Revista Mexicana de Ciencias Geológicas, volumen 14, número 2, 1997, p. 208–218.
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RELATIONSHIPS AND DIFFERENCES BETWEEN THE TRIASSIC AMMONOID SUCCESSIONS OF NORTHWESTERN SONORA, MEXICO, AND WEST-CENTRAL NEVADA, U.S.A.

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ABSTRACT

The Antimonio Formation exposed in the Sierra del Álamo, northwestern Sonora, consists of an Upper Permian-Lower Jurassic marine succession of sedimentary rocks that disconformably overlies the Guadalupian-age Monos Formation. These two lithotectonic assemblages form the Antimonio terrane which is considered to be an allochthonous block over the Caborca terrane.

The marine Triassic rocks of the Antimonio Formation contain a Triassic ammonoid fauna of Spathian, Anisian, Carnian, Norian and Rhaetian ages; the following ammonoid zones have been recognized: Nanseni (lower Carnian), Dilleri (upper Carnian), Columbianus (middle Norian), Cordilleranus, Amoenum and Crickmayi (upper Norian-Rhaetian). They also contain a Late Triassic Norian diverse fauna of corals, chambered sponges, hydrozoans, disjectoporoids, bivalves, brachiopods and gastropods within a biostromal limestone interval.

Some Norian species of corals, sponges and ammonoids from the Antimonio sequence show strong similarity with the fauna occurring at the Luning and Gabbs formations (part of the Luning Assemblage of the Mesozoic marine province of western Nevada). In adition, there are stratigraphic thicknesses, lithofacies and tectonic similarities between the Antimonio and the Luning assemblage successions. To explain these similarities, some authors have proposed a tectonic model of transcurrent strike-slip faulting through the Mojave-Sonora megashear. It accounts for the displacement of the rocks from the northwest of the Great Basin to their present position in northwestern Sonora.

Detailed comparisons however between the New York Canyon and the Union District sections of the Luning Assemblage, with those of the Antimonio Formation established herein, reflect a large number of important structural, paleontologic and stratigraphic dissimilarities. The Luning Assemblage is underlain by the regionally extensive Luning thrust, whereas in Sonora the Antimonio Formation overlies the Permian Monos Formation; the depositional settings of the regions being compared are also different. The Triassic stratigraphic record is not coeval at Sonora and Nevada; the first one began in the Spathian and the second one in the Ladinian. Therefore, the Spathian and Anisian ammonoid fauna of the Antimonio sequence is not correlatable with the Luning Assemblage at these levels. Also, no correspondence with the Ladinian ammonoid fauna of the Luning Assemblage could have been established since no fauna of this age has been found in Sonora to date.

Moreover, there are no relationships between the ammonoid associations identified for the lower and upper Carnian, and lower and middle Norian from either regions. Another significant difference is that not withstanding that the same species of corals and sponges occur both in the Luning Assemblage and in the Antimonio sequence, they are not contemporaneous. Only at the Amoenum and Crickmayi Zones of the Rhaetian there is a close paleontologic correspondence between Sonora and Nevada.

The evidence derived from this comparison indicates that sections at the Luning Assemblage are not the best to correlate with the Antimonio sequence; therefore, they do not support the Antimonio terrane tectonic model proposed previously.

Key words: Paleontology, stratigraphy, Triassic ammonoid successions, Antimonio Formation, west-central Nevada, northwestern Sonora, Mexico.

RESUMEN

La Formación Antimonio reconocida en la Sierra del Álamo, noroeste de Sonora, consiste en una sucesión de rocas sedimentarias del Pérmico Superior-Jurásico Inferior que yace discordantemente sobre la Formación Monos, del Guadalupiano. Estos dos conjuntos litotectónicos constituyen el terreno Antimonio, considerado como un bloque alóctono que cabalga sobre el terreno Caborca.

Las rocas triásicas de la Formación Antimonio contienen una fauna de amonoideos del Spathiano, Anisiano, Cárnico, Nórico y Rético. Con base en su presencia, han sido reconocidas las siguientes zonas: Nanseni (Cárnico inferior), Dilleri (Cárnico superior), Columbianus (Nórico medio), Cordilleranus, Amoenum y Crickmayi (Nórico superior–Rético). En el intervalo nórico de la formación, en capas de calizas

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biostromales, se ha descubierto fauna marina tropical diversa, constituida por corales, esponjas, hidrozoarios, disjectoporoideos, bivalvos, braquiópodos y gasterópodos.

Algunas especies de corales, esponjas y amonoideos de la secuencia del Antimonio muestran una fuerte similitud con la fauna de Nevada y constituyen la base para correlacionar a esta unidad con las formaciones Luning y Gabbs, que forman parte del Conjunto litotectónico Luning de la provincia marina mesozoica del oeste de Nevada. Además de los elementos faunísticos, hay otras similitudes en los espesores estratigráficos, litofacies e historia tectónica de las sucesiones estratigráficas del Antimonio y el Conjunto Luning.

Para explicar estas similitudes, algunos autores propusieron un modelo tectónico de fallamiento transcurrente lateral a través de la megacizalla Mojave-Sonora, considerándola como la responsable probable del desplazamiento hacia el sur de las rocas del noroeste de la Great Basin hacia su actual posición en el noroeste de Sonora.

La comparación y revisión detallada de dos secciones del Conjunto Luning, New York Canyon y Union District, con las secciones de la Formación Antimonio reflejan, sin embargo, un número mayor de diferencias estructurales, paleontológicas y estratigráficas. Una diferencia estructural importante entre las dos regiones se debe a que el Conjunto Luning yace sobre la gran falla Luning, mientras que en Sonora la Formación Antimonio descansa sobre la Formación Monos del Pérmico. También los ambientes de depósito de las regiones comparadas son diferentes. Tampoco el registro estratigráfico del Triásico de Sonora y Nevada es contemporáneo; el primero empezó en el Spathiano y el segundo en el Ladiniano. Por esta razón, los amonoideos del Spathiano y Anisiano de la secuencia del Antimonio no son correlacionables con el Conjunto Luning, ni existe correspondencia al nivel de la fauna del Ladiniano del conjunto Luning, porque en Sonora no se ha encontrado fauna de esta edad. Igualmente, no hay relación entre las asociaciones de amonoideos identificados para el Cárnico inferior y superior, Nórico inferior y medio, de ambas regiones.

No obstante que las mismas especies de corales y esponjas están presentes en Sonora y Nevada, éstas no están ubicadas en los mismos niveles estratigráficos.

Exclusivamente al nivel de las Zonas Amoenum y Crickmayi, existe una correspondencia paleontológica estrecha entre Sonora y Nevada.

La evidencia derivada de esta comparación indica que las secciones del Conjunto Luning no son las mejores para correlacionar con la secuencia del Antimonio y no apoyan el modelo tectónico propuesto para el terreno Antimonio, mencionado anteriormente.

Palabras clave: Paleontología, estratigrafía, amonoideos triásicos, Formación Antimonio, Nevada centro-occidental, noroeste de Sonora, México.

INTRODUCTION

An important succession of Triassic (Spathian, Anisian, Carnian, Norian and Rhaetian) ammonoids was discovered in the lower member and part of the upper member of a sedimentary sequence located in the Sierra del Álamo, northwestern Sonora (the Antimonio Formation of González-León [1980]) and whose age ranges from Late Permian to Early Jurassic (González-León, 1997a). Also for the Upper Triassic, the Nanseni (lower Carnian), Dilleri (upper Carnian), Columbianus and Cordilleranus zones (middle Norian and upper Norian respectively) as well as the Amoenum and Crickmayi zones for the Rhaetian, have been recognized (Figure 1). Such a complete succession does not occur in any other marine Triassic locality in Mexico. The lower member of the Antimonio Formation also contains a diverse tropical marine fauna of corals, spongiomorphs, disjectoporoids, sponges, brachiopods, gastropods, bivalves, coleoids and microcoprolites (Stanley *et al.*, 1994).

The Antimonio Formation disconformably overlies the Guadalupian-age Monos Formation (Cooper and Arellano, 1946; Cooper, 1953). These two lithotectonic assemblages form the Antimonio terrane proposed by González-León (1989) which is considered to be an allochthonous block thrusting over the Caborca terrane. The tectonic history of the Antimonio terrane and the paleobiogeographic and tectonic implications of the Triassic fossils of the Antimonio Formation were presented by Stanley and González-León (1995). They pointed out that the Norian sponges and corals in Sonora are similar to those found in west-central Nevada (Luning Formation) and also that the stratigraphic thickness, lithofacies and tectonic histories of both regions compared favorably. They proposed a tectonic model of transcurrent strike-slip faulting through the Mojave-Sonora megashear to explain these similarities; Anderson and Silver (1979) considered this megashear responsible for the southward displacement of rocks from the northwestern Great Basin to their present position in Sonora.

Stanley and González-León (1995) analyzed the distribution of the ammonoids and nautiloids that characterize the Crickmayi Zone in the Antimonio Formation and concluded that these fossils show a wide geographic distribution. However, they noted that association was similar to a previous one reported from the Gabbs Formation of west-central Nevada. Referring to the Dilleri Zone ammonoids of the Antimonio Formation, they indicated an affinity with the fauna of the Hosselkus Limestone in California. Later on, González-León and Stanley (1995), and González-León and collaborators (1996) correlated the Sonoran Amoenum and Crickmayi zones with the three members of the Nevada Gabbs Formation.

Nevertheless, this information from the Triassic Antimonio Formation raises questions about the Sonoran

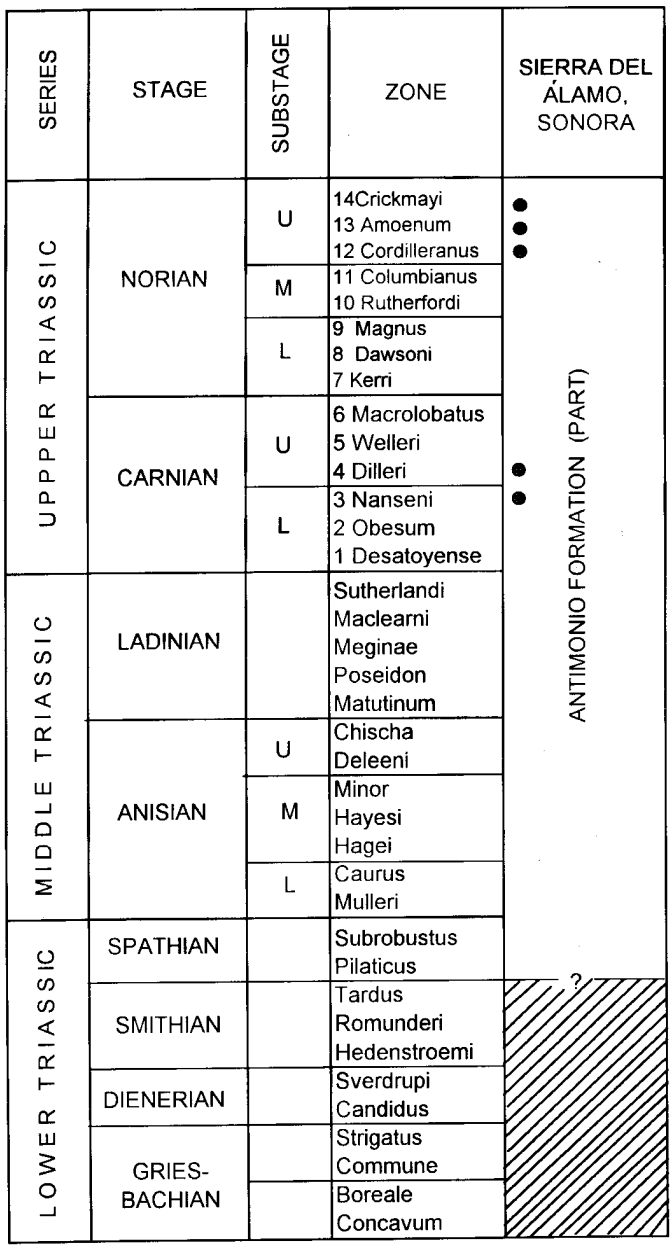

Figure 1. Biostratigraphic zonation for the Triassic, defined by Tozer (1994). Note, currently the Crickmayi and Amoenum Zones are together, included in the Rhaetian Stage. Biostratigraphic zones recognized in part of the Antimonio Formation in Sonora are indicated by large dot.

ammonoids succession: Does the same succession occur in Nevada? What are the lithologic characteristics of the stratigraphic sequences that contain similar groups of ammonoids in Nevada? At what levels do they relate to, or are differentiated from, the ammonoids in Nevada? To answer these questions, it is necessary to closely examine and objectively compare the lithostratigraphic sequences and groups of ammonoids in Sonora and Nevada, to establish relationships and differences. Through a biostratigraphic analysis, the authors pretend to contribute to a better understanding of the Antimonio terrane.

ANTIMONIO FORMATION

STRATIGRAPHY, FAUNA AND AGE

The 3.4-km-thick Antimonio Formation, redefined as an almost complete succession of marine sedimentary rocks that ranges from the Late Permian to the Early Jurassic (González-León, 1997a), disconformably overlies the Late Permian Monos Formation (Cooper, 1953). González-León (1980) originally identified two members: the lower (Carnian-Norian and Rhaetian) and the upper (Hettangian-Sinemurian) ones. He later recognized 14 stratigraphic sequences along two stratigraphic sections; section 1 comprises the originally defined lower member and section 2 the upper member (Figure 2). The first nine sequences that correspond to the Permian and Triassic are the ones described herein; the other five correspond to the Lower Jurassic (González-León, 1997a and 1997b).

The following sequences can be distinguished within section 1: Sequence I, made up of shallow marine strata with bryozoans and brachiopods of Late Permian age (Lucas *et al.*, 1997); Sequence II, composed at the base by fluvial conglomerate and grading toward the top to shallow marine strata that probably correspond to the Smithian stage (Lucas *et al.*, 1997); Sequence III has a fluvial conglomerate at its base and in its middle portion, fluvial sandstone, shallow marine siltstone and limestones with the Spathian ammonoid *Tirolites* sp. The upper part of this sequence consists of limestone with interbedded siltstone, mudstone and fine-grained sandstone. Sequence IV has, at its base, fluvial conglomerate and sandstone that grade upwards to limestone and siltstone of shallow marine origin. In the upper part there is an interval with packstone and trace fossils of the *Nereites* ichnofacies which could indicate deep marine intervals. The ammonoids identified from this sequence are: cf. *Paracrochordiceras* (Welter) and *Paranevadites* cf. *P. furlongi* (Smith) of Anisian age (Estep *et al.*, 1997). Sequence V has at its base a conglomerate followed upwards by sandstone, silstone, mudstone and limestone with unidentifiable aulacoceratids, ammmonoids and ichthyosaur bones. Sequence VI, whose base is probably covered, has in its lower part shallow water conglomeratic sandstone that grades upwards to fine- and medium-grained sandstone, siltstone, and these lithologies are overlain by limestone, aulacoceratid and ammonoid packstone, and minor sand. In this sequence occur the ammonoids *Sirenites nanseni* and *Sirenites ovatus* that characterize the lower Carnian Nanseni Zone (Estep *et al.*, 1997) and several other ammonoids of the upper Carnian Dilleri Zone.

Sequence VII is well exposed in the upper part of section 1 and lower part of section 2. This sequence consists of fluvial conglomerate that grades upwards to fluvial sandstone, siltstone and limestone with bivalves, of Late Triassic age (González-León, 1997b). Lucas and Estep (1997) reported from this part of the section the Jurassic bivalve *Weyla,* which was distributed all over the world during Sinemurian-

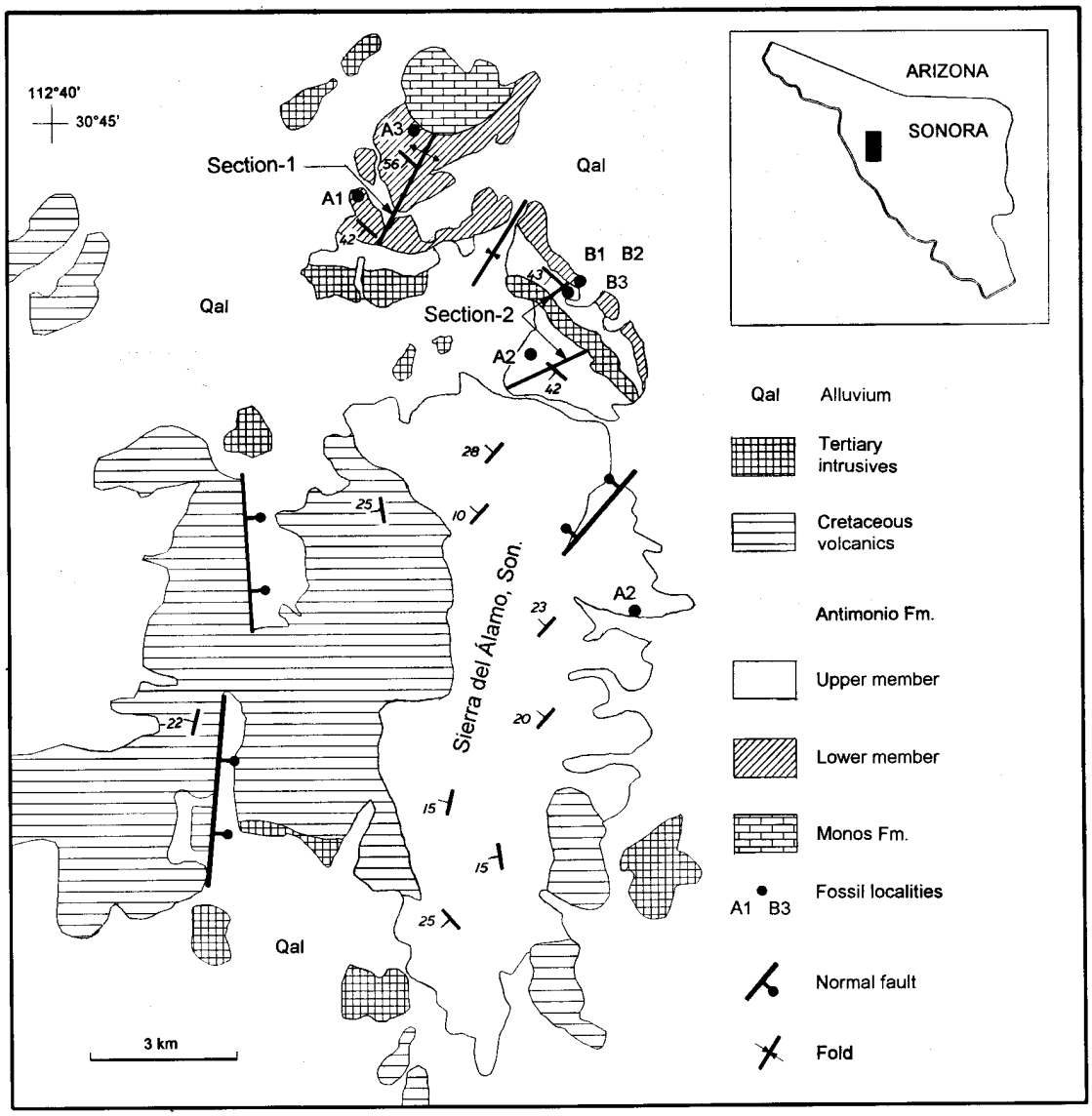

Figure 2. Geologic map of Sierra del Álamo, northwestern Sonora. A1–A3 and B1–B3, fossil localities; sections 1 and 2, detailed measured sections of the Antimonio Formation (modified from González-León, 1995).

Pliensbachian time. According to these last authors, *Weyla* strongly suggests the existence of a fault in this section. In another opinion, González-León (1997a and 1997b) considered that there is no fault in the section but a transitional contact is present between the Carnian and Norian stages. The misidentification of *Weyla* as a Triassic genus thus reduces the importance of any tectonic contact in the section (Damborenea and González-León, 1997).

Overlying these strata, the sequence consists of impure bioclastic limestones and thick-bedded biostromal limestones with an abundant shallow-water marine fauna of corals, sponges, spongiomorphs, bivalves. This sequence contains the ammonoid *Pinacoceras metternichi* (Hauer), which indicates the Columbianus Zone (Silberling, written communication, *in* González-León and Stanley, 1995) and the ammonoids *Catenohalorites* and *Sagenites* cf. *S. schaubachi* Mojs., which characterize either the upper part of the middle Norian or the lower part of the upper Norian (Columbianus or Cordilleranus Zones). However, E.T. Tozer, when reviewing this manuscript (written communication, 5/11/97) noted that *Pinacoceras metternichi* does not necessarily indicates the Columbianus Zone, but that it is more likely upper Norian. Thus, the presence of this zone in Sonora is dubious. This sequence corresponds to Package 1 of the five informal lithostratigraphic units described by González-León and collaborators (1996) (Figure 3). Sequence VII (Package 2), formed by marine siltstone, contains ammonoids of the *Sagenites* genus that according to González-León and collaborators (1996) represents the Amoenum Zone; Sequence VIII (Packages 3 and 4) whose base is made up of a calcareous tempestite that grades upward to deep marine siltstone and mudstone. Ammonoids in this sequence belong to the *Choristoceras*, *Arcestes* and

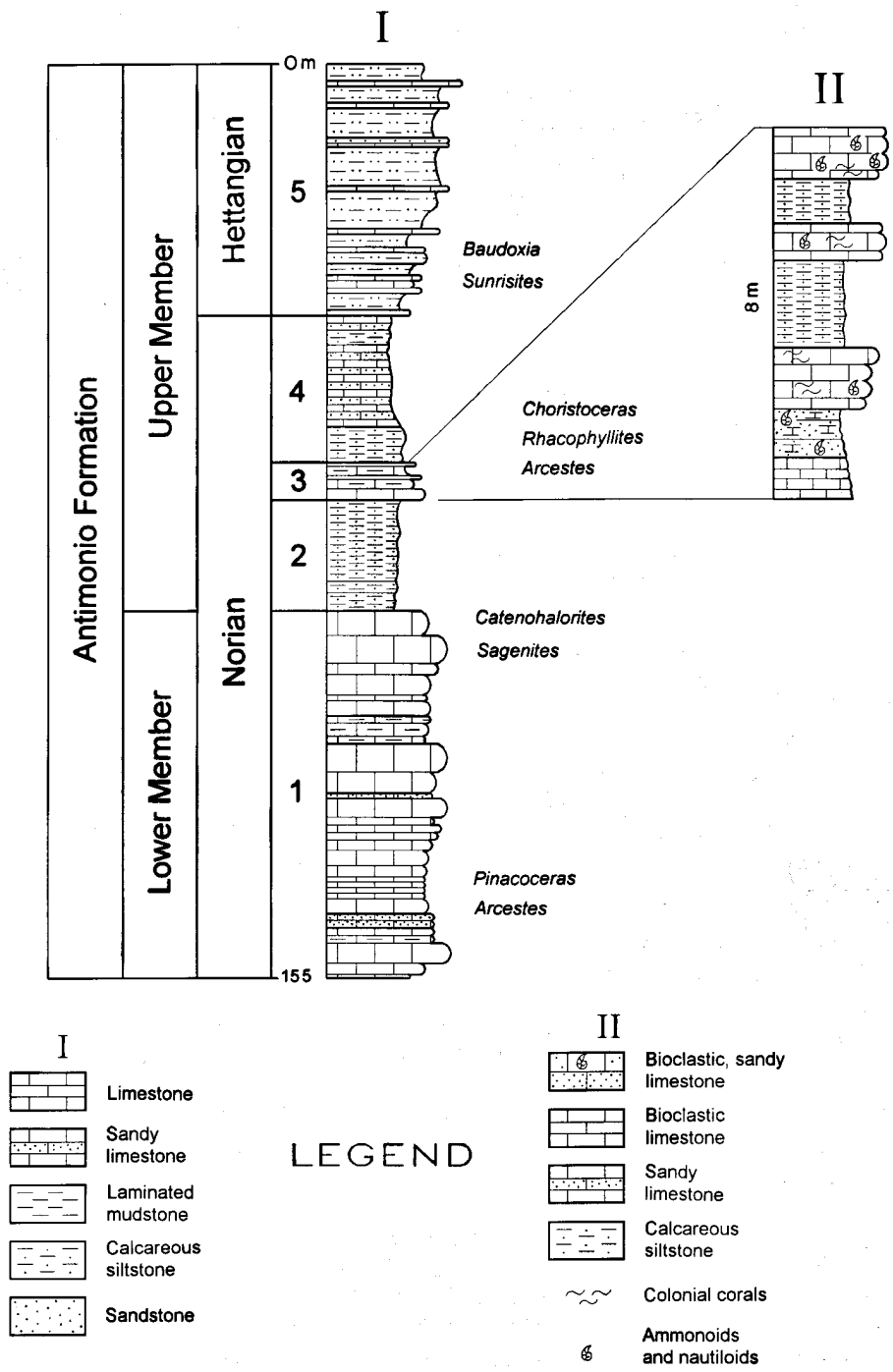

Figure 3. Stratigraphic column of the upper part of the lower member, and lower part of the upper member of the Antimonio Formation, divided into five informal packages. (Figure modified from González-León *et al.*, 1996).

Rhacophyllites genera. The first genus characterizes the Crickmayi Zone. At the top of sequence VIII, there is an erosive discontinuity that marks the Triassic-Jurassic boundary.

SOURCE AND DEPOSITIONAL ENVIRONMENT

The sedimentary petrofacies of the Antimonio Formation indicate either a continental block or recycled orogenic source for the lower member and a volcano-plutonic source for the upper member (Stanley and González-León, 1995).

Stanley and González-León (1995) inferred that the depositional setting for the Monos and Antimonio Formations, which constitute the Antimonio terrane, was that of a fore-arc developed between a continental volcanic arc to the north and a subduction zone to the west.

LUNING LITHOTECTONIC ASSEMBLAGE

The Early Mesozoic rocks that crop out in large portions of western Nevada and northeastern California, constitute the Mesozoic Marine Province of the northwestern Great Basin. These rocks were deposited in a back-arc basin limited to the west by the Sierra Nevada Arc, and to the east and south by a shallow marine shelf and continental environments (Oldow *et al.,* 1993) (Figure 4). The rocks from this Mesozoic province were divided into eight lithotectonic assemblages, five of which belong to dismembered assemblages (Oldow, 1984). Generally, the rocks from this province do not have their lower depositional contact exposed. Wherever this contact is visible, the Mesozoic units overlie diverse Paleozoic sequences with angular unconformity.

In northwestern Nevada, outcrops of the Luning and Gabbs Formations contain fauna similar to that in Sonora. These rocks are part of the Luning lithotectonic assemblage which in turn forms one of the five dismembered lithotectonic assemblages known in the region. This assemblage is underlain by the regionally extensive Luning thrust. Even if this assemblage is predominantly Mesozoic, it also holds Permian volcanic arc and Paleozoic (?) clastic rocks in small exotic thrust-slices. The Lower Mesozoic sedimentary rocks were deposited in a continental shelf environment. The shelf sequence consists of shallow marine to deltaic carbonate and clastic rocks derived from continental sources (Oldow, 1984).

The outcrops of the Luning Assemblage can be found in the Cedar Mountains, Shoshone Mountains, Pilot Mountains, Gabbs Valley Range, Garfield Hills, Paradise Range and in the Clan Alpine Mountains (Figure 5). The stratigraphic succession of the Luning lithotectonic assemblage ranges from Middle Triassic (Ladinian) or Late Triassic (Carnian) to Middle Jurassic in age. The Westgate (south of the Clan Alpine Mountains), New York Canyon (south of the Gabbs Valley Range) and Union District (south of the Shoshone Mountains) stratigraphic sections of the Luning Assemblage,

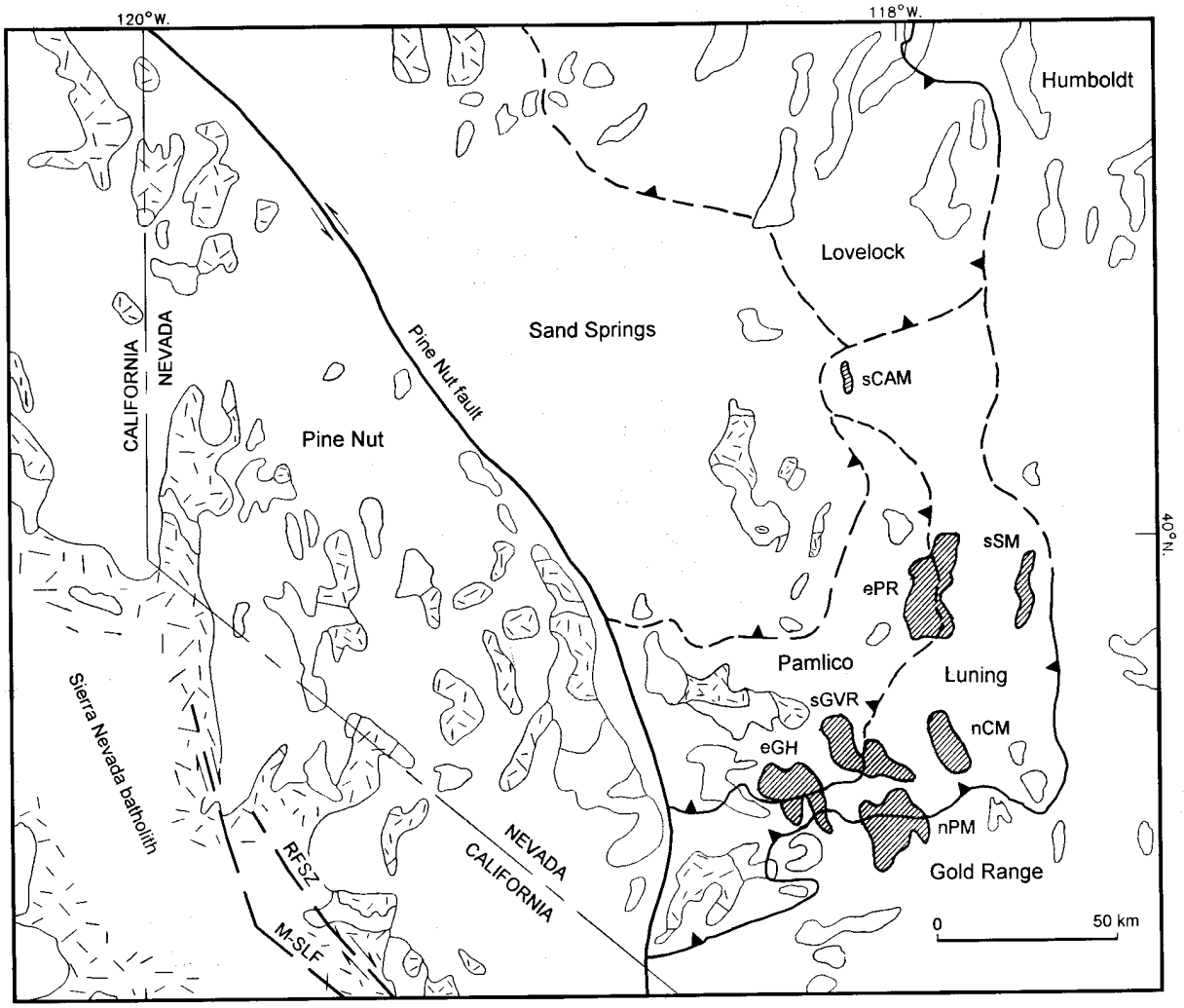

Figure 4. Lithotectonic assemblages of the Mesozoic province (names in bold type). Localities of the lithotectonic Luning assemblage nCM, northern Cedar Mountains; sSM, southern Shoshone Mountains; nPM, northern Pilot Mountains; sGVR, southern Gabbs Valley Range; eGH, eastern Garfield Hills; ePR, eastern Paradise Range; sCAM, southern Clan Alpine Mountains. Sierra Nevada: M-SLF, Mojave-Snow Lake fault; RFSZ, Rosy Finch shear zone. (Figure modified from Oldow *et al.*, 1993).

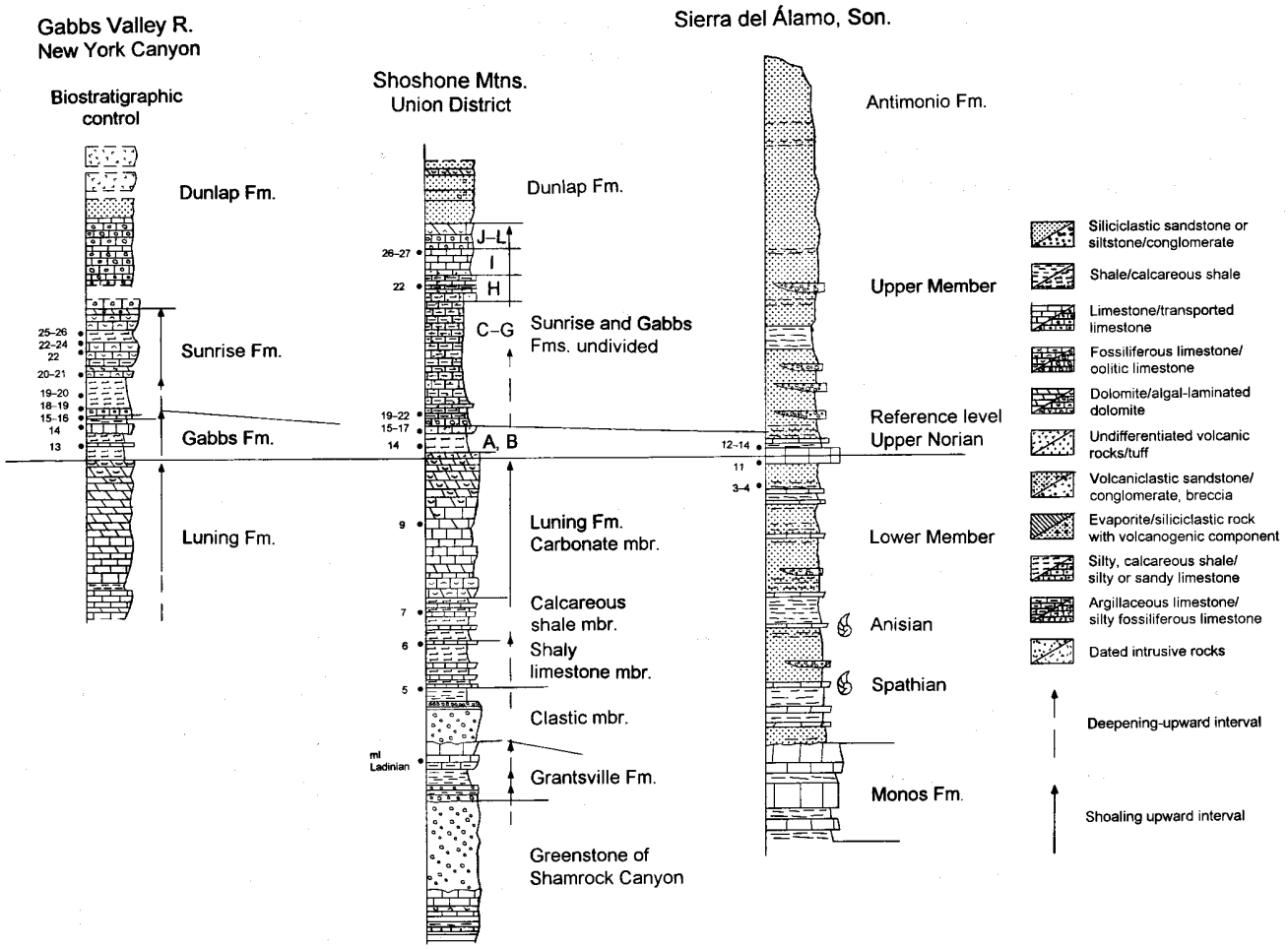

Figure 5. Stratigraphic columns of Gabbs Valley Range (New York Canyon Section), Shoshone Mountains (Union District Section) for the southern Mesozoic marine province; and generalized stratigraphic column of the Antimonio Formation in Sierra del Álamo, northwestern Sonora displaying a biostratigraphic comparison, numbers keyed to biostratigraphic zones in Figure 1. (Modified from Oldow *et al.*, 1983 and Stanley and González-León, 1995).

exposed in the south of the Marine Mesozoic Province, represent the most complete and best-dated Middle Triassic to Middle Jurassic successions (Oldow *et al.,* 1993). The New York Canyon and Union District sections were chosen for the comparison between Sonora and Nevada (Figure 5).

GRANTSVILLE FORMATION

The type locality of the Grantsville Formation (Muller and Ferguson, 1939), is located at Union Canyon in the Shoshone Mountains. This formation includes the oldest Mesozoic sedimentary rocks at this location. Two members are recognized: the lower one made up of conglomerate with interstratified argillite, and the upper one made up of limestone. The Grantsville Formation unconformably overlies volcanic rocks tentatively dated as Permian, and also unconformably underlies the Luning Formation.

The fauna of the Grantsville Formation was dated as early-Middle Triassic by Muller and Ferguson (1939) and includes *Ceratites* cf. *C. semipartitus* Montfort, *C.* cf. *C. dorsoplanus* Philippi, and *C.* cf. *C. flexuosus* Philippi. Silberling (1959) also identified two members for this formation: the lower one composed of siliceous conglomerate with interstratified silty and sandy argillite, considered as the clastic member, and the upper one comprising limestone with some shaly intercalations. He also noted that the clastic member of the Grantsville Formation overlies the green-rock member of Pablo Formation (a unit composed of greenstone, clastic and tuffaceous sedimentary rocks, and limestones of Permian? age) with an erosional unconformity and that the limestone member is unconformably covered by the Luning Formation.

Silberling (1959) identified the same *Ceratites* species reported by Muller and Ferguson (1939) from the limestone member. He also discovered three specimens of *Protrachyceras*. Based on these fossils, he assigned a Ladinian or late-Middle Triassic age to the Grantsville Formation. Because this formation is truncated by an erosional unconformity and the oldest strata of the Luning Formation that overlay it are Late Carnian, no sedimentary record of early and middle Carnian is present in that region.

LUNING FORMATION

The Luning Formation, defined by Muller and Ferguson (1936), consists of dark dolomite, limestone with interstratified argillite and shale, and coarser clastic rocks that crop out in the central portion of the Pilot Mountains which is considered the type locality. It rests unconformably over the Middle Triassic Excelsior Formation which consists predominantly of pyroclastic and extrusive rocks, with some subordinate sediments; in the Shoshone Mountains it overlies the Grantsville Formation and conformably underlies the Gabbs Formation. The best outcrops of this formation can be found in the Garfield Hills, the Gabbs Valley Range and the Pilot Mountains.

Muller and Ferguson (1939) noted that the Luning Formation varies strongly in lithology and thickness, both laterally and vertically. At Gabbs Valley Range it reaches 1,500 m in thickness and two members are identified; the lower member consists of massive limestones and subordinate dolomites and shale, and the upper member consists mainly of dolomites. In the Shoshone Mountains, the section is 1,770 m thick and includes dolomites with a subordinate proportion of limestone, shale and chert conglomerate.

Muller and Ferguson (1936, 1939) identified three different faunistic facies within the Luning Formation: (1) nearshore pelecypod facies, found in the Shoshone Mountains, the Gabbs Valley Range, the Garfield Hills, the Cedar Mountains and the Paradise Range; (2) coral reef facies, identified in the Pilot Mountains, the Gillis Range, the Garfield Hills, the Shoshone Mountains and the Cedar Mountains; and (3) offshore ammonoid facies, identified by three associations of ammonoids in the Union Canyon section at the Shoshone Mountains. The Carnian *"Carnites"* association is overlain conformably by the *Tropites* association that characterizes the late Carnian ("Juvavites" subzone of the "Tropites subbullatus" Zone identified by Smith (1927), in northern California, and the *Guembelites* association whose age is considered equivalent to late Carnian or early Norian. The *Tropites* fauna of the *Tropites welleri* and *T. reticulatus* groups which characterizes the "Juvavites" subzone of the "Tropites subbullatus" Zone was also found in the Gabbs Valley Range.

Silberling (1959) recognized four informal members for the Luning Formation at the Union District section in the Shoshone Mountains: the lower clastic member made up of non-calcareous, coarse and fine-grained strata; the shaly limestone member; the calcareous shale member; and the uppermost carbonate member (Figure 5). The clastic member of the Luning Formation overlies the Grantsville Formation. The upper contact of the Luning Formation is not exposed in the Union District. He also found three ammonoid associations in the Luning Formation, in its Union District section: *Klamathites schucherti* (equivalent to the *Carnites* fauna identified by Muller and Ferguson [1936, 1939]) near the base of the shaly limestone member; *Klamathites macrolobatus* fauna found at the top of the shaly limestone and the base of the calcareous shale members; and *Guembelites* found in the upper portion of the shaly limestone member. Silberling (*op. cit.*) proposed a name change from "Juvavites" to "Tropites welleri" for the subzone. He correlated the Klamathites schucherti Zone of the Union District section with the Tropites welleri subzone of the Tropites subbullatus Zone of late Carnian age in northern California. Tentatively, he placed the Carnian-Norian contact between the Klamathites macrolobatus and Guembelites zones. He assigned an early Norian age to the Guembelites Zone.

The Guembelites Zone later was referred to the Kerri Zone by Silberling and Tozer (1968) because it shares several elements with the typical Canadian development of the Kerri Zone. Regarding the Schucherti Zone, Silberling and Tozer (*op. cit.*) upheld the idea of an approximate correlation with the Welleri Zone in northern California.

Oldow and collaborators (1993) indicated a biostratigraphic control with ammonoids that related the carbonate member of the Luning Formation with the Magnus Zone of the lower Norian.

GABBS FORMATION

The Gabbs Formation (Muller and Ferguson, 1936), has its representative locality in the New York Canyon at the Gabbs Valley Range. It is composed of shale and limestone, conformably overlies the Luning Formation and grades upward into the Sunrise Formation.

The Gabbs Formation was subdivided into three members: the lower member made up of carbonaceous shale intercalated with beds of impure limestone; the middle member consisting mostly of limestones, and the upper member with a composition similar to the middle one but identified by its distinctive fossiliferous content. There are three ammonoid associations present in the Gabbs Formation: the *Sagenites giebeli* association near the base of the lower member, can be correlated with the Sagenites giebeli Zone of the early Norian in Europe. Tozer (written communication 5/11/97) indicated that the *Sagenites giebeli* association in the Gabbs is late rather than early Norian because the zone in Europe has been reevaluated. The *Pinacoceras metternichi* association, considered to be nearly similar to the European upper Norian Pinacoceras metternichi Zone, has been identified near the top of the lower member and throughout the middle member. The *Choristoceras* association, which can be correlated to the Pteria contorta Zone of the Rhaetian from Europe (Muller and Ferguson, 1939), was identified in the lower part of the upper member.

Taylor and collaborators (1983) formally defined the lithostratigraphic members that conform the Gabbs Formation: the Nun Mine member composed of interbedded mudstone, siltstone and black limestone whose lower contact is conformable with the underlying Luning Formation; the Mount

Hyatt member made up of interbedded silty to sandy bioclastic limestone with calcareous siltstone whose lower contact is apparently conformable with the Nun Mine member, and the Muller Canyon member composed mostly of sandy siltstone and interbedded gypsum.

Silberling and Tozer (1968) indicated that the "lower and middle members" of the Gabbs Formation in the Gabbs Valley Range, that are almost totally time-equivalent to the Nun Mine and Mount Hyatt members (Taylor *et al.,* 1983), contain fossils of the upper Norian. They assigned that fauna of the lower member of the Gabbs Formation to the Suessi Zone. The ammonoids of the "middle member" were considered as a typically Norian association present at an intermediate stratigraphic level between the Suessi and Marshi zones. They assigned the fauna of the "upper member" (partially equivalent to the Muller Canyon member) to the Rhaetian Marshi Zone.

Tozer (1980) indicated that the Suessi Zone could no longer be an integral zone because the characteristic species, *Rhabdoceras suessi*, occurs throughout the "upper Norian" = Rhaetian. He then referred the basal beds of the Gabbs Formation to the Amoenum Zone. The fauna from the "middle and upper members" of the Gabbs Formation was later correlated with the Crickmayi zone (Tozer, 1980).

COMPARATIVE ANALYSIS

When comparing the New York Canyon and Union District stratigraphic sections of the Luning Assemblage with the Antimonio Formation sections, a very notable structural difference stands out. As previously indicated, the Luning Assemblage is underlain by the Luning fault for which it is difficult to establish a relationship with the Paleozoic basement, except for the locality at the Shoshone Mountains where the Mesozoic sequence rests through an erosional unconformity over a volcanic and volcanogenic sequence of probable Permian age. On the other hand, the Antimonio Formation rests over the Upper Permian Monos Formation.

In Sonora, the presence of Spathian (Lower Triassic) and Anisian (Middle Triassic) ammonoids marks a very important difference from the ammonoid succession of the Luning Assemblage, where the oldest fauna indicates a Ladinian Middle Triassic age. The succession of Nevada is contained in a sequence (Grantsville Formation) considered to have resulted from an initial marine transgression whose deposition could have started in the Middle Triassic prior to the Late Triassic-Early Jurassic marine transgression (Silberling, 1959).

Spathian ammonoids in other parts of North America have been recorded in the Arctic Islands (Axel Heiberg, Ellesmere), the eastern Cordillera (northeastern British Columbia), southeastern Idaho, and the Humboldt Range, Nevada. In Nevada, the Spathian is well characterized by ammonoids; however, this locality forms part of the Humboldt lithotectonic assemblage. Anisian ammonoids occur also in the Arctic Islands (Ellesmere, Exmouth), the eastern Cordillera (northeastern British Columbia, Alberta) and the Humboldt Range, Nevada (Tozer, 1994; Tozer, 1971; Silberling and Tozer, 1968).

Other differences are noted. There seems to be little relationship between the ammonoid associations. In Sonora, it appears that there is no fauna correlatable with the Ladinian fauna of the shaly limestone member of the Luning Formation in the Union District section. In Sequence V of the Antimonio Formation the presence of the Nanseni (lower Carnian) and Dilleri (basal upper Carnian) zones has been established, these two zones have not yet been found in the Luning Assemblage according to the current biostratigraphic control. In the Union District section, the oldest strata that overlie the Ladinian fauna, hold ammonoids from the upper Carnian Welleri Zone. According to Silberling (1959), there is no sedimentary record of the early and middle Carnian in that area.

The biochronology for the Triassic based on ammonoids recognizes three zones for the lower Carnian: Desatoyense, Obesum and Nanseni (Tozer, 1994). The first zone is represented in New Pass Range, Nevada (Silberling, 1956; Silberling and Tozer, 1968). However, ammonoids from the other two zones, (type locality in Ewe Mountain, British Columbia) have not yet been identified in Nevada. Ammonoids from the upper Carnian basal zone (Dilleri Zone) were found in northwestern Nevada in the Humboldt Range (Silberling, 1961).

The faunal sequence identified for the Upper Triassic in the Union District section (Shoshone Mountains) is very complete. In ascending stratigraphic order it includes the Welleri, Macrolobatus (upper Carnian), Kerri and Magnus (lower Norian) zones; these zones are not represented in Sonora. It is important to note that in Nevada (Pilot Mountains) biostromes that contain the same species of corals and sponges as in Sonora, occur between the Kerri and Magnus (lower Norian) zones (Senowbari-Daryan and Stanley, 1992) whereas in Sonora these fossils are restricted to an interval belonging to the Columbianus? (middle Norian) and the Cordilleranus zones (upper Norian). In the Antimonio Formation, the Norian sequence probably contains the Columbianus zone and with certainty the Cordilleranus, Amoenum and Crickmayi zones. The first zone does not have an equivalent representative in the sections from Nevada discussed herein, but it is present in the Humboldt Range. The Cordilleranus Zone was documented in the Luning Assemblage in the Clan Alpine Mountains. Also, indicative ammonoids of the Amoenum and Crickmayi zones from both regions compared favorably, particularly for outcrops in the New York Canyon section. The Amoenum Zone was identified in the "lower" or Nun Mine member of the Gabbs Formation and is correlatable with the Antimonio Formation Package 2 fauna. In ascending order, we have the Crickmayi Zone in the Mount Hyatt and Muller Canyon members of the Gabbs Formation, whose ammonoids are correlatable with those from packages 3 and 4 of the Antimonio Formation. The Crickmayi zone is also represented in the

Union District section of the Shoshone Mountains. As González-León and collaborators (1996) noted, there is a paleontologic correspondence in the interval that comprises these zones in Sonora and Nevada. This correspondence, together with the similarity of the regressive events occurring at the top of the Amoenum Zone (González-León *et al.,* 1996), allows for a close correlation. However, this correlation is not so obvious for the rest of the Triassic section of the two regions being compared.

CONCLUSIONS

There are important structural, paleontologic and stratigraphic differences between the Triassic representative sections of the Luning Assemblage in Nevada and the Antimonio Formation of Sonora.

The lack of a Paleozoic basement at the Luning Assemblage compared to the Sonoran Antimonio Formation rocks that overlie the Upper Permian Monos Formation, constitutes a very important dissimilarity between the two regions.

Another noticeable difference is the depositional settings of the two sequences being compared. The one from the Luning Assemblage is considered as a back-arc environment whereas the Antimonio Formation is considered as a fore-arc setting (Stanley and González-León, 1995). Another dissimilarity is that the oldest stratigraphic sequence in the Antimonio Formation has been dated as Late Permian and Smithian in age, while the oldest sedimentary record in the Luning Assemblage corresponds to the Ladinian (Grantsville Formation). Ammonoids that characterize the Spathian and Anisian were found in the Antimonio Formation. However, no ammonoids from the Ladinian that would allow establishing a correlation with the Shoshone Mountains Luning Assemblage have been found. The ammonoids that characterize the Nanseni and Dilleri zones (lower Carnian and basal upper Carnian, respectively) in Sonora do not have any correlatives with the ammonoid succession of the Luning Assemblage.

The Welleri, Macrolobatus, Kerri and Magnus zones are not identified in Sonora, but they are represented in the Luning Formation of the Luning Assemblage. Furthermore, although the same species of corals and sponges occur between both the Luning Assemblage and the Antimonio sequence in Sonora, they are not contemporaneous. At the Luning Assemblage they occur at an older level between the Kerri and Magnus zones.

Representative ammonoids of the Columbianus, Cordilleranus, Amoenum and Crickmayi zones have been identified in the Antimonio stratigraphic sequence, but only the Amoenum and Crickmayi zones can be closely correlated with Nevada. The first one occurs in the Nun Mine member of the Gabbs Formation and correlates with Package 2 of the Antimonio Formation, and the second one may be recognized in the Mount Hyatt and Muller Canyon members of the Gabbs Formation and correlates with packages 3 and 4 of the Antimonio Formation.

Detailed comparisons between the Luning Assemblage sections and those of the Antimonio Formation reflect a large number of important dissimilarities, which indicate that the Luning Assemblage sections are not ideally correlated with the Antimonio sequence. Therefore, they do not provide support to the possible tectonic reconstruction proposed by Stanley and González-León (1995) which considered that rocks from the Luning Assemblage at the northwestern end of the Great Basin were displaced 800 to 1,000 km toward the southwest during the middle-Late Jurassic to its present position in Sonora.

More geochemical, tectonic, paleontologic and stratigraphic research must be conducted in Nevada, southeast California and Sonora to develop other possible paleotectonic and paleogeographic interpretations, in order to gain a deeper insight into the evolution of the southwestern margin of the North American Craton.

ACKNOWLEDGMENTS

The authors wish to thank Carlos González-León for his support during the fieldwork done at the Antimonio Sequence in Sonora through CONACYT grant 3934, for his advice concerning the geological aspects as well as for his review to improve this paper. Also we want to express our acknowledgment to Tim Tozer by his comments and critical review to the paper.

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