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PRELIMINARY GEOLOGIC MAP OF THE STOCKTON 7 1/2-MINUTE. QUADRANGLE, TOOELE COUNTY, UTAH

By

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PRELIMINARY GEOLOGIC MAP OF THE STOCKTON 7 1/2-MINUTE QUADRANGLE, TOOELE COUNTY, UTAH

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Abstract

The Stockton quadrangle is on the west side of the central Oquirrh Mountains, about 50 km west-southwest of Salt Lake City, Utah. The quadrangle is the site of two historically important Utah base- and precious-metal mining districts at Ophir and Stockton. The Oquirrh Mountains here are composed of allochthonous folded and faulted Paleozoic sedimentary rocks of the Bingham and South Mountain nappes, which are part of the Sevier thrust belt of Late Mesozoic age. The plates are differentiated on the basis of their structural and stratigraphic characteristics. Sedimentary rocks in both plates are intruded by distinctive Tertiary rhyolite porphyry, quartz monzonite, and quartz monzonite porphyry stocks, dikes, and sills. The ore deposits are spatially associated with the igneous rocks. Although the mining districts occur in different nappes, the styles of mineralization—replacement of carbonate rocks and fissure fillings—are similar. The upper parts of ore bodies are largely oxidized, grading downward into sulfides. Ore production at Stockton exceeded that at Ophir and contained more gold, lead and zinc. Ophir ores contained more silver and copper than those at Stockton.

Introduction

The Stockton quadrangle lies on the west side of the central Oquirrh Mountains, and includes the northern part of the Ophir, called the Dry Canyon area, and Stockton (Rush Valley) mining districts. Mining began in the Stockton district as early as 1864, and in the Ophir district in 1870, and continued in both districts almost uninterrupted for 70 years. However, these districts have been active only sporadically in recent years; the mines at Stockton were closed in 1970 and those at Ophir soon after in 1971. Production of base and precious metals from the districts is nearly comparable; the Ophir district produced more silver than the Stockton district, which produced more gold. The relative amounts of lead and zinc were similar. Oxidized ores were more abundant at Ophir than at Stockton, where sulfide ores predominated. During the late 1980s, exploration for disseminated gold occurred intermittently in both districts, but with only limited success.

The Stockton 7 1/2- minute quadrangle is the northwestern part of the Stockton and Fairfield (15-min.) quadrangles that were mapped by Gilluly (1932), who also described the geology and base- and precious-metal ore deposits. The present report supersedes an interim report by Tooker and Roberts (1988a) and provides the geologic information available at the conclusion of their and their collaborators' studies. Descriptions of the stratigraphic and structural features are based on geologic mapping by Roberts and Tooker, 1961-1967, and by Tooker in 1986-87 and 1991, and measured stratigraphic sections by Roberts, Tooker, and Gordon (in Tooker and Roberts, 1970), and Tooker and Gordon (1978).

The Oquirrh Mountains are composed of allochthonous folded upper Paleozoic sedimentary rocks on nappes that were emplaced in the foreland of the Sevier thrust belt during the Late Mesozoic Sevier Orogeny (Armstrong, 1968). The South Mountain nappe overlaps the Bingham nappe in the Stockton quadrangle. These nappes contain comparably-aged but distinctive assemblages of clastic calcareous and siliceous sedimentary rocks in terms of their composition and thickness. The structural configurations in the two thrust plates are also distinctively different and each provided unique structural and stratigraphic sites for subsequent intrusion by Tertiary porphyritic igneous rocks, followed by the deposition of base- and precious-metal vein and replacement deposits at Stockton and Ophir. These rocks were later segmented and tilted eastward on basin-and-range extensional faults (Gilluly, 1932).

We benefited substantially from the assistance of U.S. Geological Survey colleagues, W.J. Moore, Mackenzie Gordon, Jr., R.C. Douglass, and H.M. Duncan for map, geochronologic, and stratigraphic data. The igneous rock classification of Moore (1973) is used, and, with only minor adjustments noted in the following descriptions, the stratigraphic sequence of the lower Paleozoic sedimentary rocks of Gilluly (1932) has been followed. The characteristics of the formational units comprising these rock assemblages are summarized in the descriptions of the map units.

Geology of the Stockton Quadrangle

Location

The Stockton 7 1/2-minute quadrangle, Tooele County, Utah, includes a portion of the western flank of the central Oquirrh Mountains, about 50 km west-southwest of Salt Lake City, Utah (fig. 1). The town of Stockton lies in the northwest corner of the quadrangle at the mouth of Soldier Creek, which is one of the main west-directed drainages of the range in the quadrangle. The Stockton mining district and Dry Canyon mining area (the northern part of the Ophir mining district) are located near the western range front and are accessible via Utah Highway 36.

FIGURE 1, NEAR HERE

The mineralized ledge outcrops in the Stockton area, which were discovered by soldiers of Gen. Connor's command who were encamped in Rush Valley in 1864, proved to be rich in silver. The Ophir district ores also were discovered in 1865 by these soldiers, but the area had long been known as a sacred spot where the Indians met each year in council and to obtain metal (lead) for bullets. The Stockton and Ophir mining districts were formally organized in 1864 and 1870, respectively. Mining operations in the districts were sporadic in the latter years, as indicated by the U.S. Geological Survey and U.S. Bureau of Mines production records and the compilation by Stowe (1975). Information available about some of the long-closed individual mines in the districts may be found in Gilluly (1932) and the MRDS (1990) files of the U. S. Geological Survey.

Geologic setting

The Stockton quadrangle is in the eastern part of the Great Basin, which is a part of the Basin and Range physiographic province, an intermountain region of internal drainage and narrow, north-trending, block-faulted mountain ranges and alluvium-filled basins. Exposed ranges in the eastern Great Basin (and Stockton quadrangle) are composed of folded and faulted thrust-faulted nappes, resulting from the Late Cretaceous Sevier Orogeny (Armstrong, 1968). The nappes overlie a concealed Precambrian basement terrane (Tooker, 1979), that contains the extension of an inferred structural flaw zone in the North American craton shelf, the Uinta-Cortez lineament of Roberts, and others (1965), here called the Uinta trend (fig. 1). This structure marks a zone of accretion of Proterozoic platform shelf rocks from the south onto the Archean Wyoming shield on the north. The Precambrian rocks are known from outcrops in the Uinta and Wasatch Ranges (Crittenden and others, 1952) and in west-central Utah (Levy and Christie-Blick, 1989), and their structural disposition is inferred from geophysical data in the Great Basin (Kistler and

Peterman, 1978) and Bankey and Campbell, 1989). The quadrangle is also the locus of a series of Tertiary intrusives (Moore and McKee, 1983).

Phanerozoic sediments deposited on the craton shelf comprise an extensive sedimentary record of the Paleozoic, Mesozoic, and Cenozoic eras (Stewart and Poole, 1974). The Paleozoic rocks, which mainly are thick accumulations of carbonate-quartz clastics, quartzite, shale, limestone, and dolomite, were deposited along a miogeoclinal shelf an unknown distance west of where they now occur. A thinner autochthonous sequence of comparable sediments was deposited on the platform (Baker, and others, 1949) and is exposed in the Wasatch Mountains. The character of the shelf deposits varied from north to south depending on the source and relative amounts of sediments from the craton to the east or from the Antler uplift to the west (Roberts, 1964). Craton-derived sedimentary rocks, such as those that characterize of the Bingham and South Mountain nappes (fig. 2), were generally clean, well sorted, and compositionally similar to the platform sediments now exposed in the Wasatch Mountains. Sediments from the Antler uplift, which was of oceanic crust derivation, contain less well-sorted volcanic and deep-ocean sediments. The nappes at the north end of the Oquirrh Mountains contain greater contributions from the Antler source than those in the southern part of the range, which have a greater proportion of clean limestone-quartzite sediments (Tooker, 1983).

FIGURE 2, NEAR HERE.

The Late Cretaceous Sevier Orogeny produced an extensive decollement thrust belt of the miogeocline shelf rocks that extends from Alaska to Mexico (Armstrong, 1968, Roberts and Crittenden, 1973). Some of the Paleozoic strata are believed to have been transported as much as 160 km eastward toward a foreland zone in central Utah and aligned along the shield-platform boundary, approximately along the present trend of the Wasatch fault (Roberts, and others, 1965). The segmentation of the Sevier thrust belt into individually recognizable folded and faulted nappes in the central Utah part of the Sevier thrust belt caused by their impact on reaching foreland promontories or basins has been described by Tooker (1983) and Morris (1983). At least five nappes in the foreland of this thrust belt have been recognized in the Oquirrh Mountains by Tooker and Roberts (1988b). Early Mesozoic rocks that may have been deposited on the shelf have since been eroded. Late Mesozoic and Cenozoic sediments on the platform are mainly clastic conglomerate, sandstone, shale, and lesser carbonate sediments that were derived mainly from the erosion of the foreland thrust plates such as the remnants on the Oquirrh Mountains.

The intrusion of Oligocene igneous rocks into the nappe provided conduits that permitted the access of hydrothermal solutions from an inferred crustal source. These mineral-rich solutions were derived from the late stages of magmatism that mixed with downward circulating meteoric water. The result was deposition of the ores as veins along faults and in adjacent favorable stratigraphic units as replacement- or skarn-type deposits. The region was subjected to block faulting during the Basin and Range Orogeny, which began in the Miocene. Uplift and intense erosion during the early Quaternary unroofed the mineralized areas in the Oquirrh Mountains and elsewhere in the region, producing extensive alluvial fans and pediments along the range. The Great Salt Lake is the remnant of a more extensive freshwater Pleistocene Lake Bonneville. Lake Bonneville wave deposits, such as the Stockton bar and spit in the northwest corner of the map, were derived in large part from the redistribution of earlier alluvial deposits.
Evidence of Pleistocene glaciation is best seen in incipient cirques near the crest of the range.

Structure

The Bingham and South Mountain nappes (fig. 2) are characterized in part by distinctions in stratigraphy, but mostly by the differences in the structural style of the thrust, tear, and normal faults and folds that were produced by the convergence of the several nappes in the Oquirrh Mountains. The most distinctive structural differences between nappes in this quadrangle are in their styles of folds. A vector normal to the trend and the symmetry of folds are used to estimate the directions and magnitudes of thrust fault movement. Major folds in the Bingham nappe are shown by heavy-lined axes while minor folds or "ripples" developed in the flanks of bent major folds or on imbricate overriding thrust plates are shown by thin-lined axes. There are no comparable major fold axes in that part of the South Mountain nappe in this quadrangle. However, a major asymmetrical anticlinal fold axis occurs in the nappe on South Mountain in the west-adjoining South Mountain 7 1/2-minute quadrangle.

That part of the Bingham nappe in the Oquirrh Mountains moved generally east-northeast on the basal Midas thrust. This plate extends from the Bingham mining district (Tooker and Roberts, 1988b) to just south of the Tintic mining district and is segmented by several through-going tear faults (Morris, 1983). The upper parts of the plate are also segmented by numerous imbricate thrust and tear faults of relatively small to moderate displacement in comparison with movement on the Midas thrust. The ore deposits of the Dry Fork area of the Ophir mining district are localized in the upper plate of the Manning thrust, one of these intermediate imbricate thrusts faults. The Bingham nappe is composed generally of thick competent Paleozoic stratigraphic units. The major folds in this plate are broad, open, locally asymmetrical, trend northwestward to west-northwest in a broad arc, and plunge westward at the edge of the range. Overlying imbricate thrust faults of relatively small apparent displacement, notably on the western flanks of the Ophir anticline, produce small sub-parallel more-symmetrical but discontinuuous fold systems that are most prominent along slopes of the western range front south of Soldier Creek. Crinkling or discontinuous small-scale folds observed on the flanks of the broad folds, particularly near the leading edge of a thinned thrust sheet, occurs where the major fold is bent. Where bends in the folds become tight, locally, minor discontinuous secondary folds develop concurrent with numerous tear faults that offset the folds. The folds may become asymmetrical to slightly overturned.

The Ophir anticline and Pole Canyon syncline are the main high amplitude folds of the Bingham nappe in the quadrangle. The trace of the Ophir anticline is overridden northwest of Gisborn at the head of Dry Canyon by a series of imbricate thrust faults that conceal its apparent plunge west-northwestward. We infer that it is cut off by south-southwest extension of the north-northeast-trending tear fault that bounds the east edge of the South Mountain nappe. The northeast limb of the Ophir anticline is well exposed in the north wall of Soldier Canyon and its South Fork. The Pole Canyon syncline, the major fold structure north of Soldier Canyon, developed minor discontinuous low-amplitude crinkles along its flanks as the fold was bent and plunged westward.

The folds in the overlapping South Mountain nappe, which terminates the folds in the Bingham nappe, are generally of shallow amplitude. Folds here are close to the lead edge of the plate, are more closely spaced, generally of shallow amplitude, and become asymmetrical to overturned. They are cut by prominent tensional cross faults, which are, in many cases, sites for porphyry dikes. The South Mountain nappe, which moved north-northeastward on the Stockton thrust to overlap the Bingham nappe is also segmented by minor thrust imbrications. The Stockton district ores are located mostly in the Rush Lake unit in the imbricate upper plates of the Stockton thrust fault. The main South Mountain nappe fold axis also plunges to the west on South Mountain.

The amounts of relative movement on the basal Midas and Stockton thrusts remains conjectural. Displacement on the Midas seems to be less than 60 km (Morris, 1983), although Hintze (1973) suggests it may be a little as 19-24 km. In any case, movement on the Stockton thrust apparently is much less than that on the Midas, although there is no way to attach a numerical distance value. The South Mountain nappe is structurally overlain on the west by the Stansbury Mountain nappe, which moved eastward on the sole Tintic Valley thrust fault (Rigby, 1958; Tooker and Roberts, 1971a; Morris, 1983).

Strikes of basin-and-range fault segments along the margins of the Oquirrh Mountains are consistent with earlier-formed normal or tear faults. These generally are in conjugate northeast and northwest directions; in fact the range-front faults are generally extension of those within the range. Thus we infer that the crustal extension that produced the Great Basin structures acted to regenerate previously-formed faults. Because the Oquirrh Mountains block was tilted to the east (Gilluly, 1928; Zoback, 1983), presumably along listric range-front faults on the eastern side of the range, the western range front is more precipitous and the normal range-boundary faults are more clearly defined. The tear or strike-slip faults in the range facilitated minor intra-nappe thrust-fault movements; they also exhibit regeneration as normal extensional movement.

Stratigraphy and description of sedimentary rocks

The allochthonous Bingham and South Mountain thrust nappes are nearly comparable in thickness, and, where comparable in age, are of generally similar composition, although there are some important differences in the thickness of individually recognized constituent units. The Bingham plate consists of early to late Paleozoic sedimentary rocks. Only late Paleozoic rocks are exposed in the Stockton quadrangle and on South Mountain, immediately west of Stockton, Utah, where the type section of the South Mountain nappe was measured (Tooker and Roberts, 1988a). Corresponding parts of the stratigraphic sections in the quadrangle are diagrammed (columnar sections, figure 3); the sedimentary rocks of the South Mountain nappe include the Pennsylvanian Rush Lake and Salvation units of Tooker and Roberts (1988a). These Oquirrh Group sedimentary rocks are correlated with the upper Butterfield Peaks Formation and the Clipper Ridge Member of the Bingham Mine Formation (Tooker and Roberts (1970), also of Pennsylvanian age. A comparison of the two plates is best made in Southport Gulch in the Stockton quadrangle and in Middle Canyon in the Tooele quadrangle. Two (Jordan and Commercial) limestones marker beds are more than 200 m thick in the lowest part of the Clipper Ridge Member where they cross Middle Canyon; they can be traced undiminished eastward across the range to the Bingham district. Comparable rocks in Southport Gulch are about 100 m thick and of more quartzitic composition (Tooker and Roberts, 1970; and 1988a). The Bingham nappe also contains lower Oquirrh Group rocks, which includes the lower part of the Butterfield Peaks Formation and West Canyon Limestone, and a conformable underlying thick sequence of carbonate-rich sedimentary rocks of Mississippian and Cambrian ages.

FIGURE 3, NEAR HERE

The Lower Paleozoic stratigraphic section is attenuated in the Bingham nappe in the Oquirrh Mountains; Ordovician-, Silurian- and most of the Devonian-age sedimentary rocks, which are present in the nappe in the Tintic district, are not present here. This unconformity is inferred to be the result of irregular uplift along the Uinta trend lineament zone (Roberts and Tooker, 1969; Coats, 1987).

Unconsolidated rocks that overlie the nappes

Brief lithologic or petrologic descriptions of the unconsolidated formational units shown on the Stockton quadrangle, which overlie consolidated sedimentary rocks in both the Bingham and South Mountain nappes, are sketched briefly here. References are given for more detailed descriptions for the individual unconsolidated units described below.

Qod Mine waste dump materials (Holocene)—Unconsolidated mine dump debris and mine-mill tailings pond materials occur in and adjacent to the mining districts..

Qac Alluvium and colluvium (Holocene)—Undifferentiated and unconsolidated alluvial fan and stream gravel, sand, silt, talus, gravel, and boulder deposits occur within and bordering the mountain range. Thickness of fan deposits is variable and estimated to range from less than 0.3 m at distal edges to more than 10 m locally in the upper parts. Stream-fill deposits are estimated to be less than 1.5 m thick.

Ql Landslide debris (Holocene)—Generally irregular unconformable slide blocks in Soldier and West Canyons are composed of detached and rotated Great Blue Limestone and Manning Canyon Shale materials in structurally over-steepened, deeply-eroded thrust-faulted terranes.

Qt Talus deposits (Holocene? and Pleistocene?)—Alluvial talus slope deposits occur along the walls of the larger canyons in quartzite-dominant terranes, such as in Settlement Canyon. The poorly sorted angular to subrounded fragments range up to 0.3 m in diameter; the deposits may be several meters thick at the base. The age of these deposits is uncertain; they probably were formed during or soon after periods of intense erosion.

Qa Alluvium (Pleistocene)—Fine-grained alluvial deposits consisting of poorly sorted, thin gravel, sand, and silt layers and lenses occur in an extensive series of coalescing fans issuing from most of the canyons that empty into Rush Valley. Thickness of these fans is unknown, but is estimated to be tens of meters thick at the range front, thinning toward the distal margins of the fans, where locally they merge with shoreline deposits. The Pre- and post-Lake Bonneville fans generally lie disconformably on Harkers Alluvium and alluvium and colluvium in the broader drainages.

Qlb Lake Bonneville deposits (Pleistocene)— Undifferentiated and pluvial lake bottom deposits (Eardley and others, 1957) include a prominent sand and gravel bar and spit deposit that occurs north of Stockton, connecting the Oquirrh and South Mountains; its beveled top is at the 1,585 m (5,200 ft.) Bonneville level still-stand of Lake Bonneville. Elsewhere along the range front northeast of Stockton, the deposits are marked by wave-cut terraces of sand and gravel (derived primarily from erosion of Harkers Alluvium) at or near the 5,200 ft. elevation. Southeast of Stockton and the mouth of Soldier Canyon, the deposits overlap the large alluvial fans that mantle a prominent pediment along the west margin of Rush Valley. The maximum thickness of Lake Bonneville deposits is unknown because they are difficult to distinguish from Harkers Alluvium (Qh) in drilled well records, but the Lake Bonneville unit may be as much as a few tens of meters thick locally against normal range front faults. The deposits thin to a few meters outward from the range. Away from the edge of the range, sand and gravel bar deposits as much as 10 m thick parallel the Bonneville shorelines and are local sources of construction materials in Tooele Valley (Tooker, 1980). The very prominent Stockton bar and spit deposits are at least 91 m thick locally. The Lake Bonneville deposits unconformably overlie the Harkers Alluvium, older alluvium, and locally are overlain unconformably by Holocene alluvial and colluvial deposits.

Qh Harkers Alluvium (Pleistocene)—Undifferentiated, partly dissected, unconsolidated, thick, coarse fanglomerate deposits of poorly sorted angular to rounded boulders, coarse to fine gravel, sand, silt, and mud lie along the western range front in Rush Valley and locally up large drainages such as Settlement and Soldier Canyons (Slentz, 1955, Tooker and Roberts, 1971a). The fanglomerates project basinward as fill deposits of undetermined thickness. These deposits are notched by the Lake Bonneville (Bonneville level at 5,210 ft) shoreline, and locally are overlain, often imperceptibly, by Pleistocene pre-Lake Bonneville alluvial fan (Qa) deposits. The unit conformably overlies upper Paleozoic sedimentary rock sequences. Unit total thickness is unknown, but where erosion has cut through the coarse alluvium at the mouth of Soldier Canyon at least 61 m are exposed; this is believed to a minimal value. The age of the unit is considered Pleistocene (probably early Pleistocene); no fossils have been found.

Sedimentary rocks of the Bingham nappe

The thick sedimentary rock sequence in the nappe includes parts of the middle and lower Oquirrh Group of upper Paleozoic age that overlie formational units of lower Paleozoic ages. However, the lower Paleozoic stratigraphic section is attenuated in the Oquirrh Mountains. Ordovician-, Silurian-, and most of the Devonian-age sediments, which are present in the nappe in the Tintic district, are not present here. This unconformity is inferred to be the result of nondeposition or erosion along the irregular uplift along the Uinta trend (Roberts and Tooker, 1969; Coats, 1987). The following brief lithologic descriptions of consolidated sedimentary rocks in the Stockton quadrangle are based on data from the references cited.

Oquirrh Group (Pennsylvanian and Permian)—Originally named the Oquirrh Formation (but not subdivided into members) by Gilluly (1932), these rocks were raised to the Oquirrh Group by Welsh and James (1961), and its three formations described by Tooker and Roberts (1970). The type and reference localities of the formation are in the Lowe Peak, Stockton, Mercur, and Bingham Canyon quadrangles. The Midas thrust is not exposed in the Stockton quadrangle, but one of its upper strands crops out in the Bingham Canyon quadrangle, north of the Utah Copper open pit mine at the southeast corner of the Bingham Canyon quadrangle (Tooker and Roberts, 1988b). Oquirrh Group rocks in the Stockton quadrangle include the Middle Pennsylvanian Butterfield Peaks Formation and Lower Pennsylvanian West Canyon Limestone.

IPobp Butterfield Peaks Formation (Middle Pennsylvanian)—The formation consists of 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, brown-gray, and dark-gray arenaceous cherty, and argillaceous limestone. Limestones predominate over quartzites (Tooker and Roberts, 1970). The formation is 2,765 m thick in the type locality and is exposed, in part, in the northeastern part of the Stockton quadrangle. It is exposed more extensively in the adjoining Lowe Peak quadrangle where the type section is located (Tooker and Roberts, 1970). The Butterfield Peaks section conformably overlies the West Canyon Limestone. The formation contains an abundant brachiopod, bryozoan, coral, and fusulinid fauna. The age of the rocks is Des Moinsean (Middle Pennsylvanian) (Gordon and Duncan, 1970).

IPow West Canyon Limestone (Lower Pennsylvanian)—The formation is 438 m thick in the type section in the Lowe Peak quadrangle (Nygreen, 1958) and about 321 m thick at Lewiston Peak in the Mercur quadrangle (Tooker and Roberts, 1970). The rocks are principally cyclical clastic and arenaceous limestones, composed of quartz and calcite grains and fossil fragments, and interbedded thin chert, argillaceous, and dense crystalline limestone beds. Thin calcareous quartzite and calcareous sandstone, generally banded or cross bedded, separate thicker limestone beds. Calcareous quartzite beds thicken toward the conformable upper contact with the Butterfield Peaks Formation. The lower contact with Manning Canyon Shale is conformable in Soldier Canyon. Fossils are locally abundant. Brachiopods typical of the *Rugoclostus* zone are most abundant, bryozoan are fairly common, corals are rare, and trilobites are fragmental. Nygreen (1958) reported finding the fusulind *Millerella* in the upper part of the formation. A Morrowan age is suggested by Gordon and Duncan (1970).

IPMm Manning Canyon Shale (Lower Pennsylvanian and Upper Mississippian)—Gilluly (1932) provided 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 (Tooker and Gordon, 1978). Here the unit consists of 350 m of interbedded calcareous shale and fossiliferous, argillaceous, and thin-bedded crystalline limestone. A prominent 1.2 m ledge-forming brown weathering quartzite caps the lower one third of the formation. The section is conformable, grading from the limestone and lesser shale units of the underlying Great Blue Limestone into predominantly dark-gray carbonaceous shales and thin-bedded gray limestone. Contact with the overlying Oquirrh Group is conformable and represents a transition from shale into clastic limestone of the West Canyon Limestone. The Mississippian-Pennsylvanian boundary occurs in the upper part of the formation. Carbonate beds are abundantly fossiliferous, consisting of bryozoans (including *Archimedes*), brachiopods (including productid and spiriferid types), and corals (including *Amplexizaphrentis*) (Gordon and Duncan, 1970).

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 764 m thick Great Blue Limestone. In his three-part subdivision, Gilluly specified a type locality only for the middle unit, 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) identified the formation in the East Tintic Mountains as the Great Blue Formation, consisting of four members. There, a prominent shale and shale-rich carbonate sedimentary facies comprises the upper two members; these contrast sharply with strata of comparable age in the single upper member in the Oquirrh Mountains. There is, however, a close resemblance between the lower two members at Tintic and the lower member in the Oquirrh Mountains. The Long Trail Shale member is not recognized at Tintic. Because of the differences, Tooker and Gordon (1978) subsequently designated the Silveropolis Hill-Long Trail Gulch area in the Mercur quadrangle as the type section for the unit in the Oquirrh Mountains and retained the original name of the formation, Great Blue Limestone

Mgu Silveropolis Limestone Member—Alternating dark-gray, fossiliferous, sandy, and cherty limestone intervals and intervening shale and shaly limestone are 470 m thick. The lower part of the member is composed predominately 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. The member is exposed in the area between Soldier and Ophir Canyon, and the South Fork of Ophir Canyon in the Stockton quadrangle. Fossils are sparse. The member is Chesterian in age. The *Caninia* coral zone was recorded from 122 to 295 m above the base of the member. The only coral between the two zones is *Amplexizaphrentis* (Gordon and Duncan, 1970)

Mglt Long Trail Shale Member—The member is about 33 m thick, but is faulted and intruded by monzonite porphyry sills in its type locality and undoubtedly thinned by reverse or thrust faults. The member is offset by several thrust or reverse faults on the east side of the Ophir anticline in the Dry Canyon area, and is cut out by a normal fault and imbricate thrust of the lower member on the west side of the anticline. The Long Trail Shale is conformable with the underlying lower limestone member of the Great Blue Limestone, although outcrops generally are poorly exposed here and elsewhere in the range (Gilluly, 1932). The member consists predominantly of interbedded dark-gray to black, calcareous and carbonaceous shales with interbedded thin-bedded fray, 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 limestone. The upper contact represents an abrupt transition into silty, color-banded, thin- to medium-bedded, ledge-forming limestone. The Long Trail Shale Member contains a locally abundant coral, brachiopod, pelecypod, crinoid, and bryozoan fauna of Mississippian (Chester) age (Tooker and Gordon, 1978).

Mgl Mercur Limestone Member—The member is 260 m thick and conformable with the underlying Humbug Formation; the contact is somewhat gradational. The unit occurs along the core of the Ophir anticline where it has been cut and offset by numerous normal and thrust faults. 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 and Barrick mining companies, and locally called the Mercur mine series by them , includes the upper 73 m of the lower member (Kornze, 1984; Kornze, and others, 1985). The Mercur mine series includes a jasperoid bed at the base overlain by calcareous sandstone, fossiliferous limestone, and argillaceous limestone, becoming more argillaceous near the top, as it grades into the Long Trail Shale Member. The basal unit of the lower limestone member characteristically is composed of massive cliff-forming, medium- to thick-bedded, blue-gray limestones 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, containing 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. As Gilluly (1932) pointed out, these quartzite layers are lens-shaped and cannot be traced for great distances laterally.

Mh Humbug Formation (Upper Mississippian)—The formation is about 198 m thick, is conformable with the underlying Deseret Formation, and is well exposed locally to the south in the core of the Ophir anticline (Gilluly, 1932). In the Stockton quadrangle it occurs in irregular, separated faulted blocks across the Ophir anticline in the Dry Canyon area. It is a ledge-and-slope topographical unit characterized by alternating brown-weathering quartz sandstone or quartzite and medium-gray limestone. Fossils include brachiopods, corals, and bryozoans. A conformable basal contact is at the base of the lowest sandstone above the massive beds of the Deseret Limestone.

Md Deseret Limestone (Upper Mississippian)—The formation is about 200 m thick, is conformable with the underlying Gardison Formation and exposed in the core of the Ophir anticline in the Dry Canyon area. A basal marker bed of black shale, which contains a thin bed of phosphatic oolites at its top, separates the massive,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), these rocks have been reassigned to the Gardison Limestone because of their closer resemblance to portions of the Gardison Limestone strata in the type locality within the Bingham nappe on Gardison Ridge, in the East Tintic Mountains (Morris and Lovering, 1961). The unit is about 140 m thick in the Oquirrh Mountains where exposed in prominent cliffs on the north side of Ophir Canyon. 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 topography. The Gardison Limestone is a thin- and medium-bedded, bluish-gray, dense, cherty limestone. An abundant coral, brachiopod, and gastropod fauna from the unit was 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 because of its close resemblance, in part, to a thicker more complete section of comparable rocks in the East Tintic Mountains, on Fitchville Ridge, near Eureka, Utah (Morris and Lovering, 1961). In the Oquirrh Mountains, these rocks unconformably overly 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 to be equivalent to 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). These forms together date the rocks as very latest Devonian through 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.

Ꞓl Lynch Dolomite (Middle? and Upper Cambrian)—A thick sequence of dominantly massive gray dolomite about 251 m thick 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, that are black weathering and contain white rods and tubular marking as much as 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 tentatively considered to be upper Cambrian.

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

Sedimentary rocks of the South Mountain nappe

Oquirrh Group.—The South [Peak], Salvation, and Rush Lake units comprise a sequence of Oquirrh Group sedimentary rocks in the type locality on South Mountain; only the latter two units (see measured section in Tooker and Roberts, 1988a) occur in the northwestern part of the Stockton quadrangle. The South unit is not present in the quadrangle, but, for the record, it is described by Tooker (1992c),. The sedimentary rocks on South Mountain are roughly equivalent in age with the upper part of the Butterfield Peaks Formation, and the Clipper Ridge and Markham Peak Members of the Bingham Mine Formation in the Oquirrh Mountains. The lithologies of the units and formations in the South Mountain and Bingham sequences are similar in general, but are not directly comparable, and their structural styles on the upper plates of the Midas and Stockton thrust systems are distinctly different.

IPos Salvation unit (Middle Pennsylvanian)—Named for exposures generally north of Ben Harrison Gulch in the Stockton mining district, the type locality was designated nearby on South Mountain. The unit consists of 823 m of interbedded calcareous quartzite, orthoquartzite, and sandy, argillaceous, fossiliferous and dense crystalline limestone. Medium-bedded quartzite rocks predominate over thin-bedded limestone and shale partings. The rocks are age-correlative with the Late Pennsylvanian Clipper Ridge Member of the Oquirrh Group described by Tooker and Roberts (1970). The Salvation lithology, particularly at the base of the unit, is not fully comparable with that of the Clipper Ridge Member (fig. 3); there are no thick limestone marker beds in the Salvation unit comparable with those of the Jordan and Commercial marker beds (Tooker and Roberts, 1970).

IPor Rush Lake unit (Middle Pennsylvanian)—The type locality on South Mountain borders Rush Lake and contains nearly 1,352 m of interbedded limestone, quartzite, and occasional shale of Middle Pennsylvanian age (Tooker and Roberts, 1988a). Only the uppermost portion of the unit is exposed in the Stockton mining district. Limestone predominates and generally is medium-gray, medium-bedded, locally with shale partings, moderately fossiliferous, often sandy, silty, or bioclastic and crossbedded, frequently argillaceous, and contains black chert nodular layers. Infrequent sparse light-gray, thin-bedded and fissile shale layers occur mostly in limestone units. Quartzite units, which commonly contain thin limestone partings are buff-tan, coarse sandy, medium-bedded, and locally are crossbedded Weathered surfaces commonly are pitted. Local interbedded punky ferruginous layers contain worm trails. These rocks are are correlative with the upper part of the Butterfield Peaks Formation, but the thick cyclic repetition of limestone, sandstone, and shale characteristic of the Butterfield Peaks Foundation, described by Tooker and Roberts (1970), are absent.

Igneous rocks

The three main types of igneous rocks that crop out in the Stockton quadrangle include the Eagle Hill rhyolite, quartz monzonite, and quartz monzonite porphyry. Each occurs in a separate part of the quadrangle.

Teh Eagle Hill Rhyolite (Oligocene)—The locally porphyritic unit, originally named and described by Gilluly (1932), occurs in the Dry Canyon area, mostly on the east side of the Ophir anticline. An irregular stock north of Commodore Pass is the largest and northernmost body; a number of smaller dikes and sill-like bodies occur south and intersect the Ophir Canyon area of the mining district. A dike continues south of the quadrangle into the Ophir quadrangle and is inferred to connect with the major bodies of Eagle Hill rhyolite porphyry in the Mercur mining district (Tooker, 1987) Dikes, sills, and stock-like bodies occur underground in the Ophir mining district (Gilluly, 1932). A vertical dike, 3 to 9 m thick cuts, across the early Paleozoic sedimentary rocks on the north wall of Ophir Canyon. It seems to coalesce upward with an irregular sill-like mass of brecciated rhyolite. The common variety of rhyolite is light gray to buff, with a dense groundmass with numerous (5-10 percent) phenocrysts of quartz, up to 5 mm in diameter, feldspar, generally less than 1 mm long, and biotite, up to 2.1 cm in length. Flow structure is visible in some thin sections. The K/Ar age for samples of the rock at Mercur is 31.6^{+}-0.9 m.y. (Moore, 1973). The age of the comparable intrusive at the head of Dry Canyon has not been determined.

Tqm Quartz monzonite (Oligocene)—The main exposure of the intrusion, which lies east of the Soldiers Creek fault in the Stockton quadrangle, is known as the Soldier Canyon stock. It was described by Gilluly (1932) as "approaching quartz monzonite in composition." The elongated stock is generally subparallel with the Butterfield Peaks Formation it intrudes. A number of dioritic and monzonitic plugs and sills that occur peripheral to the stock are also described by Gilluly (1932). Most of the quartz monzonite bodies crop out in the Bingham nappe; those in the southeastern part of the South Mountain nappe are inferred to represent intrusive leakages up through a thin part of the overriding South Mountain plate. Gilluly (1932) inferred that the intrusive rocks are temporally and compositionally related to those at Bingham, and connected by a series of comparable intrusive bodies in the Bingham Canyon and Lowe Peak quadrangles that lie between the Soldier Canyon stock and the Bingham mining district (Tooker and Roberts, 1988a; Tooker 1992a). The ages of these rocks at Bingham range from 37-40 m.y. (Moore and McKee, 1983).

The central part of the Soldiers Canyon stock, described by Gilluly (1932), is granitic in texture; along the margin of the unit locally is coarser-grained and more feldspathic than in the core. Euhedral plagioclase (0.1-2 mm), and subhedral orthoclase, and microcline are also present. Microcline composes about 65 percent of the rock; anhedral quartz makes up 15 percent; and the remainder includes green pyroxene, diopside, biotite, pyrite, and accessory magnetite and apatite. Microcline is more abundant in the coarse phase than plagioclase, and pyroxene is mostly altered to hornblende; no biotite is present. The age of this unit has not been determined, but is inferred to be Oligocene on the basis of its compositional similarities and proximity to the nearby quartz monzonite porphyries in the Stockton area.

Tqmp Quartz monzonite porphyry (Oligocene)—The porphyry occurs mainly in the South Mountain nappe and is spatially related to the ore deposits of the district. The unit occurs as several textural types (Gilluly, 1932) and generally is a medium-gray porphyry containing abundant (50 percent) phenocrysts of pink orthoclase, and less conspicuous phenocrysts of quartz, plagioclase, biotite, and hornblende. The groundmass is micrograniitic. Epidote is present in mineralized areas as a replacement of mafic mineral and feldspars. The 61 m thick sill at the mouth of Silcox Canyon, at the southern end of the Tooele quadrangle, and the Raddatz porphyry, which crops out on the north side of the draw south of the Honerine mine shaft and north of the Calumet mine, are phases containing coarse-grained orthoclase phenocrysts. Fine-grained monzonite porphyry dikes and plugs of the Callumet stock crop out near the Calumet mine. Numerous small dike, sill, and plug-like bodies of fine grained monzonite-related rocks occur elsewhere in the Stockton district. The dikes commonly parallel north-northeast-trending faults. A broad, north-trending sill-like extension of the unit occurs in the north-central part of the quadrangle on the north side of the Pole Canyon syncline. The sill at the mouth of Silcox Canyon was determined to be 38.0 ± 1.1 m.a (Moore, 1973 and Moore and McKee, 1983).

Ore deposits

The base and precious metal ore deposits in the Stockton quadrangle are located about 8 km apart, one in the Dry Canyon area of the Ophir district and the other in the Stockton district. In spite of their proximity, they exhibit a number of differences in the types of ores present, their host rocks, and the amounts of production.

Dry Canyon area of the Ophir mining district.—The silver-lead-zinc ores at Ophir were largely oxidized in the upper parts, with sulfides present in lower workings. The deposits occurred mainly as replacements of lower Paleozoic limestones and dolomites adjacent to feeder fault structures, breccia zones in the carbonates and quartzite beds, and as veins locally along those faults. The sedimentary host rocks were the Lynch Dolomite and Ophir Formation , the Gardison Formation, Deseret Limestone, Humbug Formation, and Great Blue Limestone (Gilluly, 1932; MRDS, 1990).

The controlling structures of the district are a series of folded and broken imbricate thrust faults in the upper part of the Bingham nappe that have limited areal extent and displacement, and which ramped over the Ophir anticline, a major Bingham nappe fold. The feeder structures are steep-dipping normal and tear faults separating segments of a series of thrusts at the northern terminus of the more extensive Manning thrust (Tooker, 1987), which trends south into the Mercur and Ophir quadrangles, and provides the favorable sites for the localization of the deposits in the Lion Hill area of the Ophir district, south of Ophir Canyon, and at Mercur. The fault structures also are the sites of a number of dikes and sills of the Eagle Hill rhyolite porphyry.

The oxidized ores in the Dry Canyon area consist of jarosite, smithsonite, azurite, malachite, aurichalcite, plumbojarosite, limonite, and horn silver. The underlying sulfide ores include sphalerite, galena, pyrite, and chalcopyrite and a gangue of lime silicate minerals. There was little wallrock alteration away from the ores.

Almost all of the mines in the Dry Canyon area have long been closed and the only information about them was by Gilluly (1932), who even then had to rely on data from persons who had operated the then-closed mines. The production of ores in the Dry Canyon area of the Ophir district can not be separated from that of the district as a whole. The Hidden Treasure mine was one of the early mines located by General Connor's soldiers. Early assays from that mine contained from 15-40 oz silver and 20-50 percent lead (Gilluly, 1932).

The most recent production was from the Ophir Hill Consolidated or Ophir mine in the Ophir Canyon area; it was closed in 1972 when the custom mill at Midvale, Utah was closed. Data from USGS and USBM records between 1901 and 1972 indicate the following production for the Ophir mining district:

Table 1. Recorded production for the Ophir mining district, Utah, 1901-1972 [USGS, USBM, and UGS (Stowe, 1975) data.

Ore (st)	Au (oz)	Ag (oz)	Cu (st)	Pb (st)	Zn (st)
2,008,853	10,579	14,060,291	4,024	172,428	46,412

The average grade of the ore between 1901 and 1972 was 0.005 oz/t gold, 7.0 oz/t silver, 0.2 percent copper, 8.6 percent lead, and 2.3 percent zinc. Zinc production began in 1912. There were some rich shoots that contained 2-6 percent copper, and 10-25 oz silver.

Stockton mining district.—The base- and precious-metal ores mined in the Stockton district occur in Pennsylvanian Oquirrh Group rocks of the Rush Valley and Salvation units on the upper plate of the Stockton nappe (Moore and others, 1966). Ores near the surface were mostly oxidized with local residual sulfides, but below 240 m, the ores were mostly sulfides. In contrast to the Ophir ores, those at Stockton contained more gold. Most of the mines were small and their production was limited, but steady. The last operating mine was the Ben Harrison (New Stockton) mine. It was closed in 1972 Its deposits were localized along northeast-trending steep fissures and in favorable limestone horizons. The ore bodies were as much as 30 ft long in the plane of bedding and 10 feet wide. Apparently major ore production was confined to the upper plate of the nappe as no extensive mining occurred at depth

The principal ore minerals were galena, plumbojarosite, cerussite, native gold, chalcopyrite, malachite, and sphalerite; minor arsenopyrite also occurred.. The galena was silver-bearing. Gangue was mainly manganiferous calcite and quartz. Analysis of the ores (MRDS) was 22 percent lead, 13 oz/ton silver, $1.30 (.037 oz) in gold, and a small amount of copper. An exceptionally rich ore shoot in the upper workings near a porphyry dike averaged $17/ ton (0.48 oz) gold) according to Gilluly (1932).

Production from the Stockton district indicates that it was comparable in tonnage mined with that at Ophir. The latter district contained more silver and Stockton was richer in gold.

Table 2.--Recorded production of metals from the Stockton mining district, 1901-1970. [USGS, USBM, and UGS (Stowe, 1975) data]

Ore (st)*	Au (oz)	Ag (oz)	Cu (st)	Pb (st)	Zn (st)
2,138,773	74,123	10,822,137	2,865	244,720	86,369

* Ore tonnages not available 1960-1970.

The average grades of metals per ton in the Stockton district ores between 1901 and 1958 was 0.035 oz gold, 5.06 oz silver, 0.13 percent copper, 11.32 percent lead, and 3.95 percent zinc.

In summary, the Stockton mining district production exceeded that at Ophir by 140K st during comparable producing life spans. Stockton ores contained 7 times more gold and not quite twice as much lead and zinc as those at Ophir. However, Ophir ores contained more copper and silver than the Stockton ores. The districts were localized on the broken upper plates of two different thrust plates in different parts of the stratigraphic section, and were spatially associated with different igneous rocks. However, the style of mineralization--as replacements of carbonate rocks and in adjacent fissure fillings--were generally comparable. The upper parts of the ore bodies were largely oxidized, trending downward into sulfide ores.

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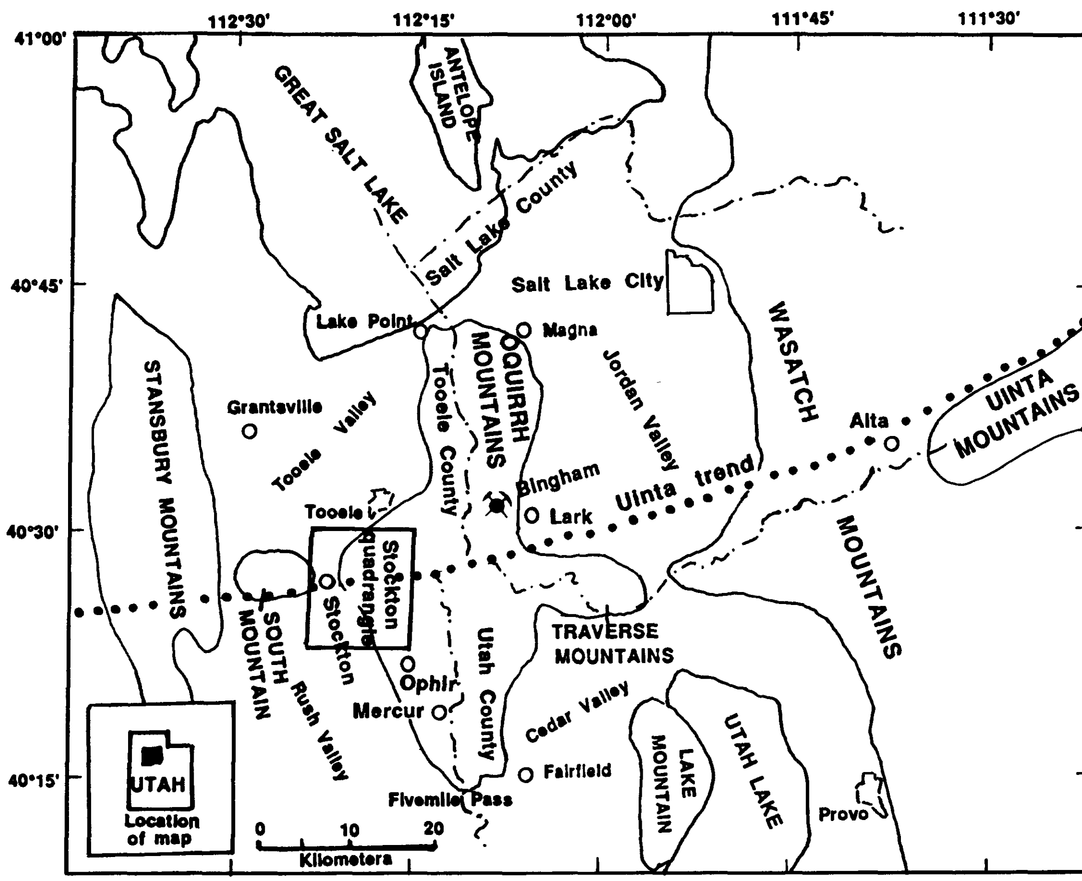

Figure 1.—Location of the Stockton 7 1/2-minute quadrangle, Utah, and the Uinta trend (heavy dots).

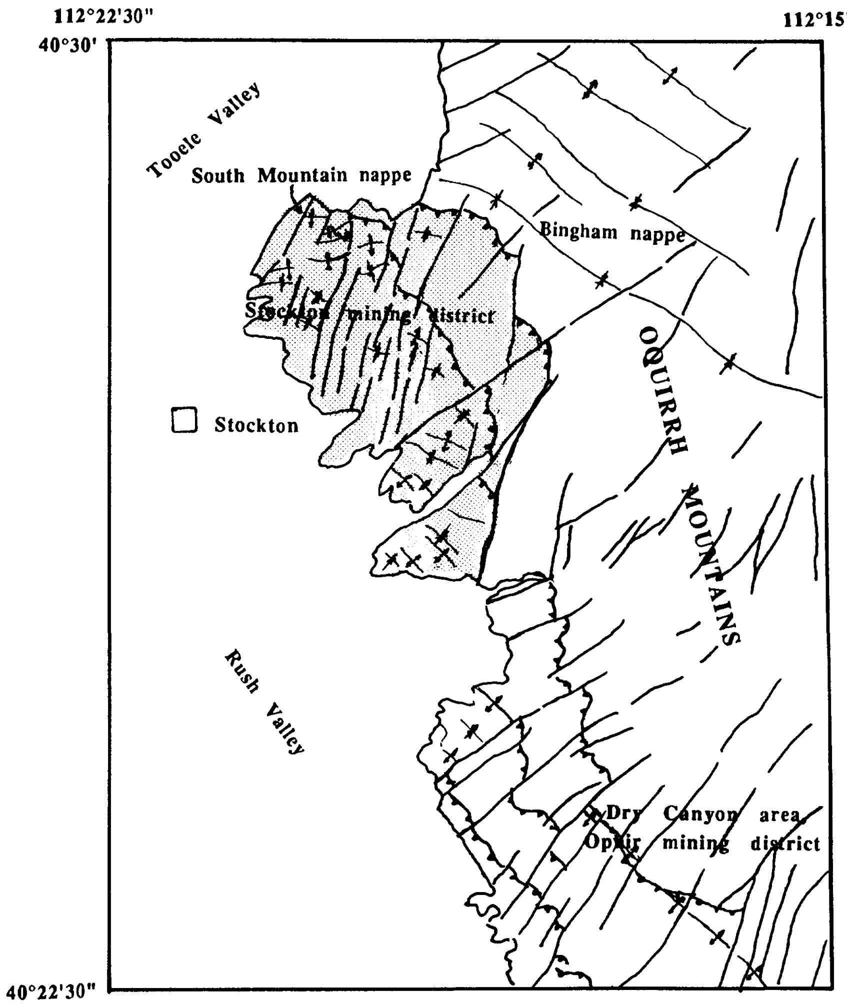

Figure 2. Location and major structures of the South Mountain and Bingham nappes in the Stockton 7 1/2-minute quadrangle, Utah.

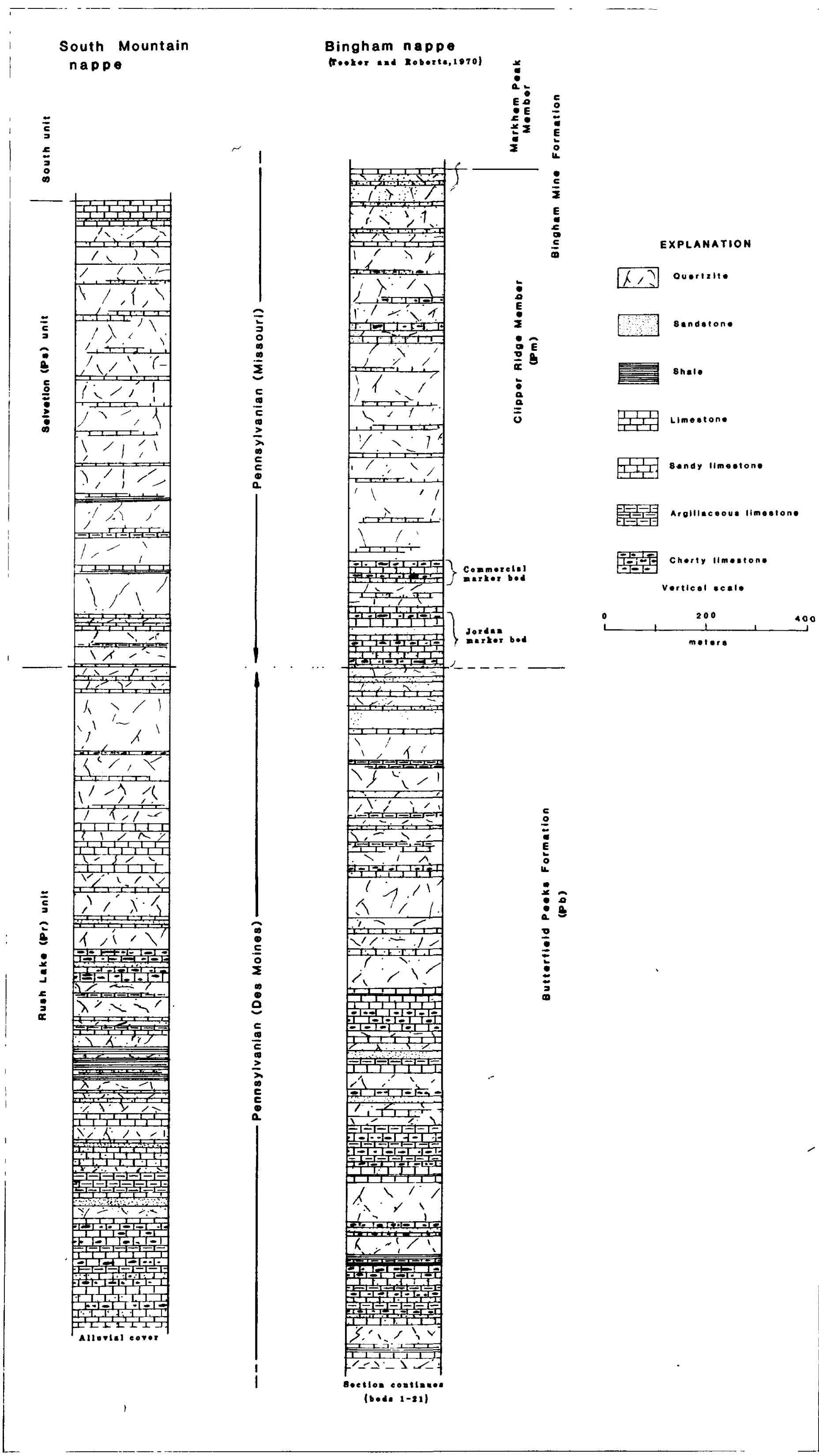

Figure 3.—Columnar stratigraphic sections of comparable parts of the South Mountain and Bingham nappes in the Stockton quadrangle, Utah.