Stratigraphy of the Lower and Middle(?) Triassic Union Wash Formation, East-Central California

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Stratigraphy of the Lower and Middle(?) Triassic Union Wash Formation, East-Central California

By PAUL STONE, CALVIN H. STEVENS, and
MICHAEL J. ORCHARD

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By Paul Stone, Calvin H. Stevens, *and* Michael J. Orchard

ABSTRACT

Marine sedimentary rocks of Early and Middle(?) Triassic age in the Inyo Mountains and nearby areas of east-central California are herein assigned to the Union Wash Formation, the type locality of which is at Union Wash on the west side of the Inyo Mountains. In the areas studied, the Union Wash Formation ranges in thickness from slightly less than 700 m to about 850 m and is divided into three informal members. The lower member, generally less than 50 m thick, is composed of silty and sandy limestone; the middle member, approximately 250 to 680 m thick, is composed of thin-bedded mudstone and micritic limestone; the upper member, approximately 450 m in maximum thickness, is composed of limestone, silty and sandy limestone, shale, quartzose siltstone, and very fine grained quartzose sandstone. This stratigraphic sequence defines a transgressive-regressive depositional cycle on the subsiding continental margin of North America. Conodonts and ammonoids indicate that the Union Wash Formation contains rocks of Smithian, Spathian, and possibly earliest Anisian age. Deposition of the Union Wash Formation followed a complex episode of basinal marine sedimentation and subsequent uplift in the Permian and was followed in later Triassic or Jurassic time by the onset of arc magmatism that continued through the remainder of the Mesozoic.

INTRODUCTION

Marine sedimentary rocks of Early and Middle(?) Triassic age crop out widely in the Inyo Mountains and nearby areas of east-central California (fig. 1). These rocks, the youngest marine rocks in the Inyo Mountains region, are composed of sediment deposited on the North American continental margin before the onset of subduction and arc magmatism in later Triassic or Jurassic time (Dunne and others, 1978).

The best-known and most accessible exposures of these Triassic marine rocks are at the west foot of the Inyo Mountains at Union Wash (fig. 1), a locality from which J.P. Smith described ammonoids early in this century (Smith, 1904, 1914, 1932). The Triassic marine rocks exposed at this locality were named the Union Wash Formation by Mount (1971), who designated the type locality on the south side of Union Wash near Smith's ammonoid localities. This formational name did not become established in the geological literature, however, and to our knowledge it has not been used since it was first proposed. We herein adopt the name Union Wash Formation as defined by Mount (1971) and extend its usage throughout the Inyo Mountains and southeastward into the vicinity of Darwin and the Argus Range.

In this report we describe the lithology, stratigraphy, and contact relations of the Union Wash Formation at its type locality and at two additional localities: (1) the Cerro Gordo area near the crest of the Inyo Mountains, 25 km southeast of Union Wash, and (2) the Darwin area, another 35 km to the southeast (fig. 1). The descriptions given herein are largely based on recent work and are intended to supersede previous descriptions of the formation by us and our coworkers (Lewis and others, 1983; Stone, 1984; Stone and Stevens, 1986). In addition, we list new conodont identifications that, together with ammonoids identified by previous workers, constrain the age of the Union Wash Formation in these three areas to Early and Middle(?) Triassic.

PREVIOUS STUDIES

The presence of Triassic marine rocks in the Inyo Mountains was first noted by J.P. Smith (1898), who subsequently described ammonoids from Triassic marine rocks exposed at Union Wash (Smith, 1904, 1914, 1932). The Triassic marine rocks of the Inyo Mountains were first mapped and described by Knopf (1918) and Kirk (1918). More recently, the Triassic marine rocks of the Inyo Mountains have been reported on by several workers, including Merriam (1963), Ross (1967), Mount (1971), Elayer (1974), Stinson (1977), Conley (1978), Lewis and others (1983), Oborne (1983), Oborne and others (1983), Stone (1984), Stone and Stevens (1986, 1987, 1988a), and Stone and others (1987). Triassic marine rocks in the Darwin area were first

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noted by Stone and others (1980) and have since been reported on by Lewis and others (1983), Stone (1984), Stone and Stevens (1987, 1988a), and Stone and others (1989). Triassic marine rocks in the Argus Range were first noted by Lewis and others (1983) and were briefly described by Stone (1984).

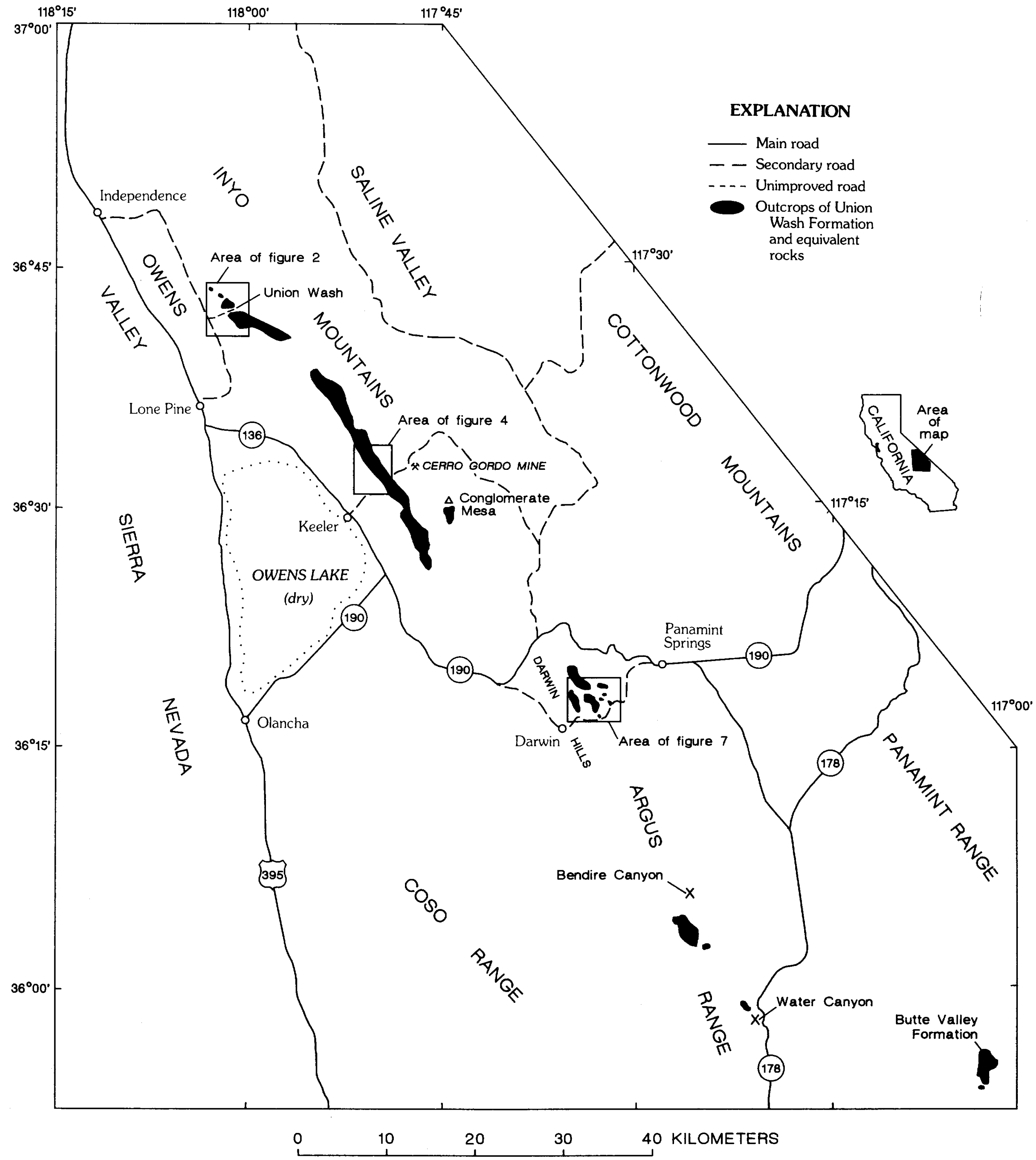


Figure 1. East-central California, showing outcrops of the Union Wash Formation and the correlative Butte Valley Formation of Johnson (1957) and Cole (1986), areas discussed in report (see figs. 2, 4, and 7), and other localities discussed in text.

OUTCROP DISTRIBUTION

Rocks herein assigned to the Union Wash Formation are exposed in the Inyo Mountains, the Darwin area, and the Bendire Canyon and Water Canyon areas in the Argus Range (fig. 1). Together, these rocks form a discontinuous, northwest-trending outcrop belt almost 100 km long. Correlative strata in the southern Panamint Range, 30 km southeast of Water Canyon (fig. 1), constitute the Butte Valley Formation of Johnson (1957) and Cole (1986).

In the Inyo Mountains, the Union Wash Formation forms a nearly continuous, northwest-striking, southwest-dipping outcrop belt approximately 35 km long (fig. 1). The type locality of the formation at Union Wash is close to the northwest end of this outcrop belt, and the exposures near Cerro Gordo are in the central part of the belt. Rocks herein assigned to the lowermost part of the Union Wash Formation also are present approximately 5 km east of the primary outcrop belt at Conglomerate Mesa. These rocks, which were referred to as unnamed Triassic rocks by Stone (1984) and Stone and others (1989), had not been previously differentiated from the underlying Permian rocks by McAllister (1956) and Ross (1967).

Near Darwin, rocks herein assigned to the Union Wash Formation form scattered outcrops within an area of about 25 km^2 (fig. 1). These rocks, which were referred to as unnamed Triassic rocks by Stone and others (1980, 1989), Lewis and others (1983), and Stone (1984), had not been previously differentiated from the underlying Permian rocks by Hall and MacKevett (1962).

In the Argus Range, rocks herein assigned to the Union Wash Formation are exposed over an area of several square kilometers near Bendire Canyon and in a smaller area near Water Canyon (fig. 1). These rocks, which were referred to as unnamed Triassic rocks by Lewis and others (1983) and Stone (1984), had not been previously differentiated from the underlying Permian rocks by Moore (1976). Our study of the Triassic rocks in these areas has not yet been completed, and these rocks are not described in this report.

STRATIGRAPHY AND CONTACT RELATIONS

In the three areas under consideration here, the Union Wash Formation ranges in thickness from slightly less than 700 m to about 850 m and is divisible into three informal members. The lower member, generally less than 50 m thick, is composed of silty and sandy limestone. The middle member, which ranges in thickness from approximately 250 m to approximately 680 m, is composed primarily of thin-bedded siliceous mudstone, calcareous mudstone, and micritic limestone. The upper member, which has a maximum exposed thickness of approximately 450 m, is composed of thin-bedded to massive micritic limestone, silty and sandy limestone, shale, quartzose siltstone, and very fine grained quartzose sandstone. Except for the resistant limestone of the lower member and some resistant limestone beds in the middle and upper members, rocks of the Union Wash Formation are generally nonresistant and form smooth slopes.

The Union Wash Formation is underlain by Permian sedimentary rocks that are assigned to the Owens Valley Group and the Keeler Canyon Formation, and it is overlain by unnamed volcanic and sedimentary rocks of Triassic and (or) Jurassic age. The depositional base of the Union Wash Formation is exposed throughout the outcrop extent of the formation, but the contact with the overlying rocks is exposed only in the Inyo Mountains. Early workers interpreted the contact between the Union Wash Formation and the underlying Permian rocks as an unconformity (Kirk, 1918; Merriam, 1963). Recent work has shown that the Union Wash Formation paraconformably overlies a lenticular sequence of Upper Permian rocks, and that an angular unconformity of regional extent separates these Upper Permian and Triassic rocks from the underlying Lower Permian rocks (Stone and Stevens, 1987, 1988a; Stone and others, 1987). The contact between the Union Wash Formation and the overlying Triassic and (or) Jurassic volcanic and sedimentary rocks has been interpreted as conformable (Kirk, 1918; Mount, 1971), as apparently conformable but possibly unconformable (Merriam, 1963), and as generally conformable but locally unconformable (Oborne, 1983; Oborne and others, 1983). Our studies indicate that this contact is unconformable at Union Wash, where relations are well preserved, but that elsewhere, as in the Cerro Gordo area, faulting has obscured the original stratigraphic relations.

Following are descriptions of the stratigraphy and contact relations of the Union Wash Formation in each of the three areas studied. The text is accompanied by geologic maps and graphic columns of stratigraphic sections measured in the three areas. Detailed written descriptions of the measured sections follow the main text of the report.

Union Wash Area

The Union Wash area is at the west foot of the Inyo Mountains in the northeast quarter of the 7 1/2-minute Union Wash quadrangle, approximately 15 km north-northeast of Lone Pine (figs. 1, 2). This area is accessible by several unimproved roads that diverge from the Owenyo—Lone Pine Road on the east side of Owens Valley.

In this area the Union Wash Formation is exposed on the ridges that bound Union Wash on the north and south, on the lowermost part of a ridge located 2 km north of Union Wash, and on Fossil Hill (fig. 2). The formation strikes northwest, dips moderately to steeply southwest, lies on Permian rocks of the Owens Valley Group, and is overlain by unnamed volcanic and sedimentary rocks of Triassic and (or) Jurassic age. The Owens Valley Group and the underlying Keeler Canyon Formation are extensively intruded by granitoid rocks and are moderately to intensely metamorphosed, but the Union Wash Formation is not extensively intruded and is only slightly metamorphosed. Dikes considered to be part of the Jurassic Independence dike swarm cut the Union Wash Formation but have not caused widespread thermal alteration.

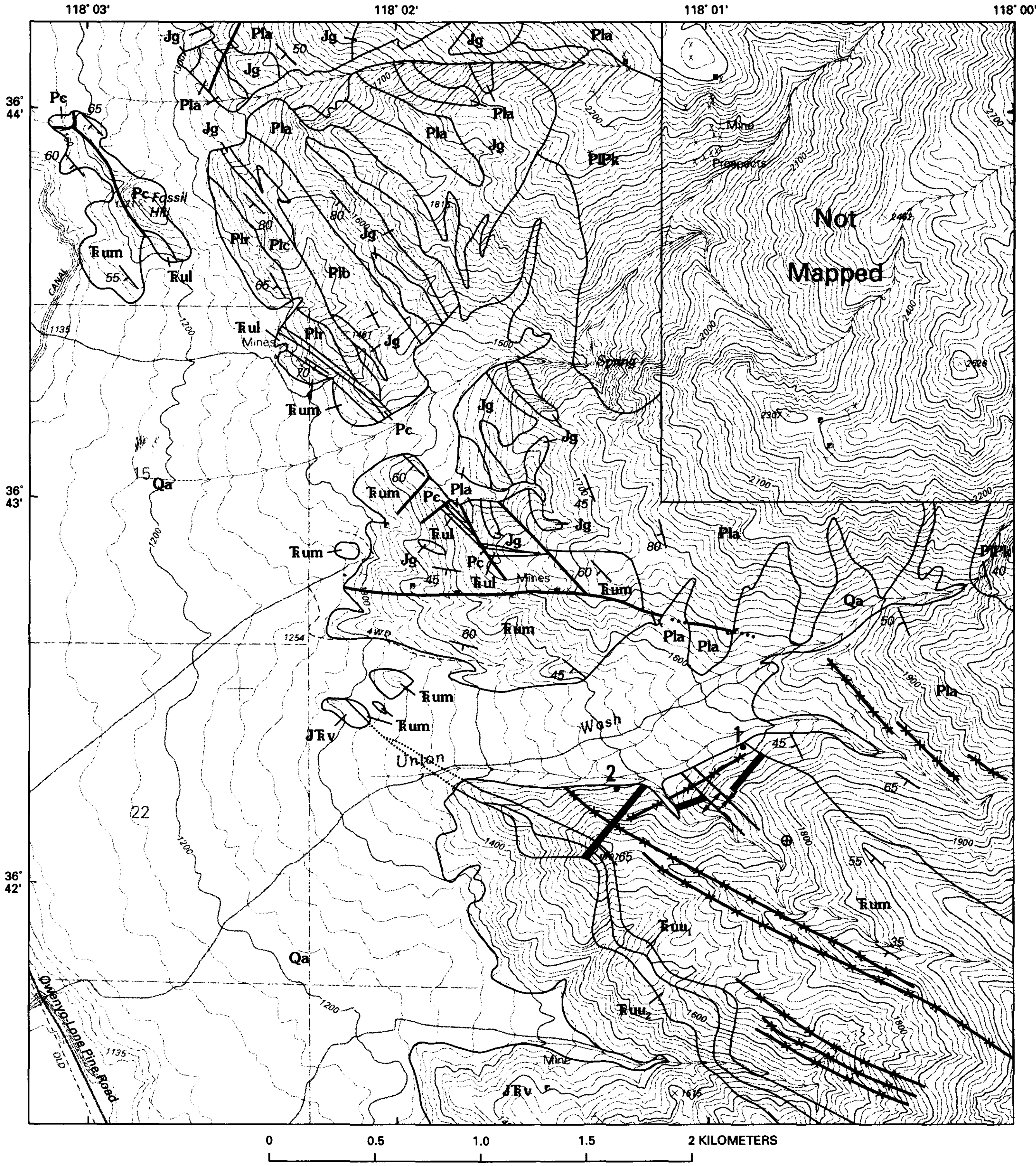


Figure 2. Geologic map of Union Wash area, Inyo Mountains, California, showing location of type section at type locality of the Union Wash Formation. See figure 1 for location of map. Base from U.S. Geological Survey, 1:24,000 scale, Union Wash quadrangle, 1982. Contour interval 20 m. Geology mapped in 1981 and 1990.

The Owens Valley Group in this area consists of two formations—the thick Lone Pine Formation of Early Permian age and the thin, lenticular Conglomerate Mesa Formation of Late Permian age—which are separated from one another by an angular unconformity (Stone and Stevens, 1987, 1988a). In the northwestern part of the area, the Union Wash Formation rests paraconformably on the Conglomerate Mesa Formation; in the southeastern part of the area, beyond the depositional wedgeout of the Conglomerate Mesa Formation, the Union Wash Formation unconformably overlies the Lone Pine Formation (fig. 2). Contact relations between the Lone Pine, Conglomerate Mesa, and Union Wash Formations are clearest on the ridge 2 km north of Union Wash, where the Reward Conglomerate Member and member C of the Lone Pine Formation are erosionally truncated beneath the Conglomerate Mesa Formation and the concordantly overlying Union Wash Formation (fig. 2).

All three members of the Union Wash Formation are present in the area, but the lower member is present only in part of the northwestern sector (fig. 2). At its type locality on the south side of Union Wash, the formation consists of only the middle and upper members. Because Mount (1971) designated no type section at the type locality, we herein designate a section that we measured on the south side of Union Wash as the type section at the type locality of the Union Wash Formation. This measured section is located in an unsurveyed part of T. 14 S., R. 36 E., in the northeast quarter of the Union Wash quadrangle (fig. 2). The measured section (fig. 3) is 773.5 m thick; the middle member is 679 m thick, and the upper member is 94.5 m thick. The section dips nearly homoclinally to the southwest except in its central part, which is folded into a syncline and an anticline (fig. 2). Continuity of measurement across the folded part of the section was maintained by tracing a zone of limestone beds around the fold hinges.

The lower member of the Union Wash Formation consists of well-indurated, ledge-forming, gray- to brown-weathering silty and sandy limestone. These rocks are characterized by crinkly or wavy lamination and locally contain minute black gastropod molds. A sharp, concordant contact described by Stone and Stevens (1986, 1987) separates these rocks from the underlying Conglomerate Mesa Formation. This contact, although sharp, is subtle because of the general lithologic similarity between the lower member of the Union Wash Formation and the Conglomerate Mesa Formation, which in this area also consists mainly of well-indurated silty to sandy limestone. The Conglomerate Mesa Formation, however, differs from the lower member of the Union Wash Formation in containing lenses of chert gravel and shell debris and in lacking minute black gastropod molds. A thin coquina is present directly beneath the base of the Union Wash Formation. Originally, the rocks now assigned to the Conglomerate Mesa Formation and to the lower member of the Union Wash Formation at this locality were considered to comprise a single formation, the Owenyo Limestone, of presumed Permian age (Kirk, 1918). Merriam and Hall

EXPLANATION

- **Qa** — Alluvium and talus (Quaternary)
- **Jg** — Granitoid rocks (Jurassic)—Primarily diorite
- **JTRv** — Volcanic and sedimentary rocks (Jurassic and (or) Triassic)—Thickness greater than 500 m

Union Wash Formation (Triassic)—Divided into:

Upper member—Divided into:

- **TRuu$_2$** — Subunit 2—Pink shale and brown-weathering siltstone. Measured thickness 40.5 m
- **TRuu$_1$** — Subunit 1—Dark-gray micritic limestone. Abundant ammonoids 1–2 m above base represent the *Parapopanoceras* bed of Smith (1904, 1914). Measured thickness 54 m
- **TRum** — Middle member—Medium- to dark-gray, thin-bedded mudstone, siltstone, very fine grained to fine-grained sandstone, and micritic limestone. *Meekoceras* ammonoid bed of Smith (1904, 1932) present at base southeast of Union Wash. Measured thickness 679 m
- **TRul** — Lower member—Gray to brown, silty and sandy limestone. Maximum thickness approximately 30–40 m

Owens Valley Group—In this area, consists of:

- **Pc** — Conglomerate Mesa Formation (Permian)—Light-gray sandy limestone and minor shale, siltstone, and sandstone. Maximum thickness approximately 150 m

Lone Pine Formation (Permian)—Divided into:

- **Plr** — Reward Conglomerate Member—Massive and thick-bedded chert-pebble conglomerate and quartzite; sandy marble at base. Thickness approximately 200 m
- **Plc** — Member C—Massive siltstone, quartzite, and minor chert-pebble conglomerate. Thickness approximately 120 m
- **Plb** — Member B—Thin-bedded calcareous mudstone and siltstone; minor bioclastic limestone. Thickness approximately 180 m
- **Pla** — Member A—Thin-bedded siliceous to calcareous mudstone, calcareous siltstone, and silty limestone. Generally weathers reddish brown. Thickness approximately 500 m
- **PIPk** — Keeler Canyon Formation (Permian and Pennsylvanian)—Thick-bedded limestone; limestone-boulder conglomerate at top. Thickness approximately 400 m

Contact—Dotted where concealed

Fault—Dotted where concealed

Anticline

Syncline

Strike and dip of beds

50 Inclined

Vertical

Horizontal

Dikes of Jurassic Independence dike swarm

Type section of Union Wash Formation

5 Location and number of conodont collection of Lewis and others (1983)

Figure 2. Continued.

AGE	ROCK UNIT (THICKNESS, IN METERS)			CONO-DONT LOCALITY	LITHO-LOGY	INTERVAL	DESCRIPTION	THICK-NESS, IN METERS	TOTAL THICK-NESS, IN METERS
JURASSIC AND (OR) TRIASSIC	Volcanic and sedimentary rocks (part)						Lowermost 7.5 m is conglomerate; overlying 10 m is brown volcanic sandstone; overlain by several hundred meters of volcanic rocks	17.5+	773.5
TRIASSIC	Union Wash Formation, 773.5 m	Upper Member (94.5m)	Subunit 2 (40.5 m)			49–54	Siltstone, dark-gray (weathers brown), laminated; and shale, pink to light-brown, fissile. Scattered ammonoids in middle part	40.5	
			Subunit 1 (54 m)			43–48	Shale, light-brown to pink, and limestone, dark-gray, thin-bedded	24	
						42	Limestone, dark-gray, fine-grained, thin-bedded; abundant ammonoids 1-2 m above base represent the *Parapopanoceras* bed of Smith (1904, 1914)	30	700
		Middle member (679 m)				35–41	Siltstone and shale, calcareous, mostly gray to light-brown but some pink; and limestone, dark-gray, micritic, thin-bedded. Dike at base	83	600
						34	Limestone, dark-gray, micritic, thin-bedded	9	
						33	Siltstone and shale, calcareous, brownish-gray	28.5	
						32	Limestone, dark-gray, micritic, thin-bedded	31.5	
						31	Siltstone and shale, calcareous, brownish-gray	12	
				UW–5		30	Limestone, dark-gray, micritic, thin-bedded	15	500
						29	Siltstone and shale, calcareous, brownish-gray	14.5	
						28	Limestone, dark-gray, micritic, thin-bedded	21	
						27	Siltstone and shale, calcareous, brownish-gray	13.5	
						26	Limestone, dark-gray, micritic, thin-bedded	37.5	
						25	Dike	13.5	400
				(2)		24	Limestone, dark-gray, micritic, thin-bedded	14.5	
						23	Largely covered; rare outcrops of dark-gray calcareous mudstone and light- to medium-gray micritic limestone	46.5	
				UW-4		22	Limestone, dark-gray, micritic, thin-bedded	31.5	
						21	Mudstone, calcareous, dark-gray; weathers reddish-brown	15	300
						20	Limestone, medium-gray, thin-bedded	15	
						18–19	Mudstone, weathers dark-gray; partly covered	27	
						17	Limestone, medium-gray; and siltstone, brown	13.5	
						13–16	Mudstone and siltstone, gray to brown; and limestone, dark-bluish-gray	33	200
						5–12	Largely covered. Outcrops and float of medium-gray to black mudstone, tan-weathering siltstone and light- to medium-gray, fine-grained limestone	138.5	100
	Lone Pine Fm. (part)					4	Mudstone, very dark, massive	15	
						2–3	Limestone, medium-gray; and siltstone, tan; lower part mostly covered	36	
				(1)		1	Limestone, light-gray, massive; contains abundant ammonoids; *Meekoceras* bed of Smith (1904, 1932)	14.5	0
PERMIAN	Lone Pine Fm. (part)	Member A (part; not measured)					Largely covered. Outcrops and float of thin-bedded, silty limestone, calcareous siltstone, and siliceous to calcareous mudstone		

Figure 3. Type section of the Union Wash Formation in Union Wash area. Location of section shown on figure 2.

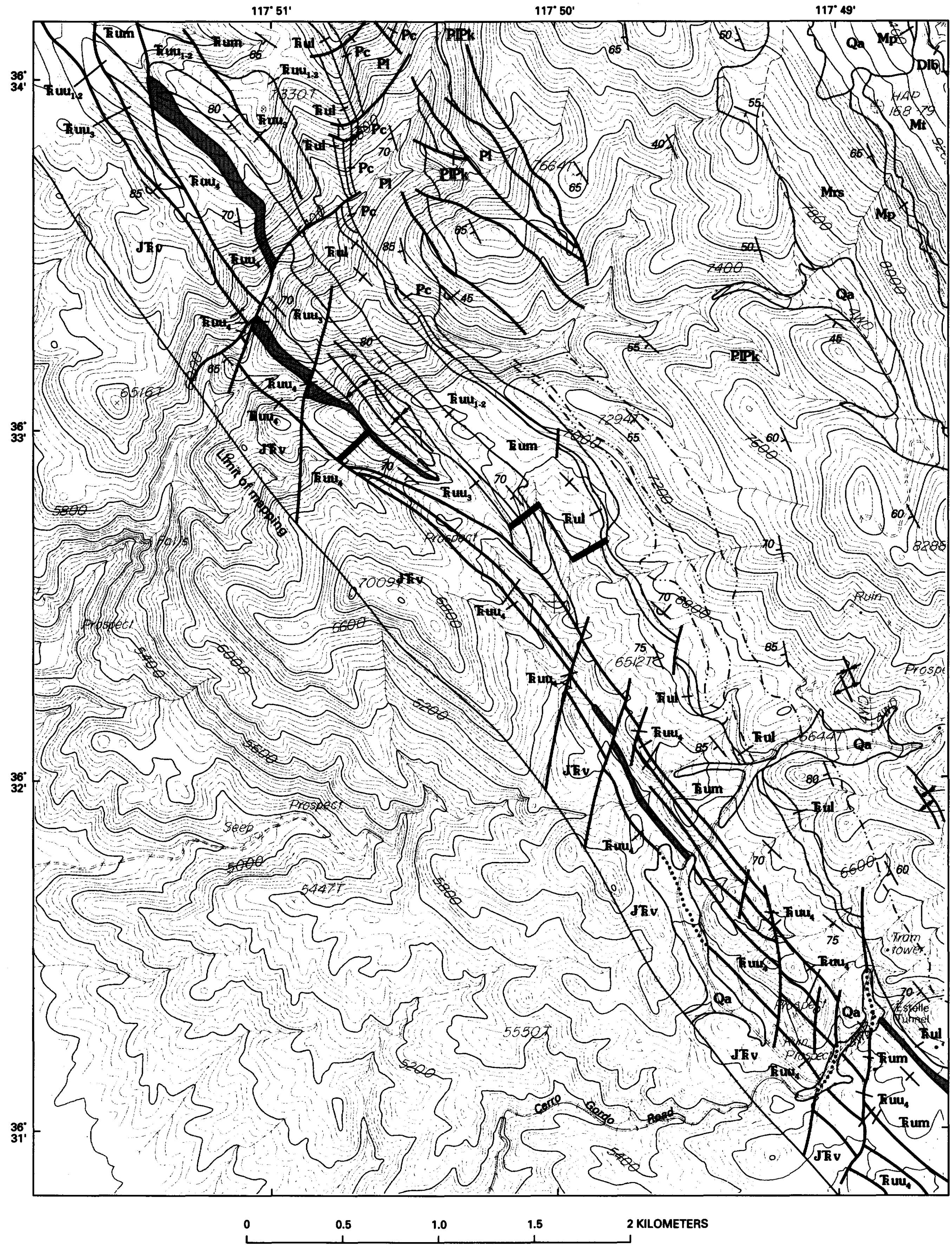
(1957) later revised the Owenyo as a member of the Permian Owens Valley Formation. The little-used name Owenyo was abandoned by Stone and Stevens (1987) when the Owens Valley was raised to group rank and the Conglomerate Mesa Formation was named.

The lower member of the Union Wash Formation is most fully developed on the ridge 2 km north of Union Wash (fig. 2), where it is about 40 m thick. Northwest of this locality, the lower member extends only as far as the southeastern part of Fossil Hill, where it is truncated by faulting. To the southeast, the lower member extends approximately to the crest of the ridge on the north side of Union Wash, where it wedges out depositionally slightly beyond the wedgeout of the underlying Conglomerate Mesa Formation (fig. 2). Southeast of these wedgeouts, member A of the Lone Pine Formation is directly overlain by rocks herein assigned to the middle member of the Union Wash Formation.

The thick, slope-forming middle member of the Union Wash Formation consists primarily of nonresistant, medium- to dark-gray, thin-bedded mudstone, siltstone, and micritic limestone. Most of the limestone is concentrated in discrete zones 10–30 m thick (fig. 3). In the northwestern part of the area, the lower part of the middle member contains abundant beds of very fine grained to fine-grained sandstone and appears to grade up from the lower member. Sandstone becomes less abundant to the southeast, however, and none is present in the vicinity of the type section of the Union Wash Formation on the south side of Union Wash, where the lower member of the formation also is absent. Here, the base of the formation, which is also the base of the middle member, is at the base of a prominent bed of massive limestone that contains abundant ammonoids—the *Meekoceras* bed of Smith (1904, 1932). This bed, which extends continuously from the south side of Union Wash to the east edge of the study area (fig. 2) and beyond, is 14.5 m thick where measured by us (fig. 3) but generally is only about 2–5 m thick. A lithologically similar, possibly equivalent ammonoid bed, 3 m thick, is locally present a few meters above the base of the middle member on the ridge immediately north of Union Wash; the ammonoid assemblage in this bed is identical to that of the *Meekoceras* bed on the south side of the wash (N.J. Silberling and E.T. Tozer, oral commun., 1988). No equivalent bed is exposed farther northwest.

Our placement of the base of the Union Wash Formation on the south side of Union Wash at the base of the *Meekoceras* bed is a significant departure from previous interpretations. Kirk (1918, p. 45–46) considered the base of the then-unnamed Triassic sequence on the south side of Union Wash to be in the deep tributary canyon downslope to the northeast from the *Meekoceras* bed (fig. 2), about 200 m stratigraphically below that bed; he interpreted the base of the sequence to be a fault, an interpretation not supported by later studies. Mount (1971) interpreted the base of the Union Wash Formation on the south side of Union Wash as disconformable and placed this surface "about 300 feet" (91 m) stratigraphically below the *Meekoceras* bed, but he did not clearly explain the lithologic basis for this interpretation. In a previous study by two of us (Stone and Stevens, 1986), we placed the base of the Union Wash Formation on the south side of Union Wash at the base of a 30-m-thick interval of fine-grained sandy limestone and calcareous sandstone, 105 m stratigraphically below the *Meekoceras* bed. In that study, we considered this interval laterally equivalent to the zone of sandy rocks that gradationally overlies the lower member of the Union Wash Formation on the ridge 2 km north of Union Wash. Mapping done during the present study indicates that these previous interpretations are in error and that the actual stratigraphic contact between the Union Wash Formation and the underlying member A of the Lone Pine Formation on the south side of Union Wash is precisely at the base of the *Meekoceras* bed. This interpretation cannot be firmly demonstrated in the immediate vicinity of Union Wash, where the nonresistant beds above and below the *Meekoceras* bed are poorly exposed on a steep, talus-covered slope. The contact relations are clear, however, on a high, relatively level ridge 1.5 km beyond the east edge of the study area, where the beds above and below the *Meekoceras* bed are not covered. At this locality, it is evident that rocks typical of member A of the Lone Pine Formation, here consisting of finely laminated, thin-bedded silty limestone, calcareous siltstone, and calcareous to siliceous mudstone, extend all the way to the base of the *Meekoceras* bed. The thin-bedded mudstone, siltstone, and limestone above the *Meekoceras* bed are grossly similar in lithology to the rocks below, but differ in detail. In particular, limestone beds above the *Meekoceras* bed are thicker, darker, and less silty that those below, and they are not laminated. The 30-m-thick interval of fine-grained sandy rocks that we previously interpreted as the basal part of the Union Wash Formation on the south side of Union Wash (Stone and Stevens, 1986) is herein reinterpreted as part of the Lone Pine Formation. We have observed no significant angular discordance between the Lone Pine and Union Wash Formations in the area south of Union Wash.

A sharp contact separates the middle member of the Union Wash Formation from the upper member, which is exposed only south of Union Wash. The upper member consists of two subunits (figs. 2, 3). Subunit 1, 54 m thick in the type section, is composed primarily of well-indurated, dark-gray micritic limestone that forms a conspicuous marker horizon. A thin, fossiliferous layer that contains abundant ammonoids is present 1–2 m above the base of this subunit. This layer, which is best developed several hundred meters northwest of the type section, is equivalent to the *Parapopanoceras* ammonoid bed of Smith (1904, 1914), described by him as a bed of impure earthy black limestone about 5 ft thick, 150 ft below the top of the Triassic marine section



117° 51'
117° 50'
117° 49'
36° 34'
36° 33'
36° 32'
36° 31'
Limit of mapping
Cerro Gordo Road
Prospect
Seep
Ruin
Tram tower
Estelle Tunnel
Qa
Mp
Dlb
Mrs
Pc
Pl
0
0.5
1.0
1.5
2 KILOMETERS

EXPLANATION

Symbol	Description
Qa	Alluvium and talus (Quaternary)
JTRv	Volcanic and sedimentary rocks (Jurassic and (or) Triassic)—Thickness greater than 500 m
	Union Wash Formation (Triassic)—Divided into:
	Upper member—Divided into:
TRuu$_4$	Subunit 4—Brown to yellowish-brown, thin-bedded siltstone and shale; upper part contains limestone and dolomite including a thick bed of medium- to dark-gray micritic limestone that is structurally repeated several times near Cerro Gordo Road. Measured thickness 234.5 m
TRuu$_3$	Subunit 3—Dark-gray micritic limestone. Measured thickness 92.5 m
TRuu$_{1-2}$	Subunits 1 and 2, undivided—Subunit 1: dark-gray micritic limestone; measured thickness 11 m. Subunit 2: yellow shale; gray, purplish-gray, brownish-gray, and brown siltstone and very fine grained sandstone; and light- to medium-gray limestone. Measured thickness 84 m
TRum	Middle member—Yellow shale and medium-gray, thin-bedded micritic limestone. Measured thickness 236.5 m
TRul	Lower member—Gray to brown, silty limestone and calcareous siltstone. Measured thickness 31.5 m
	Owens Valley Group—In this area, consists of:
Pc	Conglomerate Mesa Formation (Permian)—Light-gray sandy limestone, conglomerate, and gray to yellowish-brown sandstone. Maximum thickness approximately 200 m
Pl	Lone Pine Formation (Permian)—Lower part (member A) composed of medium- to dark-gray, thin-bedded calcareous and dolomitic mudstone, calcareous siltstone to very fine grained sandstone, and micritic dolomite. Upper part (member B) composed of light-colored mudstone, siltstone, very fine grained sandstone, and locally abundant medium- to dark-gray bioclastic limestone. Maximum thickness approximately 310 m
PIPk	Keeler Canyon Formation (Permian and Pennsylvanian)—Lower part: gray to brown calcareous siltstone and medium-gray bioclastic limestone. Upper part: medium-gray bioclastic limestone and minor gray to pink mudstone and shale. Thickness approximately 1,250 m
Mrs	Rest Spring Shale (Mississippian)—Dark-brown shale. Thickness approximately 350 m
Mp	Perdido Formation (Mississippian)—Light-brown siltstone. Thickness approximately 50 m
Mt	Tin Mountain Limestone (Mississippian)—Dark-gray limestone. Thickness approximately 50 m
Dlb	Lost Burro Formation (Devonian)—Light- to medium gray limestone and dolomite. Only uppermost part exposed

Contact

Fault—Dotted where concealed

Anticline

Syncline

Strike and dip of beds

- 50 Inclined
- Vertical
- 70 Overturned

Dikes

Marker beds in Keeler Canyon Formation

Reference section of Union Wash Formation

and 800 ft above the *Meekoceras* bed. By our measurement, Smith's *Parapopanoceras* bed is actually 665 m (2,182 ft) above the *Meekoceras* bed. Subunit 2, 40.5 m thick in the type section, is composed of pink fissile shale and brown-weathering quartzose siltstone. Rare ammonoids are observed about 20 m above the base of subunit 2 a few hundred meters northwest of the type section; this locality probably is equivalent to an ammonoid locality described by Silberling and Tozer (1968, p. 39) as "several tens of feet" above Smith's *Parapopanoceras* bed.

The upper member of the Union Wash Formation is sharply overlain by 5 to 10 m of conglomerate that contains clasts of limestone and volcanic rocks, including scattered blocks of limestone more than 1 m in diameter. This conglomerate marks the base of the unnamed sequence of Triassic and (or) Jurassic volcanic and sedimentary rocks. As was first pointed out by Oborne (1983), this conglomerate lies unconformably on the Union Wash Formation. Traced northwestward from the hilltop where the type section ends, subunit 2 of the upper member of the Union Wash Formation is gradually truncated beneath the conglomerate, which directly overlies subunit 1 at the base of the ridge (fig. 2). Less than 1 km farther northwest, on a low hill at the mouth of Union Wash, the basal rocks of the volcanic and sedimentary sequence overlie rocks of the middle member of the Union Wash Formation. Thus, the entire upper member of the formation is erosionally truncated beneath the upper contact within a distance of less than 2 km. We interpret the contact as an unconformity having slight angular discordance.

Cerro Gordo Area

The Cerro Gordo area is located on the west slope of the Inyo Mountains in the southwest quarter of the 7 1/2-minute Cerro Gordo Peak quadrangle, approximately 6 km northeast of Keeler and 3 km west of the Cerro Gordo mine (figs. 1, 4). This area is reached by Cerro Gordo Road, a steep graded road that connects Keeler and the Cerro Gordo mine.

The Union Wash Formation in the Cerro Gordo area forms a continuous northwest-striking, generally southwest-dipping belt that is complicated by faulting, folding, and dikes (fig. 4). The formation lies on Permian rocks of the Keeler Canyon Formation and Owens Valley Group and is overlain by unnamed volcanic and sedimentary rocks of Triassic and (or) Jurassic age. The depositional lower contact of the Union Wash Formation is widely exposed, but the upper contact is invariably faulted. Despite the structural complexity of the area and the presence of intrusive rocks, the Union Wash Formation and the bounding units are

◀ **Figure 4.** Geologic map of Cerro Gordo area, Inyo Mountains, California, showing location of reference section of the Union Wash Formation. See figure 1 for location of map. Base from U.S. Geological Survey, 1:24,000 scale, Cerro Gordo Peak quadrangle, provisional edition 1987. Contour interval 40 ft. Geology mapped in 1974–75 and 1982.

generally well preserved and are not significantly sheared, altered, or metamorphosed except in and near fault zones.

As in the Union Wash area, the Owens Valley Group in the Cerro Gordo area is divided into the Lone Pine Formation of Early Permian age and the Conglomerate Mesa Formation of Late Permian age. Both of these formations thin and wedge out from northwest to southeast within the area (fig. 4). In the northwestern part of the area, the Union Wash Formation rests paraconformably on the Conglomerate Mesa Formation, which in turn rests unconformably on the Lone Pine Formation. In the central part of the area, beyond the depositional wedgeout of the Conglomerate Mesa Formation, the Union Wash Formation unconformably overlies the Lone Pine Formation, which is much thinner here than to the northwest. Farther southeast, 1.5 km northwest of Cerro Gordo Road, the Lone Pine Formation wedges out, and southeast of this wedgeout the Union Wash Formation unconformably overlies the Keeler Canyon Formation. The unconformable contact between the Keeler Canyon and Union Wash Formations has a slight angular discordance; several marker beds in the Keeler Canyon Formation are truncated beneath this contact (fig. 4). Between the wedgeout of the Lone Pine Formation and Estelle Tunnel at the southeast corner of the study area, a distance of 3 km, a total of about 230 m of beds in the Keeler Canyon Formation is truncated beneath the contact with the Union Wash Formation (Stone and Stevens, 1988a).

All three members of the Union Wash Formation are present in the Cerro Gordo area. The lower and middle members extend continuously across the area and are nearly homoclinal, but the upper member is intensely faulted and folded; it is stratigraphically most complete in the northwestern part of the area (fig. 4). Our measured section of the Union Wash Formation crosses the lower member, middle member, and subunits 1–3 of the upper member approximately 2 km northwest of Cerro Gordo Road; subunit 4 of the upper member was measured 1 km farther northwest, on the southwest flank of an anticline (fig. 4). This measured section (fig. 5), herein designated as a reference section of the Union Wash Formation, is 690 m thick; the lower member is 31.5 m thick, the middle member is 236.5 m thick, and the upper member is 422 m thick. The lower and middle members of the Union Wash Formation, as defined herein, are equivalent to the "lower, brown-mottled limestone" and the "middle shale-limestone zone," respectively, described by Merriam (1963, p. 29). Subunit 4 of the upper member is equivalent, in part, to the "upper reefy limestone zone" described by Merriam (1963, p. 29). Rocks comprising subunits 1, 2, and 3 of the upper member were not described by Merriam (1963).

The lower member of the Union Wash Formation is composed of gray to brown silty limestone and calcareous siltstone that form resistant crags and hogbacks. These rocks are characterized by thin, planar to wavy bedding, a distinctive nodular texture, and the local presence of minute black gastropod molds. The lower member is readily distinguished from all of the units it overlies within the area. The uppermost part of the Conglomerate Mesa Formation consists of sandstone and conglomerate; the Lone Pine Formation consists of dark-gray, thin-bedded calcareous mudstone and siltstone; and the Keeler Canyon Formation consists of medium-gray, thick-bedded, bioclastic limestone characterized by graded bedding and local concentrations of fusulinids.

The lower member of the Union Wash Formation fines upward and grades into the slope-forming middle member, which is composed of yellow fissile shale and medium-gray, thin-bedded micritic limestone. Limestone beds are planar and 1 to 10 cm thick. Most parts of the member consist primarily of shale and scattered limestone interbeds, but a few limestone-dominated intervals 1 to 25 m thick are present. Only locally does the limestone contain bioclastic debris visible in the field, but petrographic studies reveal the local abundance of spherical radiolarians (now replaced by calcite). The uppermost shale interval in the member, 44 m thick in the measured section, is a distinctive marker zone characterized by a bright, yellowish-brown color.

A sharp contact separates the middle member of the Union Wash Formation from the lithologically heterogeneous upper member, which is divided into four subunits. In ascending order, these are called subunits 1, 2, 3, and 4; their measured thicknesses are 11, 84, 92.5, and 234.5 m, respectively (fig. 5). Subunit 1 consists of a massive ledge of dark-gray micritic limestone that stands out in marked contrast to the underlying yellow shale. Subunit 2 consists of a 10-m-thick basal zone of yellow shale overlain by 74 m of interbedded quartzose siltstone, very fine grained quartzose sandstone, and limestone. The siltstone and sandstone are gray, purplish gray, brownish gray, and light brown, and commonly are finely laminated; the limestone is light to medium gray and commonly contains thin interbeds of brown siltstone. Subunit 3 is composed primarily of dark-gray, ledge-forming micritic limestone. This limestone, despite its massive appearance, forms planar beds 1 to 5 cm thick that are separated by thin partings of light-brown siltstone or mudstone. Subunit 4 is composed primarily of brown to yellowish-brown, thin-bedded quartzose siltstone and shale, most of which is cut by a well-developed slaty cleavage. In addition, subunit 4 contains two prominent zones of carbonate rocks: (1) a resistant bed of medium-gray limestone, 4.5 m thick and 123 m above the base of the subunit, which contains local concentrations of pelecypod shells in its upper part; and (2) a zone of dark-gray limestone and light-gray-weathering dolomite, 12 m thick and 156 m above the base of the subunit. Above this upper carbonate zone, the uppermost 66.5 m of the measured section consists almost entirely of shale, which in turn is overlain by a thick unit of conglomerate comprising the basal part of the unnamed Triassic and (or) Jurassic volcanic and sedimentary sequence. A 2-m-thick conglomerate bed containing clasts of limestone and volcanic rock is present 29 m below the base of this thick conglomerate. It is not clear whether this bed and the overlying shale are in proper stratigraphic sequence or are structurally interleaved in a shear zone, although the latter interpretation is preferred.

In the vicinity of Cerro Gordo Road, intensely deformed rocks assigned to subunit 4 of the upper member of the Union Wash Formation are in fault contact with the middle member of the Union Wash (fig. 4). These are the rocks of subunit 4 that Merriam (1963) specifically referred to as the "upper reefy limestone zone" of the Triassic sequence. This belt of deformed rocks extends about 2.5 km northwest of the road and beyond the boundary of the study area to the southeast. The belt is characterized by numerous discontinuous bodies of massive, medium-gray limestone, some as thick as 15 to 20 m, that form high, resistant crags and hogbacks above the enclosing shale, siltstone, and thin-bedded carbonate rocks. Merriam (1963) counted five of these limestone bodies and implied that each was a

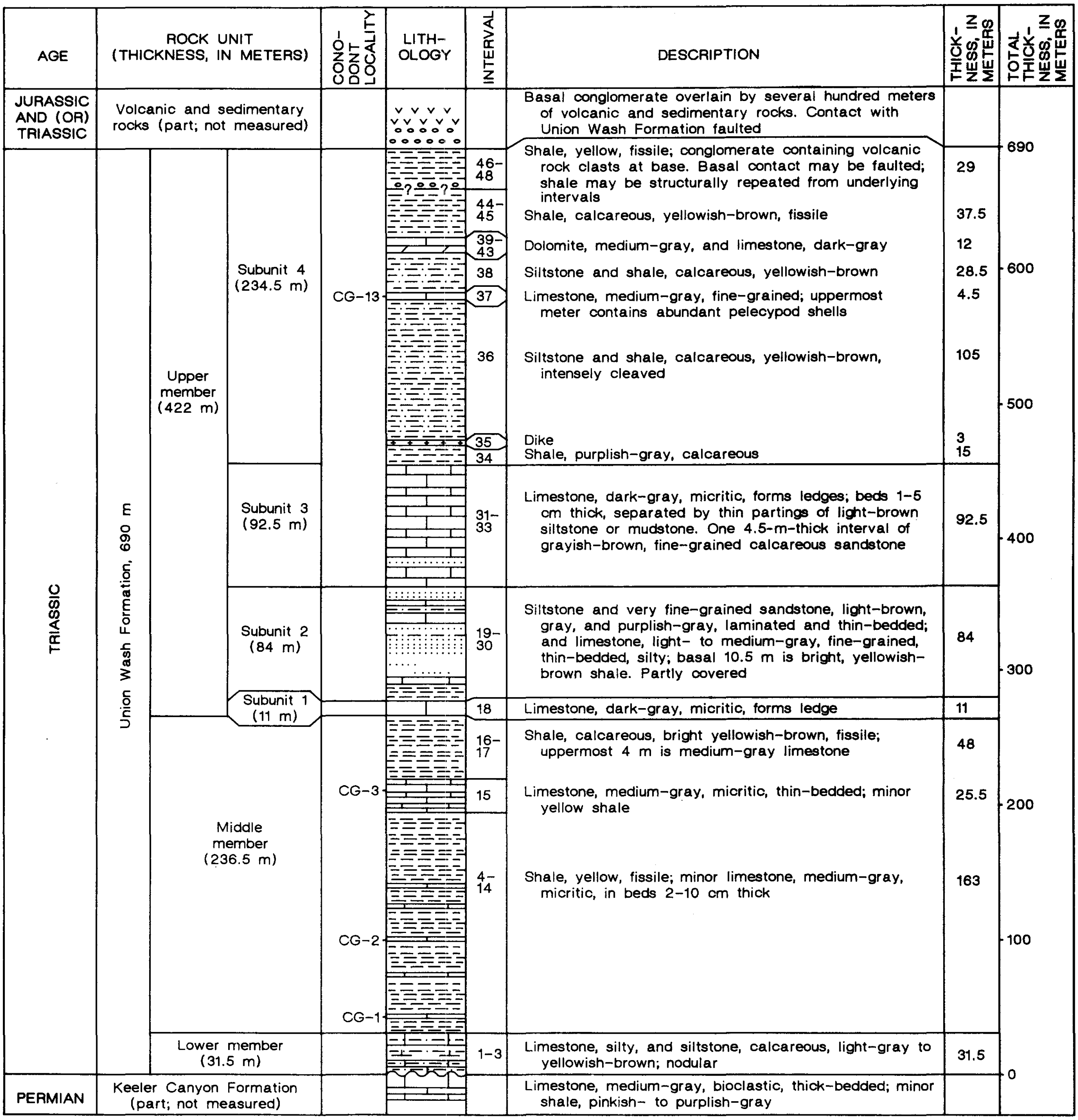


Figure 5. Reference section of the Union Wash Formation in Cerro Gordo area. Location of section shown on figure 4.

separate bed. Our mapping and stratigraphic studies, however, indicate that only one massive limestone bed, structurally repeated several times by complex folding and faulting, is present. The stratigraphy of subunit 4 in this belt is revealed by a measured section on the northwest side of Cerro Gordo Road (fig. 6), which consists of two very similar subsections (A and B) that we interpret as structurally repeated equivalents of one another. Each subsection contains the following distinctive stratigraphic sequence, listed in ascending order: (1) a bed of light-brown, mottled micritic limestone, 1 to 1.5 m thick; (2) a massive bed of medium-gray limestone, 9 m thick in subsection A and 16 m thick in subsection B, that contains local concentrations of pelecypod shells in its uppermost part; (3) an interval of tan to gray siltstone, 2 to 3 m thick; (4) an interval of thin-bedded limestone and dolomite, 7 to 8 m thick, in which thin sections reveal coated grains and ooliths; and (5) a bed of cream-colored, micritic dolomite, 1 m thick, that contains fine stromatolitic lamination (fig. 6). The lowermost bed in this distinctive sequence overlies about 60 m of brown siltstone and shale, and the uppermost bed is overlain by about 20 m of ochre to brown shale. Both the base and top of the measured section are bounded by faults, and the two subsections are separated by a narrow, inconspicuous zone of recrystallized and brecciated rocks that we interpret as a bedding-plane fault.

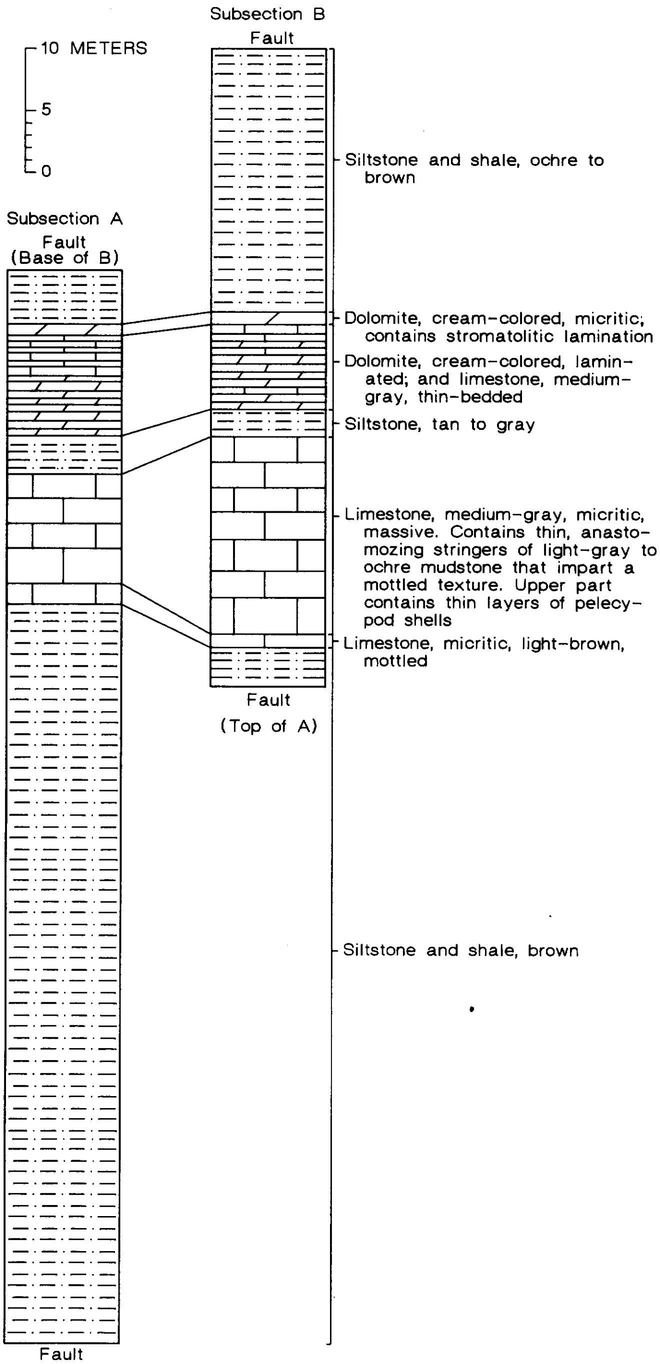


Figure 6. Measured section of structurally repeated parts of subunit 4 of upper member of the Union Wash Formation on northwest side of Cerro Gordo Road. Measured section consists of two subsections (A and B) that are inferred to be stratigraphically equivalent to one another and to be separated by inconspicuous bedding-plane fault. Subsection B structurally overlies subsection A.

We interpret the massive limestone bed in the vicinity of Cerro Gordo Road to be equivalent to the 4.5-m-thick limestone bed 123 m above the base of subunit 4 in our main measured section of the Union Wash Formation (fig. 5). That bed is thinner than the bed exposed at Cerro Gordo Road, but both beds are similar in lithology and each overlies a thick sequence of brown siltstone and shale. The overlying thin-bedded limestone and dolomite at Cerro Gordo Road probably are equivalent to the 12-m-thick zone of lithologically similar carbonate rocks 156 m above the base of subunit 4 in our main measured section (fig. 5).

Throughout the area, the upper member of the Union Wash Formation is overlain by thick-bedded, brown-weathering conglomerate that marks the base of the unnamed Triassic and (or) Jurassic volcanic and sedimentary rock sequence. The rocks directly beneath the conglomerate commonly form a shear zone as much as 30 m wide in which shale, limestone, conglomerate, and volcanic rocks are mixed together; in places, tight folds can be mapped within this shear zone. On this basis we consider the contact zone to be a fault that obscures the original stratigraphic relation between the Union Wash Formation and the volcanic and sedimentary rock sequence.

We interpret subunits 1 and 2 of the upper member of the Union Wash Formation in the Cerro Gordo area to be equivalent to the lithologically similar subunits 1 and 2 of the upper member in the Union Wash area. If this correlation is correct, subunits 3 and 4 of the upper member are not represented in the Union Wash area, presumably because they were removed by erosion before the overlying Triassic and (or) Jurassic volcanic and sedimentary rocks were deposited. Mapping in the area between the Cerro Gordo and Union Wash areas is needed to confirm this interpretation.

Darwin Area

The Darwin area is located in the central part of the 7½-minute Darwin quadrangle, approximately 2 km northeast of Darwin (figs. 1, 7). The area extends from the east side of the Darwin Hills to Darwin Canyon. Primary access to the area is by Darwin Road, which connects Darwin and Panamint Springs by way of Darwin Canyon.

The Union Wash Formation in the Darwin area overlies the Lower Permian Darwin Canyon Formation of the Owens Valley Group and is unconformably overlain by Cenozoic basalt and alluvium. The original stratigraphic top of the formation is not exposed. Exposures of the formation are present both north and south of the Darwin fault, the main structural feature in the area, which has an apparent left-lateral separation of 1.2 km (Stone and others, 1989). The most complete section of the Union Wash Formation north of the Darwin fault is in an erosional window beneath Cenozoic basalt in the northwestern part of the area (fig. 7); two less complete sections are present farther east. All three of these sections expose the base of the formation. South of the Darwin fault, the Union Wash Formation is primarily exposed in a broad, northwest-trending syncline, much of which is covered by Cenozoic basalt and alluvium (fig. 7). Small additional exposures are present in Darwin Canyon. Most parts of the Union Wash Formation are well preserved despite the effects of widespread low-grade metamorphism related to the intrusion of plutonic rocks in and adjacent to the area.

The contact between the Union Wash Formation and the underlying Darwin Canyon Formation is an angular unconformity that has been described by Stone and Stevens (1988a). In the eastern part of the area, in the vicinity of Darwin Canyon, the Union Wash Formation overlies the Panamint Springs Member of the Darwin Canyon Formation, which in turn overlies the Millers Spring Member of the Darwin Canyon Formation (fig. 7). The unconformity is superbly exposed on the south side of the Darwin fault in Darwin Canyon, 1 km north of Millers Spring (fig. 7), where the Union Wash Formation overlies the Panamint Springs Member with an angular discordance of about 15°. The unconformity cuts stratigraphically downward into the western part of the area, where the Panamint Springs Member is generally absent and the Union Wash Formation rests directly on the Millers Spring Member. Structural relief on the unconformity within the study area is at least 500 m, the approximate thickness of the Panamint Springs Member in the vicinity of Darwin Canyon (Stone and others, 1987).

All three members of the Union Wash Formation are present in the Darwin area, but the discontinuous outcrop pattern precludes measurement of the entire formation in a single traverse. Our measured section (fig. 8), herein designated as a reference section of the Union Wash Formation, consists of three subsections. The lower and middle members were measured north of the Darwin fault in two subsections (2A and 2B) separated from one another by a minor fault (fig. 7); the top of subsection 2A was correlated with the base of subsection 2B by means of marker beds. The upper member was measured south of the Darwin fault in subsection 1. The composite section of the Union Wash Formation is 853 m thick; the lower member is 22.5 m thick, the middle member is 520.5 m thick, and the upper member is 310 m thick. In the geologic map of the Darwin area by Stone and others (1989), the lower, middle, and upper members of the Union Wash Formation are referred to as units 1, 2, and 3–5, respectively, of the unnamed Triassic sedimentary rocks unit.

The lower member of the Union Wash Formation is composed primarily of light- to medium-gray, thick-bedded silty and sandy mottled limestone that contains even laminations and irregular stringers of brown siltstone. Lewis and others (1983) reported the presence of minute gastropod molds in these rocks. The largest grains in most beds are of very fine sand size, but some beds contain concentrations of coarse siliceous sand and granules. On the line of the measured section, the lower member contains lenses of massive cobble to boulder conglomerate derived from the underlying Permian rocks. The lower member is readily distinguished from both the Panamint Springs Member, which is composed of thin, graded beds of brown siltstone and very fine grained sandstone, and the Millers Spring Member, which is composed of thick-bedded brown siltstone to very fine grained sandstone and thick-bedded, medium-gray bioclastic limestone containing corals and fusulinids.

The middle member of the Union Wash Formation is composed primarily of mudstone and micritic limestone. The member consists of a dominantly siliceous lower part and a calcareous upper part. The most abundant rock type in the lower part of the middle member (approximately the lower 135 m in the measured section) is dark-gray, laminated, siliceous mudstone that commonly is reddish brown on weathered surfaces. The mudstone locally contains abundant medium-gray, spherical to subspherical concretions of micritic limestone as much as 10 cm in diameter. Thin beds of light-gray silty limestone, some of which contain small ammonoids, are present at scattered intervals. Lewis and others (1983) noted the presence of radiolarians in this part of the section. These rocks grade into the upper part of the middle member, which is composed primarily of brown-weathering, finely laminated calcareous mudstone and light- to medium-gray, thin-bedded micritic limestone. Large parts of the section are composed predominantly of calcareous mudstone with little or no interbedded limestone; other parts are composed of rhythmically alternating beds of calcareous mudstone and micritic limestone, 1 to 3 cm thick. A few intervals as much as 15 m thick, particularly in the upper part of the member, are composed primarily of thin-bedded micritic limestone interbedded with minor calcareous mudstone. These intervals stand out as conspicuous markers.

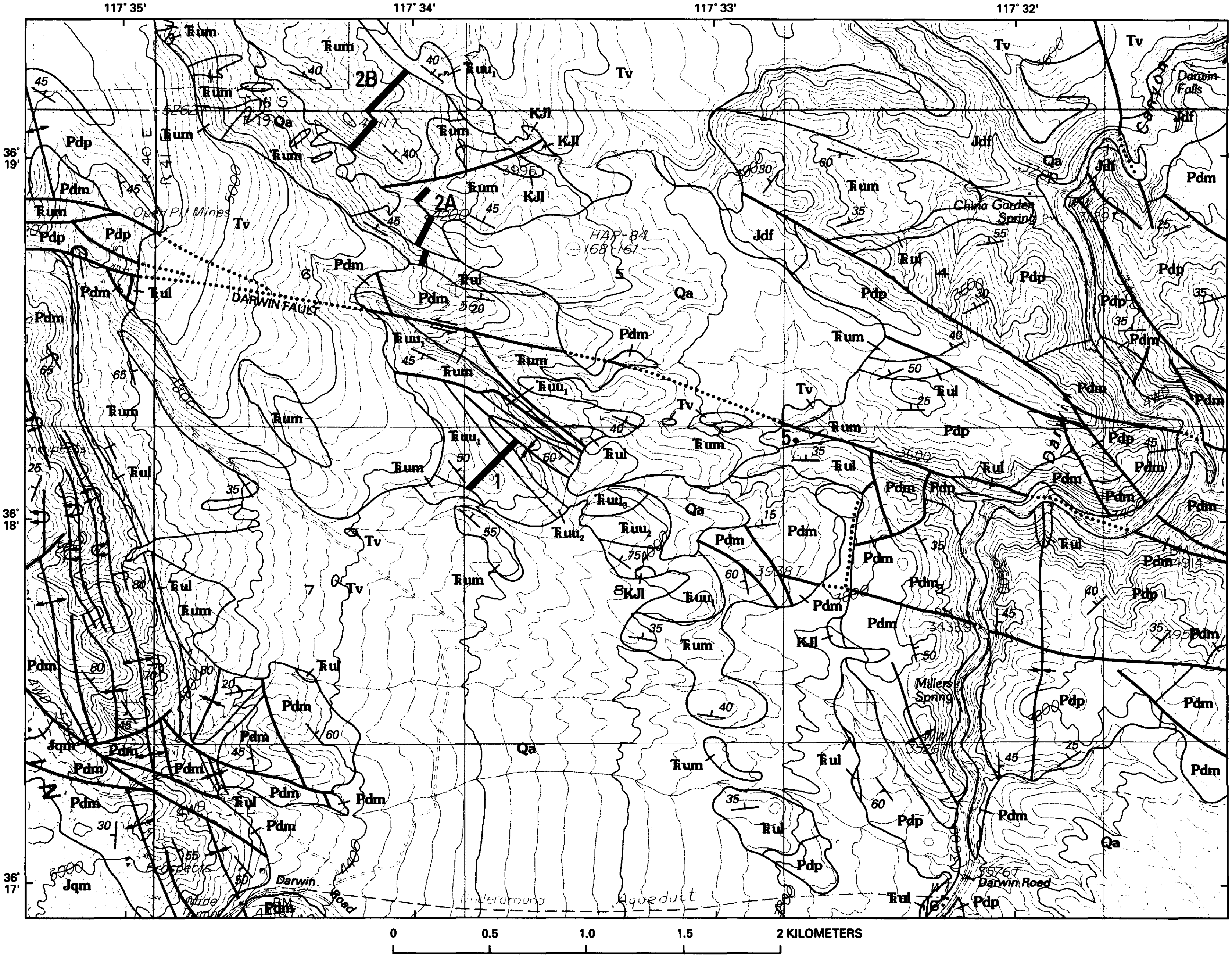


Figure 7. Geologic map of Darwin area, California, showing location of reference section of the Union Wash Formation. Reference section consists of three separate subsections (1, 2A, 2B). See figure 1 for location of map. Base from U.S. Geological Survey, 1:24,000 scale, Darwin quadrangle, provisional edition 1987. Contour interval 40 ft. Geology mapped in 1980–81.

EXPLANATION

Qa Alluvium and talus (Quaternary)

Tv Volcanic rocks (Tertiary)

KJl Leucogranite (Cretaceous or Jurassic)

Jqm Quartz monzonite (Jurassic)

Jdf Darwin Falls pluton (Jurassic?)—Gabbro, granodiorite, and minor quartz monzonite

Union Wash Formation (Triassic)—Divided into:

Upper member—Divided into:

TRuu$_3$ Subunit 3—Light- to medium-gray micritic limestone and grayish-orange silty limestone. Measured thickness 64.5 m

TRuu$_2$ Subunit 2—Brown massive siltstone. Measured thickness 62.5 m

TRuu$_1$ Subunit 1—Medium- to dark-gray micritic limestone; upper part contains marker horizon of greenish-gray to grayish-orange shale. Measured thickness 183 m

TRum Middle member—Lower part composed of dark-gray siliceous mudstone and minor silty limestone; upper part composed of brown-weathering calcareous mudstone, light- to medium-gray, thin-bedded micritic limestone, and minor limestone-clast conglomerate. Upper part contains abundant soft-sediment deformational features. Measured thickness 520.5 m

TRul Lower member—Light- to medium-gray, silty and sandy limestone; minor conglomerate containing clasts of underlying Permian rocks. Measured thickness 22.5 m; maximum thickness approximately 50 m

Owens Valley Group—In this area, consists of:

Darwin Canyon Formation (Permian)—Divided into:

Pdp Panamint Springs Member—Brown, thin-bedded siltstone and very fine grained sandstone; medium- to dark-gray limestone in lowermost part. Maximum thickness approximately 500 m

Pdm Millers Spring Member—Brown, thick-bedded, very fine grained sandstone and medium- to dark-gray, thin- to thick-bedded bioclastic to conglomeratic limestone. Locally includes fault breccia of Mesozoic or Cenozoic age. Thickness approximately 475-650 m

Contact

Fault—Dotted where concealed. Arrows show direction of relative movement

Anticline—Dotted where concealed

Overturned anticline

Syncline

Overturned syncline

Strike and dip of beds

50 Inclined

Vertical

70 Overturned

2A Reference section of Union Wash Formation—Numbers refer to segments of measured section

5 Location and number of conodont collection of Lewis and others (1983)

Figure 7. Continued.

Although most rocks in the middle member are evenly and continuously bedded, some rocks, particularly in the calcareous upper part, show evidence of soft-sediment deformation and resedimentation. Soft-sediment folds, sedimentary boudinage, zones of broken and disrupted beds, and matrix-supported limestone conglomerate beds (debris-flow deposits) are common, especially in the intervals dominated by limestone. Most clasts in the conglomerate beds are lithologically similar to the associated thin-bedded micritic limestone and probably were formed by disruption and breakage of contemporaneous limestone beds on the margins and slopes of the depositional basin. Some clasts are irregular in shape and apparently were transported and deformed while soft. On the east flank of the Darwin Hills, the siliceous lower part of the middle member contains at least one limestone slide block several meters thick and several tens of meters long.

The upper member of the Union Wash Formation, which sharply overlies the middle member, is divided into three subunits (figs. 7, 8). In ascending order, these are called subunits 1, 2, and 3, which are equivalent to units 3, 4, and 5, respectively, of the unnamed Triassic sedimentary rocks unit of Stone and others (1989). The measured thicknesses of subunits 1, 2, and 3 are, respectively, 183, 62.5, and 64.5 m. Subunit 1 is composed primarily of medium- to dark-gray micritic limestone that forms rugged cliffs and ledges. An interval of fissile greenish-gray to grayish-orange shale, approximately 20 m thick, is present in the upper part of the subunit. The limestone below the shale interval ranges from thin bedded (2 to 5 cm) in the lower part to medium and thick bedded (20 to 50 cm) in the upper part; beds commonly are separated by thin partings of grayish-orange to maroon shale. Soft-sediment folds are common. Bedding in the limestone above the shale interval is generally indistinct and disrupted; limestone conglomerate is present locally. Subunit 2 is composed almost entirely of massive brown quartzose siltstone. Subunit 3 is composed of medium- to thick-bedded, light- to medium-gray micritic limestone and grayish-orange silty limestone in which thin partings of brown siltstone are common. Subunit 3 is exposed only in the core of the large syncline south of the Darwin fault and is the highest part of the Union Wash Formation present in the area.

None of the subunits of the upper member of the Union Wash Formation in the Darwin area can be correlated with certainty with any of the subunits distinguished in the Union Wash and Cerro Gordo areas. Similar rock types are present in all three areas, however, and some of the subunits in the Darwin area resemble some of those in the other study areas. A particularly close lithologic similarity exists between subunit 1 in the Darwin area and subunit 3 in the Cerro Gordo area, both of which are composed of dark-gray micritic limestone containing irregular shaley or silty partings.

FOSSILS AND AGE

Rocks of the Union Wash Formation have yielded fossils useful for the determination of age in all three of the areas studied. The most significant fossils are ammonoids from the Union Wash area (Smith, 1904, 1914, 1932; Silberling and Tozer, 1968) and conodonts that have been identified from all three areas by Orchard during the present study. The conodonts include some specimens originally identified by Lewis and others (1983) and reexamined during the present study in addition to those collected from our measured sections. The reexamined conodonts are from localities 1, 2, 5, and 9 of Lewis and others (1983, fig. 12, table 1). Most of these conodonts are here identified as different taxa than those listed by Lewis and others (1983, table 1), and some of the age determinations are different than theirs as well. The stratigraphic positions of the conodont collections are shown in figures 3, 5, and 8; the approximate positions of the collections of Lewis and others (1983) were inferred from map localities provided by Michael Lewis (written commun, 1988). The conodonts are stored at the Geological Survey of Canada, Vancouver, B.C., and the collections have been assigned Geological Survey of Canada (GSC) locality numbers.

The age range of the Union Wash Formation, as interpreted herein, is shown in figure 9. The Triassic stage terminology followed herein is that defined by Silberling and Tozer (1968). The known stratigraphic ranges of the conodonts identified during this study are shown by Collinson and Hasenmueller (1978), Carr and Paull (1983), and Dagis (1984).

Union Wash Area

The Triassic rocks herein assigned to the Union Wash Formation were first dated by Smith (1904, 1914, 1932) on the basis of ammonoids from two limestone beds on the south side of Union Wash—the *Meekoceras* bed, at the base of the middle member of the Union Wash Formation; and the *Parapopanoceras* bed, 665 m higher, 1–2 m above the base of subunit 1 of the upper member of the Union Wash Formation (fig. 3). Smith (1904, 1914, 1932) considered the *Meekoceras* bed to be Lower Triassic and the *Parapopanoceras* bed to be lowermost Middle Triassic. In the biostratigraphic classification of Silberling and Tozer (1968), Smith's *Meekoceras* bed is considered to represent the lower Smithian *Meekoceras gracilitatis* zone and Smith's *Parapopanoceras* bed is considered to represent the uppermost Spathian *Neopopanoceras haugi* zone.

Ammonoids have been found at two other localities within the Union Wash Formation in this area. One locality, discovered during the present study, is in a limestone bed 3 m thick and a few meters above the base of the middle member on the ridge north of Union

Wash. According to N.J. Silberling and E.T. Tozer (oral commun., 1988), this bed contains many of the same ammonoid species as Smith's *Meekoceras* bed and also represents the *Meekoceras gracilitatis* zone. The other

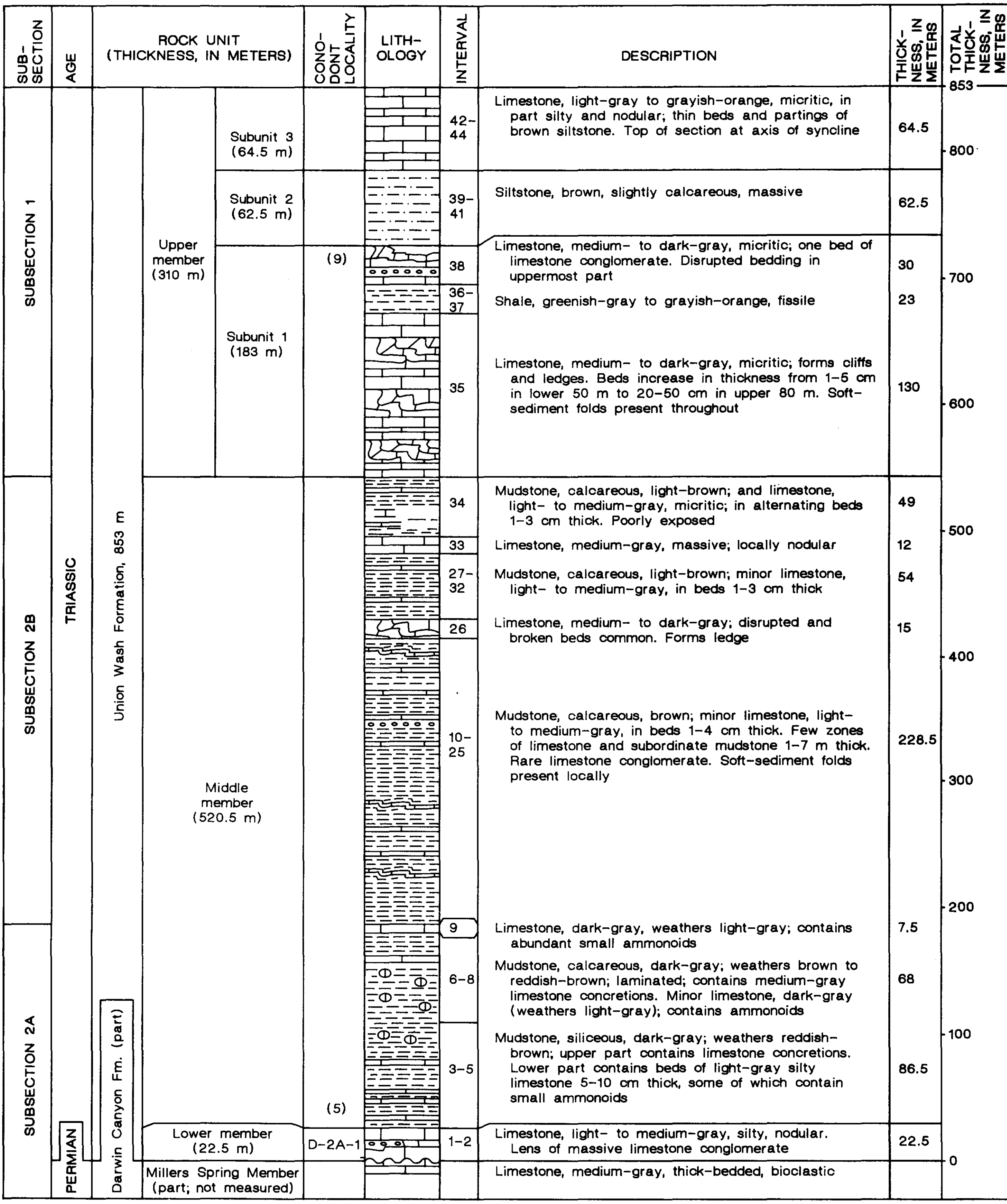


Figure 8. Reference section of the Union Wash Formation in Darwin area. Section consists of three separate subsections (1, 2A, 2B), locations of which are shown on figure 7.

locality, originally described by Silberling and Tozer (1968, p. 39) as "several tens of feet" above Smith's *Parapopanoceras* bed, is probably equivalent to a thin ammonoid-bearing layer we observed about 20 m above the base of subunit 2 of the upper member a few hundred meters northwest of our measured section. Silberling and Tozer (1968) considered the ammonoids from this locality to be similar to *Keyserlingites*, an identification compatible with a latest Spathian age.

During this study, the following conodonts were identified from the Union Wash Formation on the south side of Union Wash:

GSC Loc. Nos. C–176541 and C–176542 (Field Nos. 81–ML–5 and 81–ML–6). Equivalent to Loc. 1 of Lewis and others (1983). Union Wash Formation, middle member, *Meekoceras* ammonoid bed; corresponds to 0–14.5 m above base of member and formation in the type section (figs. 2, 3).

Neospathodus n. sp. A
Ellisonia? sp.

Age: Early Triassic (Smithian)

Remarks: *Neospathodus* n. sp. A is identical to conodonts associated with Smithian ammonoids in Oman.

GSC Loc. No. C–158468 (Field No. UW–4). Type section of Union Wash Formation, middle member, 332 m above base of member and formation (fig. 3).

Neospathodus homeri (Bender)

Age: Early Triassic (Spathian)

GSC Loc. No. C–176543 (Field No. 81–ML–9). Equivalent to Loc. 2 of Lewis and others (1983). Union Wash Formation, middle member, approximately 400 m above base of member and formation (figs. 2, 3).

Neospathodus homeri (Bender)

Age: Early Triassic (Spathian)

GSC Loc. No. C–158469 (Field No. UW–5). Type section of Union Wash Formation, middle member, 512 m above base of member and formation (fig. 3).

Neospathodus homeri (Bender)

Age: Early Triassic (Spathian)

The middle member in the Union Wash area thus ranges in age from Smithian to Spathian, and the upper member is considered to be latest Spathian in age. The lenticular lower member, from which no fossils have been recovered, is undated.

Cerro Gordo Area

In a study of the Cerro Gordo mining district, Merriam (1963) reported ammonoids from beds that we include in the lower member of the Union Wash Formation and that are located about 7 km northwest of the area shown in figure 4. Merriam identified these ammonoids as *Ussuria* and interpreted their stratigraphic position to be lower than that of the *Meekoceras* bed at Union Wash. According to N.J. Silberling (oral commun., 1976), Merriam's ammonoids probably represent either *Metussuria* or *Parussuria* and are indicative of a Smithian age.

During this study, the following conodonts were identified from the Union Wash Formation in the reference section northwest of Cerro Gordo Road (fig. 5):

GSC Loc. No. C–158459 (Field No. CG–1). Union Wash Formation, middle member, 13.5 m above base of member, 45.0 m above base of formation.

Neospathodus ex gr. *waageni* Sweet

Age: Early Triassic (Smithian)

Remarks: Basal cavity is strongly expanded in these neospathodids, which are relatively short.

GSC Loc. No. C–158460 (Field No. CG–2). Union Wash Formation, middle member, 69.0 m above base of member, 100.5 m above base of formation.

Neospathodus ex gr. *waageni* Sweet

Age: Early Triassic (Smithian)

Remarks: Basal cavity is narrow in these neospathodids, which are relatively long.

GSC Loc. No. C–158461 (Field No. CG–3). Union Wash Formation, middle member, 180.0 m above base of member, 211.5 m above base of formation.

Neospathodus ex gr. *homeri* (Bender)

Age: Early Triassic (Spathian?)

Remarks: Basal cavity is narrow in this neospathodid, which has a downturned posterior.

GSC Loc. No. C–158462 (Field No. CG–13). Union Wash Formation, upper member, subunit 4, 127 m above base of subunit, 314.5 m above base of member, 582.5 m above base of formation.

Neogondolella? sp. indet.

Age: Triassic

Remarks: Fragments only.

We thus consider the lower member of the Union Wash Formation in the Cerro Gordo area to be Smithian and the middle member to be Smithian and Spathian(?). The age of the upper member cannot be closely determined.

Darwin Area

During this study, the following conodonts were identified from the Union Wash Formation in the Darwin area:

GSC Loc. No. C–158465 (Field No. D–2A–1). Union Wash Formation, lower member, 1 m above base of member and formation in reference section (fig. 8).

Parachirognathus ethingtoni Clark
Ellisonia sp.

Age: Early Triassic (Smithian)

GSC Loc. Nos. C–176539 and C–176540 (Field Nos. 80–CB–2 and 80–CB–3A). Equivalent to Loc. 5 of Lewis and others (1983). Union Wash Formation, middle member, near base of member (figs. 7, 8).

Neospathodus ex gr. *waageni* Sweet
Neogondolella buurensis Dagis
Neogondolella sp. indet.
Ellisonia? sp.

Age: Early Triassic (Smithian)

Remarks: The neogondolellids most closely resemble species described by Dagis (1984) from the Olenekian Stage of northern Siberia, where they also occur with *Neospathodus waageni.*

GSC Loc. No. C–176544 (Field No. D–1575). Equivalent to Loc. 9 of Lewis and others (1983). Union Wash Formation, upper member, subunit 1, above shale horizon in upper part of subunit (fig. 8). Located 0.93 km beyond the northern boundary of figure 7 at lat. 36°19′53″, long. 117°34′51″.

Neogondolella cf. *N. timorensis* (Nogami)

Age: Early or Middle Triassic (Spathian-Anisian boundary?)

Remarks: The specimens at hand are mostly fragments not adequately preserved for confident assignment.

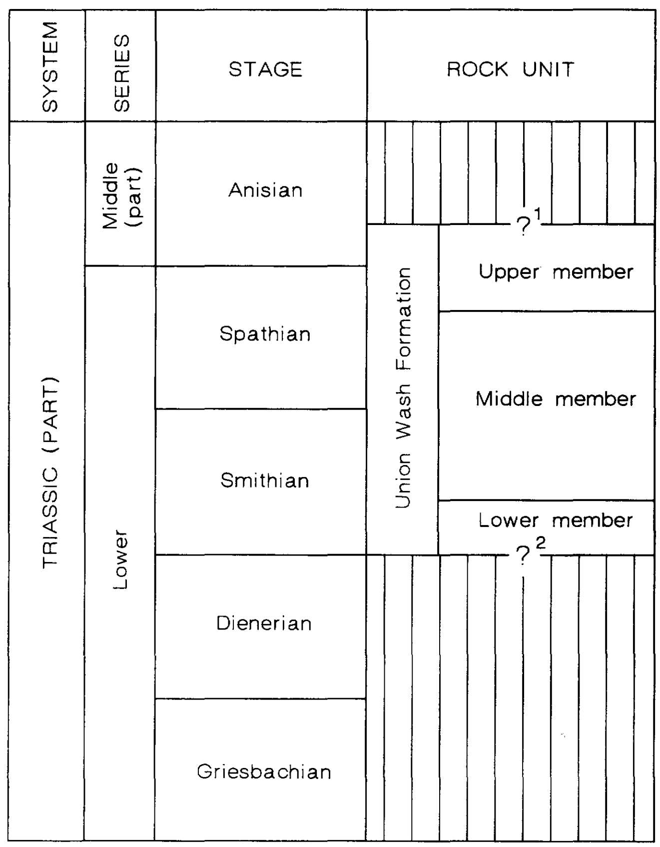
Conodonts from the lowest of the three collections indicate that the base of the Union Wash Formation in the Darwin area is no older than Smithian. Lewis and others (1983) assigned a Griesbachian age to rocks in the lowermost part of the formation on the basis of bivalves that they identified as *Claraia stachei*, a common species in Griesbachian rocks. According to recent work by Yin (1985), however, the stratigraphic range of *Claraia stachei* extends from the Griesbachian into the Smithian, so its occurrence is compatible with that of the Smithian conodonts reported herein. Reidentification of the conodonts from locality 5 of Lewis and others (1983) indicates a Smithian age for the lowermost part of the middle member of the Union Wash Formation, rather than a Dienerian age as previously reported. The age of the uppermost collection is questionable, both because the conodonts are not adequately preserved for confident identification and because the boundary between the Spathian and Anisian Stages is not clearly defined on the basis of conodont biostratigraphy. The stratigraphic range of *Neogondolella timorensis* is thought to be upper Spathian to lower Anisian (Collinson and Hasenmueller, 1978; Carr and Paull, 1983); the form in this collection may belong to this species and, if so, may indicate an age close to the Early–Middle Triassic boundary.

Summary

Based on the evidence available, we assign an age of Early and Middle(?) Triassic to the Union Wash Formation. The lower member is of Smithian age (Early Triassic), the middle member is of Smithian and Spathian age (Early Triassic), and the upper member is of latest Spathian and possibly Anisian age (Early and Middle(?) Triassic) (fig. 9). Additional study is needed to resolve the upper age limit of the upper member, from which few fossils are presently known.

DEPOSITIONAL ENVIRONMENTS

The Union Wash Formation is of marine origin. The formation appears to represent a variety of water depths and sedimentary environments, but the observations that



[1] Top of Union Wash Formation could be Spathian instead of Anisian as shown.

[2] Base of Union Wash Formation could be within the Smithian Stage instead of at the Smithian-Dienerian boundary as shown.

Figure 9. Chart showing age of the Union Wash Formation. Stages after Silberling and Tozer (1968).

have been made to date allow only general interpretations of the depositional setting.

The silty and sandy limestone that makes up the lower member of the Union Wash Formation is characterized by wavy, irregular bedding and mottled texture that may have resulted from bioturbation. We interpret the sediment that forms these rocks to have been deposited at shallow subtidal depths in a nearshore environment where currents were strong enough to winnow out most sediment finer than coarse silt.

By contrast, we interpret the middle member of the Union Wash Formation to have been deposited in quiet, moderately deep water. This interpretation is based on the dominance of mudstone and micritic limestone; the paucity of silt and sand (except in the lowermost part of the member); the thin-bedded, laminated nature of the rocks; the presence of radiolarians in the Cerro Gordo and Darwin areas; the absence of megafossils other than ammonoids; and the general lack of sedimentary features indicative of shallow-water, nearshore deposition. Features reflecting soft-sediment deformation and resedimentation in the Darwin area are suggestive of a slope or base-of-slope environment; such features are absent in the Cerro Gordo and Union Wash areas, where the middle member may have accumulated in basinal or outer-shelf environments.

The upper member of the Union Wash Formation differs from the middle member in containing a much smaller proportion of mudstone or shale and greater proportions of limestone, siltstone, and very fine grained sandstone. This general contrast in lithology suggests that the upper member accumulated in somewhat shallower water and somewhat closer to shore than the middle member. Limestone and clastic rocks in the upper member are largely segregated from one another in mappable subunits, a pattern that apparently reflects sharp fluctuations in the supply of clastic sediment. The limestones hold the best clues to the depositional environments represented by the upper member. The lower part of the upper member is dominated by dark-gray, thin-bedded micritic limestone that is lithologically similar to much of the limestone of the middle member. Such limestone forms subunit 1 in the Union Wash area, subunits 1 and 3 in the Cerro Gordo area, and most of subunit 1 in the Darwin area. This limestone, which contains no megafossils other than ammonoids, probably accumulated in moderately deep water. Soft-sediment folds and slump features in subunit 1 in the Darwin area suggest a slope or base-of-slope environment for at least some of this limestone; elsewhere, outer-shelf environments may be represented. By contrast, limestone (and dolomite) in the upper part of the upper member probably accumulated in relatively shallow water. In the Cerro Gordo area, carbonate rocks high in subunit 4 contain abundant evidence of shallow-water deposition, including ooliths, coated grains, and probable stromatolites; in the Darwin area, the light-gray, thick-bedded, mottled (bioturbated?) limestone of subunit 3 seems to reflect shallower water depths than the dark-gray, thin-bedded limestone of subunit 1. The carbonate rocks of the upper member thus appear to record shallowing of water depths through time.

In summary, we interpret deposition of the Union Wash Formation to have begun in shallow water (lower member), and then to have moved rapidly into moderately deep water (middle member and lower part of upper member) before returning into shallow water (upper part of upper member).

DEPOSITIONAL HISTORY

Deposition of the Union Wash Formation followed a period of active tectonism in the Inyo Mountains, Darwin area, and Argus Range that spanned most of Pennsylvanian and Permian time. During the Pennsylvanian and Early Permian, these areas were sites of deep-water marine sedimentation in basins interpreted by Stone and Stevens (1988b) to have formed by transtensional deformation on a segment of the continental margin that was undergoing active transform faulting. This sedimentation produced the Tihvipah Limestone (Stone and others, 1987, 1989), the Keeler Canyon Formation, and the Lower Permian formations of the Owens Valley Group. Deep-water sedimentation ended in late Early Permian time when the area was rapidly elevated to sea level and above, possibly in response to a change from a transtensional to a transpressional tectonic regime. During this event, Pennsylvanian and Lower Permian rocks were broadly folded, tilted to dips as steep as 30°, and erosionally truncated on the crests and flanks of large anticlines (Stone and Stevens, 1988a). The resulting landscape had a surface relief of at least 250 m. Deposition of the shallow-water marine to nonmarine Conglomerate Mesa Formation during the Late Permian, after tectonic activity had ceased, filled the major topographic depressions and left the surface nearly featureless. This was the surface upon which the Union Wash Formation was later deposited.

Marine transgression in late Early Triassic time resulted in deposition of the Union Wash Formation, which onlapped remaining topographic highs that had not been covered by the Conglomerate Mesa Formation. The nearshore strata of the thin lower member of the Union Wash Formation may have been deposited primarily in response to a moderate rise in eustatic sea level (Haq and others, 1987), but the ensuing increase in water depth and the accumulation of the thick middle member clearly reflect renewed subsidence of the continental margin. The tectonic significance of this late Early Triassic subsidence is not known, but it could represent the continued effects of transform faulting or the initial stages of subduction along the continental margin. An increased rate of sedimentation, a decreased rate of subsidence, or a combination of both in latest Early Triassic time led to shoaling, as represented by the lithologically heterogeneous upper member of the Union

Wash Formation. Deposition of the upper member was followed by emergence (possibly accompanied by slight tectonic deformation), erosion, and deposition of the overlying Triassic and (or) Jurassic volcanic and sedimentary rocks in nonmarine environments.

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MEASURED SECTIONS

Union Wash section (figs. 2, 3). Type section at the type locality of the Union Wash Formation. Measured on south side of Union Wash, Inyo Mountains, in September 1985. Section consists of middle and upper members of the Union Wash Formation; lower member is not present.

	Thickness in meters
Unnamed volcanic and sedimentary rocks (Triassic and (or) Jurassic) (incomplete):	
2. Sandstone, volcaniclastic, brown; overlain by a thick sequence of volcanic rocks	10.0
1. Conglomerate, composed mainly of small pebbles of limestone and volcanic rock. Scattered limestone blocks more than 1 m in diameter appear to be enclosed by the conglomerate	7.5
Incomplete thickness of unnamed volcanic and sedimentary rocks	17.5
Unconformable contact	
Union Wash Formation (Triassic):	
Upper member:	
Subunit 2:	
54. Siltstone, dark-gray, weathers brown; calcareous, plane laminated	15.5
53. Shale, pink, silty	4.0

Union Wash Formation (Triassic)—Continued	*Thickness in meters*
Upper member—Continued	
Subunit 2—Continued	
52. Siltstone, as in 54	3.0
51. Shale, fissile, pink, soft	7.5
50. Interval occupied by crosscutting dike	4.5
49. Shale, fissile, light-brown to pink	6.0
Total thickness of subunit 2	40.5
Subunit 1:	
48. Limestone, as in 42	1.0
47. Shale, light-brown	4.0
46. Limestone, as in 42	2.5
45. Shale, pink	3.0
44. Limestone, as in 42, interbedded with equal amount of light-brown to pink shale	9.0
43. Siltstone, calcareous, orange	4.5
42. Limestone, micritic, dark-gray, in platy beds typically less than 25 cm thick; interbedded with less abundant light-brown shale and siltstone. Fossiliferous, ammonoid-bearing zone 1–2 m above base is equivalent to *Parapopanoceras* bed of Smith (1904, 1914)	30.0
Total thickness of subunit 1	54.0
Total thickness of upper member	94.5
Middle member:	
41. Siltstone, shale, and limestone. Siltstone and shale calcareous, mostly gray to light brown but some pink. Limestone, micritic, dark-gray, in beds less than 20 cm thick. Forms recessive slope	48.0
40. Dolomite, light-gray to light-brown, faintly laminated	1.0
39. Limestone, dark-gray, massive; contains recrystallized shell fragments	1.0
38. Siltstone and shale, calcareous, light-brown; some pink shale	15.0
37. Limestone, dark-gray, micritic, flaggy	1.0
36. Siltstone and shale, calcareous, light-brown	11.0
35. Interval occupied by crosscutting dike	6.0
34. Limestone, as in 22	9.0
33. Siltstone and shale, as in 27	28.5
32. Limestone, as in 22	31.5
31. Siltstone and shale, as in 27	12.0
30. Limestone, as in 22; some ledges as much as 1 m thick. Conodont sample UW–5, 12 m above base	15.0
29. Siltstone and shale, as in 27	14.5
28. Limestone, as in 22, in beds to 25 cm thick	21.0
27. Siltstone and shale, calcareous, brownish-gray; weathers yellowish brown; plane laminated	13.5
26. Limestone, as in 22	37.5
25. Interval occupied by crosscutting dike	13.5

Union Wash Formation (Triassic)—Continued Middle member—Continued	*Thickness in meters*
24. Limestone, as in 22	14.5
23. Interval largely covered; rare outcrops of dark-gray mudstone as in 21 and light- to medium-gray micritic limestone in beds less than 10 cm thick	46.5
22. Limestone, micritic, dark-gray; weathers medium gray; forms even to irregular beds 5 to 15 cm thick separated by grayish-orange silty partings less than 3 cm thick. Conodont sample UW–4, 25 m above base	31.5
21. Mudstone, calcareous, dark-gray; weathers reddish brown; forms planar beds 2 to 4 cm thick	15.0
Section offset 200 m to northwest along top of 20 (in gully)	
20. Limestone, medium-gray, thin-bedded, and tan-weathering mudstone	15.0
19. Covered interval	7.5
18. Mudstone, weathers dark gray	19.5
17. Limestone, medium-gray, and brown-weathering siltstone	13.5
16. Mudstone and siltstone, dark-gray	9.0
15. Limestone, dark-bluish-gray,and tan-weathering siltstone	7.5
14. Mudstone, weathers medium brown	9.0
Minor fold in section; top of 13 traced around fold hinge	
13. Limestone, dark-bluish-gray, in beds 30 to 50 cm thick; and tan-weathering silt stone	7.5
12. Mudstone, black, poorly exposed	16.5
11. Covered interval; black mudstone in float.	41.5
10. Limestone, weathers light gray	3.0
9. Mudstone, weathers medium gray	3.0
8. Covered interval; light- to medium-gray limestone in float	10.5
7. Limestone, medium-gray, fine-grained	1.5
6. Covered interval; medium-gray, fine-grained limestone and tan-weathering siltstone in float	35.5
5. Covered interval; dark mudstone in float	27.0
4. Mudstone, very dark, massive	15.0
3. Limestone, medium-gray, and tan-weathering siltstone; interbedded in beds as thick as 15 cm	18.0
2. Interval mostly covered; medium-gray silty limestone in float	18.0
1. *Meekoceras* bed. Limestone, calcarenitic, light-gray, massive; contains abundant ammonoids except in upper 2 m; ammonoids highly concentrated. Measured 350 m southeast of 2	14.5
Total thickness of middle member	679.0
Total thickness of Union Wash Formation	773.5

Unconformable contact

Lone Pine Formation (Permian) (not measured):

Largely covered. Float and rare outcrops consist of thin-bedded silty limestone, calcareous siltstone, very fine grained calcareous sandstone, and siliceous mudstone.

Cerro Gordo section (figs. 4, 5). Reference section of Union Wash Formation measured on west slope of Inyo Mountains about 2 km north of Cerro Gordo Road in September 1985. Section consists of lower, middle, and upper members of Union Wash Formation.

Unnamed volcanic and sedimentary rocks (Triassic and (or) Jurassic) (not measured):

Conglomerate composed of volcanic rock clasts at base; overlain by a thick sequence of predominantly volcanic rocks.

Faulted contact

Union Wash Formation (Triassic): Upper member: Subunit 4:	*Thickness in meters*
48. Shale, fissile, maroon	2.0
47. Shale, fissile, yellow	25.0
46. Conglomerate composed of limestone and volcanic rock clasts; may be in fault contact with underlying shale	2.0
45. Shale, calcareous, fissile, yellowish-brown	33.0
44. Siltstone and shale, as in 36	4.5
43. Limestone, massive, dark-gray	1.5
42. Interval mostly covered; some outcrops of light-gray dolomite as in 40	3.0
41. Limestone, massive, dark-gray	3.0
40. Dolomite, massive, medium-gray; weathers very light gray	3.0
39. Limestone, massive, dark-gray	1.5
38. Siltstone and shale, as in 36	28.5
37. Limestone (calcarenite), medium-gray, fine-grained, partly bioclastic, in planar beds 30 cm to 1 m thick separated by thin partings of yellowish-brown siltstone or mudstone. Upper 1 m of unit is dark gray and mottled and contains local concentrations of pelecypod shells. Conodont sample CG–13, 4 m above base	4.5
36. Siltstone and shale, calcareous, intensely cleaved, yellowish-brown. Minor sandstone, brown, fine-grained to very fine grained, slightly calcareous, in beds 5 to 10 cm thick	105.0
35. Interval occupied by a white siliceous dike	3.0
34. Shale, purplish-gray, calcareous, silty, recessive	15.0
Total thickness of subunit 4	234.5

Union Wash Formation (Triassic)—Continued	*Thickness in meters*
Upper member—Continued	
Section offset 1 km to northwest along top of 33, which was followed around two large fold hinges	
Subunit 3:	
33. Limestone, dark-gray, micritic, ledge-forming, generally in planar beds 1 to 5 cm thick separated by thin partings of light-brown siltstone or mudstone. Locally, siltstone or mudstone forms irregular, anastomosing patterns giving limestone nodular appearance	72.0
32. Sandstone, calcareous, fine-grained, grayish-brown; weathers light brown; platy	4.5
31. Limestone, dark-gray, micritic, generally in planar beds 3 to 6 cm thick separated by thin partings of pinkish-gray mudstone	16.0
Total thickness of subunit 3	92.5
Subunit 2:	
30. Sandstone, calcareous, gray; weathers light brown; some beds of fine-grained, dark-gray limestone 1 to 5 cm thick	10.5
29. Limestone, (calcisiltite), medium-gray, massive	1.5
28. Siltstone, purplish-gray, laminated, recessive	4.5
27. Limestone (calcisiltite), medium-gray; lower part is well bedded and contains thin interbeds of siltstone; upper part is massive	8.5
26. Sandstone, light-brown, fine-grained, laminated	5.0
25. Limestone (calcarenite), light- to medium-gray, fine-grained, silty; dark-brown siltstone interbeds 1 to 3 cm thick	2.5
24. Sandstone, gray, fine-grained, plane-laminated; weathers brownish gray; contains ovate calcareous nodules 1 to 2 cm thick. Minor maroon siltstone or very fine grained sandstone near top	18.0
23. Covered interval; sandstone scree	15.0
22. Limestone, dark-gray, in beds 1 to 5 cm thick	1.5
21. Covered interval; sandstone scree	4.0
20. Limestone, as in 22	2.5
19. Shale, calcareous, fissile, bright yellowish-brown	10.5
Total thickness of subunit 2	84.0
Subunit 1:	
18. Limestone, dark-gray, micritic, massive except for irregular partings of grayish-pink mudstone; forms ledges	11.0
Total thickness of subunit 1	11.0
Total thickness of upper member	422.0

Union Wash Formation (Triassic)—Continued	*Thickness in meters*
Middle member:	
17. Limestone, medium-gray, in beds 1 to 4 cm thick	4.0
16. Shale, calcareous, fissile, bright yellowish-brown	44.0
Section offset 350 m to northwest along top of 15	
15. Limestone, medium-gray, micritic, in beds 1 to 3 cm thick; minor yellow fissile shale. Conodont sample CG–3, 17 m above base	25.5
14. Shale, fissile, yellow	6.0
13. Limestone and minor shale, as in 15; beds 1 to 4 cm thick	5.0
12. Shale, fissile, yellow; minor medium-gray, thin-bedded micritic limestone	40.5
11. Limestone and minor shale, as in 15; limestone beds 2 to 10 cm thick	4.5
10. Shale, fissile, yellow; minor medium-gray micritic limestone in beds 1 to 3 cm thick	10.5
9. Limestone and minor shale, as in 15; limestone beds 2 to 10 cm thick, some containing bioclastic debris	4.0
8. Shale, fissile, yellow; minor thin-bedded limestone	20.5
7. Limestone and minor shale, as in 15; limestone beds 2 to 8 cm thick. Conodont sample CG–2	3.0
6. Shale, fissile, yellow	3.5
5. Limestone and minor shale, as in 15; limestone beds 2 to 8 cm thick	1.0
4. Shale, fissile, yellow, and less abundant limestone, medium-gray, micritic, in beds 1 to 5 cm thick. Conodont sample CG–1, 13.5 m above base	64.5
Total thickness of middle member	236.5
Lower member:	
3. Limestone, silty, and siltstone, calcareous, light-gray to yellowish-brown; similar to rocks of unit 2 but somewhat finer grained and thinner bedded. Rare beds of gray micritic limestone 2 to 5 cm thick	10.5
2. Limestone, silty, and siltstone, calcareous. Limestone, calcarenitic, light-gray, grayish-orange, and light-brown, in planar to gently undulating beds 1 to 2 cm thick; some beds contain gray limestone nodules about 1 cm in diameter; tiny black gastropod shells locally abundant. Siltstone, gray to grayish-orange, platy, in beds less than 1 cm thick	18.0
1. Covered interval; partly occupied by dike rock	3.0
Total thickness of lower member	31.5

Union Wash Formation (Triassic)—Continued — *Thickness in meters*

Lower member—Continued

Total thickness of Union Wash Formation 690.0

Unconformable contact

Keeler Canyon Formation (Pennsylvanian and Permian) (not measured):

Limestone, calcarenitic and bioclastic, medium-gray, thick-bedded; minor pinkish-gray to purplish-gray shale.

Darwin section (figs. 7, 8). Reference section of Union Wash Formation measured between Darwin Canyon and the Darwin Hills in September 1985. Consists of three subsections. Subsection 1, south of the Darwin fault, traverses the upper member of the Union Wash Formation; subsections 2A and 2B, north of the Darwin fault, traverse the lower and middle members of the Union Wash Formation. Subsections 2A and 2B are correlated across a minor fault by means of marker beds.

Subsection 1.

Top of section at axis of syncline

Union Wash Formation (Triassic):

Upper member: — *Thickness in meters*

Subunit 3:

44. Limestone, light-gray, micritic, massive except for some closely spaced partings of brown siltstone 22.5
43. Limestone, light-gray, micritic, in beds 20 cm to 1 m thick, separated by beds 20 to 50 cm thick of grayish-orange silty limestone containing light-gray lime stone nodules 1 to 2 cm across 37.5
42. Limestone, light- to medium-gray; forms ledges 1 to 2 m thick separated by thinner zones of thin-bedded brown siltstone 4.5

Total thickness of subunit 3 .... 64.5

Subunit 2:

41. Siltstone, brown, slightly calcareous, massive; upper 3 m more calcareous 54.5
40. Limestone, micritic, light- to medium-gray, laminated 0.5
39. Siltstone, brown, slightly calcareous, massive 7.5

Total thickness of subunit 2 .... 62.5

Subunit 1:

38. Limestone, medium- to dark-gray, micritic, well bedded in lower 5 m but indistinctly bedded higher. Upper 5 m has disrupted bedding and irregular partings of pink shale. A bed of limestone conglomerate is present about 10 m above base 30.0
37. Shale, fissile, greenish-gray to grayish-orange, poorly exposed 18.0
36. Covered interval (wash bottom) 5.0

Union Wash Formation (Triassic)—Continued — *Thickness in meters*

Upper member—Continued

Subunit 1—Continued

35. Limestone, medium- to dark-gray, micritic; forms cliffs and ledges. In lower 50 m, unlaminated beds 2 to 5 cm thick alternate with laminated beds less than 1 cm to 3 cm thick and with thin partings of grayish-orange-weathering calcareous shale; in upper 80 m, limestone forms irregular, unlaminated beds 20 to 50 cm thick separated by lenticular partings of maroon-weathering shale. Soft-sediment folds are present throughout. Underlain by calcareous mudstone and minor limestone conglomerate assigned to the middle member 130.0

Total thickness of subunit 1 .... 183.0

Total thickness of upper member 310.0

Subsection 2B.

Middle member:

34. Calcareous mudstone and limestone, as in 11; beds 1 to 3 cm thick; poorly exposed. Overlain by medium-gray, thin-bedded to massive limestone that forms the lowermost part of the upper member 49.0
33. Limestone, massive, medium-gray; contains thin, irregular stringers of tan-weathering calcareous mudstone; limestone locally nodular 12.0
32. Calcareous mudstone and limestone, as in 11; beds 1 to 3 cm thick 8.5
31. Calcareous mudstone, as in 8 .... 15.0
30. Limestone and less abundant calcareous mudstone, as in 20 .... 1.5
29. Calcareous mudstone, as in 8, poorly exposed 10.0
28. Limestone, medium-gray, and minor brown-weathering calcareous mudstone; evenly bedded except at top, where bedding is disrupted 4.0
27. Calcareous mudstone, as in 8, and minor thin-bedded gray limestone 15.0
26. Limestone, medium- to dark-gray, and minor brown-weathering calcareous mudstone. Disrupted and broken beds common, especially in upper 7 m. Forms a prominent marker ledge 15.0

Section offset 100 m to northwest along top of 25

25. Calcareous mudstone and limestone, as in 11; bedding mostly planar, but soft-sediment folding is present locally 20.5
24. Limestone and less abundant calcareous mudstone, as in 20 .... 7.0
23. Calcareous mudstone, as in 8, and minor thin-bedded gray limestone 12.0

Union Wash Formation (Triassic)—Continued Middle Member—Continued	*Thickness in meters*
22. Calcareous mudstone and limestone, as in 11; well-developed soft-sediment folding at base	10.0
21. Interval mostly covered; brown-weathering mudstone scree	10.5
20. Limestone, medium-gray, micritic, in beds 1 to 2 cm thick, and less abundant brown calcareous mudstone in beds less than 1 cm thick	6.0
19. Calcareous mudstone and limestone, as in 11; beds 1 to 4 cm thick. A 0.5-m-thick limestone bed is present 6 m above base; a thin, matrix-supported limestone conglomerate is present at top	27.0
18. Interval mostly covered; brown-weathering mudstone scree	9.5
17. Limestone, medium-gray, micritic, and minor calcareous mudstone; beds less than 1 cm thick	1.0
16. Calcareous mudstone and limestone, as in 11; limestone in beds 1 to 2 cm thick, mudstone laminated; bedding mostly planar, but soft-sediment folding is locally present	67.0
15. Limestone, silty or argillaceous, light-gray, laminated	2.5
14. Calcareous mudstone, as in 8, and minor thin-bedded gray micritic limestone; some disrupted bedding	15.0
13. Calcareous mudstone and limestone, as in 11; disrupted bedding common	2.0
12. Limestone, medium-gray, strongly cleaved	1.5
11. Mudstone, calcareous; weathers light brown; laminated; and limestone, micritic, light- to medium-gray, in alternating beds 1 to 3 cm thick	4.0
10. Calcareous mudstone, as in 8. Underlain by light-gray-weathering limestone correlated with 9	33.0
Subsection 2A.	
9. Limestone, dark-gray; weathers light gray; contains abundant ammonoids 1 to 2 cm in diameter	7.5
8. Mudstone, calcareous; weathers brown; laminated	18.0
7. Limestone, silty, dark-gray; weathers light gray; plane laminated to gently cross-laminated; contains abundant small ammonoids	1.0

Union Wash Formation (Triassic)—Continued Middle Member—Continued	*Thickness in meters*
6. Mudstone, mostly calcareous except in lower 5 m, dark-gray; weathers brown to reddish brown; laminated; large, spherical to subspherical, medium-gray limestone concretions common	49.0
Section offset 100 m along strike to northwest (across wash)	
5. Mudstone, siliceous, dark-gray; contains scattered limestone concretions up to 5 cm in diameter	20.5
4. Mudstone, siliceous, very dark gray; weathers reddish brown; laminated; minor light-gray silty limestone in beds 5 to 15 cm thick	45.0
3. Limestone, silty, light-gray, in beds 5 to 10 cm thick, and mudstone, siliceous, dark-gray, laminated. A few limestone beds contain small ammonoids and other bioclastic material	21.0
Total thickness of middle member	520.5
Section offset 50 m to northwest along top of 2 Lower member:	
2. Limestone, light- to medium-gray, in beds as thick as 1 m separated by thin, even laminations of brown-weathering siltstone. Tops of beds strewn with grayish-orange-weathering granules	12.0
1. Limestone, silty, light-gray; contains irregular stringers of brown-weathering siltstone, which enclose the limestone and impart a nodular appearance. Upper 3 to 4 m composed of massive limestone conglomerate containing subangular clasts as long as 1 m and coral fragments reworked from underlying Permian rocks. Conodont sample D–2A–1, 1 m above base	10.5
Total thickness of lower member	22.5
Total thickness of Union Wash Formation	853.0
Unconformable contact	
Millers Spring Member of Darwin Canyon Formation (Permian) (not measured):	
Limestone, medium-gray, thick-bedded; contains abundant corals and other bioclastic material	

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