricated. The former juxtaposes an age-equivalent but dissimilar sedimentational facies of the upper member of the Great Blue Limestone of the Manning thrust block. The pattern of west-northwest directed, small amplitude folds in these thrust plates contrasts sharply with fold structures of the Manning upper plate.

Rocks of the Ophir fold are cut by three main sets of normal faults, which locally have produce a crackled aspect. The northeast and northwest sets seem to be oldest and may have been formed or been initiated during the Sevier Orogeny folding and uplift, particularly by the Manning thrust fault. The north-northwest set, which nearly parallels the fold, seems to be younger, and perhaps includes later movement that is the result of the basin-and-range extensional episode, during which the range was tilted about 15^{o} to the east (Gilluly, 1932). In the vicinity of Mercur, these faults appear to be reactivated and are more closely spaced, possibly due to local dilation as a result of the introduction of the intrusive sills, plugs, and dikes. Several small collapse structures in the ore zone locally strike nearly normal to the Ophir anticline and seem to be associated spatially with breccia pipes, one of which is mineralized (Faddies and Kornze, written communication, 1984). The largest of these structures is the "Lulu syncline" of earlier studies (Kornze written communication, 1985). I believe that such structures were caused by a phreatic explosion and collapse resulting from the boiling of the epithermal precursor to ore-forming solutions, which I infer was a late stage in the sequence of the intrusion of the Eagle Hill rhyolite porphyry sill.

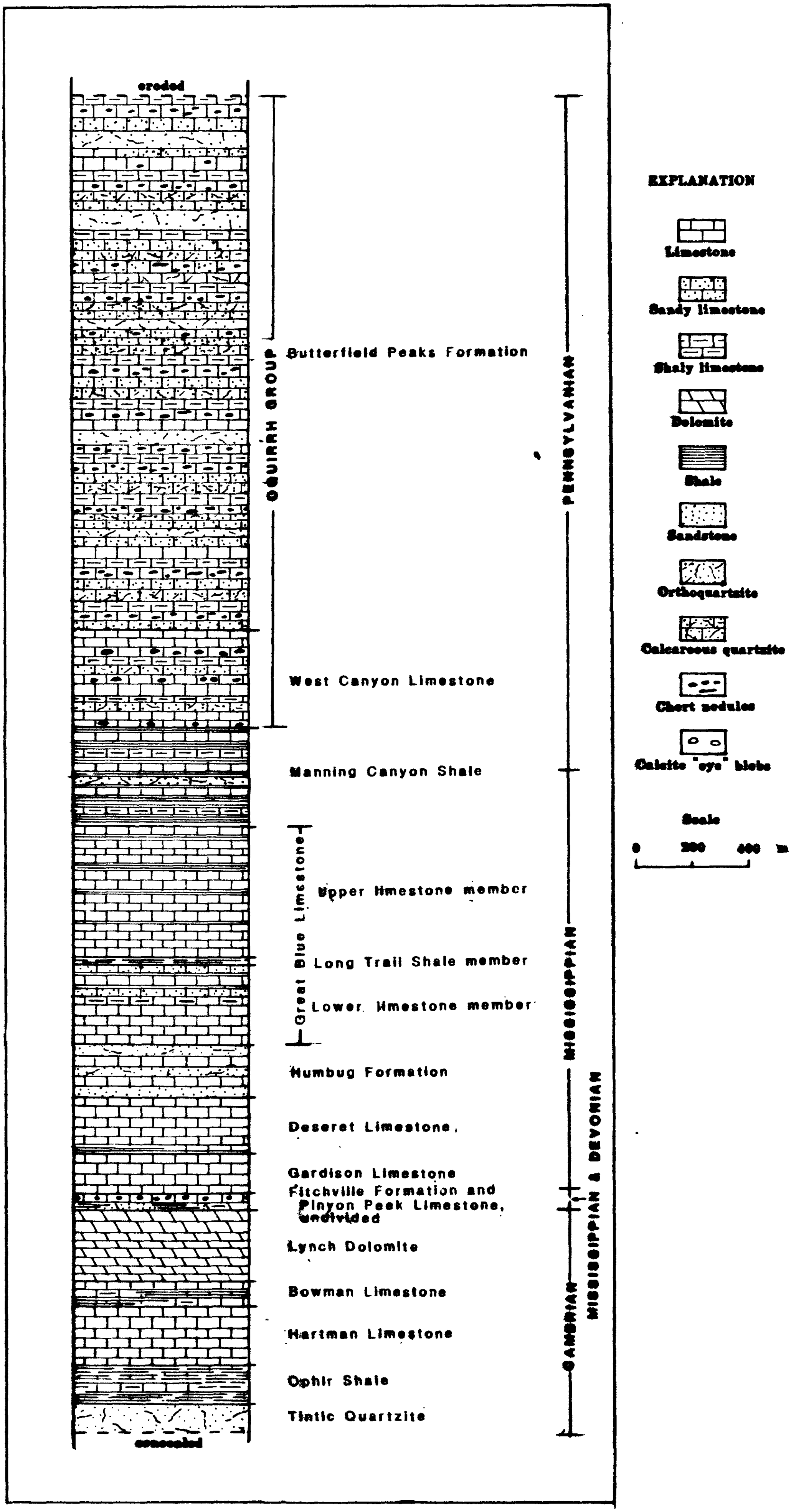
Lithology.--Partial stratigraphic sequences of clastic and carbonaceous sedimentary rocks are juxtaposed by thrust faults in these quadrangles, and intruded by porphyritic igneous rocks. The main sedimentary sequence in the range is 4,650 m thick in these quadrangles, and ranges in age from the Cambrian Tintic Quartzite to the middle of the Pennsylvanian part of the Oquirrh Group. These rock units, some of which were named by Gilluly (1932) for exposures in the range, are shown diagramatically in Figure 2. A thrust faulted sequence at the south end of the range juxtaposed parts of the Manning Canyon Shale and the upper member of the Great Blue Limestone belonging to the upper plate of the Wells-Clay Canyon thrust with comparably aged formations on the lower plate. The stratigraphic section of the thrust plate, however, is of a different sedimentational facies containing more abundant thicker shale units than those found in the type Oquirrh Mountains section. Possibly this thrust, which is believed to an imbrication in the Midas plate, has moved a sedimentary sequence containing sediments, which are believed to be transitional with those of the (uppermost) Chulios and Poker Knoll Members of the Great Blue Formation at Tintic, an unknown distance northward. The thickness of these fragmental sections is unknown. The Fivemile Pass thrust, an imbrication in the upper plate of the Wells-Clay Canyon thrust, brings a transitional facies of the Manning Canyon Shale unconformably over the upper member of the Great Blue Limestone. Brief summary descriptions are provided in the following sections describing and correlating the map units. The valleys and flanks of the Oquirrh Mountains contain unconsolidated sediments, landslide blocks, and debris of Quaternary and Tertiary ages.

Three types of porphyritic igneous plugs, sills, and dike rocks of Tertiary age intrude the sedimentary sequence and occupy areally distinct parts of the range. The main plug-like bodies of granodiorite porphyry occur in the vicinity of Porphyry Hill and Porphyry Knob, on the east side of the Ophir anticline, midway between Mercur and Ophir. A group of thinner sill-dike bodies of granodiorite porphyry trail irregularly northward to the head of Long Trail Gulch. The main bodies of the Eagle Hill rhyolite sill occur astride the Ophir anticline immediately south of the Mercur mining district. Smaller dike-sill bodies trail to the south in Sunshine Canyon and west, crossing Mercur Canyon at the range front. Thence they crop out irregularly to the south and as far north as the Ophir mining district. A lamprophyre dike crops out in the Ophir district on Lion Hill and in Hartmann Gulch. Locally, especially in the Ophir mining district, sedimentary rocks have been metamorphosed to a low grade adjacent to intrusive rocks and locally have produced biolite schists.

Ore deposits.--Some of these intrusives may have provided a source of heat and hydrothermal solutions for the formation of ore deposits. Gilluly (1932) described three main ore types of metal deposits in the Ophir and Mercur districts: gold and gold-mercury; silver and silver-lead; and lead-silver-zinc-copper. Clay materials and the mineral variscite were also mined. The metallic minerals occur as bedded and irregular replacements, as vein, disseminated, and fissure deposits. Oxidized ores near the surface became hypogene sulfide ores in the deeper mines. About 1.1 million oz (34.2 million g.) of gold and minor mercury and silver were produced in the Mercur district during its early period of activity (1871-1945), and disseminated gold and minor silver currently are being produced at Mercur (Kornze and others, 1984).

Early production data (1870-1901) for base and precious metals at Ophir were combined with those from the Rush Valley district. Proctor (1959) and Stowe (1975) estimated that the Ophir district produced 2 million tons of

Figure 2.--Generalized stratigraphic section of the consolidated sedimentary rocks of the Bingham sequences (Tooker and Roberts, 1970) exposed in the Ophir and Mercur quadrangles.


eroded
OQUIRRH GROUP
Butterfield Peaks Formation
West Canyon Limestone
Manning Canyon Shale
Great Blue Limestone
Upper limestone member
Long Trail Shale member
Lower limestone member
Humbug Formation
Deseret Limestone
Gardison Limestone
Fitchville Formation and Pinyon Peak Limestone, undivided
Lynch Dolomite
Bowman Limestone
Hartman Limestone
Ophir Shale
Tintic Quartzite
concealed
PENNSYLVANIAN
MISSISSIPPIAN
MISSISSIPPIAN & DEVONIAN
CAMBRIAN
EXPLANATION
Limestone
Sandy limestone
Shaly limestone
Dolomite
Shale
Sandstone
Orthoquartzite
Calcareous quartzite
Chert nodules
Calcite "eye" blebs
Scale
0 200 400 m

lead, silver, copper, zinc, and gold valued at more than $35 million during that period. Production at Ophir between 1960 and 1972 (Stowe, 1975) gives a better estimate of the relative proportions of metals in deeper ores, which included 1.8 million kilograms of copper, 22.7 million kilograms of lead, 15.4 million kilograms of zinc, 1,400 oz (43,500 g) of gold, and 2 million oz (62.2 million g) of silver. Tungsten (scheelite) also occurs sporadically with base metal sulfides at depth in Ophir mines (Richard Rubright, verbal commun. 1987). It was not readily separated, and no tungsten ore concentrates were produced. The district currently is inactive.

A limited production of clay materials was derived from shale beds in the upper member of the Great Blue Formation (Mguw) in the upper plate of the Wells-Clay Canyon thrust during the years 1949-1954 (Hyatt, 1956, p. 70). The main mines and pits, now closed, are located in Clay, Manning, and Wells Canyons, and nearby at Fivemile Pass (south of the mapped area). The clay apparently was used for bricks and structural clay products. Hyatt (1956, table 2, p. 34-35) provides the results of some laboratory tests of these clay materials. The gem mineral variscite ($Al(PO_4) \cdot 2H_2$) was discovered in the southern Oquirrh Mountains in 1984 near Fairfield, Utah. The mineral occurs as concretionary nodules in an iron-stained breccia zone in medium bedded, blocky black Great Blue Limestone (Mguw). Production at the Utalite Mine in Clay Canyon reached a peak in the year 1901 and 1911, and continued sporadically uptil 1942 (Sinkankas, 1959, p. 232).

DESCRIPTION OF MAP UNITS IN THE MERCUR AND OPHIR 7 1/2-MIN. QUADRANGLES, UTAH

Ql **Landslide Debris (Holocene)**--Generally irregular unconformable slide blocks composed of consolidated rocks overlying shaly beds in structurally oversteepened deeply eroded and, in some cases, thrust-faulted terranes. Most commonly, the slide blocks are derived from the lower part of the Oquirrh Group that overlies Manning Canyon Shale (ℙMm). Chaotic landslide blocks in the upper reaches of Meadow Canyon contain rocks of the Oquirrh Group that have slid over eroded Manning Canyon Shale. The landslide blocks may maintain some internal structural continuity but their rotation results in discontinuities with the regional structure. Slippage of the upper member of the Great Blue Limestone (Mgu) along shales of the Long Trail Shale Member, owing to erosion in Mercur Canyon, occurs on the north slopes of Eagle Hill, south of Mercur. Here the landslide blocks have been broken during the movement

Qac **Alluvium and Colluvium (Holocene)**--Undifferentiated, unconsolidated alluvial fan and stream gravel, sand, silt, and talus gravel and boulder deposits within and bordering the mountain range and its flanking pediments. Thickness of fan deposits is variable and is estimated to range from less than 0.3 m at distal edges to more than 10 m locally in the upper parts of fans. Stream-fill deposits are estimated to be less than 1.5 m thick except, possibly, in the large canyons such as Ophir Canyon. Talus deposits generally are irregular in shape and of variable thickness; they consist mainly of subrounded to angular quartzite and calcareous quartzite clasts derived mainly from the Humbug (Mh) and Butterfield Peaks (Pobp) Formations

Qlb **Lake Bonneville Deposits (Pleistocene)**--Undifferentiated and unconsolidated thin layers of silt, sand, and gravel in shoreline and pluvial lake bottom deposits (Eardley and others, 1957). Prominent sand and gravel bar or spit deposits, shown by a stipple pattern, commonly are sites of borrow pits. Only the uppermost of the major still-stands of the lake, as exemplified by extensive lakeshore sand and gravel bar deposits or wave-cut cliffs, occurs at about 1,585 m elevation (Bonneville level); other prominent lower lake levels, not shown, occur at about the 1,463 m elevation (Provo level) and about the 1,341 m elevation (Stansbury level). Locally, and more commonly at the Provo level, the deposits are cemented by calcareous tufa. The maximum thickness of the Lake Bonneville deposits is unknown because they cannot be differentiated from the Harkers Alluvium (Qh) in drilled well records, but the Lake Bonneville unit may be a few tens of meters thick locally against normal faults in the pediment where cut by Ophir Creek. The deposits thin to a few meters outward from the range. Local bar and spit deposits represent anomalous accumulations 15 to 30 m thick where observed in gravel pits.

The extensive, thick, poorly sorted, coarse to fine, unconsolidated Harkers Alluvium, and materials from wave-cut banks, as well as materials issuing from major streams by normal range erosion were rounded as they were moved by active lakeshore currents. Finer grained, better sorted sediments lie offshore or in local deltal deposits.

The Lake Bonneville deposits unconformably overlie the Harkers Alluvium, older alluvium (Qa), and the Jordan Narrows unit of Slentz (1955) (Qj), and are overlain unconformably by Holocene alluvial and colluvial deposits (Qac)

Qa **Alluvium (Pleistocene)**--Pre-Lake Bonneville, post-Harkers Alluvium deposits consisting of poorly sorted gravel, sand, and silt form an extensive series of coalescing fans issuing from Ophir, Mercur, Manning, and several smaller canyons in the southern Oquirrh Mountains. Thickness is unknown, but the fans are tens of meters thick at the range front, thinning toward the distal margins of the fans, where they are overlapped or notched by the Lake Bonneville shoreline deposits or lie unconformably on the Harkers Alluvium

Qh **Harkers Alluvium (Pleistocene)**--Undifferentiated, partly dissected, unconsolidated, thick coarse fanglomerate deposits at the mouth of Ophir Canyon, on the west side of the Oquirrh Mountains, project basinward as fill deposits of unknown thickness. These deposits are notched by the Lake Bonneville (Bonneville level) shoreline and locally are overlain by Pleistocene pre-Lake Bonneville alluviual fan deposits. The poorly sorted, angular to rounded boulders, coarse to fine gravel, sand, silt, and mud are assigned to the Harkers Alluvium (Tooker and Roberts, 1971). Unit thickness varies from place to place, and its maximum is unknown, but generally thins away from the mountains. At least 31 m are exposed in the pediment downslope from the mouth of Ophir Canyon. The unit unconformably overlies sedimentary rocks of Paleozoic (Mississippian) age on the south side of Ophir Canyon, near the range front. The source materials, which are mostly quartzite, calcareous quartzite, and silicified limestone (jasperoid), were derived from outcrops in the Oquirrh Mountains. The age of the unit is considered as Pleistocene (probably early Pleistocene), no fossils have been found

Qj **Jordon Narrows Unit of Slentz (1955) (Oligocene)**--Scattered small pediment surface exposures of fine-grained, white fresh water limestones, unconformably overlain by Lake Bonneville deposits, in the southwest 1/4 of Ophir quadrangle. The surface ledges define a ridge that deflected the Bonneville level shoreline. Age relations with the Harkers Alluvium cannot be determined here, but Slentz (1955) shows that the alluvium unit is younger than the Jordan Narrows unit in the type locality. In concurrence with Eardley (1955), the Jordan Narrows Unit most likely is Oligocene. No fossils were found here or in the type locality in the Salt Lake Valley

Tbp **Intrusive Breccia Pipes (Oligocene?)**--Several moderate to small size breccia pipes in the vicinity of the Mercur mining district and South Mercur (Sunshine) mining site. They are fault-controlled, vary in size from 3 m to 61 m and in form are cylindical to oval shaped nearly vertical columns. Their depth is unknown, but believed to be relatively shallow. They are composed mainly of altered angular to subrounded altered (desilicated) carbonate and chert rock fragments, generally less than 16 cm in maximum dimension. Altered igneous rock fragments have been identified in one of the pipes at Mercur. The larger pipes at Mercur are associated with adjacent fault-controlled collapse zones that are believed to have been initiated in the lower member of the Great Blue Limestone (Mgll), following local dissolution, by a phreatic explosion during the late stages of the intrusion of rhyolite porphyry caused by critically heated ground water in water-filled (karst-like) cavities. Recently William J. Tafairi (written commun. to W.C. Bagby, 1986) reported finding altered intrusive rock, which may represent a more porphyritic phase of the Eagle Hill Rhyolite (Teh) than that exposed on the surface, in the breccia pipe located near the intersection of Meadow and Mercur Canyons. Several small pipes northwest of the Sunshine (site) contain angular fragments of altered limestone and rhyolite porphyry(?). The largest pipes 61 x 183 m, in Clay Canyon, northeast of Sunshine, has been extensively altered, in part, to clay minerals. The altered fragmental portions are composed of angular altered carbonate, shale, and sandstone rocks, generally less than a few millimeters in diameter

Teh **Eagle Hill Rhyolite (Oligocene)**--Porphyry dikes, sills, and breccias composed mainly of quartz and sanidine with subordinate amounts of oligoclase and biotite. The quartz commonly is in rounded grains ranging from less than 1 mm to 5 mm or more in diameter. Untwinned feldspar grains are generally less than 1 mm. Biotite flakes as much as a centimenter long are rare, and many hand specimens contain no biotite. Flow structures and columnar jointing in sills occur locally; in the Ophir district rhyolite breccia containing limestone fragments occurs in small 8-10 cm fragments (Gilluly, 1932). Age of this unit is based on K/Ar age of 31.6±0.9 m.y. (Moore, 1973)

Tlp **Lamprophyre (Oligocene?)**--A poorly exposed altered dike about 1.2 m thick and vertical, strikes north-northwest on the northwest flank of Lion Hill. Unweathered specimens from dumps of mine workings that cut the dike show vesicular structures that suggest emplacement near the surface. The dike cannot be traced north or south because of its undetermined offset along faults. Gilluly (1932) reported three other occurrences north of Ophir (in the Stockton and Lowe Peak 7 1/2-minute quadrangles); locally underground, the dike becomes sill-like. The rock is dark-gray to greenish-gray, weathers spheroidally to greenish or greenish-brown, and is very fine grained. Biotite is the only mineral recognized in hand specimen. In thin section, biotite, olivine, mostly altered to serpentine, and augite, altered to hornblende and clay minerals, predominate; laboradorite, apatite, magnetite, and calcite were also reported by Gilluly. He infers from structural relations that the unit is probably older than Eagle Hill Rhyolite. The location of these altered dikes in the upper reaches the hydrothermal system at Ophir, possibly near the surface, and at the same general level and areas as the epithermal precious metal deposits on Lion Hill also is permissive for considering a pre-rhyolite age, based on the assumption that the rhyolite system is the source of alteration and metallization

Tgp **Granodiorite Porphyry (Oligocene)**--Intrusive sills, dikes, and plugs called "bird's-eye" porphyry by Spurr (1895) and monzonite porphyry by Gilluly (1932) are generally weathered and poorly exposed; they are best seen on Porphyry Knob and Porphyry Hill. The rock is medium-gray with phenocrysts of plagioclase feldspar (1-6 mm), biotite (about 3 mm long), hornblende (generally less than 2 mm long), and quartz (rounded grains 2 to 3 mm diameter) in a greenish-gray fine grained groundmass. Locally the rock has been hydrothermally altered to clay minerals (Gilluly, 1932). Age is based on K/Ar age of 36.7±0.5 m.y. (Moore and McKee, 1983)

Oquirrh Group (Pennsylvanian)--Originally named the Oquirrh Formation but not subdivided into members by Gilluly (1932), these rocks on the upper plate of the Midas thrust fault were raised to the Oquirrh Group by Welsh and James (1961) and its three formations described by Tooker and Roberts (1970); only the lower two formations of Pennsylvanian age occur here. The type localities of the formations are in the northern Oquirrh Mountains, near the Bingham mining district. The Midas thrust is not exposed in the Ophir and Mercur quadrangles

ℙobp **Butterfield Peaks Formation (Middle Pennsylvanian)**--Cyclically interlayered, thin- to medium-bedded, locally cross-bedded calcareous quartzite; tan to grayish-brown orthoquartzite and calcareous sandstone; medium-gray limestone and fossiliferous limestone; and olive-gray, brownish-gray, and dark-gray arenaceous, cherty, and argillaceous limestones. Limestones predominate over quartzites (Tooker and Roberts, 1970). Only the lower part (approximate 1,890 m) of an approximate total of 2,740 m of the formation is exposed in the broad symmetrical Pole Canyon syncline. The formation conformably overlies the West Canyon Limestone. Limestone beds contain an abundant brachiopod, bryozoan, coral, and fusulind fauna. Unit age is Desmoinesian (Middle Pennsylvanian), although the lower four hundred feet may be Atokan (Middle Pennsylvanian) (Gordon and Duncan, 1970).

IPowc **West Canyon Limestone (Lower Pennsylvanian)**--A cyclic, primarily clastic, thin, medium-bedded sequence of arenaceous, bioclastic, cherty, dense crystalline, and argillaceous limestones and thin calcareous quartzite in upper parts (Tooker and Roberts, 1970). About 340 m are exposed on the flanks of the Pole Canyon syncline in Manning, Ophir, and Cedar Valleys. Contacts with the underlying Manning Canyon Shale are poorly exposed, but believed conformable. Fossils, which are locally abundant but often fragmented, include abundant brachiopods, fairly common bryozoans, and rare corals, mollusks, pelecypods, and trilobites. The fusulind Millerella, reported in the upper part, suggests a Morrowan age (Gordon and Duncan, 1970)

Manning Canyon Shale (Lower Pennsylvanian and Upper Mississippian)--Gilluly (1932) gave no type locality for the Manning Canyon Shale because of poor exposures in the southern Oquirrh Mountains; he noted that the most complete stratigraphic section is exposed in Soldier Canyon (in SE 1/4, NE 1/4, sec. 33, T. 4 S., R. 4 W., in the Stockton 15-minute quadrangle, Utah). This is designated as the principal reference locality for the formation. Gilluly reported that the unit at this locality consists of 350 m of interbedded calcareous shale and fossiliferous argillaceous and thin-bedded limestone, and a prominent 1.2 m ledge-forming brown-weathering quartzite capping the lower one third. The upper contact of the unit with the West Canyon Limestone is conformable. The Mississippian-Pennsylvanian boundary occurs in the upper one-third of the unit within a transitional interval in which argillaceous and arenaceous limestones increasingly predominate over shale beds. The lower concealed contact with the Great Blue Limestone is also believed to be conformable in a transition from predominant limestone into shale beds. Thrust faults at the south end of the Oquirrh Mountain have juxtaposed two age correlative but differing facies of the formation. Thus, in the area of this report, the Manning Canyon Shale is divided into:

IPMm **Rocks comparable with those in the principal reference locality in Manning and Ophir Canyons and along the Oquirrh Mountains and Rush Valley border**--Exposed in generally narrow north-trending bands, this unit is about 400 m thick in Manning and Ophir Canyons along the flanks of the Ophir anticline and Pole Canyon syncline. The rocks have been structurally deformed, locally, and unit thickness and contacts are poorly exposed in these valleys because of overthrusting or landsliding by rocks of the Great Blue Limestone and Oquirrh Group. A complete section is not exposed in Rush Valley on the west side of the Ophir anticline owing to faults and erosion. The stratigraphic section in these areas is gradational from limestones and lesser shales of the underlying Great Blue Limestone into predominantly dark-gray carbonaceous shale and thin-bedded gray limestone. The brown-weathered quartzite, locally of variable thickness, is overlain by interbedded black shale and thin-bedded fossiliferous and argillaceous limestones. Contact with the overlying Oquirrh Group above is conformable and is transitional into clastic limestones typical of the West Canyon Limestone. The Mississippian-Pennsylvanian boundary occurs in the upper part of the formation, which, in this as well as in the reference locality areas is abundantly fossiliferous, consisting of bryozoans (including Archimedes) brachiopods (including Productid and Spirifer) and corals (including Amplexizaphrentis) (Gordon and Duncan, 1970)

IPMmw **Rocks of a different facies in a structural block southwest of Wells Canyon**--Exposed in an allochthonous thrust block capping the low ridge separating Wells Canyon from Fivemile Pass (immediately south of the quadrangle boundary), a part of the Manning Canyon Shale, about 46 m thick, is possibly correlative in age with the brown-weathering quartzite interval of the reference locality. The unit consists of a distinctively folded lithologic facies that differs from that of the reference locality. Exposures are composed of interbedded thin-bedded dark-gray-weathering argillaceous and fossiliferous limestones and dark-gray carbonaceous shale underlying a thick calcareous brown-weathering sandstone and quartzite that contains abundant fossil plant debris and a brachiopod and gastropod fauna (Gordon, verbal commun., 1984). The sequence is in thrust contact with the underlying upper member of the Great Blue Limestone (Mguw) (fig. 2)

Great Blue Limestone (Upper Mississippian)--Neither Spurr (1895), who named the formation for rocks in the Oquirrh Mountains, nor Gilluly (1932), who subdivided the unit into members there, indicated a type locality for the Great Blue Limestone. Of the three-member subdivision, Gilluly specified a type locality only for the middle, the Long Trail Shale Member at the head of Long Trail Gulch (center sec. 25, T. 5 S., R. 4 W., Mercur 7 1/2-minute quadrangle, Utah). Morris and Lovering (1961) redefined the unit in the East Tintic Mountains as the Great Blue Formation, consisting of four members. There a predominant shale and shale-rich carbonate sedimentary facies comprise the upper two members; these contrast sharply with strata of comparable age in the upper member in the Oquirrh Mountains. There is a close resemblance between the lower two members at Tintic and those in the Oquirrh Mountains. Because of these differences in the upper member, Tooker and Gordon (1978) subsequently designated the Silveropolis Hill-Long Trail Gulch area as the type section for the unit and retained the original name of the formation, Great Blue Limestone.

Upper limestone member--Exposed along the flanks of the north-trending Ophir anticline, the member is 470 m thick in the type locality, and is in conformable contact with the overlying Manning Canyon Shale and the underlying Long Trail Shale Member of the Great Blue Limestone. Owing to thrust faulting at the south end of the Oquirrh Mountains, a transitional but incomplete (Oquirrh-Tintic(?) type) sedimentary facies comprising age correlative strata from the upper member of the Great Blue Limestone are juxtaposed against upper member strata typical of the type section (fig. 2). Thus, in the area of the report the member is divided into:

Mgu **Rocks of the upper member of the Great Blue Limestone of the type locality**--Consists of an upper part composed of alternating dark-gray fossiliferous, sandy, and cherty limestone intervals and intervening shale and shaly limestone. The lower part of the member is composed predominantly of light-brownish gray and tan, thin bedded, banded, silty, and argillaceous limestone. This lithology grades upward into interbedded medium- to dark-gray silty and argillaceous limestone, calcareous shale, and sandy limestone. Fossils are sparse. The Great Blue Limestone is Late Mississippian; upper member is Chesterian in age. The Caninia coral zone was recorded from 122 m to 294 m above the base of the lower member. The only coral between the two zones is Amplexizaphrentis. Spirifer brazerianus Girty appears in the Long Trail Shale Member and continues upward to at least at the top of the Caninia zone, Tooker and Gordon, (1978).

Mguw **Rocks of the upper member in the structural block at the south end of the Oquirrh Mountains**--Consist of an allochthonous but lithologically incomplete and structurally distinct facies from that of the type section above, which is situated 10 km to the north-northwest. This exotic block is found principally in the areas drained by Wells and Clay Canyons, and southward to the edge of the quadrangle and Fivemile Pass. The difference between the neighboring stratigraphic sequences of upper member rocks was noted earlier by Bissell (1959, p. 57). Sedimentary beds in the allochthon are similar to those of comparable age in the upper limestone member in the type section, but differ in the relative proportions of shale to banded silty limestone and interbedded arenaceous, argillaceous, and fossiliferous limestone. The top and bottom beds are not present; the section present probably is from the lower middle part above the Caninia zone. Here thick black shale beds with thin interbedded chert and quartzite bands have displaced limestones, which suggests formation in a part of the sedimentary basin of the Midas thrust plate intermediate to that of the type section near Ophir, and to that of the type section of the Chiulos Shale member of the Great Blue Formation in the East Tintic Mountains (Morris and Lovering, 1961). Wells Canyon is eroded along one or more thick black shale units that locally have been altered, and are sources for several extensively quarried clay deposits along strike (Hyatt, 1956).

The shale rich horizon is overlain by massive medium bedded dark gray to black limestones, which, where brecciated locally in Clay Canyon, contains the nodular variscite deposits (Sinkankas, 1976). This part of the section may be correlative with the Poker Knoll Member of the Great Blue Formation at Tintic. The few fossils do not define a precise age for the sequence. The structural block containing these deposits is divided into two parts. The northern part contains broad anticlines and synclines trending west-northwest, in contrast to the plunging southerly trend of the Ophir anticline in the adjoining structural block to the west. The southernmost part of the block is more tightly folded, the folds nearly trending east-west, and may represents an upper imbricate thrust of the same unit subsequently down-dropped to the south by normal faulting. At the southern border of the Mercur quadrangle, brown-weathering fossiliferous sandstone and shale of the Manning Canyon Shale, probably of the same or closely related lithologic facies, has been thrust over the upper member.

Mglt **Long Trail Shale Member**--The member, about 33 m thick, is faulted and intruded by sills of monzonite porphyry in its type locality, and thinned locally along strike by reverse or thrust faults, particularly along the west side of the Ophir anticline. The unit forms a generally linear low topographic area on the east and west flanks of the Ophir anticline. On the east side it extends from Ophir Canyon to Sunshine Canyon, bending around the anticlinal axis at its southern end; on the west side it trends from Silverado Canyon, where it is cut out by the Lakes of Killarney fault, south to where it is overlapped by the alluvial fan at the mouth of Mitchell Canyon. The Long Trail Shale is conformable with the underlying lower limestone member of the Great Blue Limestone, although outcrops everywhere are generally poorly exposed (Gilluly, 1932). The member consists predominantly of interbedded dark-gray to black, calcareous and carbonaceous shales with interbedded, thin-bedded gray, fossiliferous and argillaceous limestones, and brownish-gray silty limestone. The base of the Long Trail Shale member represents a transition from brown-weathering sandy silty siliceous and fossiliferous limestones to carbonaceous shales and fossiliferous argillaceous limestones. The unit contains a locally abundant coral brachiopod, pelecypod, crinoid, and bryozoan fauna of Mississippian (Chester) age (Tooker and Gordon, 1978).

Mgll **Lower limestone member**--The member is 260 m thick and conformable with the underlying Humbug Formation. Outcrops of the unit delineate the northwest trend of the Ophir anticline, in whose core the Humbug and Deseret Formations are exposed. The upper part of the unit is interbedded dark-gray thin- to medium-bedded sandy, cherty, argillaceous, and locally fossiliferous limestones, which are correlated with the Paymaster Member of the Great Blue Formation at Tintic (Morris and Lovering, 1961); the member grades conformably into the Long Trail Shale Member. The mineralized horizon mined for disseminated gold in the Mercur mining district by the Getty Mining Company, and locally called the Mercur mine series by them, includes the upper 73 m of the lower member (Kornze and others, 1984). The Mercur mine series includes a jasperoid bed at the base overlain by calcareous sandstone, fossiliferous limestone, and argillaceous limestone, becomming more argillaceous near the top, as it grades into Long Trail Shale. The basal unit of the lower limestone member characteristically is composed of massive cliff-forming, medium- to thick-bedded, blue-gray limestone and interbedded argillaceous limestone and calcareous sandstones, a unit that is correlated with the Topliff Member of the Great Blue Formation at Tintic, Utah (Morris and Lovering, 1961). Locally the member is fossiliferous (brachiopods, bryozoans, corals) (Tooker and Gordon, 1978). The upper part of the Faberophyllum coral zone, of latest Meramecian age, occupies the lower 46 m of the member. The base of the unit is placed at the uppermost thick brown-weathering sandstone or quartzite bed characteristic of the Humbug Formation

Mh **Humbug Formation (Upper Mississippian)**--The formation is about 198 m thick, is conformable with the underlying Deseret Formation, and is well exposed locally in the core of the Ophir anticline. Its ledge-and-slope topography is characterized by alternating brown-weathering quartz sandstones or quartzite and medium-gray limestones. Fossils include brachiopods, corals, and bryozoans. A basal contact is at the base of the lowest sandstone above the massive blue-gray, fine-grained limestones of the Deseret Limestone

Md **Deseret Limestone (Upper Mississippian)**--The formation is about 200 m thick, is comformable with the underlying Gardison Formation and exposed in the core of the Ophir anticline in Ophir, Mercur, and Dry Canyons. A basal marker bed of black shale, which contains a thin bed of phosphatic oolites at its top, separates the blue-gray, fine-grained to sandy limestones with black chert of the Deseret Limestone from the underlying similar Gardison Limestone below (Gilluly, 1932). Fossils include brachiopods, bryozoans, and corals

Mg **Gardison Limestone (Lower Mississippian)**--Formerly called Madison Limestone by Gilluly (1932), now, on the basis of age and general appearance, these rocks have been reassigned to the Gardison Limestone because of their closer resemblance to portions of Gardison Limestone strata in the type locality on Gardison Ridge in the East Tintic Mountains (Morris and Lovering, 1961). The unit in the southern Oquirrh Mountains is about 140 m thick where exposed in the core of the Ophir anticline in Ophir and Dry Canyons. The formation unconformably overlies the Fitchville Formation and Pinyon Peak-Limestone, undivided, without angular discordance but along an erosional surface, or, according to Gilluly (1932) a karst topogaphy. The Gardison Limestone is a thin- and medium-bedded bluish-gray dense cherty limestone. An abundant coral, brachiopod, and gastropod fauna from the unit is reported by Gilluly (1932)

MDfp **Fitchville Formation (Lower Mississippian and Upper Devonian) and Pinyon Peak Limestone (Upper Devonian), Undivided**--This 56 m thick sequence, previously called the Jefferson(?) Dolomite by Gilluly (1932), is reassigned here, for its close resemblance, in part, to a thicker more complete section of comparable rocks in the East Tintic Mountains (Morris and Lovering, 1961), on Fitchville Ridge near Eureka, Utah. In the Oquirrh Mountains, these rocks unconformably overlie the Lynch Dolomite; the lower contact with the Lynch is at the base of a thin (2.4 m thick) clastic bed whose lower surface is irregular and is composed chiefly of dolomite, sandstone and shale fragments, and quartz grains. This bed probably represents the Pinyon Peak part of the sequence. The upper massive white siliceous limestone, medium-gray crystalline dolomite, and the dark-gray coarse-grained massive black-weathering dolomite that contains large oval calcite blebs (locally called the "eye" bed) are presumed equivalents correlative with the lower half of the Fitchville Formation at Tintic (Morris and Lovering, 1961) which contains both limestones and dolomites. A sample of recrystallized and dolomitized limestone from immediately below the "eye bed" of Gilluly contains the colonial coral Syringopora morpho group A (Sando, written commun., 1985) and fragment (Pa element) of the conodont Polygnathus Communis Branson and Mehl (Schindler, written commun., 1985). These forms together date the rocks as very latest Devonian thru Early Mississippian, which substantiates their correlation with the Tintic section. The contact between Pinyon Peak and Fitchville strata apparently is conformable here, as it is at Tintic

€l **Lynch Dolomite (Middle? and Upper Cambrian)**--A thick sequence of dominantly massive gray dolomite is about 251 m thick and is well exposed in Ophir Canyon. Lower beds apparently are conformable with the Bowman Limestone, but Gilluly (1932) reported that the dolomite and limestone beds interfinger. The lower part of the unit is an alternating sequence of limestone and dolomite that contains dark steel-gray crystalline dolomite zones, weathering black, and containing white rods and tubular markings 12.7 mm long and 1.59 mm in diameter; the unit much resembles the Bluebird Dolomite of Morris and Lovering (1961) in the Tintic district. The upper three-fourths of the Lynch is composed of massive thick-bedded, light-gray and dark-gray dolomite. Fossils are rare; Gilluly (1932) reported a single collection of Hyolithes. The age of the rocks was considered uncertain upper Cambrian

€b **Bowman Limestone (Middle Cambrian)**--Unit consists of a prominent ledge of mottled limestones and limy mudstones and shales (now hornfels) about 84 m that is best exposed in Bowman Gulch, west of Ophir, and a series of mottled shaly limestones, edgewise conglomerates, and oolite beds. The lower contact with the Hartmann Limestone is gradational but apparently conformable, according to Gilluly (1932); the upper contact with Lynch dolomite is arbitrarily drawn at the base of the lowest dolomite. Fossils, mainly trilobites, are uncommon

-Ꞓh **Hartmann Limestone (Middle Cambrian)**--The formation crops out on steep covered slopes on the north side of Ophir Canyon, where it is about 198 m thick. The contact with underlying Ophir Formation is conformable and placed arbitrarily by Gilluly (1932) at the top of the highest shale bed in a transition zone from a shale to limestone lithology. The Hartmann is predominantly a limestone unit banded with mudstone interbeds whose weathered surfaces are irregularly mottled light gray, buff, and brown. Sparse tribolite fossils were reported by Gilluly (1932)

-Ꞓo **Ophir Formation (Middle Cambrian)**--Outcropping north of Ophir, this formation, which is about 97 m thick, is a slope forming unit that overlies the Tintic Quartzite. The lower contact is within a transitional sequence and is placed at the base of the lowest shale (now schist) bed thicker than 0.3 m. The formation consists of interbedded olive-brown weathering micaceous shales, argillaceous limestone, quartzite, and shale. Near ore bodies the limestones are altered to banded and mottled crystalline "zebra rock." Productid brachiopods and trilobites (*Olenellus*) have been found in the unit

-Ꞓt **Tintic Quartzite (Lower Cambrian)**--The lowermost unit exposed north of Ophir in the Ophir anticline is more than 91 m thick; its base is not exposed. The formation consists of rocks that occur as thick-bedded, cross-bedded, white quartzite, which weathers to a rusty brown. The unit becomes shaly toward its top

CORRELATION OF MAP UNITS

The correlation of all mapped rock units in both the Ophir and Mercur quadrangles is shown on the following chart. Correlation charts for units in individual quadranges are shown on each map.

CORRELATION OF MAP UNITS

Qac, Ql	Holocene	Quaternary
Unconformity		
Qlb	Pleistocene	Quaternary
Unconformity		
Qa	Pleistocene	Quaternary
Unconformity		
Qh	Pleistocene	Quaternary
Unconformity		
Qj	Oligocene	Quaternary
Unconformity		
Tbp	Oligocene	Tertiary
Unconformity		
Teh	Oligocene	Tertiary
Unconformity		
Tlp	Oligocene	Tertiary
Unconformity		
Tgp	Oligocene	Tertiary
Unconformity		
Ꝑobp	Middle Pennsylvanian	Paleozoic
Ꝑowc	Lower Pennsylvanian	Paleozoic
ꝐMm, ꝐMmw	Upper Mississippian and Lower Pennsylvanian	Paleozoic
Mgu, Mguw	Upper Mississippian	Paleozoic
Mglt	Upper Mississippian	Paleozoic
Mgll	Upper Mississippian	Paleozoic
Mh	Upper Mississippian	Paleozoic
Md	Upper Mississippian	Paleozoic
Mg	Lower Mississippian	Paleozoic
Unconformity		
MDfp	Lower Mississippian and Upper Devonian	Paleozoic
Unconformity		
Єl	Upper and Middle(?) Cambrian	Paleozoic
Єb	Middle Cambrian	Paleozoic
Єh	Middle Cambrian	Paleozoic
Єo	Middle and Lower Cambrian	Paleozoic
Єt	Lower Cambrian	Paleozoic

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