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Geologic Map of the Cerro Gordo Peak 7.5’ Quadrangle, Inyo County, California

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INTRODUCTION

The Cerro Gordo Peak 7.5-minute quadrangle encompasses part of the southern Inyo Mountains about 25 km east of Lone Pine, California (figs. 1, 2). This area is of interest for its locally intense and historically important mineralization (McKee and others, 1985; Conrad and others, 1987) and its exposures of rocks and structural features that are key to reconstructing the geologic history and tectonic evolution of east-central California. The geologic map and cross sections presented in this report integrate the results of several different mapping efforts and related thematic studies by the authors over many years.

Parts of the Cerro Gordo Peak quadrangle were previously mapped and described by Page (1951), Merriam (1963), Elayer (1974), Stuart (1976), Stone (1977, 1984), Husk (1979), Mora (1983), Conrad (1993), Swanson (1996), and Stone and others (2000). Additional stratigraphic, paleontologic, and structural studies of the area include Merriam and Hall (1957), Gordon and Merriam (1961), Oborne (1983), Stone and Stevens (1987), Stone and others (1991), Dunne and Walker (1993), Dunne and others (1998), and Stevens and others (2001). The entire area was mapped by the late Ward C. Smith (U.S. Geological Survey) as the southeast quadrant of the New York Butte 15-minute quadrangle, but this mapping was never published. Our map incorporates Smith's structural data for a small area near the northeast corner of the quadrangle.

GEOLOGIC SETTING THROUGH TIME

In early Paleozoic time the southern Inyo Mountains area was part of the western continental shelf of North America. Ordovician to Devonian carbonate and subordinate quartzose rocks exposed in the Cerro Gordo Peak quadrangle are composed of shallow-water marine sediments that accumulated on the southwest-trending shelf (Stevens, 1986). During the latest Devonian to Early Mississippian Antler orogeny, early Paleozoic oceanic strata were thrust onto the western edge of the continental shelf to form a marginal uplifted belt. Antler thrusting and related deformation did not extend as far southeast as the Cerro Gordo Peak quadrangle, but the Late Mississippian Rest Spring Shale, considered part of a southeast-tapering wedge of siliciclastic strata derived from the Antler belt and deposited in an adjacent foreland basin (Stevens and others, 1997), is present.

By early Middle Pennsylvanian time, the orientation of the continental shelf had changed to southeastward, probably as a result of sinistral strike-slip faulting that truncated the continental margin (Stone and Stevens, 1988; Walker, 1988). Calcareous turbidites of the Keeler Canyon Formation were deposited in a basinal setting offshore from a carbonate platform that developed on the truncated continental shelf during Pennsylvanian to earliest Permian time (Stevens and others, 2001). The closest exposures of coeval shelf limestone representing the carbonate platform are in the Cottonwood Mountains 35 km east of the Cerro Gordo Peak quadrangle (fig. 1).

Early Permian strata that overlie the Keeler Canyon Formation were deposited in two basins separated by an intervening, northeast-trending submarine ridge (Stone and Stevens, 1988). The two basins received deposits of contrasting sedimentary facies, represented by the Lone Pine Formation on the northwest and the sedimentary rocks of Santa Rosa Flat on the southeast. The intervening ridge, represented by the area around Cerro Gordo Mine where strata of this age are not present, resulted from Early Permian contractional deformation and uplift (Stevens and Stone, 1988; Stevens and others, 1997).

Late Permian strata in the area (members A and B of the Conglomerate Mesa Formation) accumulated in small, shallow basins bounded by normal faults (Stone and others, 2000). Further contractional deformation in Late Permian time caused widespread tilting and additional uplift (Swanson, 1996; Stevens and others, 1997) leading to erosion that beveled an unconformity across the region prior to deposition of overlapping conglomerates of probable Early Triassic age (member C of the Conglomerate Mesa Formation). This period of conglomeratic deposition was followed by regional subsidence of the continental margin and quiescent marine deposition of the Union Wash Formation that persisted through Early Triassic and possibly into Middle Triassic time (Stevens and others, 1997; Stone and others, 2000).

Final withdrawal of marine waters from the region was followed in the Jurassic by the spread of volcanic and volcanogenic strata (Inyo Mountains Volcanic Complex) derived from the southwest. This episode persisted into the Late Jurassic (Dunne and Walker, 1993; Dunne and others, 1998) and marked one growth phase of the Sierran magmatic arc, the core of which lay west of the quadrangle. Intrusive outliers of the arc (dikes, sills, and plutons) sporadically invaded the southern Inyo Mountains region during Jurassic and Cretaceous time. Late Jurassic dikes of the Independence dike swarm (Chen and Moore, 1979; Carl and Glazner, 2002) are extensively exposed in the Cerro Gordo Peak quadrangle.

The Inyo Mountains and the adjacent bounding valleys, located in the westernmost part of the Basin and Range Province, are the result of late Cenozoic extensional faulting (Snow and Wernicke, 2000). In the Cerro Gordo

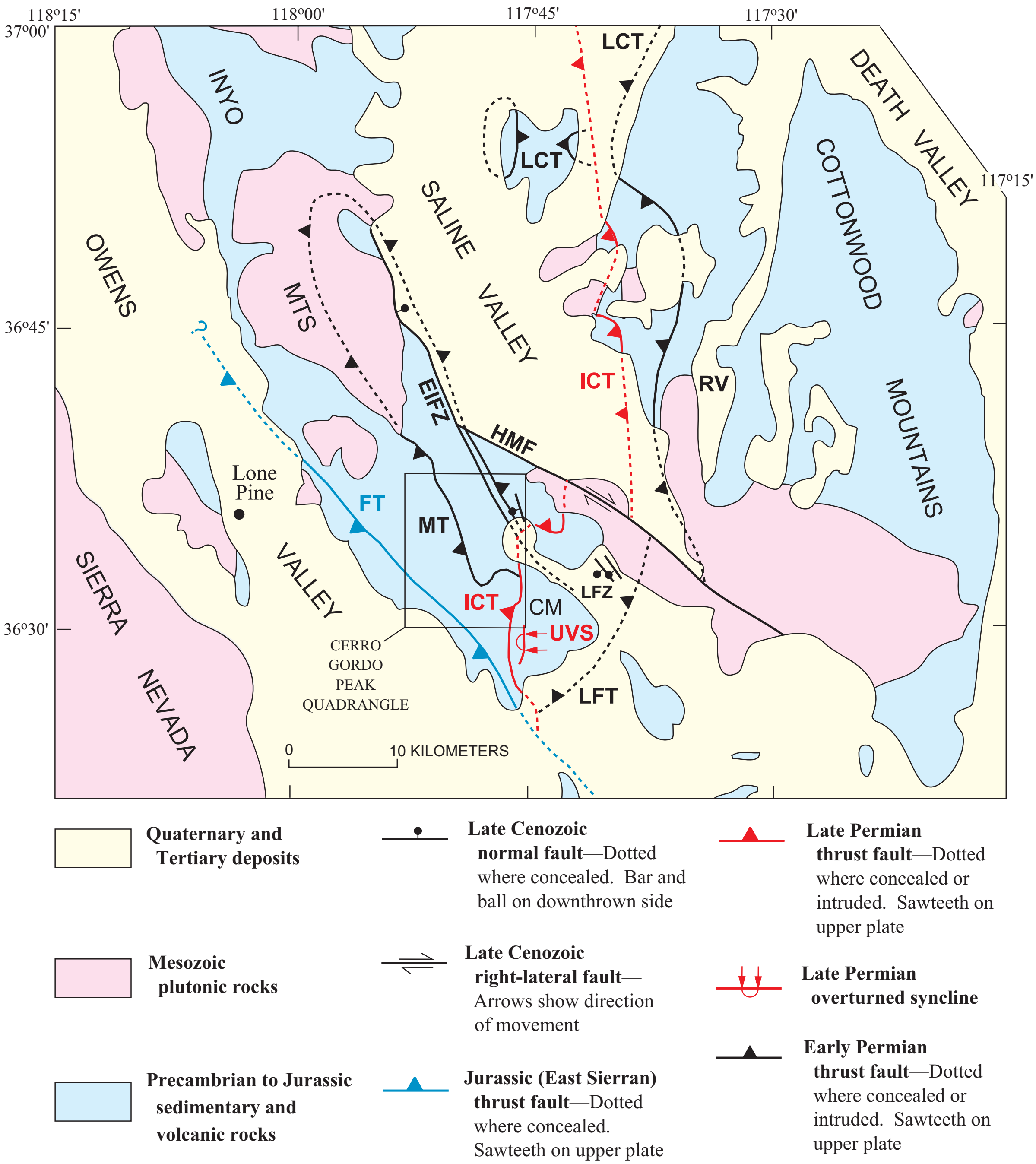

Figure 1. Generalized geologic map showing location of Cerro Gordo Peak 7.5' quadrangle in southern Inyo Mountains, California. CM, Conglomerate Mesa; EIFZ, Eastern Inyo Fault Zone; FT, Flagstaff Thrust; HMF, Hunter Mountain Fault; ICT, Inyo Crest Thrust; LCT, Last Chance Thrust; LFT, Lee Flat Thrust; LFZ, Lee Flat Fault Zone; MT, Morning Star Thrust; RV, Racetrack Valley; UVS, Upland Valley Syncline. Morning Star, Lee Flat, and Last Chance Thrusts are interpreted to have originated as related parts of an Early Permian thrust system; Inyo Crest Thrust is interpreted as Late Permian. Traces of Last Chance, Morning Star, Lee Flat, and Inyo Crest Thrusts are modified from Stevens and others (1997) based on recent studies by the authors; parts of these fault traces are speculative.

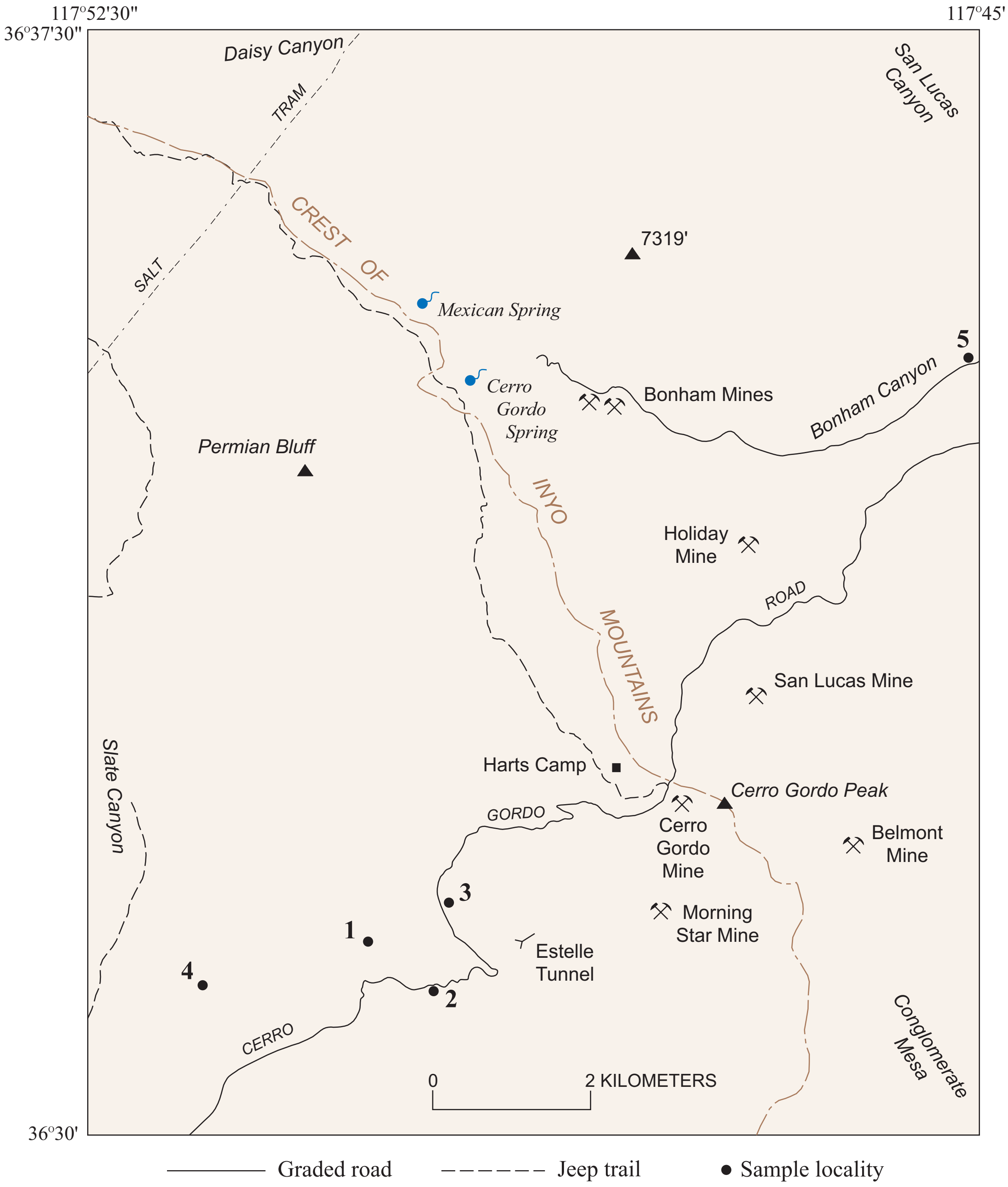

Figure 2. Map of Cerro Gordo Peak 7.5' quadrangle showing selected geographic features and geochronologic sample localities 1–5.

Peak quadrangle, early phases of uplift of the Inyo Mountains are marked by the fanglomerate of Bonham Canyon (Tfb, about 13.6 Ma) on the east side of the range (Conrad, 1993) and by the fanglomerate of Slate Canyon (Tfs, probably about 9 to 6 Ma) on the west side. Northwest-directed extensional tectonism continues in the region today (Savage and Lisowski, 1995).

MAJOR STRUCTURAL FEATURES

Rocks in the Cerro Gordo Peak quadrangle are complexly folded and faulted as a result of several episodes of deformation. Most of the structural features exposed in the quadrangle are attributed to deformation during the Permian, Jurassic-Cretaceous, and late Cenozoic.

Permian Structural Features

Structural and stratigraphic relations mapped in the Cerro Gordo Peak quadrangle and nearby areas indicate that substantial deformation, mostly contractional in nature, occurred in the area during Permian time. Our current interpretation, which modifies the synthesis of Stevens and others (1997), is that there were at least two distinct episodes of Permian contractional deformation, one Early Permian and the other Late Permian in age, and one episode of Late Permian normal faulting.

Structural relations observed on the west flank of the Inyo Mountains near Cerro Gordo Mine suggest that a major zone of thrust faulting, subparallel to bedding, is localized along the Late Mississippian Rest Spring Shale. The principle fault, called the Morning Star Thrust by Elayer (1974) in reference to the Morning Star Mine (fig. 2) that lies along it, separates the Rest Spring Shale from the overlying Keeler Canyon Formation, and we refer to the entire zone of faulting as the Morning Star Thrust Zone. Some key observations along this zone are (1) the thickness of the Rest Spring Shale varies substantially along strike; (2) the contact between the Rest Spring Shale and Keeler Canyon Formation is sheared, and at one locality shows kinematic microstructures indicating reverse sense of slip; and (3) folds in the Keeler Canyon Formation locally are truncated at the contact with the Rest Spring Shale. In the northwest part of the quadrangle, one or more low-angle faults inferred to be part of the Morning Star Thrust Zone cut through the Rest Spring Shale and place this unit on older Mississippian or Devonian rocks. In the south part of the quadrangle near the Morning Star Mine, the Rest Spring Shale locally encloses isolated blocks of Tin Mountain Limestone, Mexican Spring Formation, and Keeler Canyon Formation. The faults that bound these blocks are presumably coeval with the Morning Star Thrust.

The Morning Star Thrust Zone may be part of a widespread Early Permian thrust fault system that also includes the Last Chance Thrust of Stewart and others (1966), which is exposed both north and northeast of the Cerro Gordo Peak quadrangle (fig. 1) and typically places Precambrian or Cambrian strata on the Rest Spring Shale. As first proposed by Stevens and others (1997), the Morning Star Thrust could have developed as a distal, younger-on-older part of the Last Chance Thrust, following the structurally weak Rest Spring Shale, southeast of a major ramp anticline represented by the more typical exposures of the Last Chance allochthon (fig. 3). We continue to prefer this hypothesis and infer that most exposures of the Rest Spring-Keeler Canyon contact in the quadrangle represent parts of this major fault system. The Morning Star Thrust also may be connected to the Early Permian Lee Flat Thrust (Stevens and Stone, 1988; Stone and others, 1989) 7 km east of the quadrangle (fig. 1). Snow (1992) previously proposed a connection between the Last Chance and Lee Flat Thrusts.

An east-vergent, overturned syncline in the Keeler Canyon Formation just northwest of Conglomerate Mesa near the southeast corner of the quadrangle is unconformably overlapped by late Early Permian limestone conglomerate (Psc). This fold is thus of Early Permian age and could be coeval with the Lee Flat Thrust. The fold and overlapping unconformity probably developed on a structural high in the upper plate of the Lee Flat Thrust complex. This high separated Early Permian depositional basins of the Lone Pine Formation to the northwest and the sedimentary rocks of Santa Rosa Flat to the southeast (Stevens and Stone, 1988).

Late Permian contractional deformation in the southern Inyo Mountains is represented by the Inyo Crest Thrust of Swanson (1996) and Stevens and others (1997), which is exposed just south of the quadrangle boundary (fig. 1). There, the Inyo Crest Thrust cuts the Keeler Canyon Formation and is overlapped by the Union Wash Formation. The east-vergent Upland Valley Syncline in the footwall of the thrust in that area (fig. 1) folds rocks as young as the siltstone and pebbly limestone unit of the sedimentary rocks of Santa Rosa Flat. Detailed mapping by Swanson (1996) indicates that an early phase of folding of the Upland Valley syncline and movement on the Inyo Crest Thrust may have occurred in Early Permian time, before deposition of the siltstone and pebbly limestone unit, but the main phase of deformation represented by these structural features clearly postdated that depositional event.

We speculate that the Inyo Crest Thrust continues northward across the southeast part of the Cerro Gordo Peak quadrangle, where it is covered by late Cenozoic deposits except for an area of continuous bedrock exposure northwest of Conglomerate Mesa. There, we interpret the Inyo Crest Thrust to be marked by a zone of faulting that

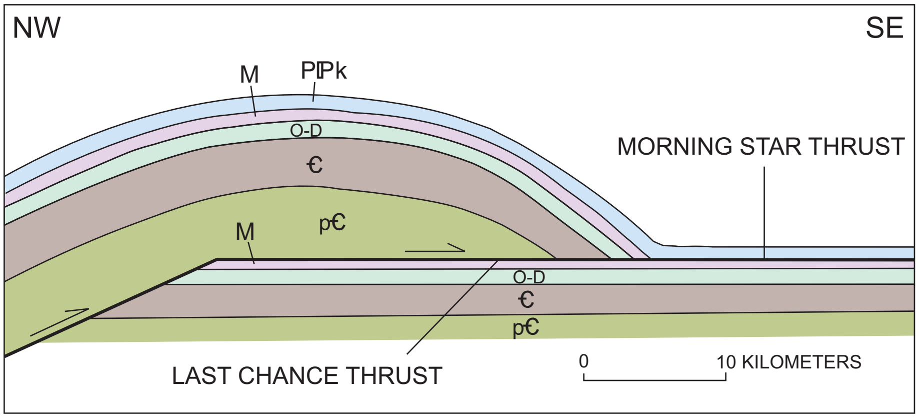

Figure 3. Model showing inferred structural connection between Last Chance Thrust, exposed in northern Inyo Mountains (north of area shown in figure 1), and Morning Star Thrust, exposed in southern Inyo Mountains including Cerro Gordo Peak quadrangle. Diagram depicts generalized structural relations thought to exist at the end of Early Permian thrusting; later deformation has greatly complicated the inferred original relations. pЄ, Precambrian rocks; Є, Cambrian rocks; O-D, Ordovician to Devonian rocks; M, Mississippian rocks, including Late Mississippian Rest Spring Shale; PIPk, Pennsylvanian to Early Permian Keeler Canyon Formation.

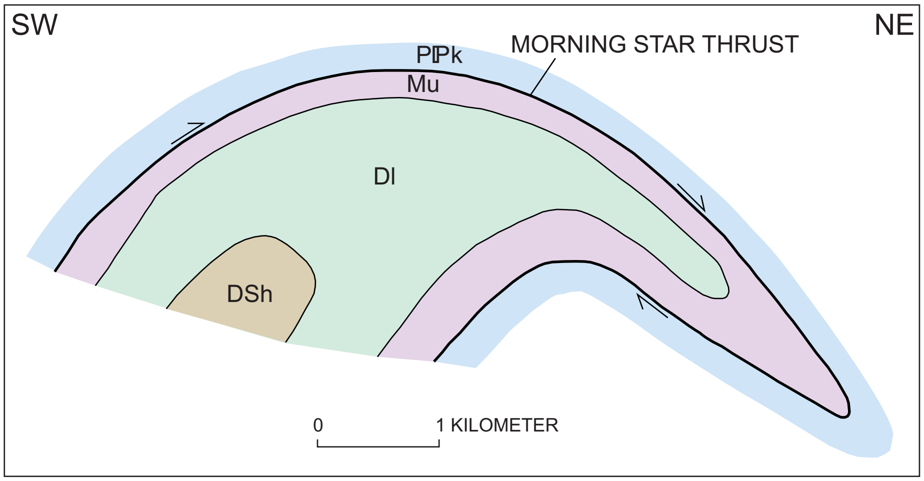

Figure 4. Generalized reconstruction of refolded overturned anticline shown in cross section *A-A'*, with younger intrusions removed and younger fault displacements restored. DSh, Hidden Valley Dolomite; Dl, Lost Burro Formation; Mu, Mississippian rocks, undivided; PIPk, Keeler Canyon Formation. In this reconstruction, Morning Star Thrust is interpreted as older than, and folded by, the overturned anticline, which was later antiformally refolded. Alternatively, fault shown here as overturned Morning Star Thrust could be a separate, structurally lower, east-directed thrust placing overturned Rest Spring Shale on Keeler Canyon Formation. Diagram does not show poorly understood faults, mapped as thrusts, that cut the Mississippian rocks in several places and locally juxtapose the Rest Spring Shale and Lost Burro Formation.

cuts the Rest Spring Shale and Keeler Canyon Formation, offsetting the eastward extension of the Morning Star Thrust. In this area, however, the Inyo Crest Thrust may have been reactivated by younger thrust faults extending northward from the west flank of Conglomerate Mesa.

In addition to these contractional events, the Cerro Gordo Peak quadrangle also was affected by Late Permian normal faulting. This faulting created basins in which members A and B of the Conglomerate Mesa Formation were deposited, as mapped and described in detail by Stone and others (2000). These basins and the bounding faults are overlapped by member C of the Conglomerate Mesa Formation, which we infer to be of Early Triassic age.

Jurassic-Cretaceous Structural Features

Northwest-trending thrust faults, folds with accompanying cleavage, general ductile flattening, and conjugate strike-slip faults in the Cerro Gordo Peak quadrangle are considered to be representatives of the East Sierran Thrust System (Dunne, 1986), a northwest-trending belt of contractional features that extends from southern Owens Valley southeastward into the Mojave Desert. Principal thrust faults of the belt, including the Flagstaff Thrust (fig. 1) that places the Lone Pine Formation above the Inyo Mountains Volcanic Complex, seem to be restricted to the west flank of the southern Inyo Mountains, but folds and cleavage extend across the full width of the range. Near the southeast corner of the quadrangle, minor thrust faults of post-Early Triassic age on the west flank of Conglomerate Mesa are probably part of the East Sierran Thrust System.

Geochronologic data and field relations outside the quadrangle indicate that some thrust faults and folds that probably represent an early phase of contraction in the East Sierran Thrust System predate Middle Jurassic plutons. Important deformational phases also affected this system during Late Jurassic and perhaps later Mesozoic time (Dunne, 1986; Dunne and Walker, 1993; Dunne and others, 1998). Estimated minimum shortening accommodated by the East Sierran Thrust System is about 15 km as measured across the southern Inyo Mountains.

Folding of Uncertain Age

Paleozoic and Mesozoic strata in the Cerro Gordo Peak quadrangle define a generally anticlinal structure evident from the map pattern of geologic units and bedding attitudes. Merriam (1963) attributed this structure to a complex anticline of presumed Mesozoic age that he called the Cerro Gordo Anticline and mapped as a single fold along and east of the crest of the Inyo Mountains.

Subsequent mapping indicates a more complex fold structure. In the south part of the quadrangle, our mapping is largely consistent with that of Merriam (1963) although continuity of the anticlinal structure is more disrupted by faulting than previously recognized. In the north part of the quadrangle, however, our mapping reveals a much more complex fold geometry that apparently evolved through at least two distinct episodes of deformation (see cross section *A-A'*). We provisionally infer that the first deformation created an eastward overturned anticline cored at the present level of exposure by the Lost Burro Formation and Hidden Valley Dolomite and involving rocks at least as young as Keeler Canyon Formation. The second deformation antiformally refolded the overturned limb of this anticline, as observed on a hill (elev. 7319 ft) 2.8 km south of the north quadrangle boundary and 4.4 km west of the east quadrangle boundary (fig. 2). The upright upper limb of the older overturned anticline presumably was antiformally refolded as well, and it apparently includes the generally east dipping, upright section of Keeler Canyon Formation exposed in the northeast part of the quadrangle, downfaulted from its original position relative to the rocks on the west. The inferred original geometry of this complex structure, reconstructed from cross section *A-A'* by removing the effects of younger intrusion and faulting, is shown in figure 4.

The ages of these folding events are uncertain. The west-dipping flank of the anticline contains rocks as young as Late Jurassic (Inyo Mountains Volcanic Complex). The younger antiform in the north part of the quadrangle, however, is apparently older than Middle Jurassic(?) granitoid rocks of varied composition (Jgv) that intrude it. Thus, much of the folding may have been completed prior to Middle Jurassic time, after which the western limb of the anticline could have been steepened by younger deformation. Preliminary reconstructions of the folds suggest that the overturned anticline in the north part of the quadrangle was originally highly asymmetrical, with a gently west dipping axial surface and a subhorizontal upper limb, and could be as old as Permian.

Late Cenozoic Structural Features

The southern Inyo Mountains are part of the westernmost uplifted block within the Basin and Range province. Unlike many nearby ranges to the east, this block has not experienced substantial unidirectional tilting either to the east or west. Instead, moderate sagging or tilting to both the west and east developed locally, suggesting that the range is a relatively simple horst bounded on both flanks by major fault zones that separate it from the Saline Valley graben to the east and Owens Valley graben to the west.

The principal bounding fault system along the east side of the southern Inyo Mountains is east and north of the Cerro Gordo Peak quadrangle (fig. 1). This fault system, which remains active today, is interpreted to have evolved during the last 3 m.y. as Panamint and Saline Valleys developed (Zellmer, 1980; Burchfiel and others, 1987; Snow and Wernicke, 2000). The northeast part of the Cerro Gordo Peak quadrangle, however, reveals evidence of an older episode of extensional faulting and range uplift. In this area, an east-dipping normal fault zone (Eastern Inyo Fault Zone of Conrad, 1993) strikes southward from the active fault zone on the west side of Saline Valley (fig. 1). Poorly constrained estimates of normal slip on this fault zone are as much as 1.2 km. The fault zone projects beneath the fanglomerate of Bonham Canyon, which represents an alluvial fan complex that spread eastward from the faulted range front. Isotopic ages of 14 to 13 Ma on tephra near the base of the fan complex provide a minimum age of faulting (Conrad, 1993).

About 1 to 2 km east of the Eastern Inyo Fault Zone, a west-dipping normal fault zone offsets the lowermost part of the fanglomerate of Bonham Canyon and its basal contact with the Keeler Canyon Formation. This fault is marked by a well-developed gouge zone. Farther south, an east-side-down fault is inferred to cut the fanglomerate of Bonham Canyon based on a moderately well defined, east-facing topographic scarp. These faults evidently postdate activity on the Eastern Inyo Fault Zone and may be structurally related to the Lee Flat Fault Zone of Zellmer (1980), a zone of northwest-striking normal faults that cut late Cenozoic basalt and alluvium probably equivalent to the fanglomerate of Bonham Canyon about 6 km to the southeast (fig. 1).

No major zone of active normal faults has been mapped along the western base of the southern Inyo Mountains. However, a prominent northwest-trending gravity anomaly located just west of bedrock exposures along the base of the southern Inyo Mountains has been inferred to delineate a major normal fault system defining the boundary between the sediment-filled Owens Valley graben and the Inyo Range horst (Pakiser and others, 1964). Some normal faulting along the west side of the range probably predated the late Miocene (9 to 6 Ma) fanglomerate of Slate Canyon now exposed there.

A conspicuous but relatively minor fault presumably related to late Cenozoic extension along the western base of the southern Inyo Mountains is poorly exposed near the southwest corner of the Cerro Gordo Peak quadrangle. This northwest-trending fault cuts the fanglomerate of Slate Canyon and drops the northeast side down; systematic dextral offset of drainages along the trace of this fault suggests that it has a component of lateral slip as well. Just south of the quadrangle, a colinear fault that cuts equivalent strata shows gently south plunging slickenlines (Swanson, 1996). The presence of these slickensides reinforces the interpretation that this is an oblique-slip fault zone accommodating both normal and dextral displacement.

Within the range block itself, several prominent north- to northwest-striking faults cut Paleozoic sedimentary rocks and Mesozoic plutonic rocks on the east slope of the Inyo Mountains in the north part of the Cerro Gordo Peak quadrangle. These faults, commonly marked by zones of intense brecciation, apparently formed at relatively shallow depths. Our mapping supports the interpretation of Merriam (1963) that most of these faults probably are steep normal faults with the west side down. The faults are of unknown age, but their structural characteristics suggest that they could be late Cenozoic.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qa	**Alluvium (Quaternary)**—Waterlain deposits of unconsolidated, locally derived gravel and sand in washes, valleys, and alluvial fans
Qt	**Talus (Quaternary)**—Unconsolidated accumulations of angular gravel deposited under influence of gravity at the bases of steep slopes
Qat	**Alluvium and talus, undivided (Quaternary)**
Qls	**Landslide deposits (Quaternary)**—Lobate, steeply sloping masses of weakly consolidated, unsorted gravel on east side of Inyo Mountains in northeast part of quadrangle. Includes a few areas of relatively intact bedrock units interpreted as slide blocks
Qoa	**Older alluvium (Quaternary)**—Weakly consolidated alluvial gravel deposits that form dissected terraces above more recent alluvial surfaces. Includes thin, dissected aprons of alluvial and (or) colluvial gravel derived from Jurassic(?) hornblende monzodiorite to monzonite porphyry (Jmp) in southeast part of quadrangle

QTr **Rubble (Quaternary or Tertiary)**—Unsorted, weakly consolidated gravel composed of reddish-brown conglomerate and sandstone west of Conglomerate Mesa near southeast corner of quadrangle. Possibly the remains of an ancient landslide deposit derived from altered (jasperized) conglomerate and sandstone of member C of the Conglomerate Mesa Formation exposed a short distance to the southeast

Tfs **Fanglomerate of Slate Canyon (Miocene)**—Weakly to moderately consolidated, bedded gravel and sand forming thick, deeply dissected deposits on west side of Inyo Mountains. Derived from Paleozoic and Mesozoic units of Inyo Mountains. Ash bed at locality 4 shown on map is interpreted as late Miocene (9–6 Ma) on the basis of tephrochronologic analysis (A.M. Sarna Wojcicki, written commun., 1998). South of quadrangle, Swanson (1996) mapped similar and presumably correlative deposits stratigraphically beneath late Miocene basalt dated as 6.7–4.3 Ma by Larsen (1979)

Tfb **Fanglomerate of Bonham Canyon (Miocene)**—Thick sequence of gravel deposits forming deeply dissected ridges on east side of Inyo Mountains. Composed of moderately to well-cemented, massive to bedded, pebble to cobble conglomerate that locally contains boulders as much as 1 m in diameter. Gravel consists primarily of limestone and dolomite (about 70 percent), siliceous sedimentary rocks (mostly siltstone) (about 25 percent), and minor igneous rocks (mostly biotite-hornblende quartz monzonite). Clast composition and paleocurrent measurements suggest a primary source area in the Inyo Mountains to west (Conrad, 1993). Unit age based on K-Ar and ^{40}Ar/^{39}Ar geochronologic analyses of biotite from ash bed 5 m above base of gravels near the east edge of quadrangle (locality 5), which indicate a middle Miocene age of 13.62 ± 0.52 Ma (Conrad, 1993). Estimated minimum thickness of unit about 365 m. Includes the following unit:

Tfbq **Quartz monzonite gravel unit**—Comprises basal part of fanglomerate in northeasternmost part of exposure area. Differs from main part of fanglomerate in consisting largely to entirely of gray, brown-weathering, hornblende-bearing quartz monzonite gravel. Boulders of quartz monzonite as much as 3 m in diameter are present locally. Probable source of this debris is the Jurassic Hunter Mountain batholith, which contains lithologically similar rocks and is widely exposed near the Cerro Gordo Peak quadrangle to the east and north (for example, McAllister, 1956; Ross, 1969)

INTRUSIVE ROCKS

[Unit ages are based primarily on general correlations with lithologically similar rocks of Cretaceous and Jurassic ages outside quadrangle and on crosscutting intrusive relations exposed in quadrangle and nearby areas.]

q **Quartz veins (Cenozoic or Mesozoic)**—Intrusive into Mississippian rocks near Cerro Gordo Mine. Includes Castle Rock vein of Merriam (1963)

KJg **Leucocratic granite (Cretaceous or Jurassic)**—Light-colored, medium-grained biotite granite exposed as small masses that intrude Lone Pine Formation in southwest part of quadrangle

KJdi **Diorite (Cretaceous or Jurassic)**—Biotite-hornblende diorite spatially associated with leucocratic granite (KJg)

KJf **Younger felsite intrusions (Early Cretaceous or Late Jurassic)**—Light-colored, aphanitic to very fine grained intrusions, primarily dikes, composed of microcrystalline feldspar, quartz, and minor muscovite; locally spherulitic. Intrusions are thoroughly hydrothermally altered but are internally undeformed and postdate NW-trending East Sierran structural features; one dike is cut by a NNE-striking fault of the younger conjugate set. Locally cuts dark-colored dikes (Jd). Dike at locality 3 shown on geologic map has a U-Pb (zircon) minimum age of 140 ± 8 Ma (Dunne and Walker, 1993)

Jd **Dark-colored dikes (Late Jurassic?)**—Dark-gray, greenish-gray, and reddish-brown, porphyritic dikes, probably of dioritic composition. Composed of 10–50 percent plagioclase, hornblende, and pyroxene phenocrysts mostly 1–3 mm long in an altered microcrystalline groundmass of relatively fresh to thoroughly saussuritized feldspar and variable amounts of hornblende, pyroxene, chlorite, epidote, calcite, limonite, opaque minerals, and, in some samples, minor quartz. Plagioclase phenocrysts range from relatively fresh to thoroughly saussuritized; hornblende and pyroxene phenocrysts are variably replaced by chlorite, epidote, calcite, and other alteration minerals. Dikes are mostly 1–5 m wide; a few are as wide as 50–100 m. Most dikes in east part of quadrangle are undeformed except by Cenozoic(?) brittle faults. Dikes in southwest part of quadrangle range from undeformed to variably sheared, cleaved, and boudinaged as a result of deformation related to the East Sierran Thrust System. Considered part of the Independence dike swarm (Moore and Hopson, 1961), which is interpreted as mainly Late Jurassic (about 148 Ma) in age (Chen and Moore, 1979), although some associated dikes are as young as Late Cretaceous (Coleman and others, 1999). Undated in quadrangle

Jmh **Mafic hypabyssal intrusion (Jurassic?)**—Large, discordant mass intrusive into lower and middle parts of the Inyo Mountains Volcanic Complex

Jf **Older felsite intrusions (Jurassic?)**—Light-colored, aphanitic to fine-grained, aphyric and porphyritic felsite that intrudes Keeler Canyon and Lone Pine Formations in southwest part of quadrangle. Composed of microcrystalline to fine-grained, variably saussuritized feldspar and rare to abundant (about 40 percent) quartz; some contains relatively fresh to thoroughly saussuritized plagioclase phenocrysts 0.5–3 mm long. Occurs primarily as sills as wide as 230 m; in Slate Canyon, forms discordant plutons. Intruded by dark-colored dikes (Jd). Inferred to predate deformation related to the East Sierran Thrust System based on field relations 2–3 km south of quadrangle (Swanson, 1996)

Ji **Altered fine-grained intrusions (Jurassic?)**—Brown to orangish-brown, highly altered and weathered intrusive rocks forming a semiconcordant sill, dismembered by younger faults, that intrudes lower and middle members of Union Wash Formation near south edge of quadrangle. Aphanitic to fine-grained, containing phenocrysts less than 2 mm in diameter; composed of sericitized plagioclase, altered pyroxene or hornblende, quartz, and abundant opaque minerals. Original composition possibly diorite. Lithologically similar rocks 1–4 km south of quadrangle are intruded by Independence dike swarm and predate deformation related to the East Sierran Thrust System (Swanson, 1996)

Jad **Altered diorite (Jurassic?)**—Variably sheared greenish-gray to reddish-brown, medium- to very fine grained hornblende(?)-biotite diorite and quartz diorite that is moderately to intensely hydrothermally altered to mixtures of white mica, chlorite, and iron oxides and hydroxides. Occurs in the Inyo Mountains Volcanic Complex as several northwest-elongate bodies coincident with a similarly oriented zone of intense pyritic and hydrothermal alteration that may mark a diffuse shear zone

Granite (Jurassic?)—Small granitic plutons intruding Mississippian and Devonian strata on east slope of Inyo Mountains in north part of quadrangle. Divided into the following subunits:

Jbg **Medium-grained biotite granite**—Light-gray, medium-grained granite containing 5–10 percent biotite and subequal amounts of zoned plagioclase, microcline, and quartz; average grain size 1–2 mm. Intruded by a dark-colored dike (Jd) at one locality

Jlg **Fine-grained leucocratic granite**—Very light colored, fine-grained granite almost devoid of mafic minerals and composed of subequal amounts of sericitized plagioclase, microcline, and quartz; average grain size about 0.5 mm. Considered Jurassic(?) in age because of proximity and general lithologic similarity to Jbg

Jmp **Hornblende monzodiorite to monzonite porphyry (Jurassic?)**—Quartz-poor porphyritic rocks forming several discordant intrusions near the Cerro Gordo Mine in southeast part of quadrangle. Composed of 75–85 percent phenocrysts in a dark, fine-grained groundmass of anhedral potassium feldspar, hornblende, minor quartz, and alteration minerals. Phenocrysts are 80–90 percent plagioclase (2–10 mm long, zoned, relatively fresh to thoroughly saussuritized); 5–20 percent hornblende (1–4 mm long, variably recrystallized and altered to calcite and chlorite); and 0–5 percent pink potassium feldspar (2–5 mm long). Hornblende phenocrysts are particularly conspicuous in mass near Harts Camp 1 km NW of Cerro Gordo Mine. Overall mineral composition is 50–70 percent plagioclase, 10–35 percent potassium feldspar, 15–25 percent hornblende, and less than 5 percent quartz; a few samples contain accessory apatite. Locally intruded by dark-colored dikes (Jd)

Jgv **Granitoid rocks of varied composition (Jurassic?)**—Lithologically varied granitoid rocks in north part of quadrangle. Consists primarily of medium-grained, locally porphyritic monzonite to quartz monzonite composed of 35–40 percent plagioclase, 30–40 percent microcline, 5–20 percent quartz, and 15–20 percent mafic minerals (hornblende ± biotite); most rocks contain less than 10 percent quartz. Porphyritic varieties contain phenocrysts of pink microcline 5–10 mm long. Includes subordinate medium- to coarse-grained, locally porphyritic granite composed of 30–35 percent plagioclase, 35–40 percent microcline, 20–30 percent quartz, and less than 10 percent mafic minerals (biotite ± hornblende); coarse-grained porphyritic varieties contain phenocrysts of pink microcline as much as 15 mm long. Granite locally intrudes the more voluminous monzonite to quartz monzonite and may represent a separate intrusive event. Southernmost exposures of unit include abundant reddish-brown-weathering, biotite-hornblende quartz diorite to quartz monzodiorite in addition to the more typical, less deeply weathered quartz monzonite. Unit is possibly correlative with lithologically similar Middle Jurassic Pat Keyes pluton (Ross, 1969; Dunne, 1970) exposed 10–30 km northwest of quadrangle

Jdi **Diorite (Jurassic?)**—Small outcrops of dark-colored, fine- to medium-grained, biotite-hornblende and biotite-clinopyroxene diorite in northeast part of quadrangle

SEDIMENTARY AND VOLCANIC ROCKS

Inyo Mountains Volcanic Complex (Jurassic)—Lithologically heterogeneous volcanic and volcanogenic sedimentary rocks. Age of complex based on U-Pb (zircon) geochronologic data from rocks exposed in quadrangle and nearby areas to northwest (Dunne and Walker, 1993; Dunne and others, 1998). Divided into the following subunits:

Jivu **Upper part (Late and Middle Jurassic)**—Volcanogenic sandstone, siltstone, and conglomerate (about 95 percent of unit), rare calcareous strata, and welded tuff and lava flows. Volcanic rocks in lower half and near middle of unit have U-Pb (zircon) minimum ages of about 163 and 148 Ma, respectively

Jivm **Middle part (Middle Jurassic)**—Silicic crystal-lithic welded ash-flow tuff (about 60 percent of unit), andesite and rhyolite lava flows (about 30 percent), and volcanogenic sandstone and conglomerate. Welded tuffs near top and middle of unit at localities 1 and 2 shown on geologic map, respectively, have preferred U-Pb (zircon) ages of 169 ± 4 Ma and 168 ± 3 Ma (Dunne and Walker, 1993)

Jivl **Lower part (Middle or Early Jurassic?)**—Volcanogenic sandstone, conglomerate and breccia in laterally variable proportions (70 to 90 percent of unit); remainder composed of basaltic lava flows and one felsic tuff. Includes basal conglomeratic unit as much as 80 m thick (cg) containing limestone clasts in the lower part and volcanic-rock clasts in the upper part. Stratigraphic relations at base of unit generally obscured along faulted contact with Union Wash Formation. Undated

Union Wash Formation (Middle? and Early Triassic)—Fine-grained marine sedimentary rocks including shale, siltstone, sandstone, and limestone. Average thickness in quadrangle 700–800 m; measured thickness 690 m in reference section 3 km southeast of Permian Bluff (Stone and others, 1991). Contains fossils of Early and Middle(?) Triassic age (Merriam, 1963; Stone and others, 1991). Divided into the following members:

Upper member (Middle? and Early Triassic) —Divided into the following subunits:

Ꞧuu$_4$ **Subunit 4**—Consists primarily of brown- to yellowish-brown, thin-bedded quartzose siltstone and shale. Upper part contains limestone and dolomite including a 4- to 20-m-thick bed of medium- to dark-gray, micritic and locally oolitic limestone (ls) that is structurally repeated by folding and faulting near Cerro Gordo Road (fig. 2). Thickness 200–300 m

Ꞧuu$_3$ **Subunit 3**—Dark-gray, ledge-forming micritic limestone. Forms planar beds 1–5 cm thick separated by thin partings of light-brown siltstone or mudstone. Thickness 75–95 m

Ꞧuu$_2$ **Subunit 2**—Consists primarily of gray, purplish-gray, brownish-gray, and brown quartzose siltstone to very fine grained sandstone and light- to medium-gray limestone; basal 10 m consists of yellow shale. Thickness 80–100 m

TRuu$_1$ **Subunit 1**—Dark-gray micritic limestone; forms a massive ledge. Average thickness about 10 m

TRum **Middle member (Early Triassic)**—Yellow shale and medium-gray, thin-bedded micritic limestone. Limestone beds planar, 1–10 cm thick. Most parts of member consist primarily of shale and widely spaced limestone interbeds, but a few limestone-dominated intervals 1–25 m thick are present. Uppermost 40–50 m is a marker zone of bright yellowish brown shale. Thickness 200–300 m

TRul **Lower member (Early Triassic)**—Gray to brown, silty to sandy limestone and calcareous siltstone to fine-grained sandstone. Characterized by thin, planar to wavy bedding, distinctive nodular texture, and local presence of minute black gastropod molds. Forms resistant crags and hogbacks. Thickness generally 30–40 m, but pinches out in some areas and locally thickens to 100 m or more in northwest part of quadrangle. Locally includes the following unit:

TRuls **Basal sandstone unit**—Yellowish-gray, fine-grained calcareous sandstone and siltstone, and subordinate dark-gray mudstone. Present only near south edge of quadrangle; maximum thickness about 40 m

Owens Valley Group (Early Triassic to Early Permian)—Lithologically diverse marine and nonmarine sedimentary rocks that have an estimated maximum stratigraphic thickness of between 1,400 and 1,900 m in northwest part of quadrangle. Largely Permian in age based on fossils previously reported from quadrangle and adjacent areas (Merriam, 1963; Stone, 1984; Stone and Stevens, 1987; Magginetti and others, 1988; Stone and others, 1989, 2000). Uppermost unit in group (member C of Conglomerate Mesa Formation), originally considered Late Permian in age, is herein interpreted as Early Triassic based on conformable relation with overlying lower member of Union Wash Formation and recent recognition of unconformity with underlying Late Permian member B of Conglomerate Mesa Formation (Stevens and others, 1997; Stone and others, 2000). In this area, consists of the following units:

Conglomerate Mesa Formation (Early Triassic and Late Permian)—Lenticular sequence of shallow-water marine and nonmarine sedimentary rocks consisting mainly of conglomerate and limestone. Exposed primarily in northwest part of quadrangle, which includes type section of formation at Permian Bluff (Stone and Stevens, 1987); also present near southeast corner of quadrangle at Conglomerate Mesa. Maximum thickness about 225 m; measured thickness 173 m at Permian Bluff. Divided into the following members:

TRcc **Member C (Early Triassic)**—Conglomerate and sandstone. Conglomerate weathers brown, ranges from massive to well bedded, and consists primarily of angular to subrounded clasts of white to light-gray chert, quartzite, and limestone in a poorly sorted, fine- to coarse-grained sandstone matrix. Chert and quartzite clasts are mostly pebble size; limestone clasts range from pebble to boulder size. Sandstone, most common near top of member, is yellowish-brown, thin-bedded to laminated, fine grained, and locally has ripple marks. Maximum thickness about 180 m. Base unconformable

Pcb **Member B (Late Permian)**—Light-gray, sandy limestone that forms resistant ledges and hogbacks. Bedding ranges from plane laminated to massive; plane-laminated facies, most common in lower part of member, alternates with thin beds and lenses of sandstone and chert-pebble conglomerate. Contains ammonoids of Late Permian age (Gordon and Merriam, 1961; Merriam, 1963; Stone and others, 2000); also contains brachiopods, gastropods, and conodonts. Maximum thickness about 130 m

Pca **Member A (Late Permian)**—Grayish-orange to yellowish-brown, fine- to coarse-grained, quartzitic sandstone and chert-pebble conglomerate. Sandstone plane laminated to gently crosslaminated; conglomerate is composed primarily of angular, white- to light-gray chert pebbles and rare limestone clasts in size-sorted, planar beds 10–15 cm thick. Maximum thickness about 100 m. Base unconformable

Sedimentary rocks of Santa Rosa Flat (Early Permian)—Internally conformable sequence of marine sedimentary rocks that underlies Conglomerate Mesa Formation in southeast part of quadrangle near Conglomerate Mesa. Component units are interpreted to be approximately correlative with units 10–12 of sedimentary rocks of Santa Rosa Flat as described by Magginetti and others (1988) and Stone and others (1989) in adjacent areas to east and southeast, but differ lithologically from those units. In this area, divided into the following units:

Pss **Siltstone and pebbly limestone unit**—Yellowish-brown to brown, calcareous siltstone and fine-grained sandstone, gray to bluish-gray, pebbly limestone, and rare brown-weathering, chert-pebble conglomerate. Pebbly limestone forms several discrete, internally massive beds 1–2 m thick in lower part of unit and a relatively well bedded zone 5–10 m thick at top of unit. Pebbly limestone is lithologically similar to underlying limestone conglomerate (Psc), but limestone clasts are generally smaller (2–3 cm average diameter) and more loosely packed. Thickness about 120 m

Psc **Limestone conglomerate unit**—Medium- to dark-gray, massive conglomerate composed of poorly sorted, tightly to loosely packed, angular to subangular limestone clasts 1–20 cm in diameter and rare angular chert pebbles in a matrix of fine-grained, silty limestone. Forms prominent ledges and crags. Conformable on underlying limestone unit (Psl); unconformable on Keeler Canyon Formation where limestone unit is absent. Thickness about 60 m

Psl **Limestone unit**—Light- to medium-gray, echinodermal limestone, interbedded with yellowish-brown siltstone in lower part of unit. Limestone locally contains abundant fusulinids that indicate an Early Permian (Leonardian) age. Present only in fault-bounded blocks where it is estimated to be 50–100 m thick. Unconformable on Keeler Canyon Formation

Pl **Lone Pine Formation (Early Permian)**—Deep-water marine sedimentary rocks that underlie Conglomerate Mesa Formation in northwest part of quadrangle; includes type section of formation at Permian Bluff (Stone and Stevens, 1987). Consists primarily of medium- to dark-gray, thin-bedded to laminated calcareous and dolomitic mudstone, thin-bedded calcareous siltstone and very fine to fine-grained sandstone, and scattered thicker beds (20–80 cm) of micritic limestone and dolomite (member A of Stone and Stevens, 1987); forms smooth, recessive slopes. Upper 40–120 m (member B, not separately mapped) consists of light-colored (mainly greenish-gray to yellowish-brown) mudstone, siltstone, and very fine to fine-grained sandstone, scattered thicker beds of olive-gray to greenish-gray micritic limestone and dolomite, and locally abundant graded beds of medium- to dark-gray bioclastic and conglomeratic limestone 5 cm to 4.5 m thick. Limestone beds contain fusulinids and conodonts that indicate an Early Permian (late Wolfcampian to Leonardian) age (Stone and Stevens, 1987; Stone and others, 2000). Formation has an estimated maximum thickness of between 1,300 and 1,800 m in northwest part of quadrangle; thins southeastward to measured thickness of 309 m at Permian Bluff; pinches out beneath unconformably overlapping Union Wash Formation farther southeast along Cerro Gordo Road. Near pinchout, formation includes the following unit:

Pll **Limestone unit**—Medium- to dark-gray, mostly thin-bedded limestone similar to rocks of Keeler Canyon Formation. Thickness about 30 m

PIPk **Keeler Canyon Formation (Early Permian and Pennsylvanian)**—Deep-water marine turbidite sequence consisting of limestone, siltstone, and minor mudstone; 1,261 m thick in representative measured section 3–4.5 km southeast of Permian Bluff (Stevens and others, 2001), where formation is conformably overlain by Lone Pine Formation. There, upper part (833 m) consists of medium- to dark-gray, thin- to thick-bedded (5 cm to 2 m; average 25–50 cm), bioclastic and silty to sandy limestone turbidites and subordinate gray, tan, and pink calcareous mudstone or shale; lower part (428 m) consists of tan-weathering, plane-laminated calcareous siltstone to very fine grained sandstone and subordinate medium- to dark-gray echinodermal limestone beds 20 cm to 1.5 m thick. Limestone beds are graded and show Bouma sequences containing intervals of plane, cross, and convolute lamination; flute and groove casts are present locally on basal bedding surfaces. Fusulinids are locally abundant, especially in upper part of formation. Some silty or sandy limestone beds contain as much as 45 percent detrital quartz. Near Mexican Spring (fig. 2), lowermost 30 m of formation consists of medium- to dark-gray micritic limestone containing small spherical nodules of dark-gray chert (often called the golfball horizon). In most other places, these rocks are absent and base of formation is in fault contact with Rest Spring Shale. In south part of quadrangle, including type section near Estelle Tunnel (Merriam and Hall, 1957), formation is unconformably overlain by Union Wash Formation with angular discordance of about 15°; approximately the upper 250 m of formation is erosionally truncated beneath the unconformity. In northeast part of quadrangle, formation is metamorphosed and consists primarily of dark-gray, fine- to medium-grained, thin- to medium-bedded tremolitic limestone and calc-silicate rocks, with subordinate dark-gray argillite; bioclastic limestone beds are absent or rare. Minimum thickness of formation in northeast part of quadrangle is about 1,200 m with top not exposed. Age of formation in quadrangle, based on fusulinids and conodonts, is early Middle Pennsylvanian (Atokan) to Early Permian (Wolfcampian) (Merriam and Hall, 1957; Merriam, 1963; Stone, 1984; Stevens and others, 2001)

Mr **Rest Spring Shale (Late Mississippian)**—Dark-gray, dark-brown, and black clay shale; commonly metamorphosed to blocky argillite. Generally forms smooth, dark-colored slopes. Thickness about 350 m. Mapped as Chainman Shale by Merriam (1963); here assigned to more locally defined Rest Spring Shale of Late Mississippian (Chesterian) age, type section of which is in Racetrack Valley area (fig. 1) about 25 km northeast of quadrangle (McAllister, 1952; Stevens and others, 1996)

Mmt **Mexican Spring Formation and Tin Mountain Limestone, undivided (Late and Early Mississippian)**—Structurally complex fault blocks of very fine grained quartzite (Mexican Spring Formation) and subordinate medium- to dark-gray limestone (Tin Mountain Limestone) near Morning Star Mine in south part of quadrangle (fig. 2)

Mm **Mexican Spring Formation (Late Mississippian)**—Very light gray to light-gray, brown-weathering, calcareous quartzose siltstone to very fine grained sandstone. Generally massive as a result of bioturbation; laminated in places; locally contains meandering grazing trails parallel to bedding. Commonly highly fractured. Thickness generally 20–40 m; absent in one place near north edge of quadrangle. Type section of formation (Stevens and others, 1996) is near Mexican Spring in northwest part of quadrangle (fig. 2), where measured thickness is 37 m. Unfossiliferous in quadrangle; Late Mississippian (Meramecian) age based on fossils from reference section in Racetrack Valley area (Stevens and others, 1996). Previously mapped as Perdido Formation (Merriam, 1963; Conrad, 1993)

Mt **Tin Mountain Limestone (Early Mississippian)**—Medium- to dark-gray or dark-bluish-gray, mostly fine grained limestone that forms steep, rugged, dark-colored slopes and cliffs and contrasts sharply with underlying light-colored Lost Burro Formation. Massive in general appearance, but unit commonly is well bedded as defined by alternating layers of lighter and darker gray. Lenticular, dark-gray to black chert present locally; some beds contain abundant coarse echinoderm debris. Basal contact locally difficult to recognize near north edge of quadrangle where color contrast with Lost Burro Formation and other lithologic characteristics have been obliterated by metamorphism. Early Mississippian (Kinderhookian to lower Osagean) age of formation established at type section in Racetrack Valley area (McAllister, 1952; Stevens and others, 1996). Thickness in quadrangle estimated as 150–180 m in most places, but as little as about 25 m near Mexican Spring

Dl **Lost Burro Formation (Late and Middle Devonian)**—Consists primarily of white and light-, medium- and dark-gray limestone or marble that typically forms steep slopes and cliffs. Massive to thick-bedded in general appearance but typically shows fine planar lamination defined by contrasting shades of gray; this lamination commonly is flattened, transposed, and deformed by small-scale isoclinal folds, particularly in north part of quadrangle. Northeasternmost outcrops are pervasively brecciated. Formation is characterized by locally abundant stromatoporoids and branching corals (Merriam, 1963). Uppermost few meters locally consist of vitreous light-gray quartzite, as observed 0.5 km east of Cerro Gordo Peak. Lower part of formation includes variable amounts of light-gray dolomite, especially near Bonham Mines, and locally contains subordinate light-gray quartzite as observed near San Lucas Mine (fig. 2). Basal sandy zone analogous to Lippincott Member in Racetrack Valley area (McAllister, 1955) not identified in quadrangle; lower contact placed at base of transitional zone about 30 m thick in which medium-gray limestone is interbedded with light-gray laminated dolomite like that in upper part of Hidden Valley Dolomite. Fossils from quadrangle and type area of formation indicate an age of late Middle to Late Devonian (McAllister, 1952; Merriam, 1963). Thickness estimated as 550–700 m

DSh **Hidden Valley Dolomite (Middle? Devonian to Early Silurian)**—Very light gray to light-gray, massive saccharoidal dolomite that typically forms irregular ledgy slopes. Bedding is locally defined by laminae of sand-size fossil debris. Thickness between 450 and 580 m. As mapped, upper part of formation contains a discontinuous zone of sandy dolomite and quartzite (not separately shown) exposed between Bonham Canyon and Holiday Mine area and south of San Lucas Mine (fig. 2). In Bonham Canyon, this zone is underlain by a zone of medium- to dark-gray, cherty dolomite and contains abundant talc deposits that have been extensively mined and prospected (Page, 1951). This sandy zone could be equivalent to basal Lippincott Member of Lost Burro Formation in Racetrack Valley area (McAllister, 1955), but it is not continuous enough to define a formational boundary. Unit age based on fossils discussed by Merriam (1963) and Stevens and Ridley (1974). Thickness in quadrangle estimated as 450–580 m

SOes **Ely Springs Dolomite (Early Silurian and Late Ordovician)**—Medium- to dark-gray, thick-bedded dolomite characterized by irregular nodules and lenses of dark-gray chert as much as 15 cm long and aligned parallel to bedding. Dolomite commonly has irregular mottled texture, possibly resulting from bioturbation; locally contains abundant sand-size fossil debris. Locally altered to talc near contacts with Eureka Quartzite in Holiday Mine area. Unit age based on conodonts from sections in nearby areas (Miller, 1975). Thickness between 180 and 250 m

Oe **Eureka Quartzite (Middle Ordovician)**—Light-tan to light-gray, vitreous, fine- to medium-grained quartzite; basal part locally consists of reddish-brown-weathering argillite or indurated siltstone that is well exposed along Cerro Gordo Road (fig. 2). Complete section of formation exposed just south of Bonham Canyon is about 120 m thick

Ob **Badger Flat Limestone (Middle Ordovician)**—Light-gray, medium-bluish-gray, and light-brown laminated dolomite; exposed along eastern front of Inyo Mountains between Bonham Canyon and Holiday Mine. Mapped as part of Pogonip Group by Merriam (1963), who reported the presence of Middle Ordovician fossils. Usage of the name Badger Flat Limestone for these dolomitic rocks in this report follows that of Stone and others (1989) in the Talc City Hills 20 km southeast of the Cerro Gordo Peak quadrangle, where this unit also is composed primarily of dolomite. Thickness in quadrangle about 250 m; base not exposed

MIXED PLUTONIC AND METAMORPHIC ROCKS

Jℙu **Plutonic and metamorphosed sedimentary rocks, undifferentiated (Jurassic? and Early Permian or Pennsylvanian)**—Jurassic(?) diorite, light-colored granitic rocks, and metamorphosed impure limestone and calc-silicate rocks of Keeler Canyon Formation. Forms small area interpreted as part of a landslide block in northeast part of quadrangle

JMDu **Granitic and metamorphosed sedimentary rocks, undifferentiated (Jurassic?, Mississippian?, and Devonian?)**—Granitic rocks, marble, calc-silicate rocks, and hornfels near north edge of quadrangle. Granitic rocks are similar to Jurassic(?) fine-grained leucocratic granite (Jlg) exposed nearby; metamorphosed sedimentary rocks could be derived from Rest Spring Shale, Mexican Spring Formation, Tin Mountain Limestone, and Lost Burro Formation. Faulted against Lost Burro Formation on northeast side; nature of contact with Tin Mountain Limestone on west side and Lost Burro Formation on southeast side uncertain

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