Revista Mexicana de Ciencias Geológicas, volumen 14, número 2,
1997, p. 149–154.
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México, D.F.

PERMIAN–TRIASSIC BOUNDARY AT EL ANTIMONIO, SONORA, MEXICO

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ABSTRACT

Newly discovered fossils indicate the Permian–Triassic boundary is in the lower Antimonio Formation. A brachiopod-dominated assemblage collected 40 m above the Monos–Antimonio Formations contact indicates a middle Permian (Guadalupian) age, and ammonites and conodonts found 380 to 530 m above the base of the Antimonio Formation indicate an Early Triassic (Spathian) age. The lower Antimonio Formation contains three unconformity-bounded sequences, one of middle Permian age, a second one of Permian or Early Triassic age and the other of Spathian age. It thus resembles Lower Triassic strata in the southwestern United States (especially southern Nevada and adjoining areas), in recording only two of the three known Early Triassic eustatic cycles.

Key words: Permian-Triassic boundary, Sonora, Mexico.

RESUMEN

Fósiles recientemente descubiertos en la parte inferior de la Formación Antimonio, indican que el límite Pérmico-Triásico está presente dentro de esta unidad. De un nivel estratigráfico ubicado a 40 m encima del contacto entre las Formaciones Antimonio y Monos se colectó una asociación dominada por braquiópodos, los cuales indican que la parte inferior de esta formación es del Pérmico medio (Guadalupiano). Del nivel estratigráfico localizado entre 380 y 530 m encima de su base fueron recolectados amonites y conodontos que indican una edad del Triásico Temprano (Spathiano) para esta parte de la formación. La Formación Antimonio contiene en su parte inferior tres secuencias limitadas por discordancias: una del Pérmico medio, una segunda que puede ser del Pérmico o del Triásico Temprano y la otra del Spathiano, y de ese modo se asemeja a rocas sedimentarias del Triásico Inferior del suroeste de los Estados Unidos (especialmente a las del sur de Nevada y áreas adyacentes), ya que registra sólo dos de los tres ciclos eustáticos del Triásico Temprano.

Palabras clave: Límite Pérmico-Triásico, Sonora, México.

INTRODUCTION

It has long been known that rocks of Permian and Triassic age crop out in the northern Sierra del Álamo Muerto near the (now abandoned) mining town of El Antimonio in northwestern Sonora, Mexico (Figure 1). Keller (1928) first reported their presence, and subsequent work, especially that of Cooper and collaborators (1953), and González-León (1980), and references cited therein, concluded that: (1) the Monos Hills, northeast of El Antimonio, are formed by the Monos Formation of Guadalupian (Wordian) age; and (2) the overlying red beds of the Antimonio Formation are of Late Triassic–Early Jurassic age. Therefore, the Permian–Triassic boundary at El Antimonio has long been perceived as a Guadalupian–Carnian unconformity that corresponds to the lithostratigraphic boundary between the Monos and Antimonio Formations (Figure 2).

Recent discoveries in the field, documented here, change this longstanding conclusion. They indicate the Permian–Triassic boundary is in the lower part of the Antimonio Formation at a Guadalupian–Early Triassic unconformity. All fossils described here are in the collection of the Estación Regional del Noroeste, Instituto de Geología, Universidad Nacional Autónoma de México, Hermosillo, Mexico, and bear ERNO catalogue numbers.

STRATIGRAPHY

Cooper (1953) described the stratigraphy of the Monos Formation, and the authors of the present paper can add little to his accurate description. In the Monos Hills, about 520 m of the Monos Formation are exposed. Most of the unit is red-bed siltstone with minor interbeds of gray dolomitic limestone (Figure 2). The uppermost 70–80 m of the Monos Formation are gray dolomitic limestone.

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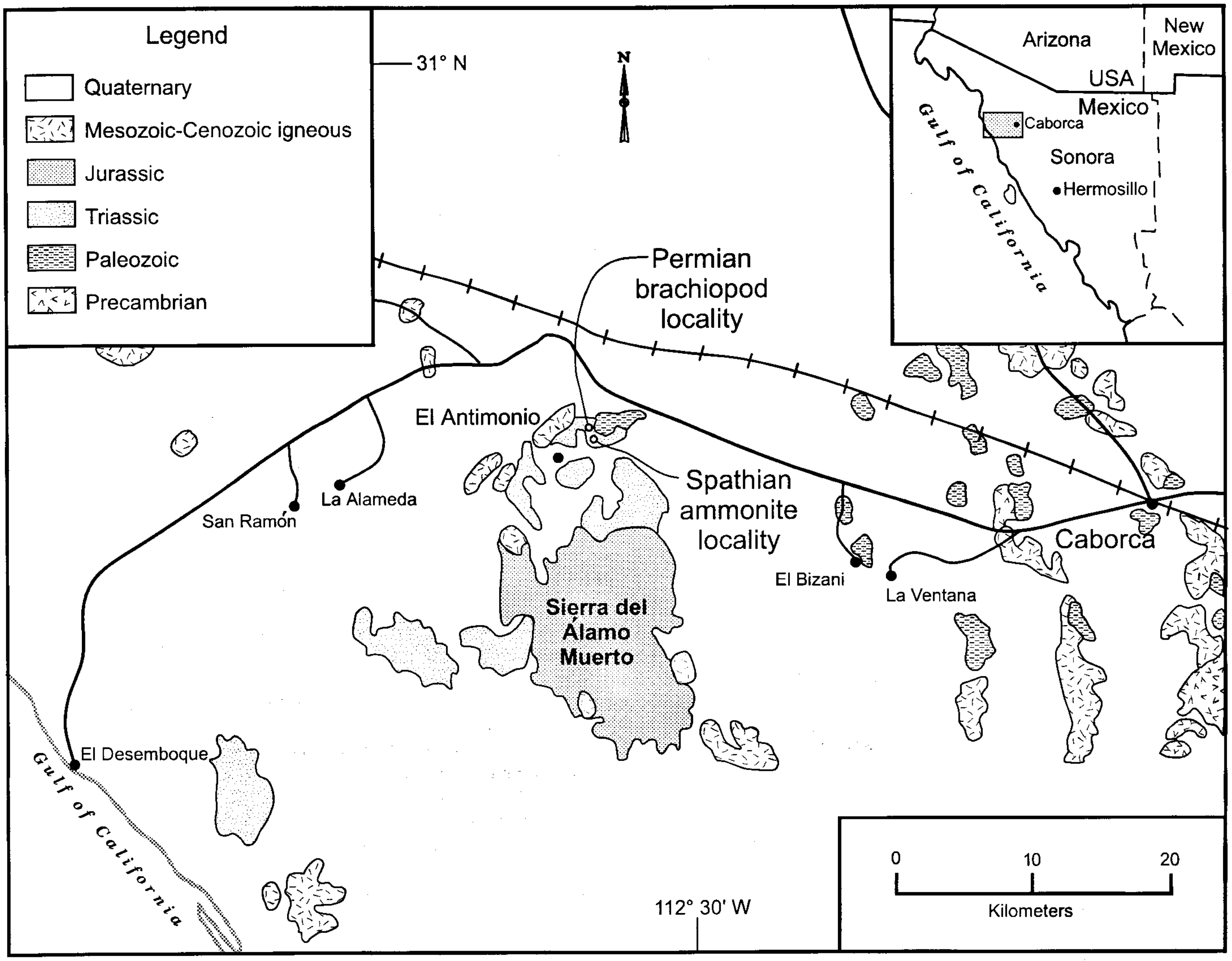

Figure 1. Generalized geologic map of the Caborca-Sierra del Álamo Muerto area, Sonora, northwestern Mexico, showing the Guadalupian and Spathian localities in the lower Antimonio Formation.

The basal strata of the Antimonio Formation rest with apparent disconformity on thick-bedded dolomitic limestone of the Monos Formation (Figure 2). The uppermost dolomitic limestone beds of the Monos Formation contain abundant chert nodules and large patches of reddish, silicified siltstone that may represent karstic structures filled by Triassic sediment. However, the contact between the Monos and the Antimonio Formations is generally poorly exposed. The lower part of the Antimonio section is widely intruded by dikes and sills that have partially recrystallized the strata (Figure 2). Thus, the exact nature of the Monos–Antimonio contact is not certain, though the Guadalupian fossils reported here from the lower Antimonio Formation indicate a very short hiatus, if any, between the Monos and Antimonio Formations.

The lowermost 90 m of the Antimonio Formation are dominated by very thin-bedded calcareous siltstone containing calcareous nodules, a few thin interbeds of chert-pebble conglomerate, and beds of very fine-grained sandstone up to 1.5 m thick. One sandstone bed (unit 8) produces brachiopod shells (mostly spiriferids) and crinoid columnals (see below) that indicate a Permian (Guadalupian) age for this part of the Antimonio Formation.

A 15-m-thick bed of massive, clast-supported conglomerate (unit 15) follows, which consists of fine- to coarse-pebble, poorly sorted, angular to subrounded clasts of Paleozoic limestone, chert, rhyolitic porphyries, and granites. An especially thick sill in the section from about 90 to 120 m above the base of the Antimonio Formation intrudes this conglomerate. The conglomerate may lie above a sequence boundary that marks the base of the Triassic section.

Upward, the section is continued by massive, reddish siltstone with calcareous nodules, calcareous mudstones, limestones, and occasional interbeds of fine-grained sandstone up to 1.5-m thick (units 16–20). Overlying these strata is a distinctive 40-m-thick interval (unit 21) of muddy to sandy limestone with unidentifiable fossil shell fragments. This sandy limestone is overlain, with erosive contact, by a 12-m-thick, clast-supported, poorly-sorted conglomerate (unit 22). Clasts of this

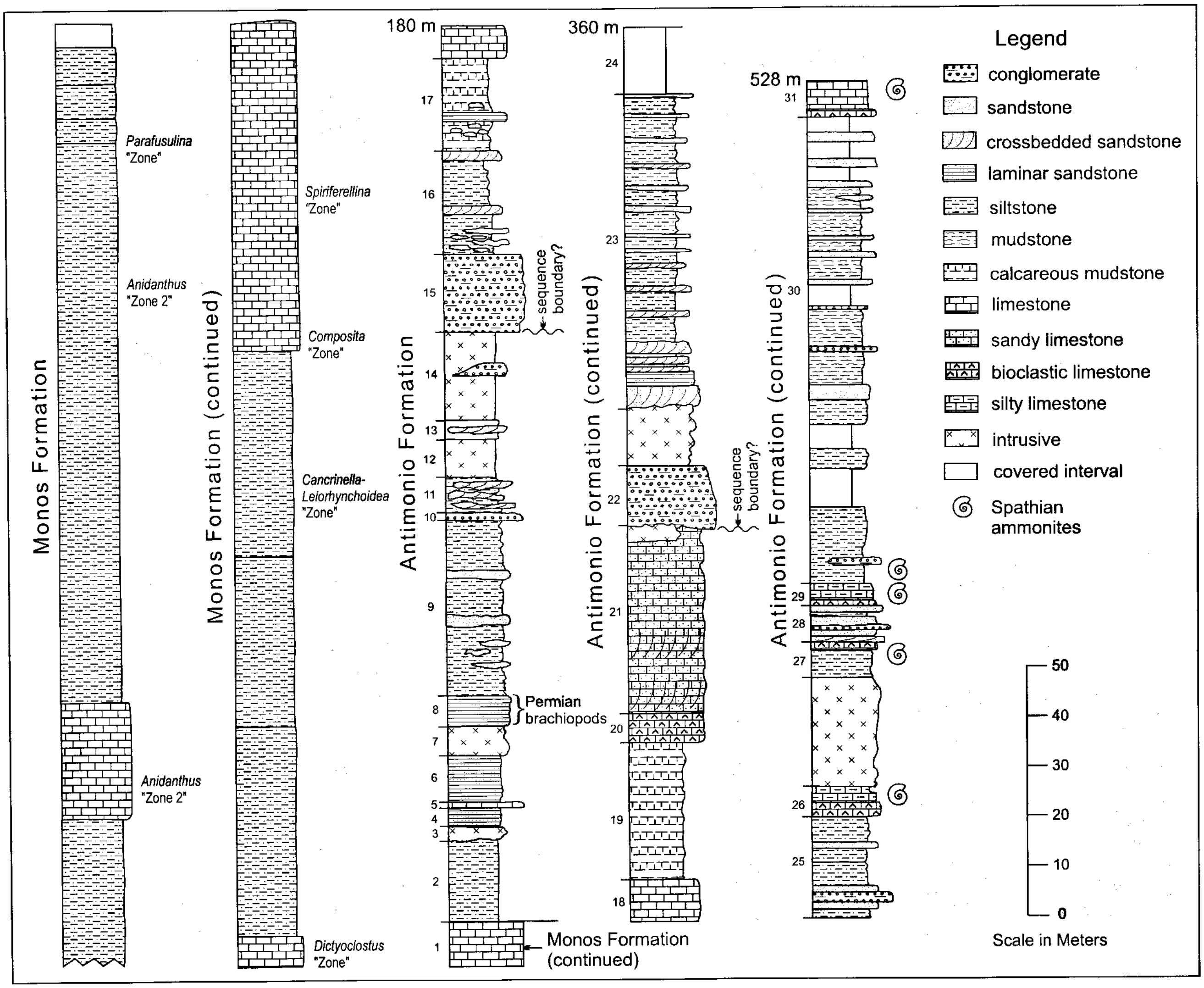

Figure 2. Measured stratigraphic section of upper part of the Monos Formation (after Cooper in Cooper *et al.*, 1953) and overlying lower part of the Antimonio Formation. For exact location and description of numbered units, see Lucas and collaborators (1997).

conglomerate are as large as 40 cm in diameter in its lower part, and grade to less than 2 cm in diameter in its upper part. They are mainly of limestone or crinoidal limestone and contain Paleozoic fossils such as brachiopods, bryozoans and the large fusulinid *Parafusulina antimonioensis* Dunbar, whose type species was described from the underlying Monos Formation (Cooper *et al.*, 1953). This conglomerate is overlain by a 110-m-thick interval (units 23–25) of thin-bedded mudstone and siltstone with interbeds of fine- to medium-grained sandstone. The uppermost part of the section (units 26–31) consists of calcareous siltstones and mudstones, thin beds of fine-grained sandstone, thin lenticular beds of coarse- to fine-pebble conglomeratic sandstone, and beds of argillaceous to sandy limestone, where Spathian ammonites and conodonts were found.

PALEONTOLOGY AND AGE OF THE LOWER ANTIMONIO FORMATION

MIDDLE PERMIAN

A sparse, poorly preserved fauna was recovered from the lower part of the Antimonio Formation (Figure 2; unit 8) at UTM zone 12, 347,955E, 3403,722N. The identifiable elements of this fauna include the brachiopods *Orbiculoidea* sp., *Spiriferellina sonorensis* Cooper, and *Composita* sp. These taxa also occur in the uppermost part of the Monos Formation (*"Spiriferellina zone"* of Cooper) and therefore indicate a middle Permian age for the lowermost Antimonio Formation.

The best preserved taxon is the inarticulate brachiopod *Orbiculoidea* sp. (Figure 3*A*), which is limited to fine-grained,

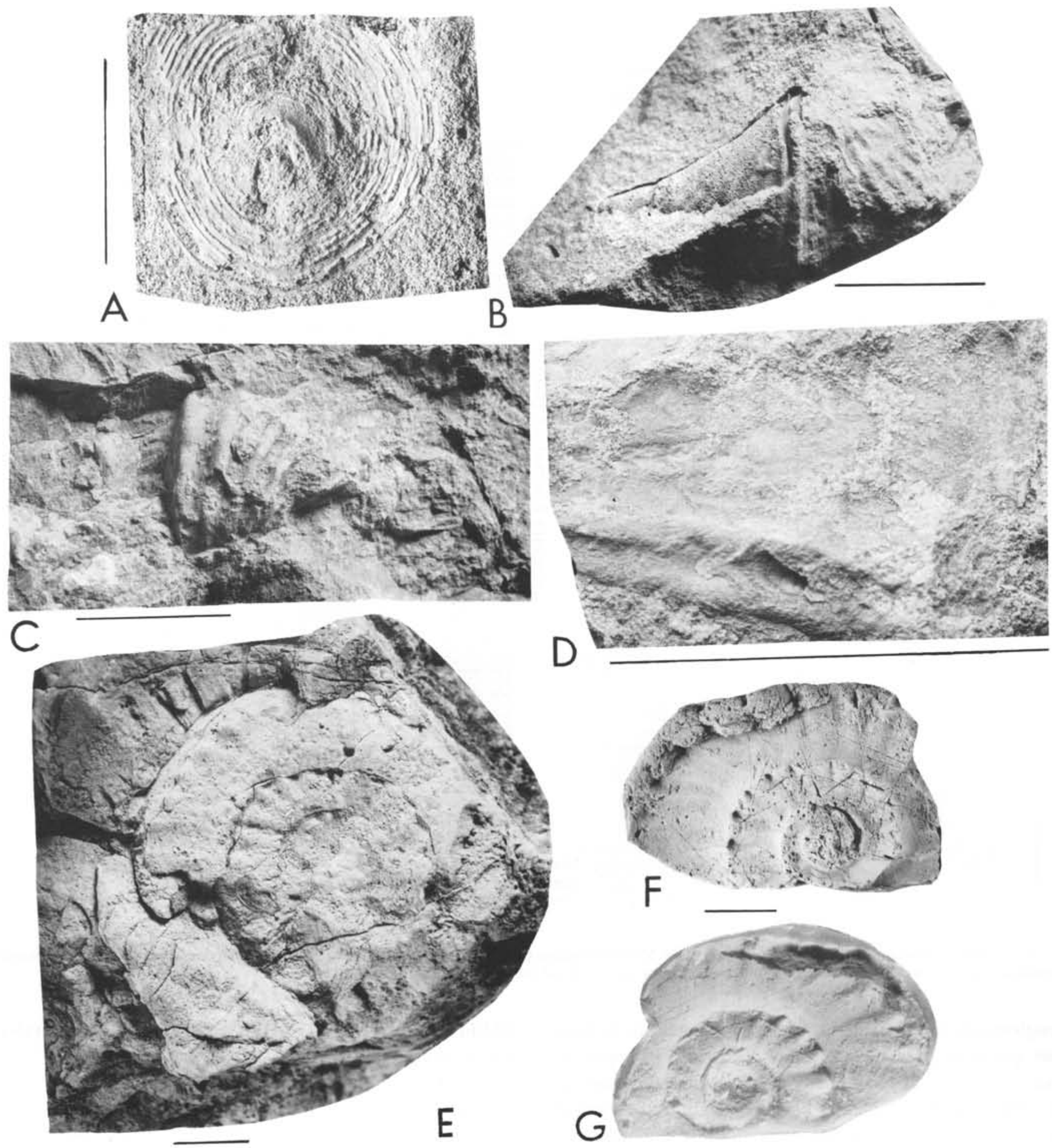

Figure 3. Selected fossils from the lower part of the Antimonio Formation. *A*: *Orbiculoidea* sp., ERNO 850, pedicle valve. *B*, *D*: *Spiriferellina sonorensis*, ERNO 851, overview of brachial valve (*B*) and detail of same showing punctae (*D*). *C*: *Spiriferellina sonorensis*, ERNO 852, partial valve. *E*: *Tirolites* sp., ERNO 780. *F*, *G*, *Tirolites* sp., ERNO 772, natural mold (*F*) and rubber peel from the mold (*G*). Bar scales = 10 mm.

red, sandstone lithologies, in which it typically is the only fossil present. All of the specimens are pedicle valves. They are circular to slightly suboval in outline, attain a maximum diameter of 20 mm, and display a slightly elevated apex that is centrally to posteriorly subcentrally situated. The pedicle foramen is relatively broad, fusiform in shape, and extends for one half to two thirds of the distance from the valve apex to the posterior margin. Ornamentation consists of strong, regular, rounded concentric ridges, about 2.5 per mm, separated by interspaces a little narrower than the width of a ridge. These specimens may be *Orbiculoidea* sp. 2 of Cooper (*in* Cooper *et al.*, 1953), which is similar in valve size and outline. Direct comparison cannot be made, however, because Cooper's specimens were brachial valves, whereas all of the specimens at hand are pedicle valves. These El Antimonio specimens clearly differ from *O. ovalis*, described by Cloud (1944) from the Guadalupian of the Las Delicias area, Coahuila, Mexico, which is a much smaller species with a pronounced oval outline. Cooper and Grant (1974) did not report *Orbiculoidea* from the Permian of west Texas. The genus is known only from the Paleozoic (Rowell, 1965).

Fragmentary specimens identified as *Spiriferellina sonorensis* Cooper (Figure 3*B–D*), occur together with *Composita* sp. in thin lenses of shell debris within red, coarsely crystalline limestone. Skeletal remains are typically coarsely recrystallized and locally severely weathered, precluding positive identification of the specimens. The *Spiriferellina* shells are nearly twice as wide as long, attaining a maximum width of about 30 mm. Each side of the valve bears up to nine, rounded prominent plications; the sulcus is relatively broad and includes one or more obscure radial costae. One specimen also displays the fine punctae characteristic of this genus (Figure 3*D*). The specimens of *Composita* are incomplete and cannot be identified to species. In addition to these brachiopods, an unidentifiable chonetoid brachiopod, a single unidentifiable gastropod steinkern, and moderate numbers of small crinoid skeletal elements were also collected from unit 8.

EARLY TRIASSIC

The authors of the present paper collected more than 50 ammonites from the lower part of the Antimonio Formation, northeast of the abandoned mining town of El Antimonio (Figure 1). Most of the ammonites, including those illustrated here (Figure 3*E–G*), come from unit 29 of our measured section, a 4-m-thick bed of red packstone (Figure 2). The principal ammonite locality is at UTM zone 12, 347,805 E, 340,3015 N, on the southwest slope of a small cuesta.

The ammonites from the lower Antimonio Formation are poorly preserved; all are steinkerns and thus lack original shell material. Few preserve suture lines or ornamental features of the shell. However, specimens readily identified as *Tirolites* Mojsisovics are present.

Specimens from the lower Antimonio Formation assigned to *Tirolites* (*e.g.*, Figure 3*E–G*) show characteristic features of the genus (Hyatt and Smith, 1905; Smith, 1932; Spath, 1934) including wide shallow umbilicus, evolute, little embracing of whorls, laterally compressed rectangular whorls, a flattened venter that lacks sculpture, and side ornamentation of ribs that terminate on the squared-off whorl shoulders as spines. Assignment of these specimens to *Tirolites* is thus certain, but they are not well enough preserved to warrant a species-level identification. *Tirolites* is the most common ammonite in the lower Antimonio Formation. Specimens occur in units 26–31 of our measured section (Figure 2), an interval almost 150-m thick.

The presence of *Tirolites* in the lower Antimonio Formation indicates these strata can be assigned to the *Tirolites* beds as defined by Hyatt and Smith (1905) and Smith (1932). The *Tirolites* beds are of early Spathian age and are considered correlative to the *Olenikites pilaticus* Zone of the Arctic Canadian ammonite zonation (Silberling and Tozer, 1968; Tozer, 1994).

A sparse but diagnostic collection of conodonts was also recovered from unit 29 (Figure 2) and identified by Rachel K. Paull. Two species of *Neospathodus*, generally assignable to the broadly construed species *N. triangularis* (Bender) and *N. homeri* (Bender), comprise the conodont fauna and also indicate a Spathian age (Lucas *et al.*, 1997).

SEQUENCE STRATIGRAPHY

Three relatively rapid Early Triassic transgressions are recorded in the Cordilleran miogeocline of the western United States, the Canadian Arctic and other Triassic depositional regions. Although all three transgressive-regressive sequences are well-documented in Lower Triassic rocks of the western United States (Paull and Paull, 1994), the earliest (Griesbachian) sequence was confined to a depositional basin centered in southern Idaho. To the south and southwest of this localized basin margin, the Permian–Triassic hiatus was significantly longer, placing Smithian (lower Olenekian) strata directly on Permian (Guadalupian or older) rocks (Paull and Paull, 1994) (Figure 4).

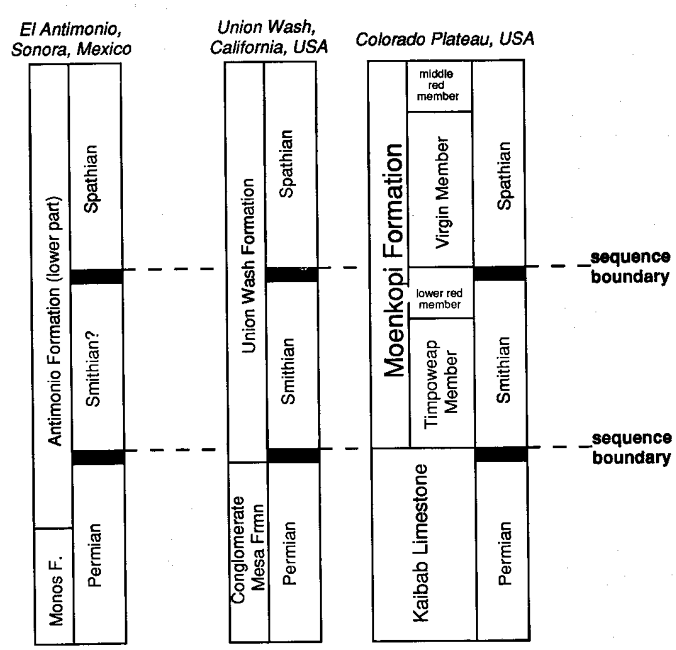

Figure 4. Correlation and inferred sequence stratigraphy of the lower Antimonio Formation, the Union Wash Formation in California and on the Colorado Plateau.

The second transgressive sequence records a significant eustatic cycle at the beginning of Smithian time. This flooding expanded south and west of the older Triassic depositional basin and produced the oldest Mesozoic sequence preserved across much of Utah and Nevada (Collinson and Hasenmueller, 1978). Extensive basal conglomerates with Permian clasts, and significant erosional relief, mark the base of this widespread Smithian sequence.

After a period of earliest Spathian progradation, the third Early Triassic transgression is reflected in the expansion of outer shelf and basinal facies over much of the area previously inundated by Smithian seas (Collinson and Hasenmueller, 1978; Carr and Paull, 1983). The increased diversity and abundance of early to middle Spathian transgressive conodont faunas reflects this eustatic event (Paull and Paull, 1994). Significantly, the fossils documented here indicate Spathian-age rocks are present in the lower Antimonio Formation. Furthermore, the authors of the present paper interpret the sequence stratigraphy of the lower Antimonio Formation to indicate it encompasses two unconformity-bounded sequences, one of possible Smithian, and the other of definite Spathian age (Figure 2). According to this interpretation, the lower Antimonio Formation preserves the same sequences as Lower Triassic strata in the southwestern United States (Figure 4). Alternatively, the lower of the two sequences could be pre-Smithian Triassic, or Permian, which somewhat reduces the similarity of the Antimonio section to sections in the southwestern United States.

Guadalupian brachiopods are known from the lowermost part of the Antimonio Formation (Figure 2), so the Permian–Triassic boundary is in the Antimonio Formation. The authors of the present paper tentatively suggest that it may be a prominent disconformity at the base of unit 15. A second disconformity is present at the base of unit 22, where boulder conglomerate (most clasts are Permian limestone) rests on limestone. These two disconformities in the lower Antimonio Formation define two fining-upward sequences. A third sequence boundary probably is present above unit 31 (Lucas *et al.*, 1996). It is overlain by progradational parasequence sets with abundant coleoid guards.

ACKNOWLEDGMENTS

CONACYT Project 3934-T supported part of this research. Rachel Paull, Norman Silberling and Tim Tozer provided valuable advice on fossil identifications, and John Marzolf and Roberto Molina-Garza provided insightful discussions. Rachel Paull reviewed an earlier version of the manuscript.

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