Mississippian Stratigraphic Framework of East-Central California and Southern Nevada with Revision of Upper Devonian and Mississippian Stratigraphic Units in Inyo County, California

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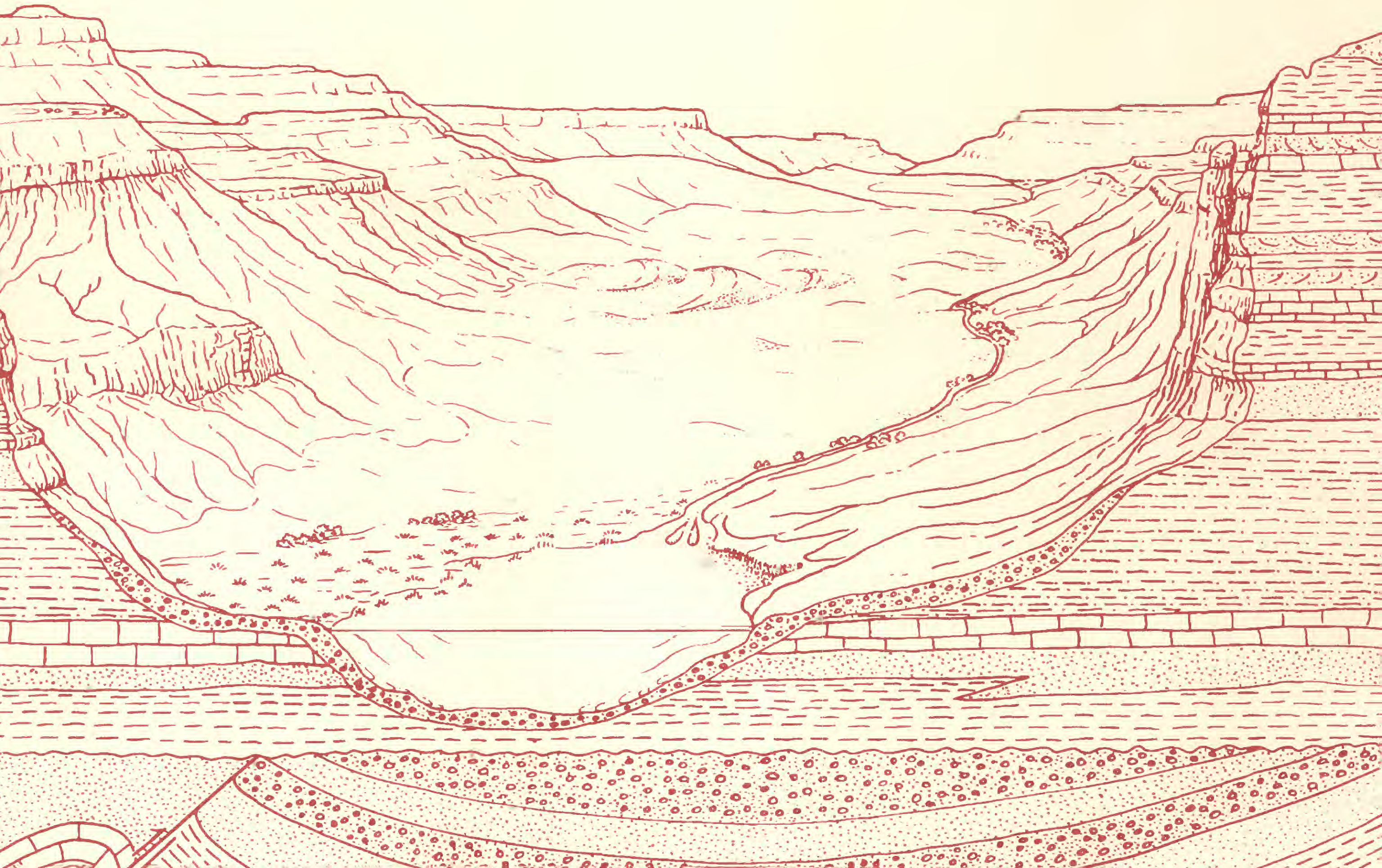

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By Calvin H. Stevens, Darrell S. Klingman, Charles A. Sandberg, Paul Stone, Paul Belasky, Forrest G. Poole, *and* J. Kent Snow

EVOLUTION OF SEDIMENTARY BASINS—EASTERN GREAT BASIN
Harry E. Cook and Christopher J. Potter, Project Coordinators

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A multidisciplinary approach to research studies of sedimentary rocks and their constituents and the evolution of sedimentary basins, both ancient and modern

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Mississippian Stratigraphic Framework of East-Central California and Southern Nevada with Revision of Upper Devonian and Mississippian Stratigraphic Units in Inyo County, California

By Calvin H. Stevens,[1] Darrell S. Klingman,[2] Charles A. Sandberg,[3] Paul Stone,[4] Paul Belasky,[1] Forrest G. Poole,[5] *and* J. Kent Snow[6]

ABSTRACT

Three contrasting lithofacies belts of Mississippian age are recognized in east-central California and southern Nevada. These belts are (1) a southeastern, predominantly limestone belt representing an extensive carbonate platform, (2) a central, mixed limestone and siliciclastic belt representing slope and base-of-slope environments, and (3) a northwestern, dominantly siliciclastic belt deposited primarily in base-of-slope and basinal environments. A useful set of stratigraphic names that reflects the lithologic differences between rocks of these belts has been developed for southern Nevada, but the stratigraphic nomenclature currently used in east-central California is incomplete and confusing. Here, a stratigraphic framework is constructed for east-central California that is more parallel with that used in southern Nevada. The Perdido Formation (Lower and Upper Mississippian) is herein raised to the rank of group, the position of its upper contact is lowered, and several new formations are named to encompass rocks of different lithologic character for which the name "Perdido Formation" had previously been used.

The Perdido Group at its type locality consists of a Lower Mississippian limestone unit herein named the Leaning Rock Formation and an Upper Mississippian, dominantly siliciclastic unit herein named the Mexican Spring Formation. The Leaning Rock Formation is composed of highly deformed dark-gray micrite interlayered with thin siliceous beds and abundant chert nodules and locally with bedded chert and limestone conglomerate. The Mexican Spring Formation consists dominantly of quartzose siltstone and very fine grained sandstone. A widespread unit of dark-gray, cherty limestone in the southeastern-facies belt formerly referred to as the limestone facies of the Perdido Formation is herein named the Stone Canyon Limestone. The name "Kearsarge Formation" is herein introduced for a Lower and Upper Mississippian unit of mixed rock types including conglomerate with carbonate or siliceous clasts, siltstone, shale, and limestone that is present in the northwestern-facies belt. Two members of the Kearsarge Formation are recognized at its type section: a lower, conglomeratic unit of Kinderhookian age composed dominantly of carbonate clasts, herein named the Bee Member, and an overlying unit of Meramecian and Chesterian age, which is herein named the Snowcaps Member. The Kearsarge Formation overlies an Upper Devonian unit, the newly described Squares Tunnel Formation, which in its type section is composed mostly of black argillite and chert. Rocks herein assigned to the Kearsarge and Squares Tunnel Formations formerly were assigned to the Perdido Formation despite significant lithologic differences with the rocks of the Perdido at its type locality.

INTRODUCTION

Mississippian rocks and their relations with underlying Upper Devonian and overlying Lower Pennsylvanian rocks

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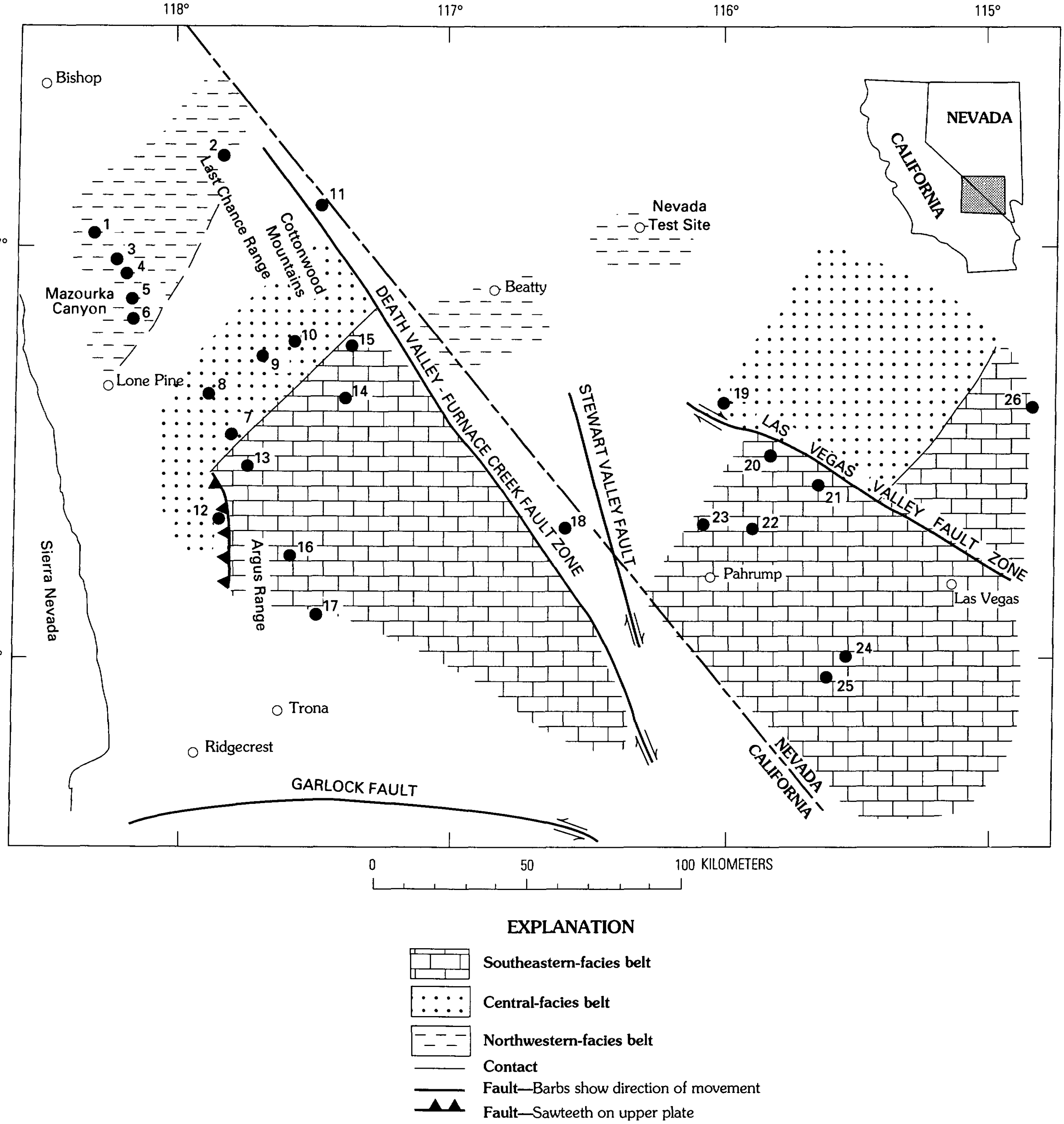


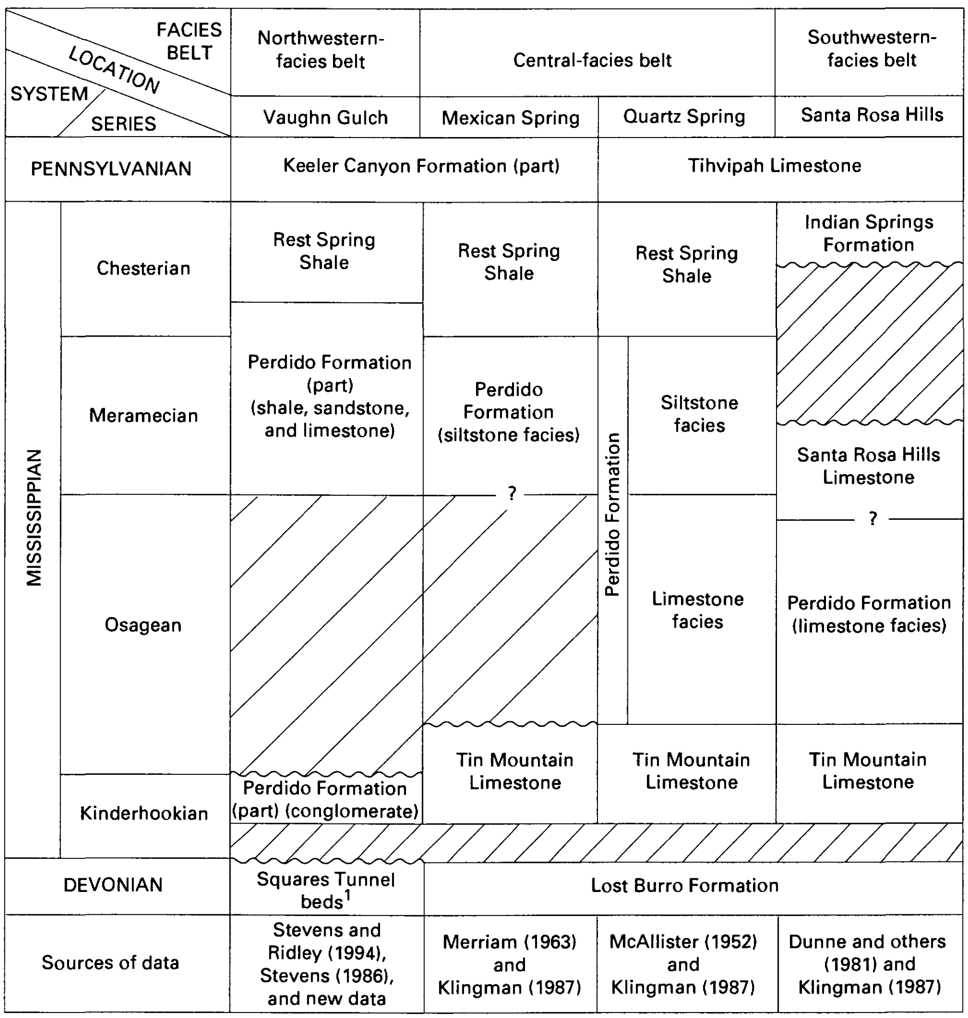
Figure 1. Map of southern Nevada and east-central California showing location of Upper Devonian and Mississippian sections and distribution of Mississippian facies belts. Localities (described in table 1): 1, Tinemaha Reservoir; 2, Last Chance Range (California); 3, Al Rose Canyon; 4, Johnson Spring; 5, Squares Tunnel; 6, Vaughn Gulch; 7, Lee Flat West; 8, Mexican Spring; 9, Ubehebe Mine Canyon; 10, Quartz Spring area (including Rest Spring Gulch, 10a; Lost Burro Gap, 10b; Bighorn Gap, 10c); 11, Grapevine Mountains; 12, Talc City Hills; 13, Santa Rosa Hills; 14, Southeast Cottonwood Mountains (including Cottonwood Canyon, 14a; Marble Canyon, 14b); 15, Dry Bone Canyon East; 16, Stone Canyon; 17, Knight Canyon; 18, Funeral Mountains South; 19, Mercury Ridge area; 20, Indian Springs (including Indian Springs, 20a; Indian Springs East, 20b); 21, Lee Canyon; 22, Trough Spring; 23, Last Chance Range East (Nevada); 24, Mountain Springs Pass; 25, Potosi Mine; 26, Tungsten Gap.

Table 1. Locality register of 26 sections in east-central California and southern Nevada.
[Localities are shown by number in figure 1]

No.	Locality	Physiographic setting	Land-grid location	County	Latitude (north), longitude (west)	Topographic map (7.5 minute)
			CALIFORNIA			
1	Tinemaha Reservoir	Inyo Mtns., Owens Valley	W½ sec. 13, T. 10 S., R. 34 E.	Inyo	37.08°, 118.20°	Tinemaha Reservoir
2	Last Chance Range	Last Chance Range	T. 8 S., R. 39 E. (unsurveyed)	Inyo	37.23°, 117.72°	Hanging Rock Canyon
3	Al Rose Canyon	Inyo Mountains, west side	T. 11, 12 S., R. 36 E. (unsurveyed)	Inyo	36.94°, 118.09°	Mazourka Peak
4	Johnson Spring	Inyo Mountains, west side	T. 12 S., R. 36 E. (unsurveyed)	Inyo	36.91°, 118.08°	Mazourka Peak
5	Squares Tunnel	Inyo Mountains, west side	S½ sec. 30, T. 12 S., R. 36 E. (unsurveyed)	Inyo	36.87°, 118.08°	Bee Springs Canyon
6	Vaughn Gulch	Inyo Mountains, west side	NE¼SE¼ sec. 8, T. 13 S.,R. 36 E.	Inyo	36.82°, 118,08°	Bee Springs Canyon
7	Lee Flat West	Inyo Mountains, east side	Sec. 26, T. 16 S., R. 39 E. (unsurveyed)	Inyo	36.52°, 117.70°	Nelson Range
8	Mexican Spring	Inyo Mountains, east side	T. 15 S., R. 38 E. (unsurveyed)	Inyo	36.61°, 117.74°	Cerro Gordo Peak
9	Ubehebe Mine Canyon	Last Chance Range, east side	T. 14 S., R. 40 E. (unsurveyed)	Inyo	36.76°, 117.60°	Teakettle Junction
10	Rest Spring Gulch–Quartz Spring area (10a)	Cottonwood Mountains	Sec. 31, T. 13 S., R. 42 E. (unsurveyed)	Inyo	36.77°, 117.45°	White Top Mtn
	Lost Burro Gap (10b)	Cottonwood Mountains	SW¼ sec. 4, T. 14 S., R. 41 E. (unsurveyed)	Inyo	36.74°, 117.52°	Ubehebe Peak
	Bighorn Gap (10c)	Cottonwood Mountains	Sec. 25, T. 13 S., R. 41 E. (unsurveyed)	Inyo	36.79°, 117.46°	White Top Mtn
11	Grapevine Mountains	Northern Grapevine Mtns.	T. 9, 10 S., R. 42 E. (unsurveyed)	Inyo	37.11°, 117.41°	Ubehebe Crater
12	Talc City Hills	Talc City Hills	SW corner, T. 18 S., R. 40 E. (unsurveyed)	Inyo	36.34°, 117.66°	Talc City Hills
13	Santa Rosa Hills South	Santa Rosa Hills	T. 17 S., R. 40 E. (unsurveyed)	Inyo	36.45°, 117.62°	Lee Wash
14	Cottonwood Canyon (14a)	Cottonwood Mountains	Sec. 8, T. 16 S., R. 43 E. (unsurveyed)	Inyo	36.58°, 117.32°	Cottonwood Canyon
	Marble Canyon (14b)	Cottonwood Mountains	Sec. 1, T. 16 S., R. 42 E. (unsurveyed)	Inyo	36.61°, 117.33°	Cottonwood Canyon
15	Dry Bone Canyon East	Cottonwood Mountains	T. 13 S., R. 42 E. (unsurveyed)	Inyo	36.76°, 117.29°	Dry Bone Canyon
16	Stone Canyon	Northern Argus Range	Secs. 27, 28, T. 19 S., R. 42 E. (unsurveyed)	Inyo	36.26°, 117.44°	Panamint Springs
17	Knight Canyon	Eastern Argus Range	Secs. 13, 18, T. 21 S., R. 42, 43 E. (unsurveyed)	Inyo	36.11°, 117.39°	Maturango Peak
18	Funeral Mountains South	Funeral Mountains	S½ sec. 2, T. 25 N., R. 4 E. (unsurveyed)	Inyo	36.33°, 116.51°	East of Ryan
			NEVADA			
19	Mercury Ridge	Spotted Range	NW¼ sec. 20, T. 15 S., R. 54 E. (unsurveyed)	Nye	36.63°, 115.95°	Mercury
20	Indian Springs (20a)	Northern Spring Mountains	S½SW¼ sec. 35, T. 16 S., R. 55½ E.	Clark	36.51°, 115.74°	Indian Springs
	Indian Springs East (20b)	Northern Spring Mountains	S½S½SE¼ sec. 25, T. 16 S., R. 55½ E.	Clark	36.52°, 115.71°	Indian Springs
21	Lee Canyon	Northern Spring Mountains	NE¼ sec. 34, T. 17 S., R. 57 E.	Clark	36.43°, 115.56°	Charleston Peak NE
22	Trough Spring	Northern Spring Mountains	NE¼ sec. 22, T. 18 S., R. 55 E.	Clark	36.37°, 115.78°	Wheeler Well
23	Last Chance Range East	Last Chance Range	Center SE¼NE¼ sec. 31, T. 18 S., R. 53 E.	Nye	36.35°, 116.05°	Last Chance Range
24	Mountain Springs Pass	Central Spring Mountains	NE¼ sec. 19, T. 22 S., R. 58 E.	Clark	36.03°, 115.51°	Mountain Springs
25	Potosi Mine	Central Spring Mountains	Center N½SW½NE¼ sec. 12, T. 23 S., R. 57 E.	Clark	35.97°, 115.53°	Potosi
26	Tungsten Gap	Arrow Canyon Range	Center N½ sec. 10, T. 15 S., R. 64 E. (unsurveyed)	Clark	36.65°, 114.81°	Arrow Canyon

are quite similar in southern Nevada and east-central California, but the different systems of nomenclature used in these two areas and the major displacements by strike-slip faulting have tended to obscure the similarities. In both areas, the Mississippian rocks are divisible into three major lithofacies belts: (1) a southeastern, predominantly limestone belt representing an extensive carbonate platform; (2) a central belt consisting of a lower limestone unit, a middle unit of quartzose siltstone and fine-grained sandstone, and an upper unit of dark shale, representing an upward-deepening sequence of beds deposited mostly in slope and basinal environments; and (3) a northwestern shale or argillite belt that includes beds of conglomerate, conposed of limestone and chert clasts, deposited primarily in base-of-slope and deep basinal environments (see for example, Rose, 1976; Poole and Sandberg, 1977; Stevens, 1986). In this report, these three lithologic belts are referred to as the southeastern-facies belt, the central-facies belt, and the northwestern-facies belt. Distribution of these belts in southern Nevada and east-central California is shown in figure 1.

The nomenclature developed for Mississippian rocks in southern Nevada reflects the lithologic characteristics of these three lithofacies belts. Thus, in this region, several sets of formational names are used for the different Mississippian rocks. The nomenclature presently used in east-central California (fig. 2) is, however, incomplete and unsatisfactory. In this paper, we present new paleontologic and stratigraphic data for these rocks and, on the basis of this new information, revise the nomenclature of the Mississippian units (and an underlying Upper Devonian unit) in east-central California to produce a nomenclature set that is different from, but more parallel with, the one employed in southern Nevada, and we compare and correlate units in these two areas (fig. 3). Following the general usage of names, we employ the southern Nevada nomenclature in the areas east of the Death Valley–Furnace Creek fault zone and south of the Garlock



[1] Informal name.

Figure 2. Mississippian stratigraphic nomenclature currently used in east-central California.

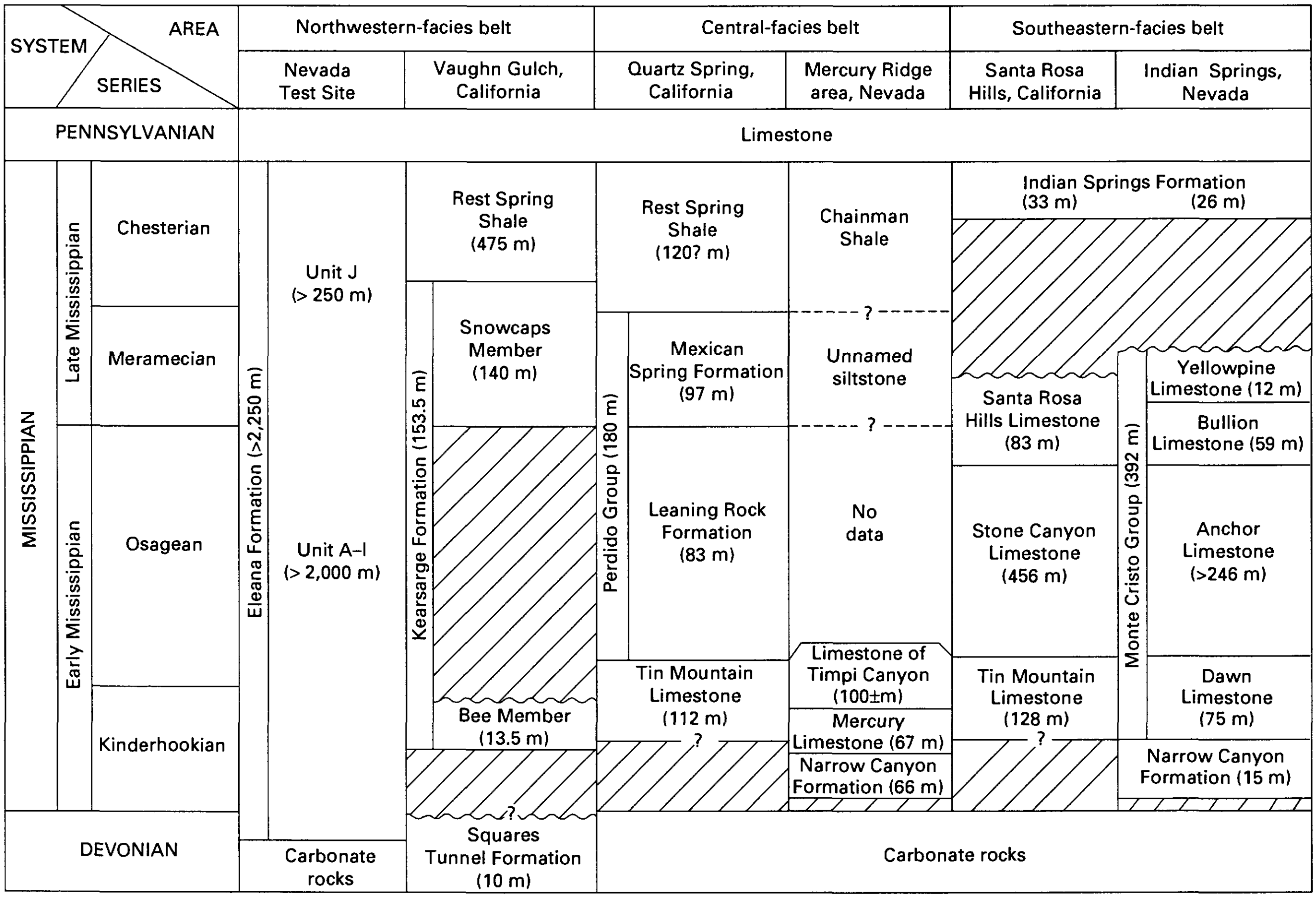


Figure 3. Proposed Mississippian stratigraphic nomenclature for east-central California compared to nomenclature in use in southern Nevada. Rocks comprising the Stone Canyon Limestone were formerly included within the Perdido Formation, which is herein redefined as the Perdido Group.

fault. The east-central California nomenclature is used in the area north and west of these faults.

Much of the stratigraphic and paleontologic data on which this report is based originally were collected and analyzed by Klingman (1987) and Belasky (1988) in east-central California and southern Nevada, respectively. This work included the collection and study of many fossil samples, particularly conodonts. These data, with the addition of some newer data, were utilized by Stevens and others (1995) to develop a model for the evolution of the Mississippian carbonate platform in east-central California and southern Nevada.

For the present study, all of the conodont samples collected by Klingman (1987) and Belasky (1988) were restudied by Sandberg and augmented by many new samples. The conodont data now available allow considerable refinement of the ages of Mississippian rocks in east-central California and southern Nevada. All conodont samples to which reference is made herein have been entered into the D/C (Devonian/Carboniferous) Conodont Database (Charpentier and Sandberg, 1992). We follow Poole and Sandberg (1991) in correlating the conodont zones distinguished in this report with provincial series of the type Mississippian (figs. 4, 5) because the majority of the ages are based on conodont zones. These correlations generally are compatible with the coral- and foraminiferal-based provincial series correlations of Mamet and Skipp (1970), Sando (1985), and Sando and Bamber (1985), except that the Osagean-Meramecian boundary is placed somewhat higher by Poole and Sandberg (1991). Therefore, in appendix 1, in which faunal and age data are given, the conodont zones are used as often as is practicable. In the text, however, we generally use series names for simplicity. The most important stratigraphic sections containing age-diagnostic fossils are correlated with one another and with an intensively studied section on the east side of the Arrow Canyon Range northeast of the area of this study (Poole and Sandberg, 1991) in figure 4. Regional correlation of the herein described Devonian Squares Tunnel Formation is shown in figure 5.

Acknowledgments.—We are grateful to William J. Sando, U.S. Geological Survey, who identified the corals reported on here and who also through conversations helped us to keep a regional perspective in focus; Paul Brenckle, Amoco Production Company, who identified the foraminiferal-algal samples; and Benita Murchey, U.S. Geological Survey, who prepared and identified the radiolarians.

MISSISSIPPIAN STRATIGRAPHIC NOMENCLATURE IN SOUTHERN NEVADA

SOUTHEASTERN-FACIES BELT

The southeastern-facies belt is represented throughout the southeastern part of southern Nevada. South of the Las Vegas Valley fault zone, these Mississippian rocks are represented by the Monte Cristo Limestone as defined by Hewett (1931), which is herein raised to group rank. The rocks of this group generally overlie Devonian carbonate rocks unconformably and are overlain unconformably by the Upper Mississippian Indian Springs Formation. The Lower Mississippian Narrow Canyon Formation (herein renamed) is present below the Monte Cristo Group in some areas, and the Upper Mississippian Battleship Wash Formation of Langenheim and Langenheim (1965) locally is present between the Monte Cristo Group and the Indian Springs Formation. The Mississippian sequence is overlain by Pennsylvanian limestone of the Bird Spring Formation (fig. 3).

As originally defined by Hewett (1931), the Monte Cristo Limestone consists of five members: the Dawn Limestone Member, Anchor Limestone Member, Bullion Dolomite Member, Arrowhead Limestone Member, and Yellowpine Limestone Member. Later, Langenheim (1956) and Langenheim and others (1962) were among those workers who referred to these units as formations. Here, we raise the Monte Cristo Limestone to group rank, in agreement with the usage noted above, and also raise four of its members to formation rank; namely, the Dawn Limestone, Anchor Limestone, Bullion Limestone (locally renamed here as shown, but renamed as the Bullion Dolomite at its type locality), and Yellowpine Limestone. These formations are widely distributed and mappable in southern Nevada from the Beaver Dam Mountains near the Nevada-Arizona State line on the east through the Spring Mountains into the Last Chance Range near Pahrump, Nevada, on the west. We here rename the Arrowhead Limestone Member, a thin (generally less than 6 m thick), discontinuous unit composed of wavy- to nodular-bedded, argillaceous micrite and calcareous shale, as the Arrowhead Member and reassign it as the basal member of the Yellowpine Limestone.

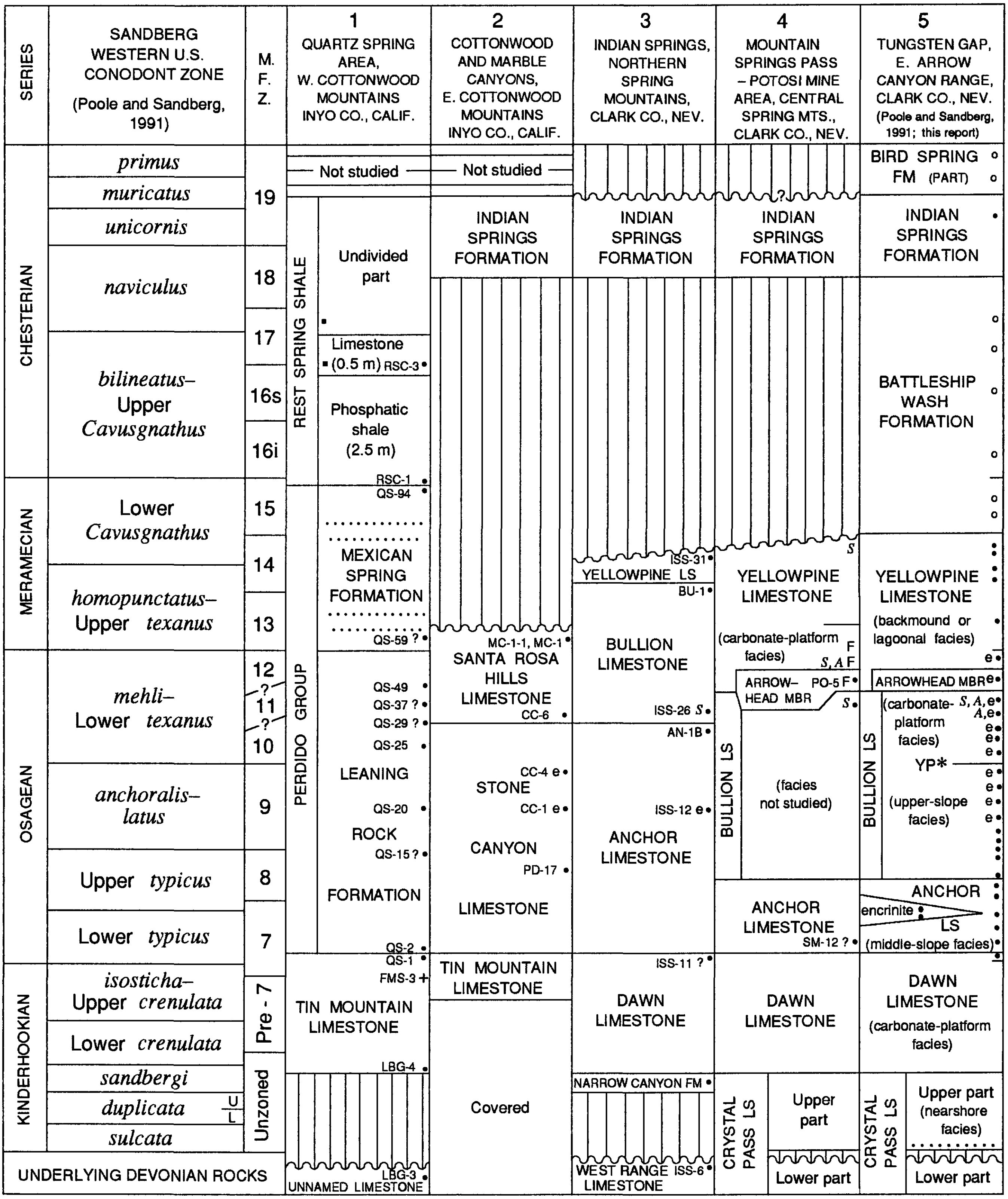
The Dawn Limestone, the lowest formation of the Monte Cristo Group, consists primarily of medium-bedded, relatively chert free, dark-gray micrite and spiculiferous lime wackestone, locally containing some interbeds of crinoidal limestone. The overlying Anchor Limestone consists predominantly of fine-grained, thin- to medium-bedded, dark-gray, spiculiferous lime wackestone interbedded with partially silicified micrite and abundant dark-brown chert in nodules and nodular layers and locally interbedded with medium-gray, coarse-grained crinoidal limestone. The Bullion Limestone overlies the Anchor Limestone and commonly is characterized by thick-bedded, fine- to coarse-grained, light-gray, crinoidal calcarenite with sparse chert nodules and nodular layers. The Yellowpine Limestone, the uppermost unit of the Monte Cristo Group, consists of thin- to thick-bedded, medium- to dark-gray, medium-grained crinoidal lime wackestone and packstone with abundant rugose corals (Langenheim and others, 1962; Belasky, 1988). Throughout this facies belt, the Dawn, Bullion, and Yellowpine Limestones are interpreted to represent shallow-water, carbonate-platform deposition. The Anchor Limestone is considered to represent deeper water platform deposition in the southeastern part of this lithofacies belt, whereas in the northwestern part of the belt it is inferred to represent slope deposition (Stevens and others, 1995).

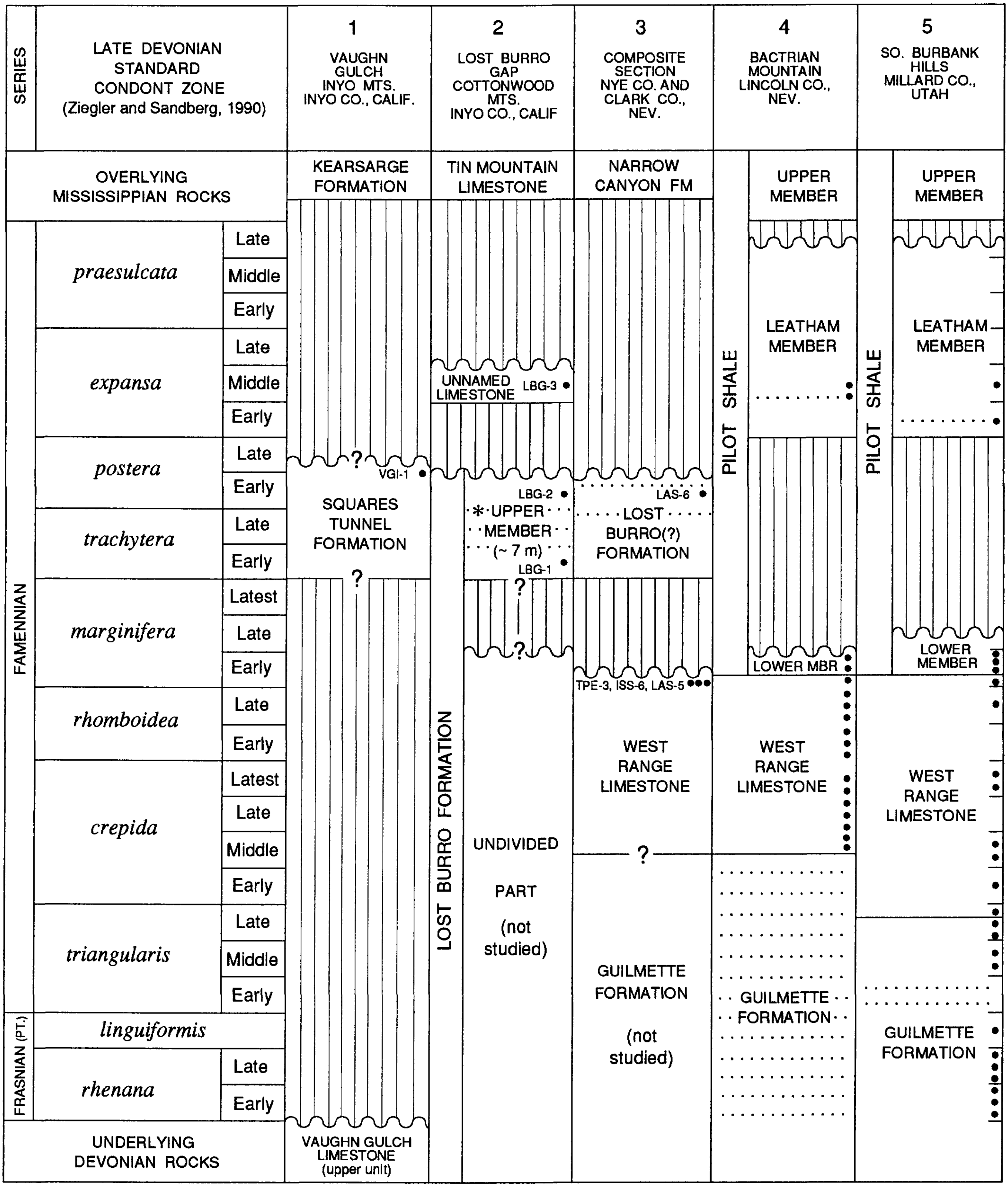
The Monte Cristo Group generally is unconformably overlain by the Upper Mississippian (Chesterian) Indian Springs Formation, a thin sequence of interbedded shale, pale-red to light-brown, fine-grained quartzite, and thin-bedded, olive-gray limestone that was considered by Gordon and Poole (1968) to be laterally equivalent to the Chainman Shale.

CENTRAL-FACIES BELT

Well-exposed sections of the central-facies belt, which lies northwest of the southeastern-facies belt (fig. 1), are uncommon in southern Nevada. This belt is perhaps best displayed in the Mercury Ridge area (fig. 1) (Poole and others, 1961; Barnes and others, 1982; F.G. Poole and C.A. Sandberg, unpub. data). The Mississippian sequence there

Figure 4 (facing page). Time-rock correlation chart of Mississippian rocks straddling southern part of carbonate-platform margin, California and Nevada. M.F.Z. refers to Mamet foraminiferal zone. Solid circle indicates conodont collection identified by Sandberg, diagnostic of zone at left; open circle indicates conodont collection identified by others. Plus (+) indicates Sandberg collection from southern Funeral Mountains; query (?) indicates collection lacking zonal indicators; letter "e" indicates eotaphrid conodont biofacies, diagnostic of platform margin–upper slope setting. Corals (identified by W.J. Sando): *A*, *Ankhelasma*; *S*, *Siphonodendron.* Letter F indicates foraminiferal collection, identified by B.L. Mamet, diagnostic of Mamet foraminiferal zone at left. Solid square indicates ammonoid collection identified by M. Gordon, Jr. YP* indicates base of Yellowpine Limestone of Pierce and Langenheim (1974). Dots(.....) indicate sandstone. Numbers to left of symbols are conodont collection numbers. See appendix table 2 for faunal lists of unqueried collections in column 1. Conodont dating of Narrow Canyon Formation is based on collection TPE–5 (Sandberg, unpublished data) from Mercury Ridge area (table 1, loc. 19).


SERIES
SANDBERG WESTERN U.S. CONODONT ZONE (Poole and Sandberg, 1991)
M. F. Z.
1 QUARTZ SPRING AREA, W. COTTONWOOD MOUNTAINS INYO CO., CALIF.
2 COTTONWOOD AND MARBLE CANYONS, E. COTTONWOOD MOUNTAINS INYO CO., CALIF.
3 INDIAN SPRINGS, NORTHERN SPRING MOUNTAINS, CLARK CO., NEV.
4 MOUNTAIN SPRINGS PASS – POTOSI MINE AREA, CENTRAL SPRING MTS., CLARK CO., NEV.
5 TUNGSTEN GAP, E. ARROW CANYON RANGE, CLARK CO., NEV. (Poole and Sandberg, 1991; this report)
CHESTERIAN
MERAMECIAN
OSAGEAN
KINDERHOOKIAN
primus
muricatus
unicornis
naviculus
bilineatus– Upper Cavusgnathus
Lower Cavusgnathus
homopunctatus– Upper texanus
mehli– Lower texanus
anchoralis– latus
Upper typicus
Lower typicus
isosticha– Upper crenulata
Lower crenulata
sandbergi
duplicata
U
L
sulcata
19
18
17
16s
16i
15
14
13
12
?
11
?
10
9
8
7
Pre - 7
Unzoned
UNDERLYING DEVONIAN ROCKS
Not studied
Not studied
REST SPRING SHALE
Undivided part
Limestone (0.5 m) RSC-3
Phosphatic shale (2.5 m)
RSC-1
QS-94
PERDIDO GROUP
MEXICAN SPRING FORMATION
QS-59 ?
QS-49
QS-37 ?
QS-29 ?
QS-25
LEANING ROCK FORMATION
QS-20
QS-15 ?
QS-2
QS-1
FMS-3
TIN MOUNTAIN LIMESTONE
LBG-4
LBG-3
UNNAMED LIMESTONE
INDIAN SPRINGS FORMATION
MC-1-1, MC-1
SANTA ROSA HILLS LIMESTONE
CC-6
CC-4 e
STONE CANYON LIMESTONE
CC-1 e
PD-17
TIN MOUNTAIN LIMESTONE
Covered
INDIAN SPRINGS FORMATION
ISS-31
YELLOWPINE LS
BU-1
BULLION LIMESTONE
ISS-26 S
AN-1B
ISS-12 e
ANCHOR LIMESTONE
ISS-11 ?
DAWN LIMESTONE
NARROW CANYON FM
WEST RANGE LIMESTONE ISS-6
?
INDIAN SPRINGS FORMATION
S
YELLOWPINE LIMESTONE
(carbonate-platform facies)
F
S,A F
ARROW– HEAD MBR PO-5 F
S
BULLION LS
(facies not studied)
ANCHOR LIMESTONE
SM-12 ?
DAWN LIMESTONE
CRYSTAL PASS LS
Upper part
Lower part
BIRD SPRING FM (PART)
INDIAN SPRINGS FORMATION
BATTLESHIP WASH FORMATION
YELLOWPINE LIMESTONE
(backmound or lagoonal facies)
e
ARROWHEAD MBR e
BULLION LS
(carbonate- platform facies)
S, A, e
A, e
YP*
(upper-slope facies)
ANCHOR LS
encrinite
(middle-slope facies)
DAWN LIMESTONE
(carbonate-platform facies)
CRYSTAL PASS LS
Upper part (nearshore facies)
Lower part



SERIES
LATE DEVONIAN STANDARD CONDONT ZONE (Ziegler and Sandberg, 1990)
1 VAUGHN GULCH INYO MTS. INYO CO., CALIF.
2 LOST BURRO GAP COTTONWOOD MTS. INYO CO., CALIF
3 COMPOSITE SECTION NYE CO. AND CLARK CO., NEV.
4 BACTRIAN MOUNTAIN LINCOLN CO., NEV.
5 SO. BURBANK HILLS MILLARD CO., UTAH
OVERLYING MISSISSIPPIAN ROCKS
KEARSARGE FORMATION
TIN MOUNTAIN LIMESTONE
NARROW CANYON FM
UPPER MEMBER
UPPER MEMBER
FAMENNIAN
praesulcata
expansa
postera
trachytera
marginifera
rhomboidea
crepida
triangularis
FRASNIAN (PT.)
linguiformis
rhenana
Late
Middle
Early
Latest
UNNAMED LIMESTONE
LBG-3
VGI-1
SQUARES TUNNEL FORMATION
LBG-2
UPPER MEMBER (~ 7 m)
LBG-1
LAS-6
LOST BURRO(?) FORMATION
LEATHAM MEMBER
LEATHAM MEMBER
PILOT SHALE
PILOT SHALE
LOWER MBR
LOWER MEMBER
TPE-3, ISS-6, LAS-5
LOST BURRO FORMATION
UNDIVIDED PART (not studied)
WEST RANGE LIMESTONE
WEST RANGE LIMESTONE
WEST RANGE LIMESTONE
GUILMETTE FORMATION (not studied)
GUILMETTE FORMATION
GUILMETTE FORMATION
UNDERLYING DEVONIAN ROCKS
VAUGHN GULCH LIMESTONE (upper unit)

consists of a lower carbonate and an upper siliciclastic sequence and rests on the Devonian West Range Limestone (fig. 4). The lower, carbonate part of the sequence consists of, in ascending order, the Narrow Canyon Formation, which is older than the Dawn Limestone in the southeastern-facies belt; the Mercury Limestone, which is temporally equivalent to the lower part of the Dawn Limestone, and the limestone of Timpi Canyon, which is correlative with the upper part of the Dawn Limestone (C.A. Sandberg and F.G. Poole, unpub. data). The upper, siliciclastic part of the sequence consists of an unnamed, yellowish-weathering, fine-grained, siliciclastic unit and the overlying olive- to dark-gray Chainman Shale.

The Narrow Canyon Formation and Mercury Limestone represent platform deposition. The remainder of the section exposed in the Mercury Ridge area represents deeper water deposition in slope and basinal environments.

NORTHWESTERN-FACIES BELT

The northwestern-facies belt consists of argillite, impure chert, siliceous siltstone, fine-grained quartzite, limestone, and conglomerate containing chert, quartzite, argillite, quartz, and limestone clasts. The most extensive outcrops of this belt in southern Nevada are represented by the Eleana Formation in the Nevada Test Site. Poole and others (1961) measured 2,350 m of section in the Nevada Test Site that they divided into 10 informal units (units A–J) lying between Devonian and Pennsylvanian carbonate rocks (fig. 3). Cashman and Trexler (1991, 1994) reexamined the Eleana Formation and concluded that its eastern outcrops, consisting of unit J (of Poole and others, 1961), and its western outcrops (units A–I) represent lateral facies juxtaposed by thrust faulting. The eastern outcrops are composed primarily of mudstone and quartzite that have shallow-water sedimentary features, whereas the western outcrops of the Eleana Formation are composed mostly of relatively deep water, fine- to coarse-grained, turbiditic siliciclastic sandstone, containing significant amounts of feldspar and both sedimentary and volcanic grains, and calciclastic rocks (Cashman and Trexler, 1991, 1994). The available conodont and ammonoid data show that the dated part of unit I is older than the dated part of unit J (Poole and Sandberg, 1991, unpub. data; Alan Titus, oral commun., 1994). These data do not resolve the question of whether the eastern and western outcrops have been juxtaposed by thrust faulting, as proposed by Cashman and Trexler (1991, 1994), or represent a single stratigraphic sequence, as indicated by Poole and others (1961, 1965). Comparison with the section of the Eleana Formation on Bare Mountain (Monsen and others, 1992) about 50 km southwest of the Nevada Test Site suggests, however, that these facies are in stratigraphic sequence. At Bare Mountain, the section is predominantly siliciclastic and consists of fine-grained lower and upper parts and a middle conglomeratic section containing some volcanic clasts (C.H. Stevens, unpub. data), as the section in the Nevada Test Site would appear if units A–I and J were superimposed there. Regardless of the structural interpretations, however, the sedimentary data strongly support the interpretation that the western outcrops (composed of units A–I) are deep-water deposits derived generally from northern sources, probably directly or indirectly from the Antler orogenic belt. The eastern outcrops (consisting of unit J of Chesterian age) are composed of shallow-water deposits derived from a mature continental source, such as the craton (Cashman and Trexler, 1994), or, alternatively, multiple sources including reworked older Eleana orogenic sediment (Poole and Claypool, 1984; Poole and Sandberg, 1991).

STRATIGRAPHIC NOMENCLATURE IN EAST-CENTRAL CALIFORNIA

SOUTHEASTERN-FACIES BELT

Mississippian rocks of the southeastern-facies belt in east-central California (fig. 1) consist of a thick carbonate sequence and a thin siliciclastic unit. This sequence rests upon the dominantly calcareous Middle and Upper Devonian Lost Burro Formation (McAllister, 1952) and is overlain by Pennsylvanian carbonate rocks of the Tihvipah Limestone or Bird Spring Formation. In this region, the Mississippian limestone sequence consists of three recognizable lithologic units that, from lower to upper, have been called

Figure 5 (facing page). Time-rock correlation chart of Upper Devonian rocks across carbonate platform in east-central California and southern Nevada and along east side of Pilot Basin (Sandberg and others, 1989) in eastern Nevada and western Utah. VGI–1•, number and position of conodont collection, identified by Sandberg, diagnostic of zone at left. In column 3, collection number prefixes refer to these localities: LAS, Last Chance Range East (table 1, loc. 23); ISS, Indian Springs (table 1, loc. 20); TPE, Mercury Ridge area (table 1, loc. 19). For collection numbers and faunal lists for column 4 see Sandberg and Ziegler (1973) and for column 5, see Sandberg and others (1989, fig. 10). Dots (....) indicate sandstone and quartzite. Asterisk (*) indicates top of Quartz Spring Sandstone Member of Langenheim and Tischler (1960), who included highest limestone beds of Lost Burro Formation as well as overlying unnamed limestone (~3 m thick) within their Tin Mountain Limestone.

the Tin Mountain Limestone, the limestone facies of the Perdido Formation, and the Santa Rosa Hills Limestone (fig. 2). The Tin Mountain and Santa Rosa Hills Limestones represent shallow-platform deposition throughout this lithofacies belt. The limestone facies of the Perdido Formation, on the other hand, shoals upward from deep-water facies to shallower water facies. The Santa Rosa Hills Limestone is overlain by a thin, primarily siliciclastic, shallow-water unit of Late Mississippian age that has been assigned to the Indian Springs Formation (Stevens, 1986).

CENTRAL-FACIES BELT

The central-facies belt is present northwest of the southeastern-facies belt (fig. 1). The Mississippian sequence rests on Middle and Upper Devonian rocks of the Lost Burro Formation, which is composed primarily of carbonate rocks, and is overlain by Pennsylvanian limestones of the Keeler Canyon Formation. The lower part of the Mississippian sequence in this belt consists of limestone assigned to the Tin Mountain Limestone and formerly to the limestone facies of the Perdido Formation. The limestone facies of the Perdido Formation, which thins rapidly westward, is present only in the eastern part of this lithofacies belt. This limestone sequence is overlain by a distinctive quartzose siltstone and very fine grained sandstone unit that has been referred to as the siltstone facies of the Perdido Formation (Stevens, 1986). The upper part of the section is composed of dark-gray shale assigned to the Upper Mississippian (mainly Chesterian) Rest Spring Shale (fig. 2).

The Tin Mountain Limestone in this facies belt probably represents central to outer platform deposition. The overlying rocks formerly assigned to the Perdido Formation are slope and base-of-slope deposits, and the Rest Spring Shale consists of basinal deposits.

NORTHWESTERN-FACIES BELT

The stratigraphic section in the western Inyo Mountains and other areas northwest of the central-facies belt (fig. 1) is substantially different from that in the region to the southeast (Stevens, 1986). The Upper Devonian is represented by eugeoclinal, radiolarian-rich, black chert and argillite originally included by Ross (1966) in the Perdido Formation. Stevens and Ridley (1974) noted the lithologic dissimilarity between these beds and those in the type locality of the Perdido Formation and informally called these rocks the Squares Tunnel beds. The Squares Tunnel unit is overlain by a lithologically diverse sequence consisting of megabreccia, conglomerate, pebbly mudstone, shale, siltstone, fine-grained sandstone, and limestone that compose the upper part of the Perdido Formation as recognized by Ross (1966). These rocks are overlain by the Rest Spring Shale, which in turn is overlain by Pennsylvanian limestone of the Keeler Canyon Formation (fig. 2).

The Squares Tunnel beds were deposited primarily in submarine channels, the rocks assigned to the Perdido Formation are slope and base-of-slope deposits, and the Rest Spring Shale represents basinal deposition.

PROPOSED REVISIONS IN STRATIGRAPHIC NOMENCLATURE

The three Mississippian lithofacies belts in east-central California are lithogenetically similar to, and originally were continuous with, those in southern Nevada. The present stratigraphic nomenclature in east-central California fails, however, to adequately reflect the differences between the units in these facies belts. The primary problem is that several lithologically distinct units have been assigned to a single formation, the Perdido Formation, and thus are not formally distinguished in the stratigraphic nomenclature.

The Perdido Formation was named by McAllister (1952) for a heterogeneous sequence of strata cropping out near Quartz Spring in the northern Cottonwood Mountains (fig. 1). In the area of Quartz Spring, the Perdido Formation consists of a diverse assemblage of carbonate rocks and quartzose sandstone and siltstone underlain by the Lower Mississippian Tin Mountain Limestone and overlain by the Upper Mississippian Rest Spring Shale (fig. 2). The Perdido Formation consists of two lithologically distinct facies: (1) a lower, dominantly carbonate facies composed primarily of micrite and black chert, some of it characterized by soft-sediment deformation, and limestone conglomerate, and (2) an upper, mostly siliciclastic facies composed of quartzose siltstone and sandstone, calcarenite, and limestone-intraclast conglomerate (McAllister, 1952; Langenheim and Tischler, 1960; Klingman, 1987; Snow, 1990). Both of these facies also are present in the western Lee Flat area and in Ubehebe Mine Canyon (localities 7 and 9, fig. 1).

Stratigraphic confusion began when the name "Perdido Formation" was extended into areas where only one or neither of the two major facies exhibited at the Perdido type locality is present. For instance, the name "Perdido Formation" has been applied to sequences of interbedded micrite, chert, and minor silicified limestone at many localities southeast of the Inyo Mountains in the southeastern-facies belt, including the Santa Rosa Hills (Hall and MacKevett, 1962) and the Argus Range (Hall, 1971) (fig. 1). Throughout a large area, this limestone facies of the Perdido Formation is overlain by a light-colored limestone unit, the Santa Rosa Hills Limestone of Dunne and others (1981), instead of quartzose siltstone and very fine grained sandstone as at the type locality. The name "Perdido Formation" also has been used in parts of the southeastern Inyo Mountains (Merriam, 1963) where quartzose siltstone and very fine grained sandstone are the only rocks present. Finally, Ross (1965, 1966) applied the name "Perdido Formation" to an extremely heterogeneous assemblage of rocks in the Mazourka Canyon area in the western Inyo Mountains, where most of the rocks are very different from those in either of the major facies in the Quartz Spring area.

Although the concept of a heterogeneous assemblage of units at this stratigraphic level is useful, the confusion and lack of precision in the application of the name "Perdido Formation" indicate the need for a revision of the nomenclature. To resolve this problem, we here raise the Perdido Formation at its type locality to the rank of group composed of two new formations. The two new formations are the Leaning Rock Formation and the Mexican Spring Formation, encompassing the interval of dominantly limestone and quartzose sandstone and siltstone, respectively, which previously had been assigned to the Perdido Formation at its type locality. The limestone facies of the Perdido Formation as employed by many earlier workers for an interbedded micrite, silicified micrite, and chert interval in the southeastern facies-belt is herein named the Stone Canyon Limestone. The Upper Devonian Squares Tunnel Formation in the northwestern-facies belt is herein formally defined, and the name "Kearsarge Formation" is applied to an overlying sequence of Mississippian rocks. These latter two units comprise the rocks in the western Inyo Mountains originally assigned to the Perdido Formation by Ross (1965, 1966). The Kearsarge Formation contains two intervals of considerably different lithology and age and is, therefore, subdivided into two members, the Bee Member (Lower Mississippian) and the overlying Snowcaps Member (Upper Mississippian). All of these new units, correlated with their most comparable units in southern Nevada, are shown in figure 3. Locations of type or reference sections for these new units are shown in figure 6. Descriptions of the type sections of the new formations, as well as a reference section for the Mexican Spring Formation, are given in appendix 2.

PERDIDO GROUP

The Perdido Group is composed of all the strata between the Tin Mountain Limestone and the Rest Spring Shale, the base of which is revised (later) at the type locality of the Perdido in the Quartz Spring area in the northern Panamint Range (McAllister, 1952). There, the Perdido consists of the Leaning Rock Formation and the overlying Mexican Spring Formation (fig. 3). Because the name "Perdido" is firmly entrenched in the geologic literature, we continue to employ this term, but only as a group name, to include all the strata in the central-facies belt present between the Tin Mountain Limestone and the Rest Spring Shale. Rocks in the southeastern facies-belt that heretofore were assigned to the Perdido are removed from the Perdido Group and are herein reassigned to the Stone Canyon Limestone. Rocks in the northwestern-facies belt originally placed in the Perdido also are removed from the Perdido Group and are herein reassigned to the Squares Tunnel and Kearsarge Formations.

LEANING ROCK FORMATION

The Leaning Rock Formation is here named to comprise a sequence of interbedded, commonly deformed, dark-gray, cherty micrite, chert, mudstone, and shale that is well exposed in its type section about 1 km south of Rest Spring in the Quartz Spring area (fig.7). This formation, named for Leaning Rock Peak about 3 km southeast of the type section, is represented in the eastern part of the central-facies belt in the easternmost Inyo Mountains, the western Cottonwood Mountains, and the Talc City Hills (fig. 1).

The Leaning Rock Formation conformably overlies the Tin Mountain Limestone and is overlain, generally conformably, by the Mexican Spring Formation. The lower contact is placed at the base of the lowest bedded-chert unit in the dominantly limestone sequence. The upper contact is placed at the base of the lowest siltstone or sandstone in the overlying dominantly siliciclastic sequence.

In its type section, the Leaning Rock Formation is 83 m thick and is divided into three subunits (fig. 8). The lowest subunit (unit 1) is 7 m thick and consists of dark-gray chert, spiculite, micrite, and silicified micrite. The chert is in 4–10-cm-thick beds and as irregularly shaped nodules. Horizontal grazing trails are uncommon, and macrofossils are limited to minute pelmatozoan debris. Unit 2 is 33 m thick and consists of reddish-brown-weathering, flaggy mudstone, thin- to medium-bedded, dark-gray, spiculiferous chert, and deformed submarine-slide masses composed of micrite and chert. Unit 3 is 43 m thick and consists mostly of thin- to medium-bedded, dark-gray, argillaceous micrite, silicified limestone, and spiculiferous chert; macrofossils include pelmatozoan debris and rare horn corals and brachiopod fragments. Throughout the formation, bioturbation features are common and include both horizontal grazing trails and vertical burrows. The Leaning Rock Formation thins abruptly northwestward so that at Bighorn Gap less than 4 km northwest of the type section this formation is only 23 m thick. Abundant slump folds and other deformational features suggest that this formation was deposited primarily in a base-of-slope environment.

The Leaning Rock Formation is late Early Mississippian (Osagean) in age, and conodont faunas representing three of the four Osagean conodont zones (Lower *typicus* Zone, *anchoralis-latus* Zone, and *mehli*-Lower *texanus* Zone) have been recovered from the section of the formation exposed near Rest Spring (locality 10a) in the Quartz Spring area. The Lower *typicus* Zone has been recognized in sample QS–1 from the uppermost part of the Tin Mountain Limestone and in sample QS–2 from 0.1 m above the base of the Leaning Rock Formation (appendix 1). The younger

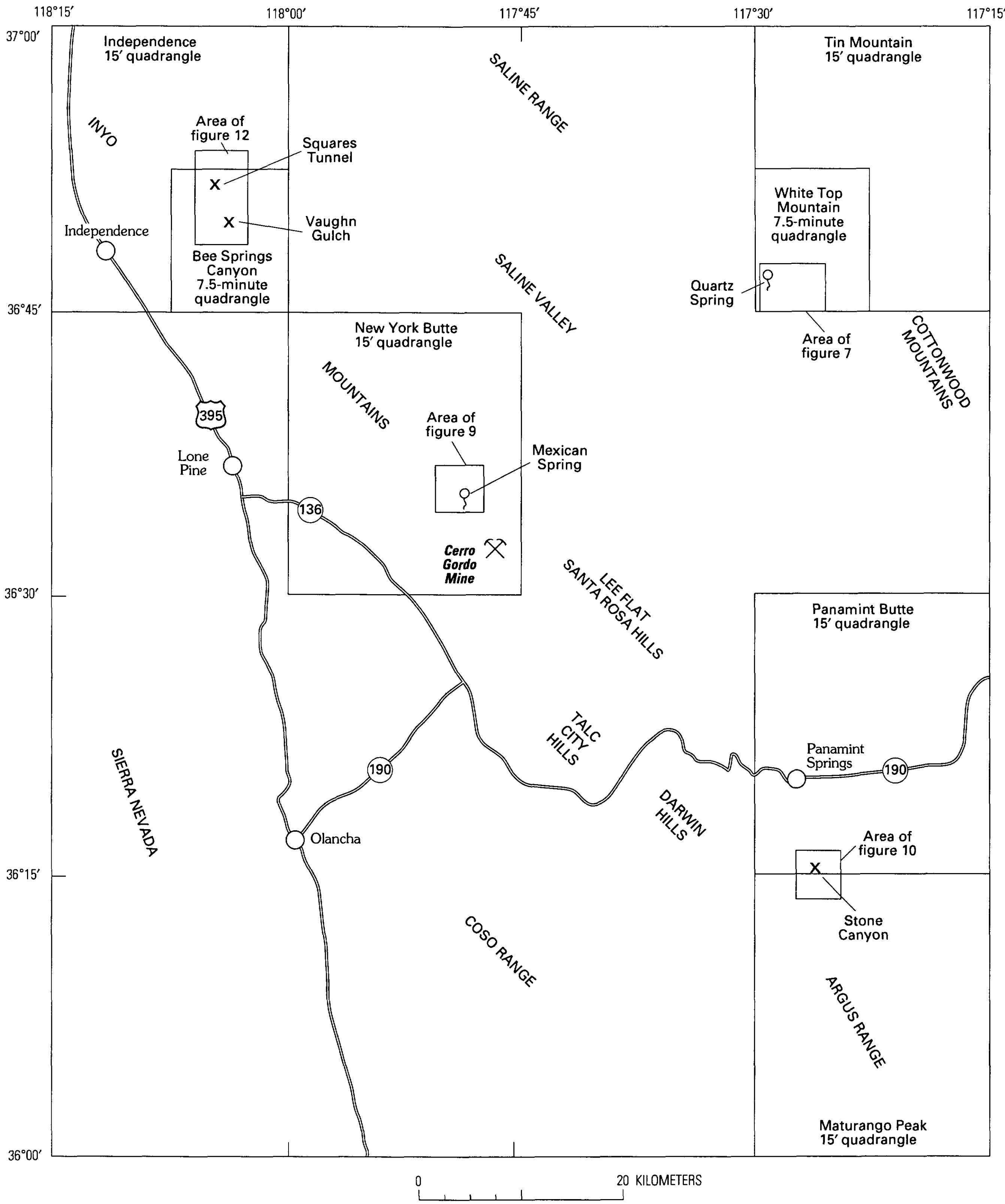


Figure 6. Map of east-central California showing locations of measured sections.

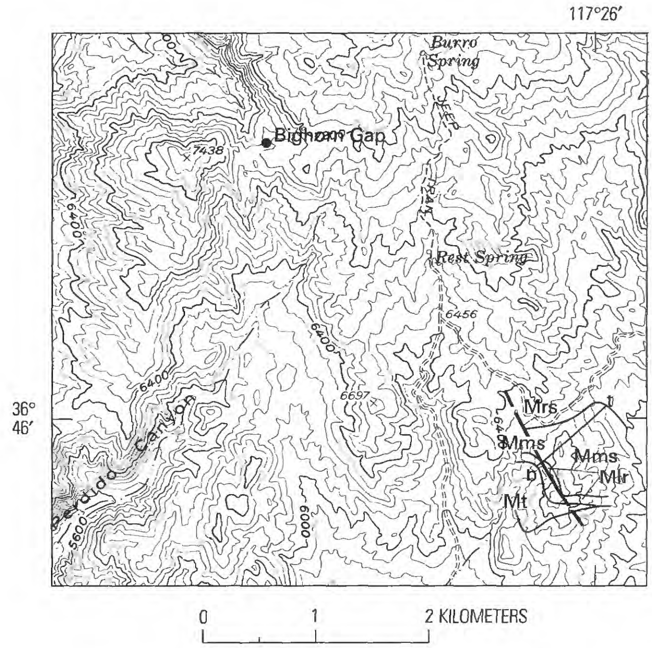
anchoralis-latus Zone has been recognized in sample QS–20, 27 m above the base of the Leaning Rock Formation, and the *mehli*-Lower *texanus* Zone is in samples QS–25 and QS–49 in the upper part of the formation (fig. 8). A comparison of the Leaning Rock Formation near Rest Spring and Bighorn Gap, which are only about 4 km apart, shows that the formation becomes increasingly condensed northwestward. For instance, the *mehli*-Lower *texanus* Zone is present in the Rest Spring section about 60 m above the base of the Leaning Rock Formation, but at Bighorn Gap it is only 19 m above the base (sample BG–108). This condensed stratigraphic interval, representing slow sedimentation, is similar in age and paleogeographic position to that of the condensed Delle Phosphatic Member (of the Woodman Formation, Deseret Limestone, and Chainman Shale) in eastern Nevada and western Utah (Sandberg and Gutschick, 1984).

MEXICAN SPRING FORMATION

The Mexican Spring Formation is here named to comprise a dominantly quartzose siltstone and very fine grained sandstone sequence that is exposed in the southern and eastern Inyo Mountains, Talc City Hills, and northwestern Cottonwood Mountains (fig. 1). The type section of the Mexican Spring Formation is near Mexican Spring, for which the unit is named, in the southern Inyo Mountains, about 7 km northwest of the Cerro Gordo Mine in the southeastern part of the New York Butte 15-minute quadrangle (fig. 9). This section comprises rocks originally assigned to the Perdido Formation by Merriam (1963). In addition, we have designated a measured reference section for the Mexican Spring Formation near Rest Spring in the Quartz Spring area (fig. 8), where this unit lies above the type section of the Leaning Rock Formation.

At its type section, the Mexican Spring Formation unconformably overlies the Tin Mountain Limestone and is conformably overlain by the Rest Spring Shale. Here, the Mexican Spring Formation is 37 m thick and is composed entirely of brown-weathering, massive, highly bioturbated, calcareous, quartzose siltstone and very fine grained sandstone (Klingman, 1987). Elsewhere, the siliciclastic rocks commonly are interbedded with limestone-intraclast conglomerate. Primary sedimentary structures in the siltstone generally are obscure, although, locally, meandering horizontal grazing trails typical of middle slope environments (Gutschick and Sandberg, 1983) are numerous. The siliciclastic rocks consist of quartz and some feldspar, but virtually no chert grains, and about 15 percent carbonate cement and clay matrix. This formation commonly forms smooth, rounded slopes covered with brownish-orange rubble.

In the type section, the base and top of the Mexican Spring Formation are placed below and above the lowest and highest prominent siltstone or sandstone beds, respectively. The top of this new unit and the top of the Perdido

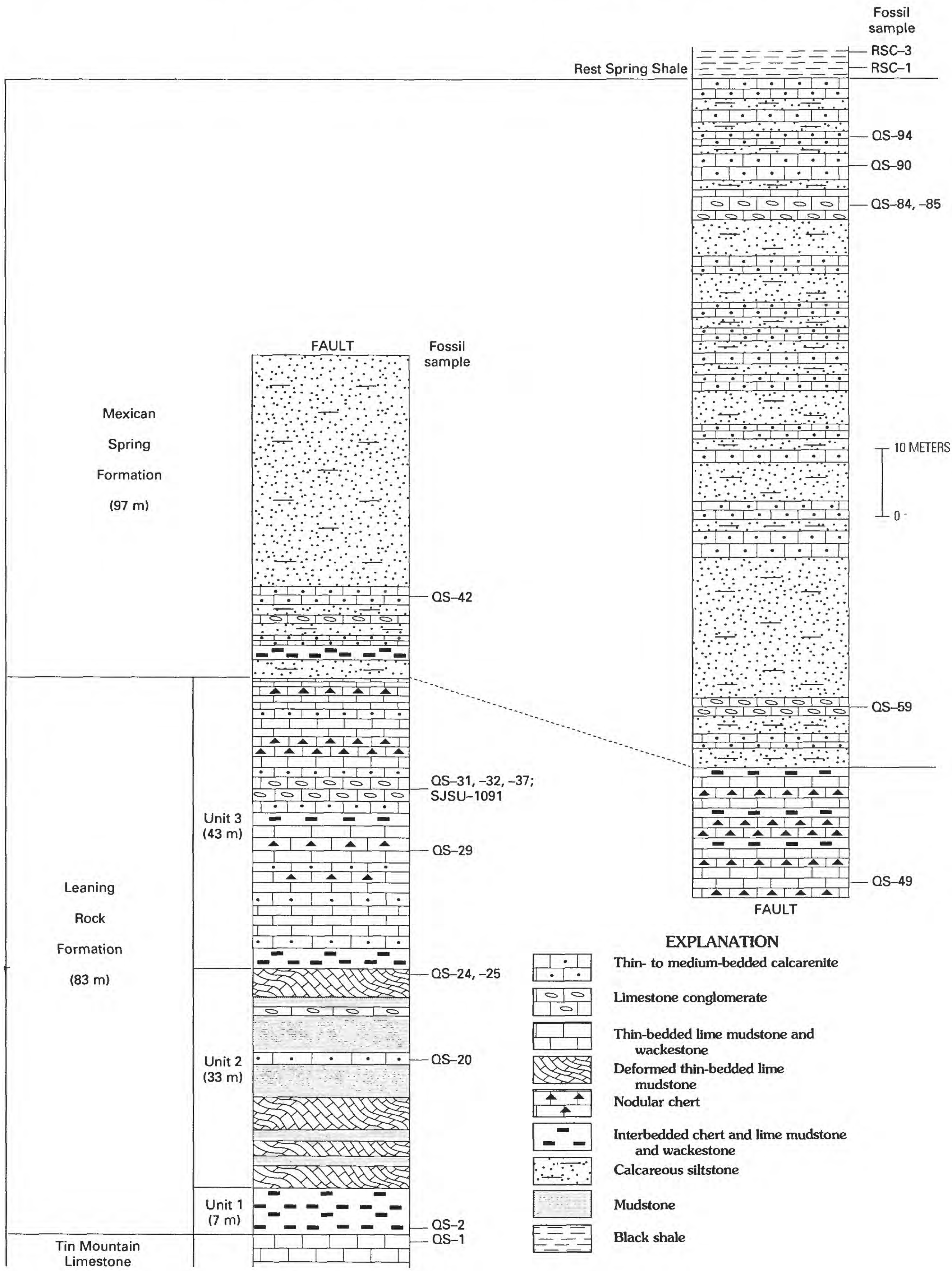


EXPLANATION

Mrs	Rest Spring Shale (Mississippian)
Mms	Mexican Spring Formation (Mississippian)
Mlr	Leaning Rock Formation (Mississippian)
Mtm	Tin Mountain Limestone (Mississippian)
b——t	Line of section—b indicates base of section, t, top
–——-	Fault in section

Figure 7. Map showing outcrop relations and location of type section of the Leaning Rock Formation and reference section of the Mexican Spring Formation (Perdido Group) in the Quartz Spring area. See figure 6 for location of map area. Base from U.S. Geological Survey, 1:62,500-scale, Tin Mountain quadrangle.

Group near Quartz Spring (in comparison with the upper contact of the Perdido Formation as defined by McAllister, 1952) is lowered by about 3 m to exclude a very fine grained, ammonoid-bearing, argillaceous limestone that lies directly above the quartzose siliciclastic and bioclastic limestone sequence; these very fine grained rocks are reassigned to the Rest Spring Shale. This is a better lithologic boundary for the formation (and the group) because it can be recognized regionally and it represents a significant depositional change. Therefore, near Rest Spring (fig. 7) the upper contact of the formation is placed at the top of the highest siltstone, sandstone, or limestone turbidite bed below a thin bed of dark-gray, very fine grained, phosphatic limestone that forms the basal part of the dominantly dark-gray, carbonaceous Rest Spring Shale (fig. 8). The maximum thickness of the Mexican Spring Formation, about 100 m, is near Rest Spring.


Fossil sample
RSC–3
Rest Spring Shale
RSC–1
QS–94
QS–90
QS–84, –85
10 METERS
0
QS–59
QS–49
FAULT
FAULT
Fossil sample
Mexican Spring Formation (97 m)
QS–42
QS–31, –32, –37; SJSU–1091
Unit 3 (43 m)
QS–29
Leaning Rock Formation (83 m)
QS–24, –25
QS–20
Unit 2 (33 m)
Unit 1 (7 m)
QS–2
QS–1
Tin Mountain Limestone
EXPLANATION
Thin- to medium-bedded calcarenite
Limestone conglomerate
Thin-bedded lime mudstone and wackestone
Deformed thin-bedded lime mudstone
Nodular chert
Interbedded chert and lime mudstone and wackestone
Calcareous siltstone
Mudstone
Black shale

Although fossils have not been recovered from its type section, numerous fossils recovered from its reference section show that the Mexican Spring Formation spans almost the entire Meramecian (lower Upper Mississippian). Based on macrofossils, McAllister (1952) and Langenheim and Tischler (1960) previously suggested a Late Mississippian age for the rocks herein assigned to the Mexican Spring Formation in the Quartz Spring area. Conodonts from a sediment-gravity-flow deposit in the lower part of the reference section (locality 10a, sample QS–59, fig. 8) probably are early Meramecian in age, and throughout much of the section, limestone turbidite interbeds within the unit (samples QS–42, QS–84, QS–90, fig. 8) contain middle Meramecian foraminifers. Conodonts from the uppermost part of the section (sample QS–94, fig. 8) are late Meramecian in age, and a transported brachiopod recovered from the highest limestone sediment-gravity-flow deposit near Rest Spring was similarly interpreted as late Meramecian in age by Mackenzie Gordon, Jr. (written commun., 1980). Finally, the presence of transported Zone IIIA or IIIB corals in sample SJS–1091 and conodonts of the *mehli*-Lower *texanus* Zone in sample QS–37 (upper Osagean) in the underlying Leaning Rock Formation and Lower *Cavusgnathus* Zone conodonts in the basal part of the overlying Rest Spring Shale (sample RSC–1), interpreted as Meramecian in age here but as Chesterian by Gordon (1964) and Alan Titus (oral commun., 1994) on the basis of ammonoids, suggests that the Mexican Spring Formation here is entirely Meramecian in age.

The siltstone and very fine grained sandstone of the Mexican Spring Formation were deposited in a relatively deep water environment, similar to that of the prodeltaic part of the Humbug Formation in Utah, when a eustatic sea level fall exposed much of the carbonate platform in the western United States (Sandberg and others, 1983). The high degree of bioturbation indicates that this depositional setting was well oxygenated.

STONE CANYON LIMESTONE

The Stone Canyon Limestone is here named to comprise a sequence of thinly interbedded, dark-gray, cherty limestone, chert, and mostly silicified micrite beds that is well exposed about 0.5 km north of Stone Canyon, for which the unit is named, on the east flank of the Argus Range (fig. 10); these exposures are designated as the type section for the formation. Locally the Stone Canyon Limestone contains micrite, calcarenite, and rarely limestone conglomerate. This formation is widely distributed and has been mapped throughout east-central California from the Santa Rosa Hills and eastern Cottonwood Mountains eastward to the Death Valley–Furnace Creek fault zone and southward to the Garlock fault (fig. 1).

The Stone Canyon Limestone conformably overlies the Tin Mountain Limestone and is conformably overlain by the Santa Rosa Hills Limestone. The lower contact of the Stone Canyon Limestone is placed at the base of the lowest bedded chert interval in the limestone sequence; the upper contact is placed where the limestone becomes much lighter gray, more massive, coarser grained, and more pelmatozoan rich with much less chert. The most characteristic feature of the Stone Canyon Limestone is its thin interbedding of dark-gray limestone, chert, and silicified micrite. This formation is distinguished from the overlying Santa Rosa Hills Limestone and from the underlying Tin Mountain Limestone by the alternation of these different rock types and by the browner appearance of its weathered outcrops.

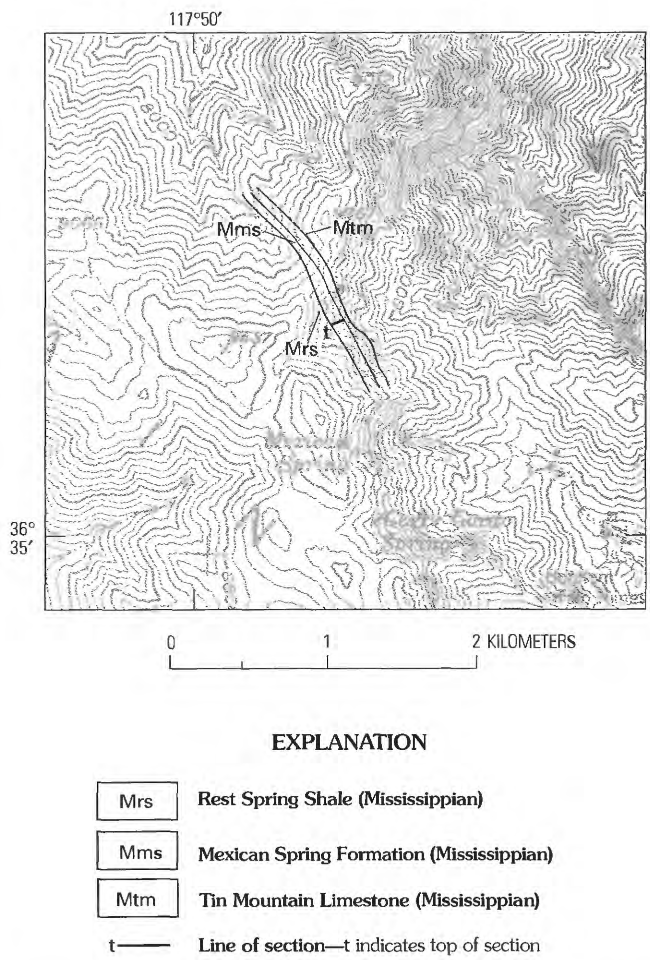


Figure 9. Map showing outcrop relations and location of the type section of the Mexican Spring Formation. See figure 6 for location of map area. Geology modified from Merriam (1971). Base from U.S. Geological Survey, 1:62,500-scale, New York Butte quadrangle.

Figure 8 (facing page). Type section of the Leaning Rock Formation and reference section of the Mexican Spring Formation (Perdido Group) in the Quartz Spring area showing positions of fossil samples. Fault along line of section shown in figure 7 repeats the section as indicated.

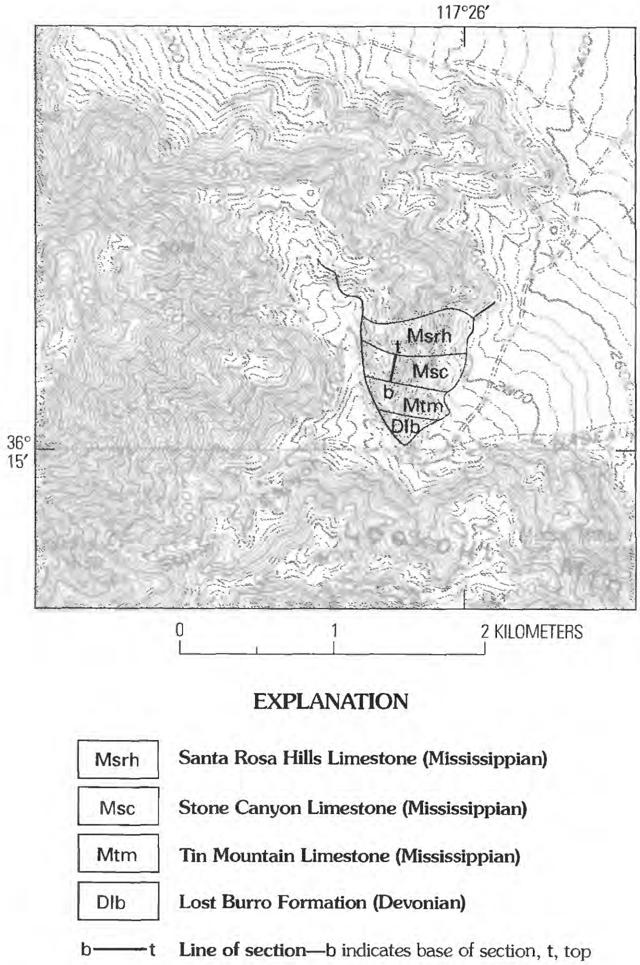


Figure 10. Map showing outcrop relations and location of the type section of the Stone Canyon Limestone. See figure 6 for location of map area. Geology modified from Hall (1971). Base from U.S. Geological Survey, 1:62,500-scale, Panamint Butte and Maturango Peak quadrangles.

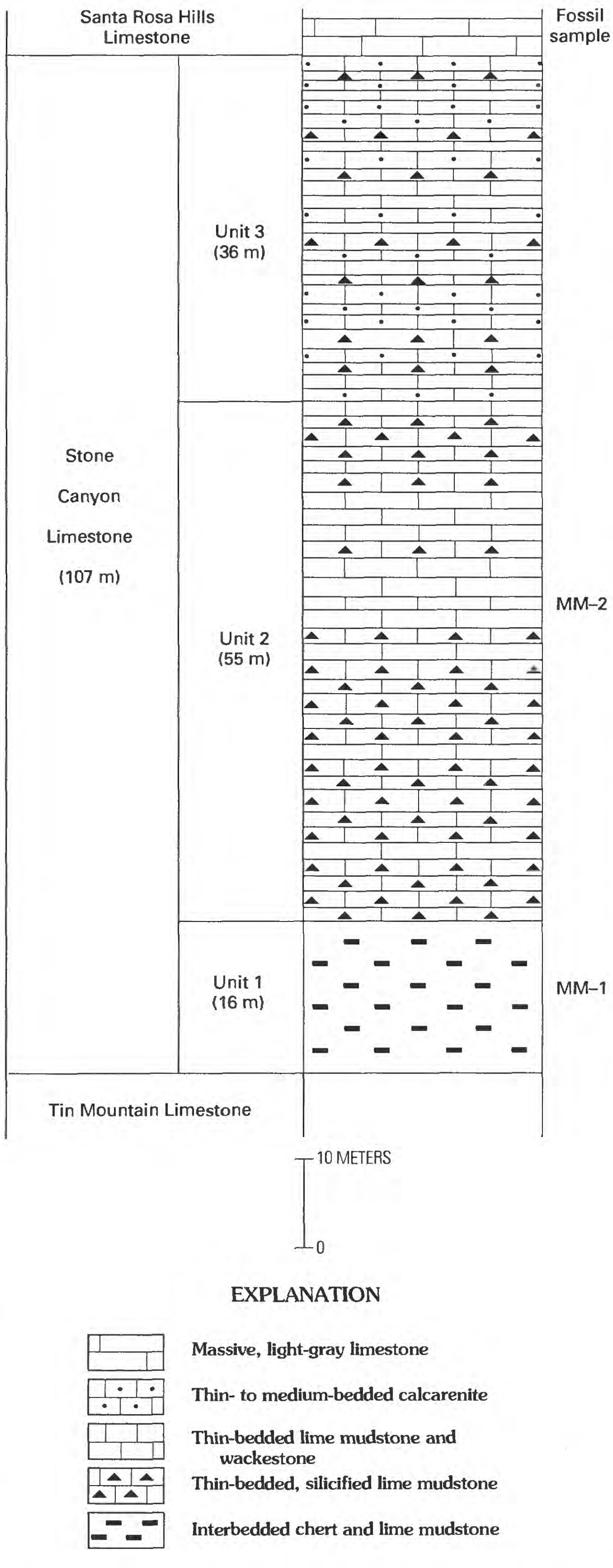
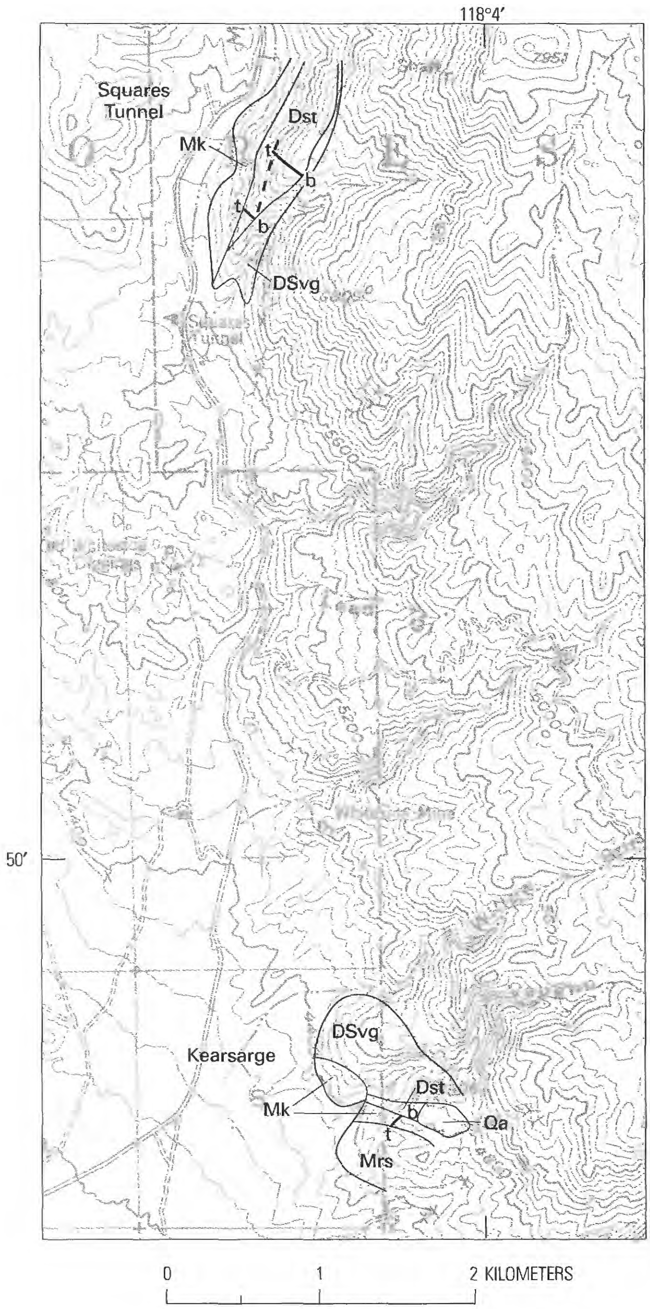


Figure 11. Type section of the Stone Canyon Limestone showing positions of fossil samples. Location of type section is shown in figure 10.

At its type section, the Stone Canyon Limestone is 107 m thick and comprises three subunits (fig. 11). The lower subunit (unit 1) is 16 m thick and consists of approximately 40 percent thin- to medium-bedded, dark-gray micrite and wackestone, 45 percent brown-weathering, dark-gray, spiculitic chert (both as irregular beds 1–15 cm thick and as nodules), and 15 percent orangish-brown-weathering, thin- to medium-bedded, dark-gray, spiculiferous, silicified micrite. Macrofossils other than scattered pelmatozoan ossicles are sparse in these rocks.

Unit 2 is 55 m thick and consists of the same lithologic components as unit 1, but chert is much less abundant, occurring only as discontinuous lenses and nodules.



EXPLANATION

Qa	**Alluvium (Quaternary)**
Mrs	**Rest Spring Shale (Mississippian)**
Mk	**Kearsarge Formation (Mississippian)**
Dst	**Squares Tunnel Formation (Devonian)**—Dashed line is marker bed along which section is offset
DSvg	**Vaughn Gulch Limestone (Devonian? and Silurian)**
b——t	**Line of section**—b indicates base of section, t, top

Unit 3, which is 36 m thick, consists of dark-gray micrite and wackestone, similar to those lithologies in unit 1, silicified micrite, and discontinuous lenses and nodules of chert. Beds and lenses of light- to medium-gray-weathering, pelmatozoan-rich, bioclastic limestone differentiates unit 3 from unit 2. This rock type becomes increasingly abundant upward through unit 3.

The Stone Canyon Limestone thickens northwestward from 107 m at its type section in the Argus Range to 456 m in the Santa Rosa Hills (Dunne and others, 1981). Farther north and west the formation interfingers with the much thinner, more heterogeneous Leaning Rock Formation.

In Cottonwood Canyon, a reference section 417 m thick is designated for the Stone Canyon Limestone. It is composed mostly of dark-gray, thin- to medium-bedded micrite, black chert, and brown-weathering, silicified micrite. For a more detailed description of the Cottonwood Canyon section, see Stevens and others (1995).

We interpret the Stone Canyon Limestone to have accumulated mostly as a relatively deep ramp or upper slope deposit. Unit 1 at the type section probably was deposited in a relatively deep water environment. In the Santa Rosa Hills and eastern Darwin Hills, temporally equivalent rocks contain several limestone turbidite and debris-flow beds. Unit 2 at the type section is similar to unit 1 except that it contains less chert. Unit 3 is intermediate in composition between unit 2 and the pelmatozoan-rich Santa Rosa Hills Limestone above. Thus, units 2 and 3 represent a shallowing-upward sequence deposited initially in deep water but later aggrading to above storm-wave base.

The three highest of the four Osagean conodont zones are represented in the Stone Canyon Limestone in the reference section designated in Cottonwood Canyon: the Upper *typicus* Zone (sample PD–17), the *anchoralis-latus* Zone (samples CC–1 and CC–4), and the *mehli*-Lower *texanus* Zone (sample CC–6). Because the Lower *typicus* Zone has been recognized in sample QS–1 from the uppermost part of the Tin Mountain Limestone and in sample QS–2 from 0.1 m above the Tin Mountain in the Leaning Rock Formation near Rest Spring and the next younger Upper *typicus* Zone is recognized in sample PD–17 from only 1 m above the Tin Mountain Limestone near the base of the Stone Canyon Limestone at Cottonwood Canyon, the zonal boundary between the Lower and Upper *typicus* Zones evidently is just above the top of the Tin Mountain Limestone.

Figure 12 (facing column). Map showing outcrop relations and location of the type sections of the Squares Tunnel Formation (top) and the Kearsarge Formation (bottom). See figure 6 for location of map area. Base from U.S. Geological Survey, 1:62,500-scale, Independence quadrangle.

SQUARES TUNNEL FORMATION AND KEARSARGE FORMATION

In a study of the Independence quadrangle on the west slope of the Inyo Mountains, Ross (1965, 1966) assigned all of the rocks above the Silurian and Lower Devonian(?) Vaughn Gulch Limestone and the partially coeval Sunday Canyon Formation and below the Upper Mississippian Rest Spring Shale to the Perdido Formation. This stratigraphic assignment was based on the lithologic heterogeneity of the rocks, a characteristic McAllister (1952) gave for the Perdido Formation at its type locality. Most of the rock types in the western Inyo Mountains bear little resemblance, however, to those McAllister (1952) included in the Perdido Formation. In addition, geologic mapping and dating (Stevens and Ridley, 1974; Stevens, 1986; this report) show that the distinctive lowermost part of this sequence contains Famennian (late Late Devonian) fossils and that only the upper part is Mississippian in age. On the basis of data now available, we propose two new formations to encompass the rocks previously assigned to the Perdido Formation in this area.

The lower part of the sequence, the Squares Tunnel Formation, is herein described, and the upper part of the sequence is herein named the Kearsarge Formation. Type sections of both formations are in the Mazourka Canyon area on the western flank of the Inyo Mountains near Independence, California (figs. 1, 6). The type section of the Squares Tunnel Formation (fig. 12) is on a ridge 1 km north-northeast of Squares Tunnel; the type section of the Kearsarge Formation (fig. 12) is on the ridge south of Vaughn Gulch.

SQUARES TUNNEL FORMATION

The Squares Tunnel Formation, the rocks of which originally were informally referred to as the Squares Tunnel beds by Stevens and Ridley (1974), is composed primarily of

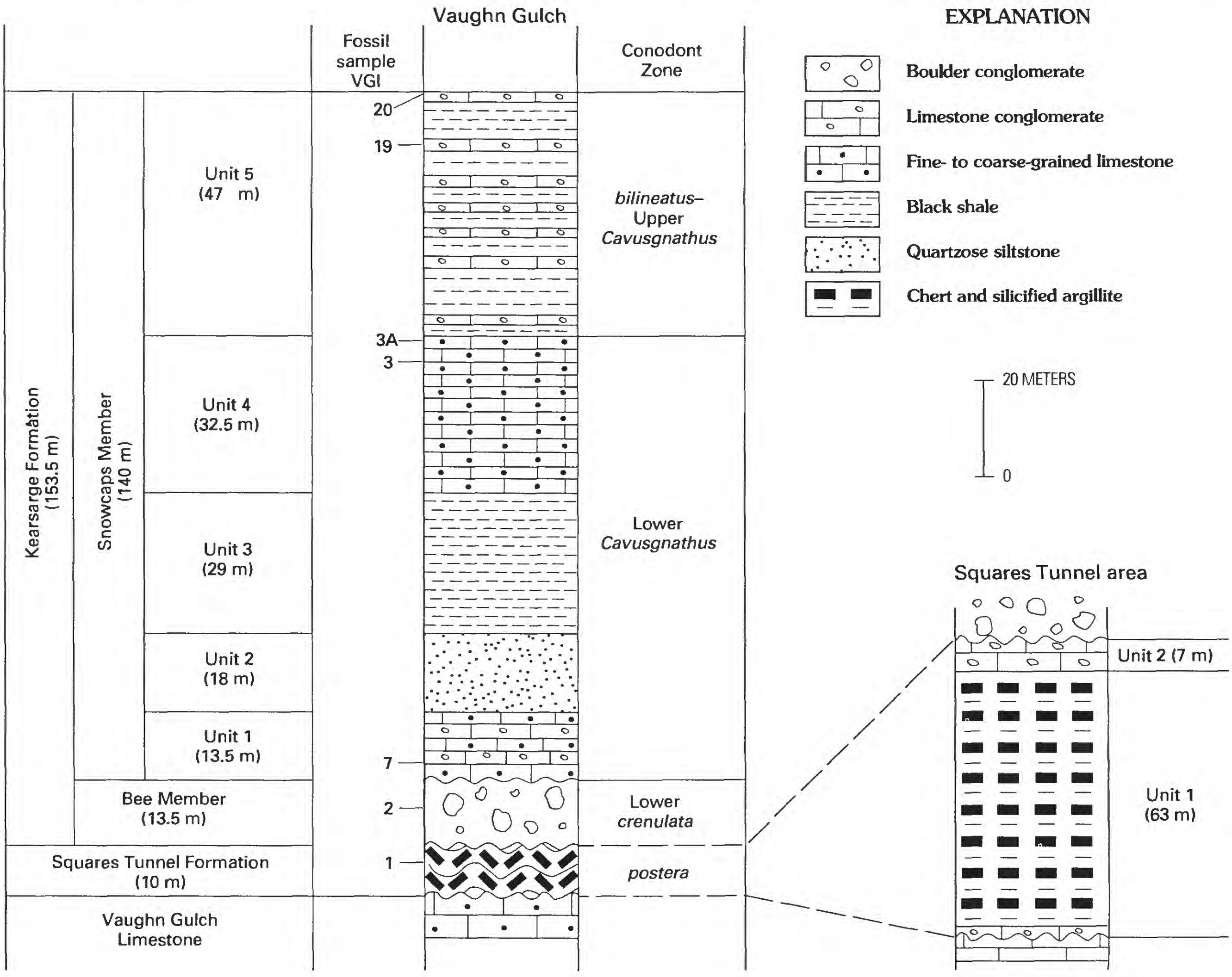


Figure 13. Type sections of the Squares Tunnel Formation (Squares Tunnel area) and Kearsarge Formation (Vaughn Gulch) showing positions of fossil samples. Location of type sections is shown in figure 12.

black chert and siliceous argillite and is exposed discontinuously along the western slopes of the Inyo Mountains. This unit also has been reported in the Last Chance Range, California, by Casteel (1986) and in the northern Grapevine Mountains (Mitch Casteel, oral commun., 1992). Although not formally proposed, this name was used in a chart by Boucot and Potter (1977). We here formally name the Squares Tunnel Formation and designate a type section for the unit near Squares Tunnel, for which the unit is named, in the Mazourka Canyon area in the western Inyo Mountains.

The Squares Tunnel Formation unconformably overlies the Silurian and Lower Devonian(?) Vaughn Gulch Limestone and is unconformably overlain by the Mississippian Kearsarge Formation. The Squares Tunnel Formation is divided into two subunits at its type section north-northeast of Squares Tunnel (fig. 13), a lower, dominantly chert and argillite unit (unit 1) 63 m thick and an upper, conglomeratic limestone unit (unit 2) about 7 m thick. Unit 1 consists of black argillite and impure chert in beds commonly 2–8 cm thick. Some of the chert beds contain distinctive light-gray stringers and (or) blebs as thick as 1 cm that were determined by Ross (1966) to be phosphatic. Unit 2 consists of conglomeratic limestone that contains clasts as long as 12 cm composed of limestone and, locally, of argillite and chert apparently derived from unit 1.

In its type section, the Squares Tunnel Formation occupies a channel cut deeply into the underlying Silurian and Lower Devonian(?) Vaughn Gulch Limestone (Stevens and Ridley, 1974). The basal contact is marked by a pebble conglomerate less than 1 m thick composed of clasts of limestone and black chert as much as 8 cm across in a medium-gray limestone matrix.

Southwestward along the ridge from the type section toward Squares Tunnel, the Squares Tunnel Formation thins abruptly due to onlap of the unit against the western margin of the channel, and all the black chert and argillite of its unit 1 is missing near the south end of the ridge, 0.3 km south of the type section. The upper contact of the Squares Tunnel Formation is placed at the base of a megabreccia that forms the basal part of the Kearsarge Formation.

North of Water Canyon, 8.5 km north of its type section, rocks that we questionably assign to the Squares Tunnel Formation consist primarily of siliceous, slaty siltstone (Ridley, 1971). These rocks appear to be conformable with the underlying Silurian and Devonian Sunday Canyon Formation. The contact between the Sunday Canyon Formation and the beds questionably assigned to the Squares Tunnel Formation is placed between lower calcareous and upper noncalcareous beds, in the same position that Ross (1966) placed the contact between the Sunday Canyon and Perdido Formations.

At the south end of the outcrop belt of the Squares Tunnel Formation, in the bottom of Vaughn Gulch, a large mass of folded, thin-bedded, black chert containing phosphatic eyelets and stringers, essentially identical to the most distinctive rock type at the type section, is well exposed. The folding is interpreted here to represent soft-sediment deformation, and the entire outcrop may represent a large, submarine landslide. On the ridge south of Vaughn Gulch, a 50-m-thick sequence of thin-bedded, fine-grained, dark-colored limestone and chert and thin beds of limestone conglomerate, which may be assignable to the Squares Tunnel, overlies the unconformity at the top of the Silurian and Devonian(?) Vaughn Gulch Limestone.

We interpret the Squares Tunnel Formation to be entirely Late Devonian in age. A Devonian fish plate has been reported from float (Stevens and Ridley, 1974), and Late Devonian (Famennian) radiolarians identified by Benita Murchey were recovered from the type section near Squares Tunnel (Stevens and others, 1995) (sample S–0654, appendix 1). We also have recovered conodonts of the *postera* Zone from a thin micritic limestone lens or concretion in Vaughn Gulch (sample VGI–1), narrowing the age of this part of the Squares Tunnel Formation to the late Famennian (fig. 5). Eifelian (early Middle Devonian) conodonts have been recovered from the older Sunday Canyon Formation (Stevens and Ridley, 1974), and late Kinderhookian conodonts have been recovered from the overlying Kearsarge Formation (sample VGI–2). Temporally and lithogenetically, the Squares Tunnel Formation correlates with the upper parts of the western-facies Slaven Chert and transitional-facies Woodruff Formation, which also contain black chert and phosphatic nodules, in central Nevada.

We interpret the Squares Tunnel Formation to have been deposited primarily in deep-water submarine channels locally cut at least 125 m deep into the slope deposits of an Early to Middle Devonian carbonate platform. This interpretation is based on the following evidence: (1) the Vaughn Gulch Limestone into which the channels were cut is a relatively deep water unit, (2) the Squares Tunnel Formation itself is characterized by radiolarian chert and argillite, and (3) in situ conodonts in a micritic concretion or limestone lens (sample VGI–1) represent the moderately deep water palmatolepid-polygnathid biofacies (Sandberg and Dreesen, 1984) (fig. 4).

KEARSARGE FORMATION

The Kearsarge Formation is here named to comprise a heterogeneous assemblage of Mississippian rocks exposed in Mazourka Canyon in the western Inyo Mountains. This unit also is present in the Tinemaha Reservoir area and the Last Chance Range, California (fig. 1). It is named for the site of a railroad station that once stood next to the Mazourka Canyon road in the Bee Springs Canyon 7.5-minute quadrangle near the town of Independence (fig. 6). The Kearsarge Formation generally rests on the Upper Devonian Squares Tunnel Formation, but locally it rests upon the underlying Vaughn Gulch Limestone. Extending from its type section on the ridge south of Vaughn Gulch northward to Johnson

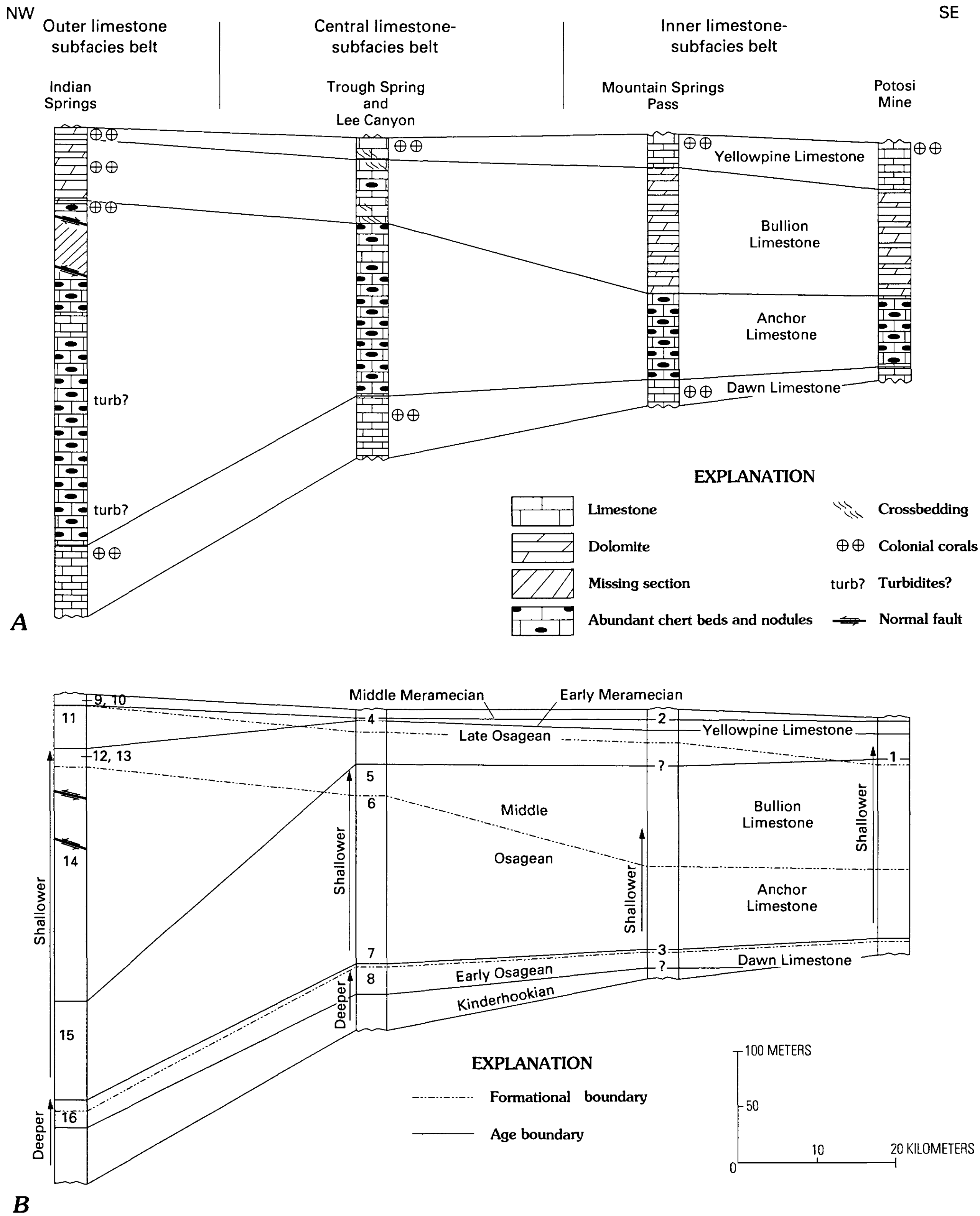


Figure 14. Stratigraphic sections from Indian Springs to Potosi Mine, Nevada. Location of sections shown in figure 1. Modified from Stevens and others (1995). *A*, Formational units, some important environmental indicators, and generalized lithology. *B*, Interpreted deepening and shallowing trends, time lines, and the position of time-significant fossil samples as indicated by the following numbers: 1, PO–5; 2, YPC–4; 3, SM–12; 4, LC–YP–3; 5, LC–BU–8; 6, LC–AN–1; 7, TS–AN–14; 8, DCF–1; 9, ISD–1; 10, IST–BU–1; 11, ISS–31; 12, IST–1; 13, ISS–26; 14, ISB–AN–1B; 15, ISS–12; 16, ISS–11. Middle Osagean = Upper *typicus* and *anchoralis-latus* Zones.

Spring (fig. 1), the lower contact of the Kearsarge Formation is placed at the base of a megabreccia containing large blocks and boulders of limestone and quartzite. Farther north, the lower contact is placed provisionally at the base of the lowest pebbly mudstone in the sequence. If the age of a thin sequence of siliceous, slaty siltstone below the lowest pebbly mudstone should be determined as Mississippian, the contact of the Kearsarge Formation should be lowered to include these beds. The Kearsarge Formation is conformably overlain by the Rest Spring Shale. Following Ross (1966) in his placement of the lower contact of the Rest Spring Shale, we place the upper contact of the Kearsarge Formation (= lower contact of the Rest Spring) at the top of the highest major limestone or sandstone bed in this part of the sequence. The Kearsarge Formation ranges from about 47 to 154 m in thickness in the Mazourka Canyon area (Ridley, 1971).

In its type section, the Kearsarge Formation is 153.5 m thick and consists of two members (fig. 13). The lower member, here named the Bee Member after Bee Springs in the lower Mazourka Canyon area, consists of a 13.5-m-thick basal megabreccia. The upper member, here named the Snowcaps Member for the Snowcaps Mine near the mouth of Mazourka Canyon, comprises five subunits, in ascending order: a 13.5-m-thick sequence of calcareous turbidites (unit 1), a 18-m-thick quartzose siltstone unit (unit 2), a 29-m-thick black shale unit (unit 3), a 32.5-m-thick sequence of resistant limestone turbidites (unit 4), and a 47-m-thick sequence of interbedded black shale, limestone debris-flow deposits, and turbidites (unit 5).

The Bee Member (megabreccia) in its type section, which is designated as the same as part of the type section of the Kearsarge Formation on the ridge south of Vaughn Gulch, contains blocks and boulders of quartzite and limestone and some chert clasts (Ridley, 1971). Some quartzite boulders are 1 m in diameter, and many show prominent crossbedding. Some of the limestone blocks, containing "two-hole" crinoid ossicles of late Early to early Middle Devonian age (Johnson and others, 1968), are as large as 13 m. The relatively uncommon chert clasts are as long as 6 cm. The matrix consists of medium-gray calcarenite that has yielded Lower *crenulata* Zone (Kinderhookian) conodonts (sample VGI–2). This demonstrates that the time of emplacement of this unit was not before late Kinderhookian (Early Mississippian) time, which is here regarded as the age of the member.

The overlying Snowcaps Member of Late Mississippian age, the type section of which is designated as the same as part of the type section of the Kearsarge Formation on the ridge south of Vaughn Gulch, comprises five subunits. Unit 1 is exposed only on the south side of Vaughn Gulch where it consists of several thick, graded, bioclastic limestone beds.

Unit 2 is composed of quartzose siltstone that weathers orangish brown. This rock type consists mostly of quartz silt and 9–15 percent potassium feldspar (Donald Peters, written commun., 1989). The lithologic character of the rocks comprising this unit suggests that it may be a tongue of the Mexican Spring Formation, which is present in the southeastern Inyo Mountains about 30 km to the southeast.

Unit 3 is composed of black shale and argillite that contain abundant horizontal grazing trails. Rocks of this unit are similar to, although harder and apparently more siliceous than, those that compose the lower part of the overlying Rest Spring Shale.

Unit 4 consists of 32.5 m of amalgamated limestone turbidites, some of which show T_{ab} Bouma divisions and others only T_b. Individual beds as thick as 1 m characteristically consist of a medium-gray-weathering, normally graded, crinoidal calcarenite lower part and a brown-weathering, laminated upper part containing abundant quartz silt.

Unit 5 consists of black shale interbedded with two limestone debris-flow beds containing clasts of dark chert and several normally graded, locally channelized, bioclastic limestone turbidite beds 0.5–1.5 m thick.

Unit 4 and the limestones in unit 5 evidently pinch out within a very short distance north and west of Vaughn Gulch; where the limestones in units 4 and 5 are not present, unit 3 is virtually indistinguishable lithologically from the Rest Spring Shale. The Bee Member and unit 2 of the Snowcaps Member are recognizable extending from their type sections for about 10 km northward to a point just north of Johnson Spring (fig. 1), where they apparently pinch out. Farther north, for instance in Al Rose Canyon (fig. 1) in the northern part of Mazourka Canyon about 13 km north of Vaughn Gulch, Donald Peters (written commun., 1989) has recognized in the Kearsarge Formation several different rock types—bioclastic calcarenite and calcarenite containing large amounts of quartz silt; chert-pebble conglomerate; pebbly mudstone in which the clasts are composed of mudstone, chert, and angular quartz; and black shale. These different rock types are complexly interbedded, and only the quartz silt-bearing beds and black shale closely resemble rocks of the Kearsarge Formation at its type section. In Al Rose Canyon, many of the mudstone and chert clasts in these rocks evidently have been reworked from the underlying Squares Tunnel Formation or from the lower part of the Kearsarge Formation (Ridley, 1971; Donald Peters, written commun., 1989), but some may have been derived ultimately from the Antler orogenic belt to the northwest. Although these rocks in the northern part of Mazourka Canyon are quite different from those in the southern part of the canyon, all are here included in the Kearsarge Formation because facies change across very short distances and it is impractical to apply separate names to each facies.

Unit 1 of the Snowcaps Member contains conodonts of the Lower *Cavusgnathus* Zone (sample VGI–7) and thus is Meramecian in age. Unit 2 is lithologically correlative with the Meramecian Mexican Spring Formation at its type section, and unit 4 yielded late Meramecian conodonts (samples VGI–3 and VGI–3A) correlative with the uppermost part of the Mexican Spring Formation in the Quartz Spring area. Stevens and Ridley (1974) reported a conodont (*Cavusgnathus altus*), considered to indicate Chesterian age, from one of the highest limestone beds in the Kearsarge Formation south of Johnson Spring (Ridley, 1971), and sample VGI–20 from the uppermost part of unit 5 in the type section yielded Chesterian conodonts of the *bilineatus*-Upper *Cavusgnathus* Zone. Thus, the Kearsarge Formation apparently includes all of Meramecian time and extends into the early Chesterian. Because the Bee Member apparently is of Kinderhookian age, Osagean beds evidently are not present in the type section of the Kearsarge Formation.

COMPARISON OF MISSISSIPPIAN STRATIGRAPHY AND STRATIGRAPHIC NOMENCLATURE IN SOUTHERN NEVADA AND EAST-CENTRAL CALIFORNIA

Three major Mississippian lithofacies belts—the southeastern, central, and northwestern—are readily recognizable in both southern Nevada and east-central California. Within these belts, especially the southeastern-facies belt, the stratigraphic and lithologic similarities between the two areas are striking.

SOUTHEASTERN-FACIES BELT

Throughout east-central California and southern Nevada, a Mississippian limestone sequence, representing an extensive carbonate platform, rests on Devonian carbonate sequences. In both areas, this southeastern-facies belt can be subdivided into three subfacies belts (Stevens and others, 1995) that have been called the outer limestone-subfacies belt, the central limestone-subfacies belt, and the inner limestone-subfacies belt (figs. 14, 15). The generally lowest Mississippian units, the Dawn Limestone (in Nevada) and the Tin Mountain Limestone (in California), in all three subfacies belts consist of medium- to dark-gray limestone that ranges in age from Kinderhookian into early Osagean. In all areas, these rocks are shallow-water carbonate-platform deposits. The overlying Anchor Limestone (in Nevada) and the Stone Canyon Limestone (in California) are both distinguished by medium- to dark-gray micrite that contains an abundance of interbedded chert and silicified micrite beds and lenses. Deposition of these strata, which accumulated in outer platform environments in the inner limestone-subfacies belt and in lower slope environments in the central and outer limestone-subfacies belts, began in early Osagean time near the boundary between the Upper and Lower *typicus* Zones. These are the deepest water rocks in the sequence and correlate temporally with the Delle Phosphatic Member (of the Woodman Formation, Deseret Limestone, and Chainman Shale) in Utah and Nevada, which has been interpreted as representing a deep-water environment by some authors (Sandberg and Gutschick, 1984), or a shallow-water environment by others (Nichols and Silberling, 1990). In both east-central California and southern Nevada, this unit thickens greatly to the margin of the platform, and its uppermost part becomes much younger, as shown in the stratigraphic cross sections drawn for eastern California (fig. 14) and southern Nevada (fig. 15).

In southern Nevada the upper part of the Mississippian limestone sequence is composed of two formations, the Bullion and Yellowpine Limestones, whereas in California only one formation, the Santa Rosa Hills Limestone, is recognized. Generally, the Santa Rosa Hills Limestone is light gray and highly crinoidal, similar to the Bullion Limestone, although in the northeastern Cottonwood Mountains it is dark gray and appears to be quite fine grained. In this latter area, the Santa Rosa Hills Limestone is more similar to the Yellowpine Limestone. The Bullion Limestone, lower part of the Yellowpine Limestone, and Santa Rosa Hills Limestone were interpreted by Stevens and others (1995) to be progradational units on the basis of their sedimentologic and paleontologic characteristics and the age relationships shown in figures 14 and 15. The character of the progradation of these shallow-water facies, composed primarily of bioclastic limestone, across the platform from the middle Osagean to the earliest Meramecian also can be shown in map view (figs. 16–18). As shown on these maps, by early Meramecian time shallow-water deposits had prograded to near the margin of the platform. In both east-central California and southern Nevada, carbonate sedimentation ceased, probably in the middle Meramecian (Stevens and others, 1991, 1995), because of a sea-level fall that led to development of a widespread karst plain throughout the western United States (Sandberg and others, 1983). Later, near the end of the Mississippian, the carbonate platform was covered by the dominantly siliciclastic Indian Springs Formation, upon which Pennsylvanian limestones were deposited as part of a transgression that began in Chesterian time (Poole and Sandberg, 1991).

Although similar in most respects, the sequences deposited in southern Nevada and east-central California differ in scale. The sequence in California is almost twice as thick as that in Nevada, and the original distance, after accounting for thrust faulting, separating the inner limestone-subfacies and outer limestone-subfacies belts apparently was much greater in Nevada than that in California.

CENTRAL-FACIES BELT

The details of the central-facies belt in east-central California and southern Nevada are somewhat different. Upper Devonian carbonate sequences underlie the Mississippian rocks in each area, but in parts of southern Nevada the mixed siliciclastic and calciclastic Narrow Canyon Formation, which apparently has no counterpart in California, was deposited during earliest Mississippian time. The succeeding

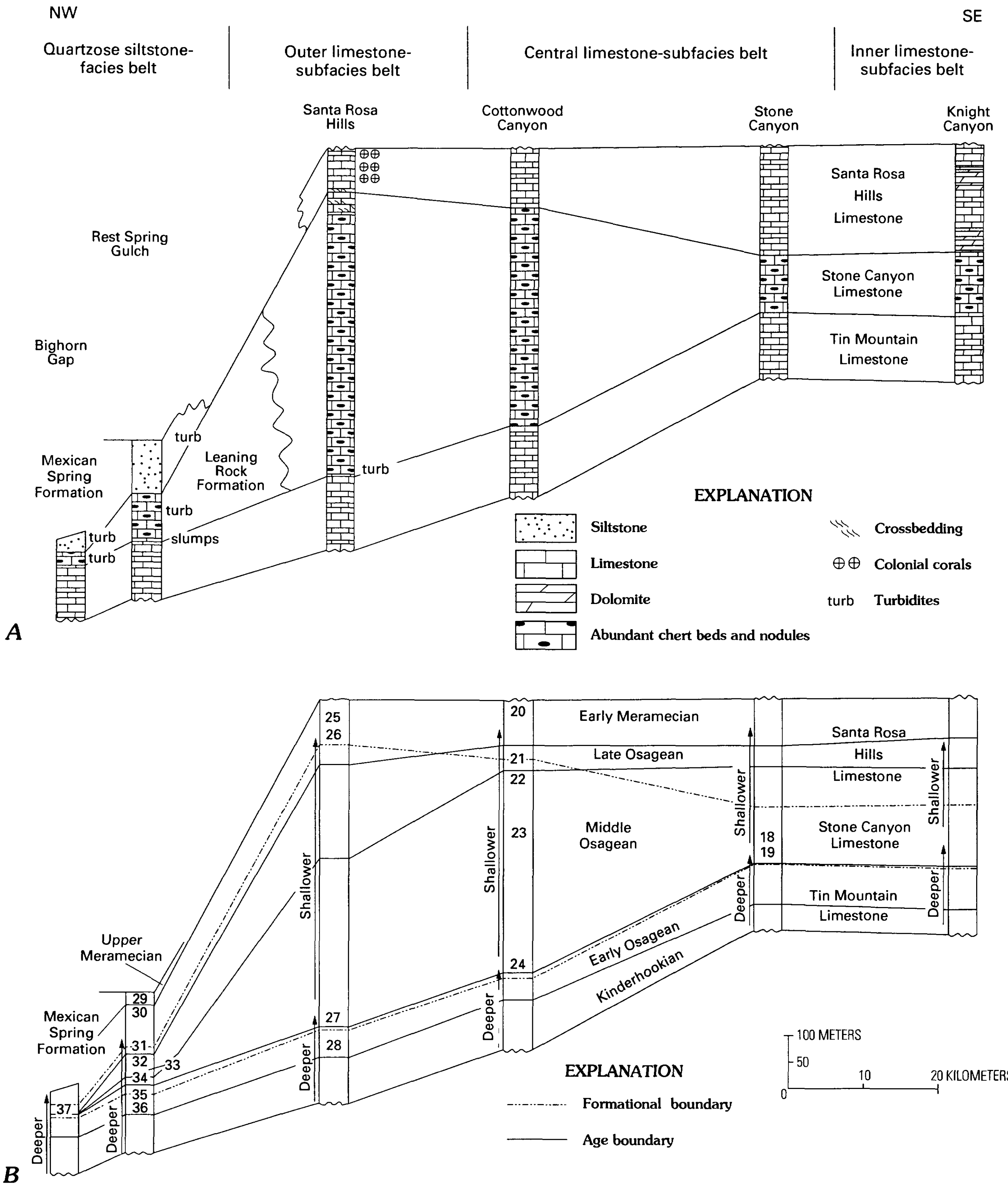


Figure 15. Stratigraphic sections from Bighorn Gap to Knight Canyon, California. Location of sections shown in figure 1. Modified from Stevens and others (1995). *A*, Formational units, some important environmental indicators, and generalized lithology. *B*, Thicknesses, interpreted deepening and shallowing trends, time lines, and the position of time-significant fossil samples as indicated by the following numbers: 18, MM–2; 19, MM–1; 20, MC–1; 21, CC–6; 22, CC–4; 23, CC–1; 24, PD–17; 25, SR–31, SR–31A; 26, C–1; 27, SRA–1; 28, SRA–22; 29, QS–94; 30, QS–42, QS–84, QS–85, QS–90; 31, QS–59; 32, QS–37, SJS–1091; 33, QS–25; 34, QS–20; 35, QS–2; 36, QS–1; 37, BG–108. Middle Osagean = Upper *typicus* and *anchoralis-latus* Zones.

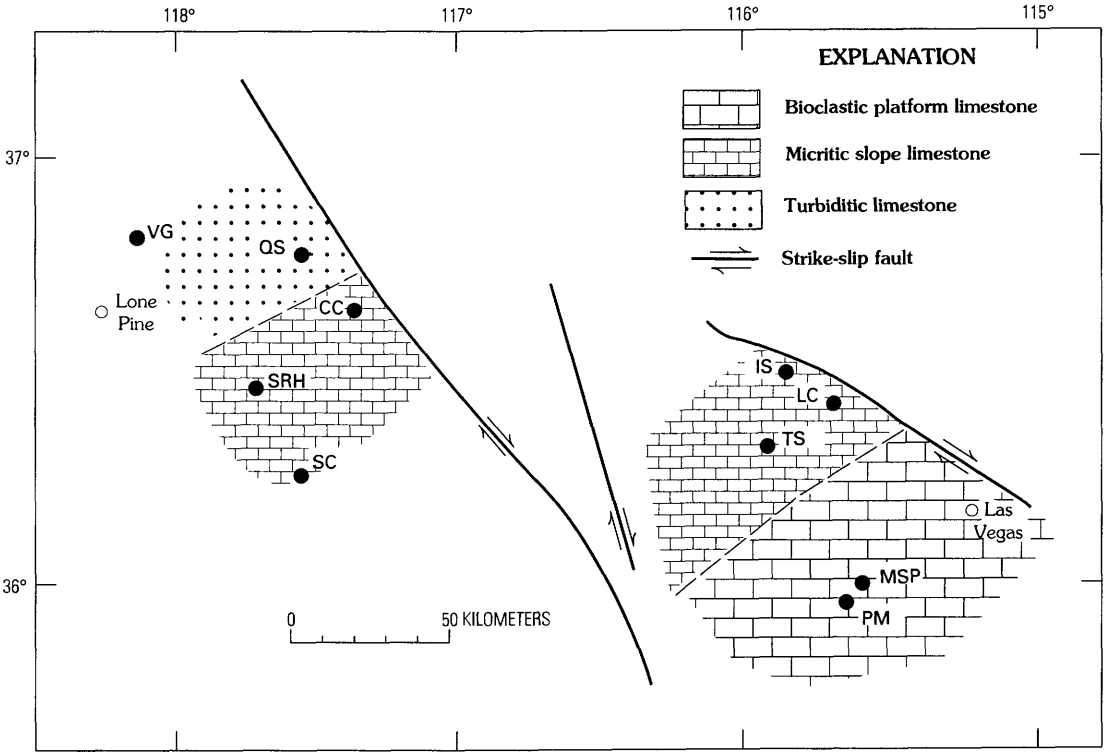


Figure 16. Map showing distribution of middle Osagean (Upper *typicus* and *anchoralis-latus* Zones) lithofacies in southern Nevada and east-central California. Sample localities (solid circles): CC, Cottonwood Canyon; IS, Indian Springs; LC, Lee Canyon; MSP, Mountain Springs Pass; PM, Potosi Mine; QS, Quartz Spring; SC, Stone Canyon; SRH, Santa Rosa Hills; TS, Trough Spring; VG, Vaughn Gulch.

unit in the Mercury Ridge area (including the North Ridge and South Ridge in addition to Mercury Ridge) in Nevada is the Mercury Limestone, which has a lithologic and at least a partial temporal equivalent in the lower part of the Tin Mountain Limestone in east-central California. Above the Mercury Limestone, a limestone lithogenetically equivalent to the Tripon Pass Limestone in central Nevada was studied and informally termed the "Timpi limestone" unit in 1965 by Poole (unpub. field data) and subsequently referred to as the limestone of Timpi Canyon by Poole and Sandberg (1977) and mapped by Barnes and others (1982). This unit is late Kinderhookian and early Osagean in age (Sandberg and Poole, unpub. data) and is temporally equivalent to the upper part of the Tin Mountain Limestone in east-central California. The limestone of Timpi Canyon, however, represents a deeper water environment than the Tin Mountain Limestone.

In the Mercury Ridge area, middle and upper Osagean rocks may be lacking or may be present only in a thin covered interval representing a condensed section somewhat similar to the condensation of the Leaning Rock Formation at Bighorn Gap in California (fig. 15). In both areas, the limestone sequence is succeeded by a predominantly quartzose siltstone and very fine grained sandstone unit (an unnamed siltstone in Nevada and the Mexican Spring Formation in California) that is overlain in turn by olive-gray to black shale (Chainman Shale in Nevada and Rest Spring Shale in California). In east-central California, the siliciclastic sequence is overlain by Lower Pennsylvanian limestone; the top of the Mississippian section is not exposed in the Mercury Ridge area of southern Nevada.

The Tin Mountain Limestone in California and the combined Narrow Canyon Formation, Mercury Limestone, and limestone of Timpi Canyon in Nevada represent deepening-upward sequences. The upper parts of these sequences and the overlying siltstones probably are slope deposits. The overlying shale units were deposited under basinal conditions.

NORTHWESTERN-FACIES BELT

The differences between the rocks of the northwestern-facies belt in east-central California and in southern Nevada are somewhat greater than those of the other facies belts. In southern Nevada, the Eleana Formation consists of a great thickness of Mississippian rocks above a thin sequence of Devonian rocks (unit A and lower part of unit B of Poole and others, 1961). A comparison of sections in the Eleana Range and at Bare Mountain suggests that the Mississippian part of

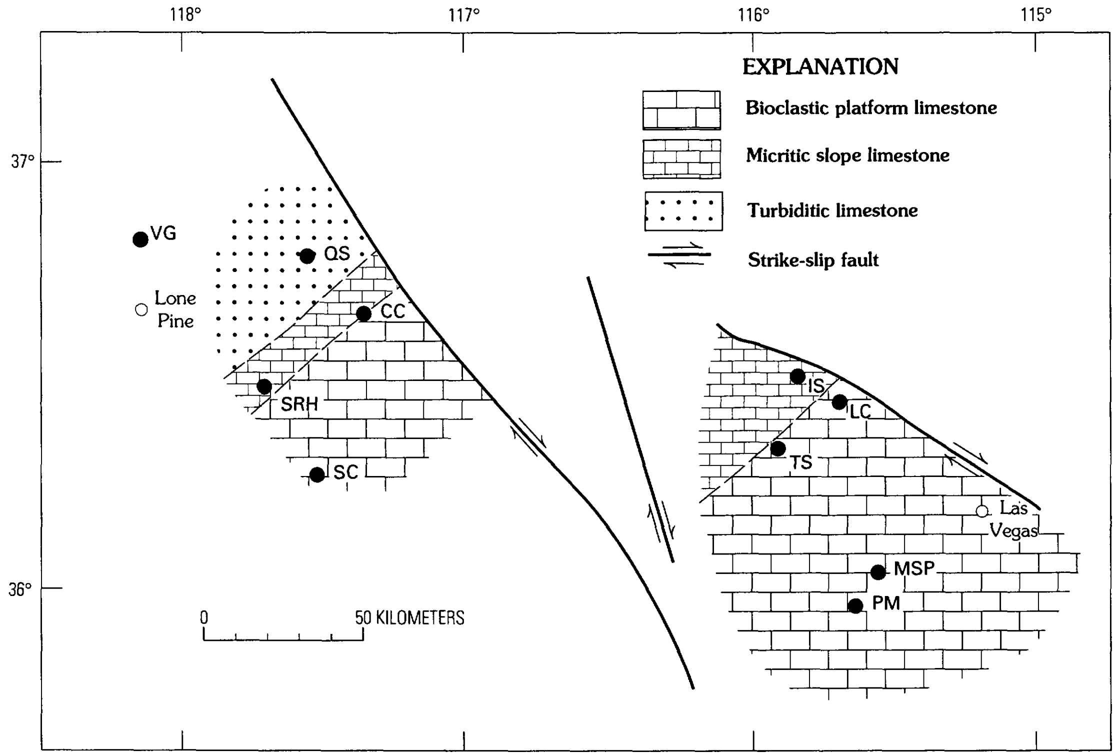


Figure 17. Map showing distribution of upper Osagean (*mehli*-Lower *texanus* Zone) lithofacies in southern Nevada and east-central California. Sample localities (solid circles): CC, Cottonwood Canyon; IS, Indian Springs; LC, Lee Canyon; MSP, Mountain Springs Pass; PM, Potosi Mine; QS, Quartz Spring; SC, Stone Canyon; SRH, Santa Rosa Hills; TS, Trough Spring; VG, Vaughn Gulch.

the sequence consists mostly of fine-grained siliciclastic rocks near the base, overlain by many chert-pebble conglomerate units representing an Antler orogenic-belt source to the northwest, and capped by fine-grained rock composed of siliciclastic sediment possibly derived primarily from the craton.

In east-central California, the sequence of strata is somewhat similar. Here, the Upper Devonian is represented by chert and argillite of the Squares Tunnel Formation, which is, in part, a temporal equivalent of the lowermost part of the Eleana Formation as mapped by Monsen and others (1992) at Bare Mountain in southern Nevada (Poole and Sandberg, 1993). The Mississippian sequence in the western Inyo Mountains is represented by the mixed clastic rocks (including conglomerate) of the Kearsarge Formation and the overlying Rest Spring Shale. Most of the medium- to coarse-grained clastic sedimentary materials in the southern exposures of the Kearsarge Formation were derived from the east (Stevens and Ridley, 1974; Stevens, 1986), but some of the chert-pebble conglomerate in northern Mazourka Canyon and farther north may have had an Antler-orogen source to the north or northwest. Rocks of the Kearsarge Formation have lithologic counterparts in the Eleana Formation, and the sequence of rock types in the two areas (the coarse-grained Kearsarge Formation overlain by the fine-grained Rest Spring Shale) is similar. The differences between the sequences in the two areas, especially the thicknesses, probably are due to differences in the positions of the two depositional sequences within the trough, the Eleana Formation having been deposited closer to the axis of the flysch trough than the type section of the Kearsarge Formation, which was deposited on its eastern flank. Because of the difference in distance from the carbonate platform, the positions of the Nevada and California sections in the northwestern-facies belt are intentionally reversed from that of the other two belts in figure 3.

SUMMARY

Three major Mississippian lithofacies belts are represented in southern Nevada and east-central California: a southeastern (limestone)-facies belt; a central (mixed limestone and siliciclastic)-facies belt; and a northwestern (primarily siliciclastic)-facies belt. Rocks within each of these lithofacies belts are broadly similar, but, because of some lithologic differences and resulting separate nomenclatures in southern Nevada and east-central California, correlation between the two areas has been confusing.

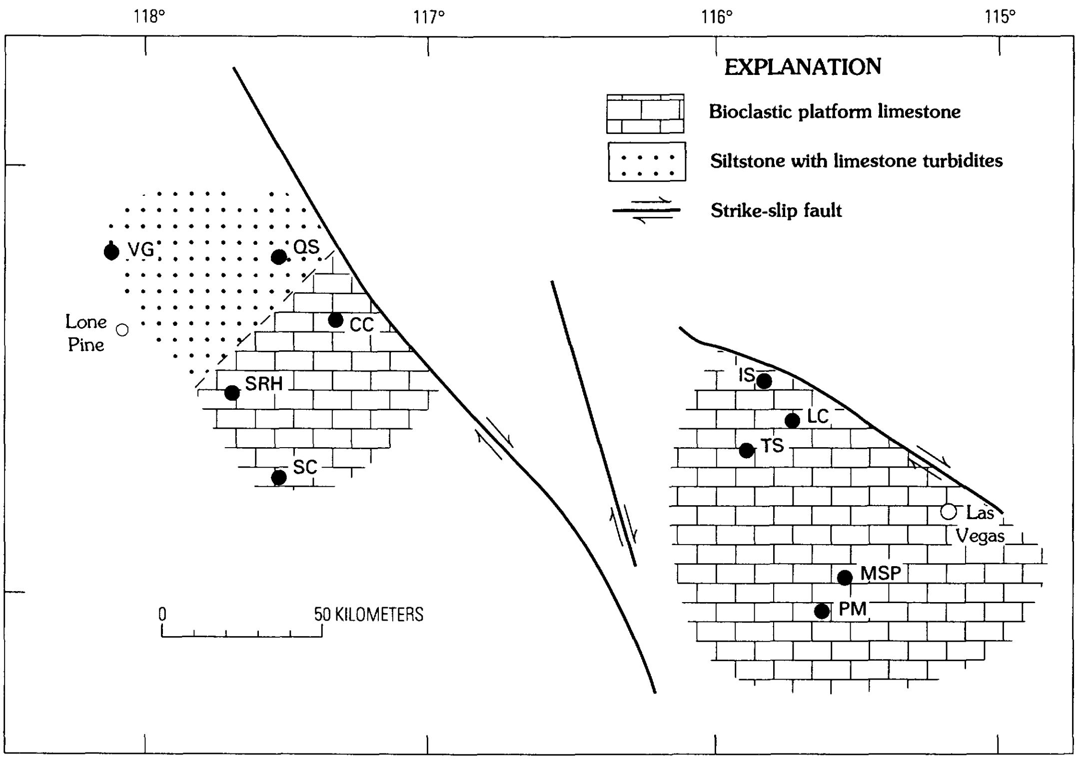


Figure 18. Map showing distribution of lower Meramecian (*homopunctatus*-Upper *texanus* Zone) lithofacies in southern Nevada and east-central California. Sample localities (solid circles): CC, Cottonwood Canyon; IS, Indian Springs; LC, Lee Canyon; MSP, Mountain Springs Pass; PM, Potosi Mine; QS, Quartz Spring; SC, Stone Canyon; SRH, Santa Rosa Hills; TS, Trough Spring; VG, Vaughn Gulch.

The stratigraphic nomenclature in east-central California has been revised herein to better reflect lithologic differences between rocks in different lithofacies belts, as was done previously for southern Nevada. This revision comprises elevation of the Perdido Formation to group rank, naming of four new Mississippian formations (Leaning Rock Formation, Mexican Spring Formation, Stone Canyon Limestone, and Kearsarge Formation with two members named the Bee and Snowcaps Members), and formal definition of one Devonian unit (Squares Tunnel Formation). The revised nomenclature and new age data clarify the lithologic and age differences between rocks in different lithofacies belts in east-central California, bring the stratigraphic nomenclature more in line with that used in southern Nevada, and emphasize the stratigraphic similarities of facies belts in the two areas.

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APPENDIX 1
PALEONTOLOGIC SAMPLES

[Localities are shown by number in figure 1]

LOCALITY 1—TINEMAHA RESERVOIR

Conodonts (CAI average 5.5)
Sample TR–1 (Kearsarge Formation, base of exposed section)
Bispathodus sp.
Gnathodus sp. aff. *G. delicatus*
Gnathodus pseudosemiglaber
Gnathodus texanus (late form)
Gnathodus sp.
Polygnathus communis communis
Polygnathus longiposticus
Taphrognathus varians
Palmatolepis sp. (reworked Famennian)
Pseudopolygnathus cf. *P. micropunctatus* (reworked Famennian)
Siphonodella isosticha (reworked Kinderhookian)
Siphonodella isosticha-obsoleta (reworked Kinderhookian)
Zone: *homopunctatus*-Upper *texanus*
Age: early Meramecian

LOCALITY 5—SQUARES TUNNEL

Radiolarians
Sample S–0654 Squares Tunnel Formation (unspecified part of section)
Ceratokiskum sp.
Holoeciscus sp.
Paleoscenidium sp.
Popofskyellum sp.
Various entactiniids
Age: Famennian

LOCALITY 6—VAUGHN GULCH

[South side of gulch unless otherwise specified; fossils are listed in appendix table 1]

Conodonts (CAI range 5–7; average 6)
Sample VGI–1 (Squares Tunnel Formation, base of exposed section)
Zone: *postera*
Age: late Famennian
Sample VGI–2 (Kearsarge Formation about 1 m above base)
Zone: Lower *crenulata*
Age: late Kinderhookian
Sample VGI–7 (Kearsarge Formation, near base of unit 1)
Zone: Lower *Cavusgnathus*
Age: late Meramecian
Sample VGI–3 (Kearsarge Formation, 6 m below top of unit 4)
Zone: Lower *Cavusgnathus*
Age: late Meramecian
Sample VG1–3A (Kearsarge Formation, near top of unit 4, north side of Vaughn Gulch)
Zone: Lower *Cavusgnathus*
Age: late Meramecian
Sample VGI–19 (Kearsarge Formation, 10 m below top)
Zone: *bilineatus*-Upper *Cavusgnathus*(?)
Age: early Chesterian
Sample VGI–20 (Kearsarge Formation, 0.1 m below top)
Zone: *bilineatus*-Upper *Cavusgnathus*
Age: early Chesterian

LOCALITY 7—LEE FLAT WEST

Conodonts (CAI average 5)
Sample LF–19 (Leaning Rock Formation, 16 m above base of exposed section)
Bispathodus utahensis
Gnathodus punctatus
Gnathodus semiglaber
Gnathodus texanus (early form)
Hindeodus cristulus
Taphrognathus varians
Vogelgnathus deflexus
Zone: mehli-Lower *texanus*
Age: late Osagean
Sample LF–23 (Mexican Spring Formation, 99 m above base of exposed section)
Cavusgnathus unicornis
Lochriea commutata
Paragnathodus homopunctatus
Zone: Lower *Cavusgnathus*
Age: late Meramecian

LOCALITY 9—UBEHEBE MINE CANYON

Foraminifers
Sample UMC–13 (Mexican Spring Formation, at base)
Tetrataxis sp.
Eoendothyranopsis sp.
Stacheoides sp.
Age: late Osagean or Meramecian

LOCALITY 10a—NEAR REST SPRING IN QUARTZ SPRING AREA

[Fossils from most samples are listed in appendix table 2]

Conodonts (CAI average 4)
Sample QS–1 (Tin Mountain Limestone, 1 m below top)
Zone: Lower *typicus*
Age: early Osagean
Sample QS–2 (Leaning Rock Formation, at base)
Zone: Lower *typicus*
Age: early Osagean
Sample QS–15 (Leaning Rock Formation, about 18 m above base)
Bispathodus utahensis
Zone: Upper *typicus*(?)
Age: middle Osagean(?)
Sample QS–20 (Leaning Rock Formation, 26 m above base)
Zone: *anchoralis-latus*
Age: middle Osagean
Sample QS–25 (Leaning Rock Formation, 43 m above base)
Zone: *mehli*-Lower *texanus*
Age: late Osagean
Sample QS–29 (Leaning Rock Formation, 60 m above base)
Bispathodus utahensis
Zone: *mehli*-Lower *texanus*(?)
Age: late Osagean(?)
Sample QS–37 (Leaning Rock Formation, 68 m above base)
Taphrognathus varians
Zone: *mehli*-Lower *texanus*(?)
Age: late Osagean(?)
Sample QS–49 (Mexican Spring Formation, 17 m below top)
Zone: *mehli*-Lower *texanus*
Age: late Osagean

Sample QS–59 (Mexican Spring Formation, 8 m above base)
Gnathodus texanus (late form)
Zone: *homopunctatus*-Upper *texanus*(?)
Age: early Meramecian(?)
Sample QS–94 (Mexican Spring Formation, 9 m below top)
Zone: Lower *Cavusgnathus*
Age: late Meramecian
Sample RSC–1 (Rest Spring Shale, 0.1 m above base)
Zone: Lower *Cavusgnathus*
Age: late Meramecian
Sample RSC–3 (Rest Spring Shale, about 3 m above base)
Zone: *bilineatus*-Upper *Cavusgnathus*
Age: early Chesterian
Foraminifers and *algae
Sample QS–24 (Leaning Rock Formation, 43 m above base; upper unit)
Earlandia clavatula group
Earlandia elegans group
Earlandia moderata group
"Priscella prisca"(?)
Tetrataxis sp.
Endothyridae indeterminate
*Aoujgaliaceae(?) indeterminate
Age: late Osagean
Samples QS–31 and QS–32 (Leaning Rock Formation, 68 m above base)
Earlandia clavatula group
Earlandia elegans group
Earlandia moderata group
Endothyra sp.
"Priscella prisca"(?)
Tetrataxis sp.
Endothyridae indeterminate
Age: late Osagean or early Meramecian
Samples QS–42, QS–84, QS–85, and QS–90 (Mexican Spring Formation, from about 12 m above the base to 12 m below top)
Archaediscus koktjubensis(?)
Archaediscus sp.
Brunsia lenensis
Earlandia clavatula group
Earlandia elegans group
Earlandia moderata group
Earlandia vulgaris group
Endostaffella cf. *E. discoidea*
Endothrya bowmani group
Endothyra sp.
Eoendothyranopsis utahensis(?)
Eoendothyranopsis "ermakiensis"(?) group
Eoendothyranopsis sp.
Eoforschia sp.
Globoendothyra sp.
Paraarchaediscus sp.
Planoarchaediscus spirillinoides
Planoarchaediscus sp.
Pseudoammodiscus sp.
"Priscella prisca"(?)
Pseudoglomospira sp.
Septabrunsiina(?) sp.
Tetrataxis sp.
Valvulinella sp.
Endothyridae indeterminate
Palaeotextulariidae indeterminate
*Aoujgaliaceae indeterminate
**Calcisphaera laevis*
**Diplosphaerina inaequalis*
**Fourstonella* sp.
**Mametella chautauquae*
**Stacheoides meandriformis*
**Stacheoides tenuis*
**Stacheoides* sp.
Zone: 13 or 14
Age: early to early late Meramecian
Corals
Sample SJS–1091 (Leaning Rock Formation, 68 m above base)
Stelechophyllum mclareni(?)
Zone: IIIA or IIIB
Age: late Osagean

LOCALITY 10b—LOST BURRO GAP (QUARTZ SPRING AREA)

Conodonts (CAI average 5)
Sample LBG–1 (Lost Burro Formation, about 7 m below top)
Bispathodus stabilis
Palmatolepis glabra distorta
Palmatolepis marginifera marginifera
Palmatolepis quadrantinodosa inflexa
Polygnathus brevilaminus
Polygnathus sp. cf. *P. inornatus*
Polygnathus communis communis
Polygnathus subirregularis
Zone: Early *trachytera*
Age: middle Famennian
Sample LBG–2 (Lost Burro Formation, 2.5 m below top)
Bispathodus stabilis
Mehlina strigosa
Palmatolepis glabra lepta (late form)
Palmatolepis perlobata helmsi
Pelekysgnathus inclinatus
Polygnathus homoirregularis (early form)
Polygnathus margaritatus
Polygnathus perplexus
Polygnathus procerus
Polygnathus semicostatus
Polygnathus sp.
Zone: Early *postera*(?)
Age: late Famennian
Sample LBG–3 (unnamed limestone, 2 m above top of Lost Burro Formation)
Bispathodus aculeatus aculeatus
Bispathodus costatus
Bispathodus spinulicostatus
Bispathodus stabilis
Polygnathus communis communis
Polygnathus delicatulus
Polygnathus obliquicostatus
Polygnathus procerus
Polygnathus semicostatus
Polygnathus sp.
Zone: Middle *expansa*
Age: late Famennian
Sample LBG–4 (Tin Mountain Limestone, less than 5 m above base; fossils are listed in appendix table 2)
Zone: *sandbergi*
Age: Kinderhookian

LOCALITY 10c—BIGHORN GAP (QUARTZ SPRING ARE)

Conodonts (CAI average 4.5)
Sample BG–108 (Leaning Rock Formation, 19 m above base)
Bispathodus utahensis
Gnathodus texanus (early form)
Taphrognathus varians
Zone: *mehli*-Lower *texanus*
Age: late Osagean
Corals
Sample BG–1 (Leaning Rock Formation, 6 m above base)
Stelechophyllum mclareni(?)
Age: late Osagean(?)

LOCALITY 12—TALC CITY HILLS

Conodonts (CAI average 5)
Sample TCH–1 (Mexican Spring Formation, near top)
Cavusgnathus unicornis
Gnathodus texanus
Zone: Lower *Cavusgnathus*(?)
Age: late Meramecian(?)

LOCALITY 13—SANTA ROSA HILLS SOUTH

Conodonts (CAI range 5–7; average 6)
Sample SRA–22 (Tin Mountain Limestone, 1.5 m below top)
Gnathodus cuneiformis
Gnathodus punctatus
Polygnathus communis communis
Zone: Lower *typicus*
Age: early Osagean
Sample SRA–1 (Stone Canyon Limestone, 12.75 m above base)
Bispathodus utahensis
Clydagnathus cavusformis(?)
Eotaphrus burlingtonensis
Eotaphrus sp. cf. *E. bultyncki*
Polygnathus communis communis
Zone: *anchoralis-latus*
Age: middle Osagean
Corals
Sample C–1 (Santa Rosa Hills Limestone, near base)
Siphonodendron warreni(?)
Siphonodendron sp. A (Armstrong, 1970b)
Stelechophyllum sp. aff. *S. birdi*
Age: Meramecian(?)
Samples SJS–979, SJS–931–d (Santa Rosa Hills Limestone, near top)
Siphonodendron sinuosum
Age: early or middle Meramecian
Sample SJS–931–a (Santa Rosa Hills Limestone, in float)
Stelechophyllum aff. *S. baffense*
Age: early or middle Meramecian
Sample SJS–777 (Santa Rosa Hills Limestone, 15 m below top)
Stelechophyllum aff. *S. birdi*(?)
Age: early or middle Meramecian
Sample SJS–931–g and SJS–931–e (Santa Rosa Hills Limestone, in float)
Stelechophyllum sp. – *S. macouni*(?) group
Age: early or middle Meramecian

Foraminifers and *algae
Samples SR–15 and SR–16 (Stone Canyon Limestone, near base of upper unit)
Earlandia clavatula group
Earlandia elegans group
Earlandia moderata(?) group
Earlandia vulgaris group
Endothyra(?) sp.
Eoendothyranopsis(?) sp.
Age: late Osagean or Meramecian
Samples SR–31 and SR–31A (Santa Rosa Hills Limestone, near middle)
Earlandia clavatula group
Earlandia moderata group
Earlandia vulgaris group
Eoendothyranopsis "ermakiensis" group
Eoendothyranopsis scitula
Eoendothyranopsis sp.
Endothyra sp.
"Priscella prisca"(?)
Tetrataxis sp.
**Mametella?* sp.
Zone: 13 or 14
Age: early to early late Meramecian

LOCALITY 14a—COTTONWOOD CANYON

Conodonts (CAI average 5)
Sample PD–17 (Stone Canyon Limestone, 1 m above base)
Bispathodus utahensis
Gnathodus sp.
Hindeodus sp.
Polygnathus communis communis
Pseudopolygnathus nudus morphotype 1
Pseudopolygnathus nudus morphotype indet.
Pseudopolygnathus oxypageus morphotype 3
Vogelgnathus n. sp. NLC
Zone: Upper *typicus*
Age: middle Osagean
Sample CC–6 (Santa Rosa Hills Limestone, 16 m above base)
Bispathodus utahensis
Hindeodus cristulus
Zone: *mehli*-Lower *texanus*
Age: late Osagean
Sample CC–4 (Stone Canyon Limestone, about 50 m below top
Bispathodus utahensis
Eotaphrus burlingtonensis (early form)
Zone: *anchoralis-latus*
Age: middle Osagean
Sample CC–1 (Stone Canyon Limestone, 260 m above base)
Bispathodus utahensis
Doliognathus latus
Eotaphrus burlingtonensis
Polygnathus communis communis
Zone: *anchoralis-latus*
Age: middle Osagean

LOCALITY 14b—MARBLE CANYON

Conodonts (CAI average 5.5)
Sample MC–1–1 (USGS loc. 28900–PC) (Santa Rosa Hills Limestone, uppermost part)

Bispathodus utahensis
Hindeodus cristulus
Hindeodus penescitulus
Taphrognathus varians
Zone: *homopunctatus*-Upper *texanus*
Age: early Meramecian
Sample MC–1 (Santa Rosa Hills Limestone, uppermost part)
Bispathodus stabilis
Hindeodus penescitulus
Taphrognathus varians
Vogelgnathus campbelli
Zone: *homopunctatus*-Upper *texanus*
Age: early Meramecian
Corals
Sample PD–1 (Stone Canyon Limestone, 23 m below top)
"*Diphyphyllum*"
Zone: probably IIID (equivalent to foraminiferal zone 13 or 14) based on age of samples BUF–1 and BUF–2 in Trough Spring section
Age: early to early late Meramecian

LOCATION 15—DRY BONE CANYON EAST

Corals
Sample SJS–1086 (Santa Rosa Hills Limestone, near top)
Siphonodendron "whitneyi"
Acrocyathus pennsylvanica(?)
Stelechophyllum mclareni(?)
Zone: IIID (equivalent to foraminiferal zone 13 or 14)
Age: early to early late Meramecian

LOCALITY 16—STONE CANYON

Conodonts (CAI average 6)
Sample MM–1 (Stone Canyon Limestone, 5 m above base)
Bispathodus utahensis
Eotaphrus sp. cf. *E. bultyncki*
Gnathodus cuneiformis
Pseudopolygnathus nudus morphotype 1
Zone: Upper *typicus*
Age: middle Osagean
Sample MM–2 (Stone Canyon Limestone, 50 m above base)
Bispathodus utahensis
Gnathodus cuneiformis
Hindeodus crassidentatus
Hindeodus penescitulus
Polygnathus communis communis
Pseudopolygnathus nudus morphotype 1
Zone: Upper *typicus*
Age: middle Osagean

LOCALITY 18—FUNERAL MOUNTAINS SOUTH

Conodonts (CAI average 4)
Sample FMS–3 (Tin Mountain Limestone, 42.7 m below top; fossils are listed in appendix table 2)
Zone: *isosticha*-Upper *crenulata*
Age: late Kinderhookian

LOCALITY 20a—INDIAN SPRINGS

Conodonts (CAI average 4)
Sample ISS–6 (West Range Limestone, 5 m below top)
Mehlina strigosa
Palmatolepis glabra acuta
Palmatolepis glabra pectinata
Palmatolepis glabra
Palmatolepis marginifera marginifera
Palmatolepis quadrantinodosa inflexoidea
Palmatolepis sp.
Pelekysgnathus inclinatus
Polygnathus sp. cf. *P. inornatus*
Polygnathus semicostatus
Polylophodonta sp.
Zone: Early *marginifera*
Age: middle Famennian
Sample ISS–11 (Dawn Limestone, 0.1 m below top)
Bispathodus utahensis
Gnathodus cuneiformis
Polygnathus communis communis
Vogelgnathus n. sp. NLC
Vogelgnathus n. sp. ISS
Zone: Lower *typicus*(?)
Age: early Osagean
Sample ISS–12 (Anchor Limestone, 24 m above base)
"Polygnathus" mehli
Bactrognathus n. sp. LSZ
Bispathodus utahensis
Doliognathus latus
Eotaphrus burlingtonensis
Eotaphrus burlingtonensis (tr. *Dollymae hassi*)
Polygnathus communis communis
Polygnathus communis (with nodose margins)
Zone: *anchoralis-latus*
Age: middle Osagean
Sample ISB–AN–1B (Anchor Limestone, 220 m above base)
Taphrognathus varians
Zone: *mehli*-Lower *texanus*
Age: late Osagean

LOCALITY 20b—INDIAN SPRINGS EAST

Conodonts (CAI average 4)
Sample ISS–26 (Bullion Limestone, 1 m above base)
Bispathodus utahensis
Taphrognathus varians (late form)
Zone: *mehli*-Lower *texanus*
Age: late Osagean
Sample IST–BU–1 (Bullion Limestone, 4 m below top)
Taphrognathus varians
Zone: *homopunctatus*-Upper *texanus*
Age: early Meramecian
Sample ISS–31 (Yellowpine Limestone, 1 m below top)
Bispathodus sp.
Cavusgnathus sp.
Hindeodus sp.
Age: Meramecian
Corals
Sample ISDC–1 (Dawn Limestone, lower part)
"Thysanophyllum" cf. *"T." astreiformis*
Age: nondiagnostic

Sample IST–1 (Bullion Limestone, 20 m above base)
Stelechophyllum birdi(?)
Siphonodendron aff. *S. oculinum*
Zone: probably IIIA (equivalent to foraminiferal zone 10 or 11)
Age: late Osagean
Samples IST–2, IST–3, IST–4, BU–2 (Bullion Limestone, uppermost 40 m)
Siphonodendron aff. *S. oculinum*
Stelechophyllum aff. *S. birdi*
Age: probably late Osagean
Sample ISD–1, ISD–2, ISD–3 (Yellowpine Limestone, about 18 m below top)
Petalaxis tabulatus
Zone: IIID or IV (equivalent to foraminiferal zone 13, 14, or 15)
Age: Meramecian

LOCALITY 21—LEE CANYON

Conodonts (CAI average 4)
Sample LC–AN–1 (Anchor Limestone, 2 m below top)
Eotaphrus burlingtonensis (early form)
Hindeodus sp. cf. *H. crassidentatus*
Polygnathus communis communis
Zone: *anchoralis-latus* or younger
Age: middle Osagean or younger
Sample LC–BU–8 (Bullion Limestone, 1 m above base)
Bactrognathus n. sp. LSZ
Eotaphrus burlingtonensis (early form)
Polygnathus communis communis
Zone: *anchoralis-latus*
Age: middle Osagean
Sample LC–YP–3 (Yellowpine Limestone, 7 m below top)
Cavusgnathus unicornis
Zone: Lower *Cavusgnathus*
Age: late Meramecian

LOCALITY 22—TROUGH SPRING

Conodonts (CAI average 4.5)
Sample TS–AN–14 (Anchor Limestone, 12 m above base)
Gnathodus cuneiformis
Gnathodus typicus
Hindeodus sp.
Polygnathus communis communis
Pseudopolygnathus nudus morphotype 1
Zone: Upper *typicus*
Age: middle Osagean
Corals
Sample DCF–1 (Dawn Limestone, near top)
Stelechophyllum micrum
"Thysanophyllum" sp.
Zone: II (equivalent to foraminiferal zone 7, 8, or 9)
Age: early or middle Osagean

LOCALITY 23—LAST CHANCE RANGE EAST (NEVADA)

Conodonts (CAI average 4.5)
Sample LAS–5 (West Range Limestone, 12 m below top)
Mehlina sp.
Palmatolepis marginifera
Polygnathus planirostratus
Polygnathus procerus
Polylophodonta concentrica
Zone: Early *marginifera*(?)
Age: middle Famennian
Sample LAS–6 (Lost Burro(?) Formation, near top)
Bispathodus stabilis
Palmatolepis perlobata postera
Palmatolepis perlobata schindewolfi
Polygnathus sp. cf. *P. inornatus*
Polygnathus homoirregularis (early form)
Polygnathus perplexus
Polygnathus procerus
Polygnathus semicostatus
Polygnathus subirregularis
Zone: Early *postera*(?)
Age: late Famennian

LOCALITY 24—MOUNTAIN SPRINGS PASS

Conodonts (CAI average 2)
Sample SM–12 (Anchor Limestone, 0.6 m above base)
Bispathodus utahensis
Hindeodus penescitulus
Polygnathus communis communis
Vogelgnathus n. sp. NLC
Zone: Lower *typicus*(?)
Age: early Osagean
Corals
Sample YPC–4 (Yellowpine Limestone, 15 m below top)
Siphonodendron "whitneyi"
Zone: IIID or IV (equivalent to foraminiferal zone 13, 14, or 15)
Age: Meramecian

LOCALITY 25—POTOSI MINE

Conodonts (CAI average 3)
Sample PO–5 (Arrowhead Member of Yellowpine Limestone)
"Polygnathus" mehli
Bispathodus utahensis
Hindeodus sp. cf. *H. crassidentatus*
Hindeodus cristulus
Zone: *mehli*-Lower *texanus*
Age: late Osagean

Appendix table 1. Occurrence of conodonts in biostratigraphically significant samples in the Upper Devonian and Mississippian sequence in Vaughn Gulch, on the west side of Inyo Mountains, California.

[Yields are given only for samples processed by Sandberg. Asterisk (*) indicates reworked]

Conodont Zone	*postera*	Lower *crenulata*	Lower *Cavusgnathus*	Lower *Cavusgnathus*	Lower *Cavusgnathus*	*bilineatus*–Upper *Cavusgnathus*	*bilineatus*–Upper *Cavusgnathus*
Sample number	VGI–1	VGI–2	VGI–7	VGI–3	VGI–3A	VGI–19	VGI–20
Formation	Squares Tunnel	Kearsarge	Kearsarge	Kearsarge	Kearsarge	Kearsarge	Kearsarge
Member	–	Bee	Snowcaps	Snowcaps	Snowcaps	Snowcaps	Snowcaps
Unit	–	–	1	4	4	5	5
Meters from base (top)	?	1	?	(6)	(~3)	(10)	(0.1)
Conodont biofacies	Palmatolepid–polygnathid	Siphonodellid	–	Cavusgnathid	Mixed	Mixed	Mixed
Yield (conodonts/kg)	76	2	–	11	–	–	–
Palmatolepis gracilis gracilis	1	0	0	0	0	0	0
Pa. gracilis sigmoidalis	7	0	0	0	0	0	0
Pa. perlobata postera	6	0	0	0	0	0	0
Pa. rugosa n. subsp.	1	0	0	0	0	0	0
Polygnathus procerus	13	0	0	0	0	0	0
Apatella sp.	1	0	0	0	0	0	0
Branmehla sp.	2	0	0	0	0	0	0
Mehlina sp.	10	0	0	0	0	0	0
Siphonodella crenulata	0	1	0	0	0	0	0
S. sulcata	0	2	0	0	0	0	0
Siphonodella sp.	0	3	0	0	0	0	0
Polygnathus c. communis	0	1	0	0	1*	0	0
Bispathodus sp.	0	1	0	0	0	0	0
Cavusgnathus unicornis	0	0	2	13	2	7	16
C. altus	0	0	0	0	0	1	0
Cavusgnathus sp.	0	0	0	19	4	0	0
Gnathodus texanus	0	0	0	0	0	0	5
G. texanus EARLY FORM	0	0	0	2	3	0	0
G. texanus LATE FORM	0	0	1	1	0	3	0
G. semiglaber	0	0	0	6	0	0	0
G. bilineatus	0	0	0	0	0	0	7
Hindeodus cristulus	0	0	6	0	0	0	0
Hindeodus sp.	0	0	0	1	0	0	0
Paragnathodus girtyi?	0	0	0	0	0	1	1
Pa. homopunctatus	0	0	0	0	1	0	2
Lochriea commutata	0	0	0	0	0	2	1
Vogelgnathus campbelli	0	0	0	0	0	0	1
Reworked Famennian sp.	0	0	0	0	0	0	0
Icriodus sp.	0	1*	0	0	0	0	0
Polygnathus hassi?	0	0	0	1*	0	0	0
Pol. cf. *marginvolutus*	0	0	0	0	0	1*	0
Palmatolepis minuta	0	0	0	0	0	0	1*
TOTAL Pa elements	41	9	9	43	11	15	34

Appendix table 2. Occurrence of conodonts in biostratigraphically significant samples in the Mississippian sequence in Quartz Spring (QS)–Rest Spring (RSC) area of Cottonwood Mountains, Inyo County, California.

[Samples from Tin Mountain Limestone in Lost Burro Gap (LBG) and at south end of Funeral Mountains (FMS) are also included. Localities shown in figure 1. Yields are given only for samples processed by Sandberg. Asterisk (*) indicates reworked]

Conodont Zone	*sand-bergi*	*isosticha*–Upper *crenulata*	Lower *typicus*		*anchoralis*–*latus*	*mehli*–Lower *texanus*		Lower *Cavusgnathus*		*bilineatus*–Upper *Cavusgnathus*
Sample number	LBG–4	FMS–3	QS–1	QS–2	QS–20	QS–25	QS–49	QS–94	RSC–1	RSC–3
Formation	Tin Mountain Limestone			Leaning Rock Formation				Mexican Spring Formation	Rest Spring Shale	
Meters from base (top)	1?	(–42.7)	(–1)	0.1	27	43	96	(–9)	0.1	3
Conodont biofacies	Siphono-dellid	Siphono-dellid–gnathodid	Gnathodid		Bactro-gnathid	Mixed	Gnathodid	Mixed	Mixed	Gnathodid
Yield (conodonts/kg)	404	51	–	–	419	–	–	–	9	19
Pinacognathus profundus	1	0	0	0	0	0	0	0	0	0
Polygnathus spp.	78	0	0	0	0	0	0	0	0	0
Pol. longiposticus	5	0	0	0	0	0	0	0	0	0
Siphonodella cooperi Morphotype 2	11	0	0	0	0	0	0	0	0	0
S. duplicata sensu Hass	18	0	0	0	0	0	0	0	0	0
S. quadruplicata	1	0	0	0	0	0	0	0	0	0
S. obsoleta	2	0	0	0	0	0	0	0	0	0
S. sandbergi	2	0	0	0	0	0	0	0	0	0
Siphonodella spp.	1,114	0	0	0	0	0	0	0	0	0
S. isosticha-obsoleta	0	12	0	0	0	0	0	0	0	0
Gnathodus punctatus	0	21	21	18	0	0	2*	0	0	0
G. cuneiformis	0	0	6	4	0	0	0	0	0	0
Pseudopolygnathus multistriatus	0	0	0	2	0	0	0	0	0	0
Gnathodus semiglaber	0	0	0	0	2	0	0	0	0	0
G. subbilineatus	0	0	0	0	2	0	0	0	1	0
Gnathodus spp.	0	0	0	0	4	0	0	0	3	0
Bactrognathus n. sp.	0	0	0	0	70	0	0	0	0	0
Doliognathus latus	0	0	0	0	6	0	0	0	0	0
Eotaphrus burlingtonensis	0	0	0	0	17	0	0	0	0	0
Gnathodus texanus	0	0	0	0	0	6	14	9	12	0
G. pseudosemiglaber	0	0	0	0	0	3	0	0	0	0
Taphrognathus varians	0	0	0	0	0	5	1	0	0	0
Vogelgnathus deflexus	0	0	0	0	0	3	0	0	0	0
Paragnathodus homopunctatus	0	0	0	0	0	0	0	7	0	0
Para. girtyi girtyi	0	0	0	0	0	0	0	1	7	13
Cavusgnathus unicornis	0	0	0	0	0	0	0	3	10	2
Lochriea commutata	0	0	0	0	0	0	0	3	0	7
Para. girtyi collinsoni	0	0	0	0	0	0	0	0	0	16
Vogelgnathus campbelli	0	0	0	0	0	0	0	0	0	3
Gnathodus bilineatus	0	0	0	0	0	0	0	0	0	8
Bispathodus stabilis	6	0	0	0	0	0	10	0	0	0
B. utahensis	0	7	4	0	134	26	0	0	0	0
Hindeodus penescitulus	1	0	0	0	0	3	0	0	1	0
H. cristulus	0	0	0	0	0	1	0	0	0	0
Polygnathus communis communis	7	31	2	1	364	0	0	0	0	0
TOTAL Pa elements	1,246	71	33	25	599	47	27	23	34	49

Appendix table 3. Conodont collections arranged by Conodont Zone or approximate age in terms of Mississippian provincial series.
[Localities shown by number in figure 1]

Conodont Zone or series	Locality (number)	Sample number	Conodont color alteration index (CAI)
	FAMENNIAN		
Early *marginifera*	Indian Springs (20a)	ISS–6	4
Early *marginifera* (?)	Last Chance Range East (23)	LAS–5	4
Early *trachytera*	Lost Burro Gap (10b)	LBG–1	4.5
Early *postera* (?)	Last Chance Range East (23)	LAS–6	4.5
Early *postera* (?)	Lost Burro Gap (10b)	LBG–2	5
postera	Vaughn Gulch (6)	VGI–1	6
Middle *expansa*	Lost Burro Gap (10b)	LBG–3	4.5
	KINDERHOOKIAN		
sandbergi	Lost Burro Gap (10b)	LBG–4	5
Lower *crenulata*	Vaughn Gulch (6)	VGI–2	6
isosticha–Upper *crenulata*	Funeral Mountains South (18)	FMS–3	4
	OSAGEAN		
Lower *typicus*	Quartz Spring area (10a)	QS–1	4
Lower *typicus*	Quartz Spring area (10a)	QS–2	4
Lower *typicus*	Santa Rosa Hills South (13)	SRA–22	5.5
Lower *typicus* (?)	Indian Springs (20a)	ISS–11	3.5
Lower *typicus* (?)	Mountain Springs Pass (24)	SM–12	2
Upper *typicus*	Cottonwood Canyon (14a)	PD–17	5
Upper *typicus*	Stone Canyon (16)	MM–1	5.5
Upper *typicus*	Stone Canyon (16)	MM–2	8
Upper *typicus*	Trough Spring (22)	TS–AN–14	4.5
Osagean	Quartz Spring area (10a)	QS–15	4
Osagean	Quartz Spring area (10a)	QS–29	4
anchoralis–latus	Cottonwood Canyon (14a)	CC–1	5
anchoralis–latus	Cottonwood Canyon (14a)	CC–4	5.5
anchoralis–latus	Indian Springs (20a)	ISS–12	4
anchoralis–latus	Lee Canyon (21)	LC–AN–1	4
anchoralis–latus	Lee Canyon (21)	LC–BU–8	4
anchoralis–latus	Quartz Spring area (10a)	QS–20	4.5
anchoralis–latus	Santa Rosa Hills South (13)	SRA–1	6
mehli–Lower *texanus*	Bighorn Gap (10c)	BG–108	4.5
mehli–Lower *texanus*	Indian Springs (20a)	AN–1B	4
mehli–Lower *texanus*	Indian Springs East (20b)	ISS–26	4
mehli–Lower *texanus*	Lee Flat West (7)	LF–19	5
mehli–Lower *texanus*	Potosi Mine (25)	PO–5	3
mehli–Lower *texanus*	Quartz Spring area (10a)	QS–25	4
mehli–Lower *texanus*	Quartz Spring area (10a)	QS–49	4
mehli–Lower *texanus* (?)	Quartz Spring area (10a)	QS–37	4
mehli–Lower *texanus* (?)	Cottonwood Canyon (14a)	CC–6	6
	MERAMECIAN		
homopunctatus–Upper *texanus*	Marble Canyon (14b)	MC–1, MC–1–1	5.5
homopunctatus–Upper *texanus*	Tinemaha Reservoir (1)	TR–1	5.5
homopunctatus–Upper *texanus* (?)	Quartz Spring area (10a)	QS–59	4
homopunctatus–Upper *texanus* (?)	Indian Springs East (20b)	BU–1	4
Meramecian	Indian Springs East (20b)	ISS–31	4
Lower *Cavusgnathus*	Lee Canyon (21)	LC–YP–3	4
Lower *Cavusgnathus*	Lee Flat West (7)	LF–23	5
Lower *Cavusgnathus*	Quartz Spring area (10a)	QS–94	4
Lower *Cavusgnathus*	Rest Spring (10a)	RSC–1	4
Lower *Cavusgnathus*	Talc City Hills (12)	TCH–1	5
Lower *Cavusgnathus*	Vaughn Gulch (6)	VGI–7	5.5
Lower *Cavusgnathus*	Vaughn Gulch (6)	VGI–3	5.5
Lower *Cavusgnathus*	Vaughn Gulch (6)	VGI–3A	5.5
	CHESTERIAN		
bilineatus–Upper *Cavusgnathus*	Rest Spring (10a)	RSC–3	4
bilineatus–Upper *Cavusgnathus*	Vaughn Gulch (6)	VGI–19	5.5
bilineatus–Upper *Cavusgnathus* (?)	Vaughn Gulch (6)	VGI–20	5.5

APPENDIX 2
MEASURED SECTIONS

TYPE SECTION OF LEANING ROCK FORMATION AND REFERENCE SECTION OF MEXICAN SPRING FORMATION (FIGS. 7, 8)

Section measured by D. Klingman, 1987, near Rest Spring in Cottonwood Mountains, about 4 km east of mouth of Perdido Canyon, between elevations of 6,240 and 6,160 ft, in northwest corner sec. 31, T. 13 S., R. 42 E., lat 36°45′30″ N., long 117°26′27″ W., White Top Mountain 7.5-minute quadrangle, Inyo County, California.

Thickness (meters)

Rest Spring Shale (Upper Mississippian): Thin-bedded, very fine grained, fossiliferous, phosphatic, dark-gray limestone overlain by black shale

Conformable contact

Mexican Spring Formation (Upper Mississippian):

8. Siltstone (70 percent), reddish-brown, calcareous, fairly massive, highly bioturbated, *Nereites* trace fossils. Interbedded limestone (fossiliferous lime packstone), thin- to thick-bedded, forming T_a, T_{ab}, and T_b carbonate turbidites with sharp, erosive bases and planar to slightly undulose tops; normal grading of fossil debris and intraclasts, some amalgamation of beds; contains pelmatozoan, brachiopod, and gastropod debris, calcareous foraminiferans, sparse ooids, and intraclasts of lime mudstone and wackestone, chert, and siltstone 16.0
7. Conglomerate, pinkish-gray, massive, predominantly matrix supported, channelized, containing intraclasts of lime packstone, wackestone, and grainstone, and siltstone, and micrite as much as 1.3 m across; clasts are mostly subrounded, some are tabular; matrix consists of fossil debris and silty micrite 6.5
6. Siltstone, reddish-brown, calcareous, massive, highly bioturbated 4.0

Fault (minor displacement?)

5. Siltstone (70 percent), reddish-brown, calcareous, fairly massive, highly bioturbated, *Nereites* trace fossils. Interbedded limestone (fossiliferous lime packstone), medium- to thick-bedded, forming T_a, T_{ab}, and T_b carbonate turbidites with sharp, erosive bases and planar to slightly undulose tops; normal grading of fossil debris and intraclasts; some cobble-bearing gravels and deposits of surging turbidity currents, no amalgamation of beds; contains pelmatozoan, brachiopod, and gastropod debris, calcareous foraminifers, sparse ooids, and intraclasts of micrite and wackestone, chert, and siltstone 34.5

Fault (minor displacement?)

4. Siltstone (70 percent), reddish-brown, calcareous, fairly massive, highly bioturbated, *Nereites* trace fossils. Interbedded limestone (fossiliferous lime packstone), medium- to thick-bedded, forming T_a, T_{ab}, and T_b carbonate turbidites with sharp, erosive bases and planar to slightly undulose tops; normal grading of fossil debris and intraclasts; some cobble-bearing gravels and deposits of surging turbidity currents, no amalgamation of beds; contains pelmatozoan, brachiopod, and gastropod debris, calcareous foraminifers, sparse ooids, and intraclasts of micrite, lime wackestone, chert, and siltstone 5.3
3. Siltstone, reddish-brown, calcareous, massive, highly bioturbated 22.0

Section offset approximately 100 m northwest

2. Conglomerate, bluish-gray, predominantly matrix supported; intraclasts are micrite and chert as much as 15 cm across; matrix is argillaceous micrite 0.7
1. Siltstone (70 percent), reddish-brown, calcareous, fairly massive, highly bioturbated, *Nereites* trace fossils. Interbedded limestone (fossiliferous lime-packstone), medium- to thick-bedded, forming T_a, T_{ab}, and T_b carbonate turbidites with sharp, erosive bases and planar to slightly undulose tops; normal grading of fossil debris and intraclasts; some cobble-bearing gravels and deposits of surging turbidity currents; no amalgamation of beds; contains pelmatozoan, brachiopod, and gastropod debris, calcareous foraminiferans, sparse ooids, and micrite, lime-wackestone, chert, and siltstone intraclasts 8.0

Total thickness of Mexican Spring Formation 97.0

Fault repetition of 19.7 m of Leaning Rock Formation and 46 m of Mexican Spring Formation along the line of section

Conformable contact

Leaning Rock Formation (Mississippian)

Unit 2:

6. Limestone (micrite and lime wackestone), dark-gray, thin- to medium-bedded, argillaceous; some beds silicified and orangish-brown-weathering; mostly massive, commonly thinly laminated. Chert beds, lenses, and nodules 20 cm thick. Interbedded T_a and T_{ab} carbonate turbidites, 20–30 cm thick, with sharp erosive bases and almost planar tops; normally graded; some with internal laminations; contain fossil debris (mostly pelmatozoan ossicles) and intraclasts of micrite, lime wackestone, and chert 14.0
5. Conglomerate, medium-gray, brownish-gray-weathering, both matrix-supported and clast-supported; contains clasts of micrite, chert, fossiliferous wackestone, packstone, and *Stelechophyllum* as much as 40 cm across; local crudely developed coarse-tail grading, slightly erosive base and irregular top with projecting clasts; matrix of dark-gray micrite and fossil debris 2.5
4. Limestone (micrite and lime wackestone), dark-gray, thin- to medium-bedded, argillaceous; some beds silicified and orangish-brown-weathering; mostly massive; bioturbated with vertical and horizontal burrows; contains minor pelmatozoan debris, horn corals, and brachiopod debris. Interbedded dark-gray chert, dark-brownish-gray- to grayish-black-weathering, in sequences as thick as 4 m; individual beds 5–20 cm thick, separated by thin partings of argillaceous limestone. Dark-gray chert lenses and nodules, dark-brown to almost black-weathering, as thick as 10 cm. Interbedded T_a and T_{ab} carbonate turbidites as thick as 50 cm; some amalgamated, with sharp, erosive bases, fairly planar tops, normally graded, some with internal laminations 26.5
3. Limestone (micrite and lime wackestone), dark-gray; beds folded and contorted, as thick as 10 cm, some silicified; minor chert nodules as thick as 8 cm 3.0
2. Mudstone, reddish-brown-weathering, flaggy, bioturbated. Interbedded T_{ab} carbonate turbidite, 30 cm thick, sharp, erosive base (scours as deep as 10 cm) and fairly planar top, normally graded with pelmatozoan debris and intraclasts, imbricated N. 41° W., groove lineations on

base. Debris-flow conglomerate, 25 cm thick, dark-gray clasts of micrite and chert, matrix-supported, planar base and top 14.0

1. Limestone (micrite and lime wackestone), dark-gray, three masses with folded and contorted beds; individual beds as thick as 10 cm, some silicified; minor chert beds as thick as 15 cm. Mudstone, reddish-gray, reddish-brown-weathering, flaggy, bioturbated, slightly calcareous 16.0

Total thickness of unit 2 .... 76.0

Unit 1: Limestone (micrite and lime wackestone), dark-gray, yellowish-brown-weathering, thin- to medium-bedded, commonly silicified, sponge-spicule-rich. Interbedded with argillaceous micrite, medium- to dark-gray-weathering, thin- to medium-bedded. Contains chert nodules (most common in upper 3 m of unit) 7.0

Total thickness of Leaning Rock Formation 83.0

Conformable contact

Tin Mountain Limestone (Lower Mississippian): Medium-gray to dark-gray limestone

TYPE SECTION OF MEXICAN SPRING FORMATION (FIG. 9)

Section measured by D. Klingman, 1987, near Mexican Spring, southern Inyo Mountains, approximately 7.2 km northwest of Cerro Gordo Mine, between elevations of about 8,920 and about 8,970 ft, in T. 15 S., R. 38 E., lat 36°35′48″ N., long 117°26′34″ W., New York Butte 15-minute quadrangle, Inyo County, California.

Thickness (meters)

Rest Spring Shale (Upper Mississippian): Black shale

Conformable contact

Mexican Spring Formation (Upper Mississippian):

1. Siltstone, grayish-brown, light-brown-weathering, massive, calcareous, highly bioturbated; abundant trace fossils..... 37.0

Total thickness of Mexican Spring Formation 37.0

Unconformable contact

Tin Mountain Limestone (Lower Mississippian): Medium- to dark-bluish-gray limestone

TYPE SECTION OF STONE CANYON LIMESTONE (FIGS. 10, 11)

Section measured by D. Klingman, 1987, near Minnietta Mine along east flank of the Argus Range, approximately 500 m north of Stone Canyon, between elevations of about 3,440 and about 3,120 ft, in secs. 27 and 28, T. 19 S., R. 42 E., lat 36°15′13″ N., long 117°26′28″ W., Panamint Butte 15-minute quadrangle, Inyo County, California.

Thickness (meters)

Santa Rosa Hills Limestone (Upper Mississippian): Light-gray limestone and marble

Conformable contact

Stone Canyon Limestone (Lower Mississippian)

Unit 3:

2. Limestone (micrite and lime wackestone), medium-bluish-gray, thin- to medium-bedded, massive to faintly laminated; some vertical burrows; sparse chert nodules as thick as 8 cm. Pelmatozoan calcarenite, medium- to light-gray, in beds as thick as 25 cm with sharp bases and gradational tops; crude normal grading of pelmatozoan ossicles; some beds display internal parallel laminations 9

1. Limestone (micrite and lime wackestone), medium-blueish-gray, mostly medium bedded, mostly massive; occasional laminations; vertical burrows present but rare. Approximately 25 percent of limestone is silicified and weathers medium brown to reddish brown. Sparse chert nodules as thick as 10 cm. Pelmatozoan calcarenite, medium-gray to light-gray; beds as thick as 25 cm are present both as diffuse lenticular accumulations as thick as 15 cm and as beds with sharp bases and gradational tops showing crude normal grading of pelmatozoan ossicles 27

Total thickness of unit 3 36

Unit 2:

2. Limestone (micrite and lime wackestone), medium-blueish-gray, thin- to medium-bedded, mostly massive; scattered pelmatozoan debris; approximately 10 percent of limestone is silicified and weathers orangish brown. Chert, in nodules and discontinuous lenses as thick as 10 cm and 1.5 m across, constitutes about 20 percent of unit 34

1. Limestone (micrite and lime wackestone), medium- to dark-blueish-gray, thin-bedded; a few beds faintly laminated with minute pelmatozoan debris; about 30 percent of limestone is silicified and weathers medium brown to orangish brown. Chert, in nodules and discontinuous lenses as thick as 15 cm and 5 m across, weathers dark brown to almost black and constitutes 30 percent of unit 21

Total thickness of unit 2 55

Unit 1: Chert, dark-gray, weathering dark brown to almost black, in irregular beds and nodules as thick as 15 cm; constitutes about 45 percent of unit. Limestone (micrite and lime wackestone), dark-bluish-gray, thin- to medium-bedded, massive; occasional pelmatozoan debris; constitutes about 40 percent of unit. Silicified limestone, dark-gray, weathering orangish brown, thin- to medium-bedded, sponge-spicule-rich; constitutes about 15 percent of unit 16

Total thickness of Stone Canyon Limestone 107

Conformable contact

Tin Mountain Limestone (Lower Mississippian): Medium-gray to dark-gray limestone

TYPE SECTION OF KEARSARGE FORMATION (FIGS. 12, 13)

Section measured by C. Stevens and P. Stone, August 1989, on ridge on south side of Vaughn Gulch, about 11.5 km east of Independence, NEπ SEπ sec. 8, T. 13 S., R. 36 E., lat 36°49′36″ N., long 118°04′24″ W., Bee Springs Canyon 7.5-minute quadrangle, Inyo County, California.

Thickness (meters)

Rest Spring Shale (Upper Mississippian)—Shale, black

Conformable contact

Kearsarge Formation, Snowcaps Member (Upper Mississippian)

Unit 5:

14. Limestone; lithology similar to bed 6; channel-form; thickness ranges from 30 cm to 2 m in distance of 10 m 1.5
13. Shale, black, fissile 8.5
12. Limestone; lithology similar to bed 6 .... 0.5
11. Shale, black, fissile 6.0
10. Limestone; lithology similar to bed 6 .... 1.0

9. Shale, black, fissile; several thin, fine-grained, medium-gray limestone beds near top	4.5
8. Limestone; similar to bed 6; thin, parallel laminations at top	1.0
7. Shale, black, fissile	3.0
6. Limestone, medium- to dark-gray; forms a single, graded bed with some pelmatozoan stems as long as 12 cm at base; very fine grained at top	1.5
Transfer around a small fold	
5. Shale, black, fissile; many horizontal trace fossils	5.5
4. Conglomerate, mostly dark-gray and black siliceous or chert clasts, as large as 1.5 cm, in matrix of medium-gray, fine-grained limestone	0.5
3. Shale, black, fissile; 30-cm-thick bed of fine-grained, medium-gray limestone near base	9.0
2. Conglomerate; clasts, as large as 8 cm, composed of chert, limestone, and rarely sandstone, in matrix of medium-gray, fine-grained limestone	1.5
1. Shale, black, fissile	3.0
Total thickness of unit 5	47.0
Unit 4: Limestone, mostly medium to fine grained, in beds mostly as thick as 1 m, some having a coarse-grained basal part with clasts as large as 3 mm. All beds generally fine upward and are capped by laminated silty limestone or calcareous siltstone; most beds are partly or completely laminated; highest bed is a single conglomeratic turbidite 2.5 m thick	32.5
Unit 3: Shale, black, fissile; abundant horizontal trace fossils	29.0
Unit 2: Siltstone, quartzose; gray on fresh surfaces, light-reddish-brown on weathered surfaces; poorly exposed but beds probably about 30 cm thick	18.0
Unit 1:	
2. Limestone, bioclastic, medium-gray, coarse-grained with clasts as large as 4 mm, generally graded normally	7.0
1. Limestone, medium-gray, medium-grained, interbedded with limestone conglomerate, some graded coarse to fine; conglomerate with large pelmatozoan columnals and limestone, sandstone, and uncommon black chert clasts. Fine-grained laminated limestone 60 cm thick at top	6.5
Total thickness of unit 1	13.5
Total thickness of Snowcaps Member	140.0
Kearsarge Formation, Bee Member (Lower Mississippian):	
1. Megabreccia; blocks as large as 10 m of quartzite, limestone, and chert (in decreasing order of abundance) in fine-grained, medium-gray limestone matrix. Largest limestone blocks contain pelmatozoan ossicles that have a dilumen central canal	13.5
Total thickness of Bee Member	13.5
Total thickness of Kearsarge Formation	153.5
Unconformable contact	
Squares Tunnel Formation (Upper Devonian): Black chert	

TYPE SECTION OF SQUARES TUNNEL FORMATION (FIGS. 12, 13)

Section measured by C. Stevens and P. Stone, August 1989, in Mazourka Canyon in western Inyo Mountains, 0.9 km north-northeast of Squares Tunnel and about 13 km northeast of Independence, in S∫ sec. 8, T. 12 S., R. 36 E., lat 36°52′12″ N., long 118°04′54″ W., Bee Springs Canyon 7.5-minute quadrangle, Inyo County, California.

	Thickness (meters)
Kearsarge Formation (Mississippian): Megabreccia	
Unconformable contact	
Squares Tunnel Formation (Upper Devonian):	
Unit 2: Limestone, altered, bleached light gray; 20-cm-thick chert-pebble conglomerate in lower part, altered limestone pebbles in upper part. Laterally contains many clasts reworked from underlying unit 1	7.0
Unit 1:	
2. Interbedded chert and siliceous argillite, black, blocky weathering, generally thin bedded. Some beds in upper part weather reddish brown. Chert commonly contains phosphatic light-gray stringers and beds as thick as 1 cm	62.5
1. Pebble conglomerate, containing clasts of altered limestone and black chert mostly 6 cm and rarely 20 cm across in medium-gray limestone matrix	0.5
Total thickness of unit 1	63.0
Total thickness of Squares Tunnel Formation	70.0
Unconformable contact	
Vaughn Gulch Limestone (Lower Devonian? and Silurian): Limestone, medium-gray, fine-grained, thin-bedded	

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