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MICROFACIES AND MICROFOSSIL ASSEMBLAGES (SMALLER FORAMINIFERS, ALGAE, PSEUDOALGAE) OF THE HUECO GROUP AND LABORCITA FORMATION (UPPER PENNSYLVANIAN-LOWER PERMIAN), SOUTH-CENTRAL NEW MEXICO, USA

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Abstract. During the latest Carboniferous and earliest Permian (Virgilian - Wolfcampian), the eastern margin of the Orogrande Basin in south-central New Mexico was rimmed by a narrow, tectonically unstable shelf, on which sediments of the Laborcita and Abo formations were deposited. Sediments of the Hueco Group accumulated on the more stable western margin of the Orogrande Basin.

On the eastern shelf, the Laborcita Formation of the northern Sacramento Mountains represents a transition from marine to terrestrial facies and is composed of clastic-carbonate cycles. Limestones accumulated during relative sea-level highstands in a shallow marine shelf environment. Clastic sediments were deposited during relative sea-level lowstands when there was strong clastic influx in a nearshore to terrestrial environment. The overlying Abo Formation is composed of terrestrial red beds.

On the western shelf, the Shalem Colony Formation of the Hueco Group, equivalent to the Laborcita Formation, is composed of mostly normal marine shallow shelf limestones with only minor interbedded clastics. The Robledo Mountains Formation of the Hueco Group reflects a trend from a restricted shallow shelf and tidal flat clastics facies in the lower part to more open marine conditions in the upper part, which also prevailed during deposition of the overlying Apache Dam Formation.

Limestones of the Laborcita Formation and Hueco Group contain smaller foraminifers, algae and problematic carbonate microfossils. All taxa except two pseudoalgae in open nomenclature (*Litostroma* (?) sp. and "problematicum gen. 1") are taxa already described. Compared with the Carnic Alps (Austria/Italy), the assemblages of smaller foraminifers of the Laborcita Formation and Shalem Colony Formation are very similar to those of the Auernig and Carnizza Formations (Auernig Group), and Lower Pseudoschwagerina Limestone (Rattendorf Group), indicating an Orenburgian ("Bursumian") to Asselian age. Smaller foraminifers of the Robledo Mountains Formation allow correlation with the Grenzland Formation and Upper Pseudoschwagerina Limestone (Rattendorf Group) of the Carnic Alps, dated as Asselian to Sakmarian. Smaller foraminifers of the Apache Dam Formation suggest an Artinskian age, correlating with the Wolfcampian, or the Trogkofel Group of the Carnic Alps.

Riassunto. Il margine orientale del Orogrande Basin nel New Mexico centro-meridionale, durante il Carbonifero terminale e nel Permiano inferore, fu orlato da una stretta piattaforma, tettonicamente instabile. Su di essa si depositarono i sedimenti delle formazioni Laborcita and Abo. Invece i sedimenti del Gruppo Hueco si accumularono sul margine occidentale, più stabile, del Orogrande Basin.

Sulla piattaforma orientale, la Formazione Laborcita della parte settentrionale delle Sacramento Mountains rappresenta la transizione dalle facies marine a quelle continentali ed è costituita da cicli carbonato-clastici. I calcari si accumulavano durante gli intervalli di stazionamento alto in condizioni di piattaforma marina poco profonda. I sedimenti clastici si accumulavano durante gli intervalli di stazionamento basso, quando l'influsso terrigeno era più sensibile negli ambienti vicini alla costa o continentali. La sovrastante Formazione Abo è formata da red beds continentali.

Sulla piattaforma occidentale, la Formazione Shalem Colony del Gruppo Hueco, equivalente della Formazione Laborcita, è formata in prevalenza da calcari di piattaforma marina poco profonda, con minori intercalazioni terrigene. La Formazione Robledo Mountains del Gruppo Hueco riflette la tendenza da condizioni di piattaforma confinata e piane tidali terrigene nella parte inferiore, a condizioni di mare più aperto nella parte superiore, che pure prevalsero durante la deposizione della soprastante Formazione Apache Dam.

I calcari della Formazione Laborcita e del Gruppo Hueco contengono piccoli foraminiferi, alghe e microfossili calcarei problematici. Tutti i taxa, ad eccezione di due pseudoalghe lasciate in nomenclatura aperta (*Litostroma* (?) sp. e "problematicum gen. 1") sono forme già descritte in letteratura. Operando un confronto con quelle delle Alpi Carniche (Italia/Austria), le associazioni a piccoli foraminiferi delle formazioni Laborcita e Shalem Colony sono molto simili a quelle delle formazioni Auernig e Carnizza (Gruppo dell'Auernig), e del Calcare a Pseudoschwagerina Inferiore (Gruppo di Rattendorf), indicando quindi un'età da Orenburgiana ("Bursumian") ad Asseliana. I piccoli foraminiferi della Formazione Robledo Mountains consentono la correlazione con la Formazione Grenzland e il Calcare a Pseudoschwagerina Superiore (Gruppo di Rattendorf) delle Alpi Carniche, che vengono riferirite all'Asseliano e Sakmariano. I piccoli foraminiferi della Formazione Apache Dam suggeriscono un'età Artinskiana e si possono correlare con il Wolfcampiano, o il Gruppo del Trogkofel delle Alpi Carniche.

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Introduction

In New Mexico, uppermost Pennsylvanian and lowermost Permian strata record a transition from a marine environment represented mostly by marine shelfal limestones of the Madera Group, to a terrestrial environment represented by red beds of the Abo Formation reflecting increased tectonic activity of the Ancestral Rocky Mountain orogeny.

In many sections of central New Mexico, transitional beds of latest Pennsylvanian to early Wolfcampian age, termed Bursum Formation, occur between the marine carbonates and the nonmarine red beds. In the northern Sacramento Mountains, these transitional beds are represented by the Laborcita Formation. In the Robledo Mountains, Bursum-equivalent limestones are included in the lowermost part of the Hueco Group (Wahlman & King 2002). Throughout south-central New Mexico, Abo terrestrial red beds prograde southward and interfinger with marine limestones of the Hueco Group.

Whereas fusulinids from these Upper Pennsylvanian and Lower Permian limestones have been studied quite extensively (e.g. Needham 1937; Thompson 1954; Skinner & Wilde 1965; Williams 1966; Steiner & Williams 1968; Wilde 1975; Ross 1984; Myers 1988; Ross & Ross 1994; Spencer & Ross 1997; Lucas 1995; Lucas et al. 2000; Lucas & Wilde 2000; Wahlman & King 2002), little is known about smaller foraminifers (Toomey et al. 1977), which have been studied in other North American paleoprovinces (Toomey 1974; Groves & Wahlman 1997; Pinard & Mamet 1998; Groves & Boardman 1999; Groves 2000). Some algae from New Mexico were illustrated and discussed by Toomey et al. (1977) and Wahlman (1988).

The aims of the paper are (1) to present a microfacies analysis, (2) to discuss the depositional environments, (3) to describe the smaller foraminifers, some algae and pseudoalgae, and (4) to discuss the stratigraphy of the Laborcita Formation of the northern Sacramento Mountains and part of the Hueco Group (Shalem Colony Formation and Robledo Mountains Formation) of the Robledo Mountains, and (5) to correlate these sequences with the late Paleozoic succession of the Carnic Alps (Austria/Italy). This study illustrates again the relative paucity and the low diversity of North American smaller foraminifers and calcareous algae compared to the Tethyan region. The correlations proposed by Davydov (1996) for the Virgilian, "Bursumian" and Wolfcampian are confirmed by comparison of material from New Mexico and the Carnic Alps (Vachard & Krainer 2001 a, b).

Location and methods

The Laborcita Formation was studied in the northern Sacramento Mountains at the type locality at

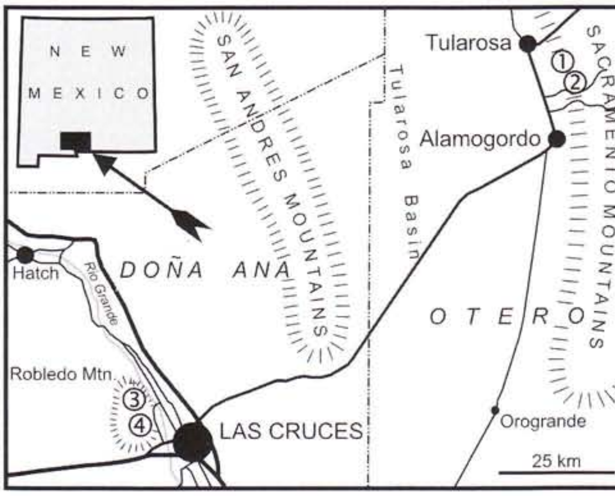


Fig. 1 - Map of part of southern New Mexico showing locations of the studied sections in the northern Sacramento Mountains (1 Laborcita Canyon, 2 Fresnal Canyon) and Robledo Mountains (3 Robledo Peak, 4 north of Picacho Mountain).

Laborcita Canyon northeast of La Luz and along a road in Fresnal Canyon east of La Luz (north of Alamogordo; Fig. 1). UTM coordinates (NAD 27 datum) for Laborcita Canyon are 413240E, 3652756N, zone 13 (base of section) and 414595E, 3652131N, zone 13 (top of section). For Fresnal Canyon the UTM coordinates are 414536E, 3649595N, zone 13 (base of section) and 414733E, 3649563N, zone 13 (top of section). Samples were also collected from the Laborcita Formation at Scorpion Mound in Tularosa Canyon, and from the underlying Holder Formation at Dry Canyon.

We investigated limestones of the lower Hueco Group (Shalem Colony Formation and Robledo Mountains Formation) in the Robledo Mountains (Figs. 2, 3). There, we studied an almost complete section that encompasses the Pennsylvanian-Permian boundary and corresponds to the upper part of the Bursum equivalent and the lower part of the Hueco Group (section L of Wahlman & King 2002). This section (Robledo Mountain A on Fig. 3) is exposed just west of Robledo Mountain (location 3 on Fig. 1) and is assigned to the lower part of the Shalem Colony Formation. The coordinates for Robledo Mountain A are 318270E, 3590149N (base of section) and 318291E, 3589563N (top of section), zone 13.

We measured another section about 500 m W of Robledo Peak, which is correlated to the upper part of the Shalem Colony Formation at Robledo Mountain (Robledo Mountain B); coordinates are 318291E, 3589563N (base of section), and 318241E, 3589538N (top of section), zone 13 (location 3 on Fig. 1, section B on Fig. 3).

Limestones from the Robledo Mountains Formation and the lowermost part of the Apache Dam Formation were studied at outcrops about 3.2 km north of

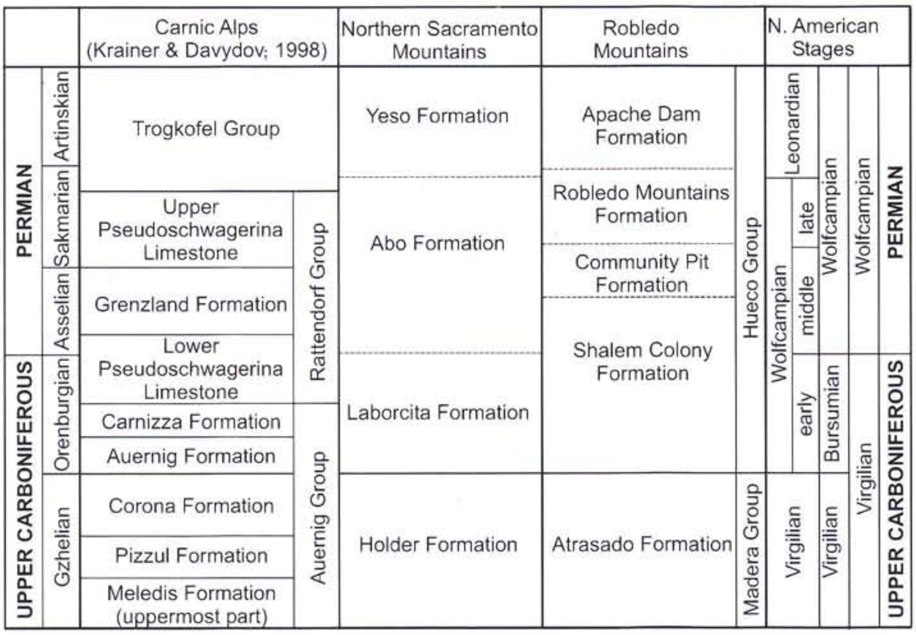


Fig. 2 - Stratigraphic correlation of Late Pennsylvanian and Early Permian strata of the northern Sacramento Mountains, Robledo Mountains (New Mexico, USA) and Carnic Alps (Austria/Italy).

Picacho Peak (ca. 11 km northeast of Las Cruces; sections A, B, and C of Krainer & Lucas 1995).

The sections mentioned above were measured and sampled in detail, and a total of 243 large thin sections were prepared for microfacies analysis and the determination of smaller foraminifers, algae and pseudoalgae.

In the Robledo Mountains, Pennsylvanian limestones below the Hueco Group are attributed to the Atrasado Formation of the Madera Group by Kues (2001). Limestones of the Madera and Hueco Groups exposed in the Robledo Mountains were deposited on the Robledo shelf between the Florida uplift to the west and Orogrande Basin to the east.

Chronostratigraphy

The main chronostratigraphical problem addressed here is the interpretation and correlation of the "Bursumian"-Wolfcampian with the Gzhelian, the Permo-Carboniferous boundary, and the Cisuralian of the Urals and the Carnic Alps.

The Carboniferous (Pennsylvanian)/Permian boundary in North America (classically equivalent to the Virgilian/Wolfcampian boundary) has been studied by many authors, using, for example, the ranges of the fusulinaceans *Triticites, Leptotriticites, "Schwagerina"* and *Pseudoschwagerina*: e.g., Thompson (1954), Ross (1984), Wilde (1975, 1990), Wardlaw & Davydov (2000), Ross & Ross (1994), and Lucas & Wilde (2000) among others. However, the newly defined GSSP for the Carboniferous-Permian boundary places this boundary within the North American Wolfcampian. This means that the Carboniferous-Permian boundary no longer corresponds to a stage boundary on the North American scale. Two solutions have been advocated, either extend the Virgilian upward to the new system boundary or create a new stage ("Bursumian") for the early Wolfcampian interval that is now Carboniferous (Fig. 2).

Recognition of a "longer" Virgilian in the Midcontinent (Baars et al. 1992; 1994a, b; Barrick & Heckel 2000) so that it partly corresponds to what were formerly lower Wolfcampian deposits (Thompson 1954; Wilde 1975, 1990) is controversial (Lucas & Wilde 2000). The designation of the early Wolfcampian as a "Bursumian" stage is justified by fusulinacean biostratigraphy (Ross & Ross 1994; Davydov 1996; Wardlaw & Davydov 2000). However, if the Bursumian correlates to an Orenburgian/Asselian interval (Davydov 1996), the Carboniferous/Permian boundary crosses through the "Bursumian" (Wardlaw & Davydov 2000).

The Bursum Formation was established by Wilpolt et al. (1946), and used extensively by Thompson (1954). Although not mentioned by Ross (1984), the name "Bursumian" appears in Ross & Ross (1987) and was first correlated with the *Daixina sokensis* fusulinid zone on the Russian platform. According to Wilde (1990), the "Bursumian" represents the first zone, PW-1, of the Wolfcampian stage. Ross & Ross (1994) advocated the necessity of a "Bursumian" stage for the North American stratigraphic scale. Davydov (1996) detailed the correlation of the "Bursumian" and Wolfcampian with the Orenburgian, Asselian, Sakmarian and Artinskian. Lucas and Wilde (2000) considered the "Bursumian" as the upper part of the *Ultradaixina* (*Bosbytauella*) zone, which was initially interpreted as the base of the Permian (Chuvashov et al. 1986).

Lucas et al. (2000) demonstrated that the fusulinid fauna of the Bursum type section is characteristic of the early Wolfcampian, and that the distribution of the fusulinid fauna of the type section indicates that the base of the lithostratigraphic unit Bursum Formation does not correspond to the base of a fusulinid zone. The base of a "Bursumian" stage, if it corresponds to a fusulinid zone, lies stratigraphically lower, within the Madera Group. The problem of the "Bursumian" stage is discussed in length by Davydov (2001) and Lucas et al. (2002), who list a number of reasons to abandon the "Bursumian" stage.

Our investigations of smaller foraminifers in New Mexico confirm that "Bursumian" and Orenburgian are coeval, as previously indicated on the basis of conodonts and fusulinids by Chernyk & Ritter (1994), Davydov (1996), Nilsson & Davydov (1997), Davydov et al. (1997), Davydov & Nilsson (1999), and Wardlaw & Davydov (2000). Our data also support Davydov´s (1996) conclusion that the Wolfcampian stage corresponds more or less to the Asselian, Sakmarian and Artinskian stages of the international Cisuralian series (see Fig. 2).

Hueco Group

The term Hueco limestone was established by Richardson (1904) as a sequence up to 1500 m thick, composed mainly of massive, fossiliferous limestone, and locally including beds of shale and sandstone. It was named after the Hueco Mountains in El Paso County, West Texas.

Later, this thick sequence was divided into the Helms Formation (Mississippian), the Magdalena Limestone (Pennsylvanian) and an unconformably overlying sequence termed Hueco Limestone. According to King (1942), the Hueco Limestone includes all beds above the unconformity at the top of the Magdalena Limestone, up to the highest occurrence of *Pseudoschwagerina* and associated fossils.

In the Robledo Mountains, Thompson (1954) recorded an early Wolfcampian fusulinid fauna containing species of *Dunbarinella* (now *Leptotriticites*) and a species of *Pseudofusulina* (now *Stewartina*, a dainellid taxon) from limestones he referred to the Bursum Formation, which are underlain by limestones of what he termed the Fresnal (= Madera) Group and overlain by Hueco Limestone. Jordan (1975) divided the Hueco Limestone of the Robledo Mountains into four subunits: two limestone subunits below the Abo tongue (lower and middle member), red beds of the Abo tongue, and Hueco Limestone above the Abo tongue (upper member). Lucas et al. (1998 a, b) revised the stratigraphy of the Hueco Limestone by raising the Hueco to group status and renaming the members of Jordan (1975) as Shalem Colony Formation, Community Pit Formation, Robledo Mountains Formation, and Apache Dam Formation from base to top (see also Cook et al. 1998). The total thickness of the Hueco Group in the Robledo Mountains is 491 m. Krainer et al. (2000) confirmed that there is no lithologic basis for identifying the Bursum Formation in the Robledo Mountains and that the "Bursum" interval of Thompson (1954) should be assigned to the Hueco Group. Limestones referred to the Bursum equivalent, which are dated as "Bursumian" (latest Pennsylvanian) by Wahlman & King (2002), are included in the Shalem Colony Formation sensu Lucas et al. (1998b).

Facies of the Shalem Colony Formation at Robledo Peak

In the Robledo Mountains, section A represents the lower part, and section B the upper part of the Shalem Colony Formation (see Fig. 3).

Section A (lower Shalem Colony Formation): Section A is 56.5 m thick and is assigned to the Hueco Limestone of Thompson (1954, fig. 8). The sequence starts on top of a several meter thick cliff formed of massive limestone of the uppermost Atrasado Formation (Fig. 3). The lower part (0 - 29 m) is composed of different types of gray, bedded limestones, nodular limestones and intercalated reddish marly shale with limestone nodules. The upper part (29 - 56.5 m) consists of indistinctly bedded, laminated limestone, locally bioturbated, dm-bedded limestone, algal limestone, nodular limestone and intercalated grainstone beds, all gray colored.

Limestones are mostly composed of different types of wackestones, all being nonlaminated, bioturbated and poorly sorted. Bioclastic wackestone is most abundant and contains a diverse biota, including fragments derived from bivalves, brachiopods, gastropods, echinoderms, bryozoans, ostracods, fusulinids, smaller foraminifers, rare brachiopod spines, trilobite fragments and *Spirorbis*. Among the calcareous algae, recrystallized phylloid algal fragments are most abundant; *Epimastopora*, ?*Anthracoporella* and *Eflugelia* are subordinate. Locally, bioclasts, particularly shell fragments, are microbially encrusted and contain a few sessile foraminifers, forming small oncoids (oncoidal wackestone). Micritic intraclasts are rare. The matrix is micrite, and frequently pelmicrite with abundant small peloids forming bioclastic peloidal wackestone.

Fusulinid wackestone composed of abundant fusulinid tests and some other bioclasts is rare. Algal wackestone occurs in the upper part of the section and is composed of abundant large, completely recrystallized fragments of phylloid algae, which are embedded in a micritic and pelmicritic matrix. Ostracods, bryozoans and smaller foraminifers are rare in this microfacies.

Peloidal wackestone, locally grading into grainstone, is recognized in the middle part of the section. This microfacies contains abundant calcivertellid foraminifers, some ostracods and a few larger shell fragments, a pelmicritic matrix and microspar cement, and

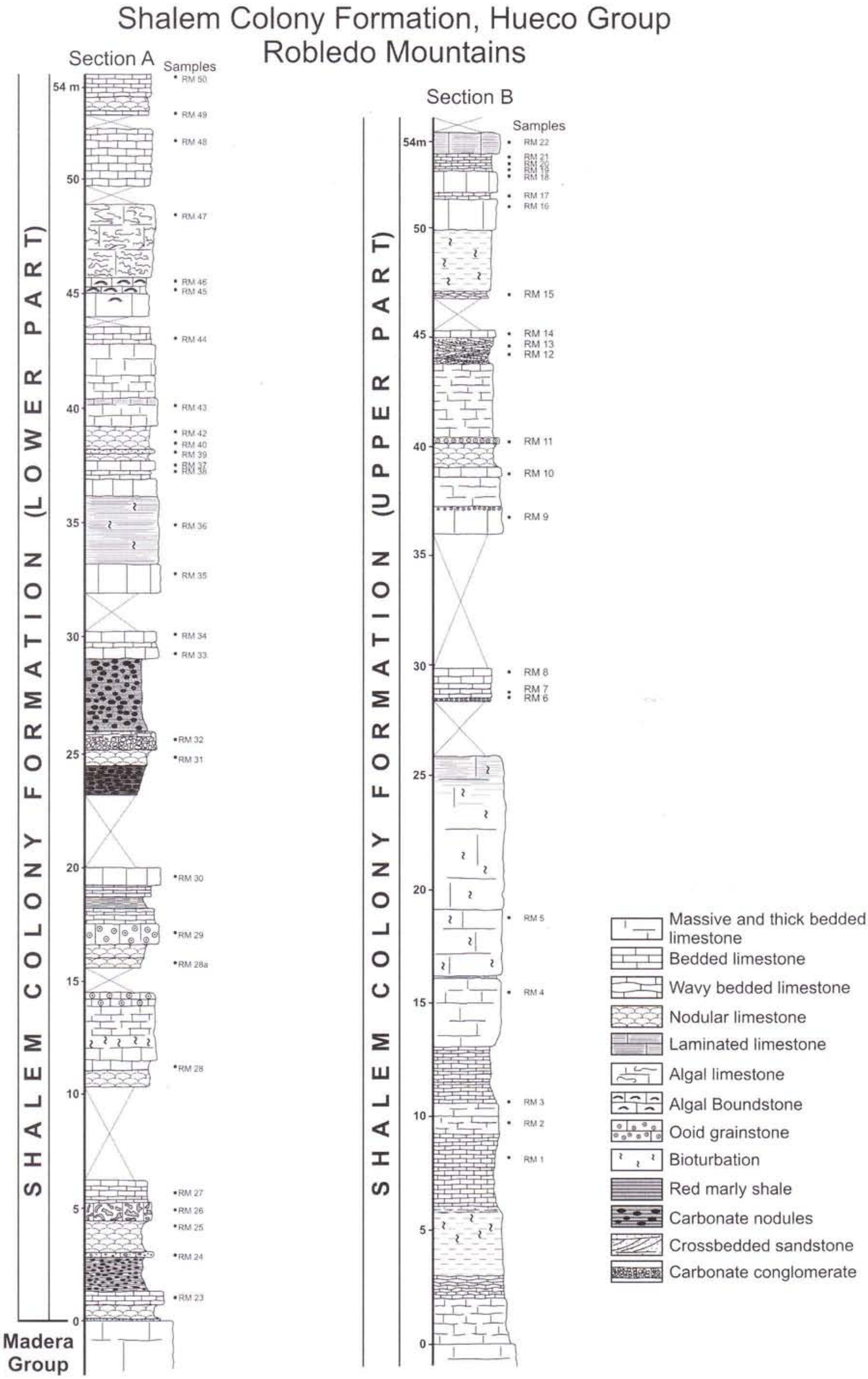


Fig. 3 - Measured stratigraphic sections through the lower part (section A) and upper part (section B) of the Shalem Colony Formation (Hueco Group) at Robledo Peak (location see Fig. 1).

locally a few siliciclastic grains. This microfacies is interbedded with boundstone composed of irregular crusts formed of cyanobacteria, pelmicrite, sparry calcite and a few bioclasts.

Grainstones are subordinate in the section, passing into wackestone as well as packstone. Bioclastic grainstone is poorly sorted and cemented by sparry calcite, and contains a biota similar to that of the bioclastic wackestones (Pl. 1, fig. 1). A few micritic intraclasts are present, too. Many of the bioclasts and intraclasts are surrounded by micrite envelopes, and some are encrusted by cyanobacteria and sessile foraminifers. Locally, the matrix contains abundant small peloids and some micrite, forming a bioclastic peloidal grainstone.

In the upper part of the section, at the base of the massive algal limestone (biostrome), boundstones formed of algal crusts are developed (Pl. 1, fig. 6). The algal crusts consist of *Archaeolithophyllum lamellosum*, *Archaeolithoporella*, some other algae, and calcivertellid foraminifers. Between these algal laminae there is an inhomogenous micritic matrix containing fragments of molluscs, bryozoans, echinoderms, ostracods and abundant smaller foraminifers. Individual crusts are up to several cm thick.

Section B (Upper Shalem Colony Formation): Section B (Fig. 3) is located about 500 m west of section A (western Robledo Peak). The measured section is 54.5 m thick and starts above a massive limestone cliff. The lower 26 m are composed of wavy and nodular, gray micritic limestone, laminated and partly bioturbated gray limestone, and indistinctly bedded to massive gray limestone, composed of wackestone, packstone and grainstone. Bioclastic wackestone contains a diverse biota, small peloids and micrite, and locally grades into packstone. Some bioclasts display micrite envelopes. In peloidal packstones a few ostracod shells are the only fossil constituents.

Grainstones are poorly sorted, nonlaminated, and cemented by sparry calcite. Constituents are micritic intraclasts, shell debris, algal fragments, ostracods, a few tuberitinid foraminifers and *Spirorbis*. Micrite envelopes occur around intraclasts and bioclasts. Locally, thin coatings and layers of cyanobacteria forming bindstone are present.

Oolitic grainstone is well sorted, indistinctly bedded and composed of single ooids formed of large nuclei and relatively thin cortices (Pl. 1, fig. 7). Average grain size of the ooids is 0.2 mm. The nuclei of most ooids are recrystallized fossil fragments; in some ooids, the cortices display radial structures. A few shell fragments are present.

Above a 2.5-m-thick covered interval, bedded gray limestones are exposed. The lowermost bed is an oolitic limestone, overlain by fossiliferous limestones composed of algal wackestone and bioclastic grainstone/packstone.

Algal wackestone is composed of large, in most cases, completely recrystallized fragments of phylloid algae, which are embedded in a micritic and pelmicritic, bioturbated matrix. In addition, diverse shell fragments, ostracods, gastropods, trilobite fragments, smaller foraminifers and rare fusulinids are present.

Bioclastic grainstone/packstone contains large amounts of smaller foraminifers, particularly calcivertellid forms. Other bioclasts include shell fragments, ostracods, echinoderms, bryozoans and trilobite fragments. A few detrital quartz grains are present.

The uppermost 19.5 m of section B consist of gray, bedded, micritic limestone with varying bed thickness (from a few cm up to 1.4 m), laminated and partly bioturbated limestone, nodular limestone, thin oolitic limestone beds and a 1.2 m thick interval of crossbedded, pebbly sandstone composed of siliciclastic grains

PLATE 1

Thin section photomicrographs of characteristic microfacies types of the Shalem Colony Formation at Robledo Mountain. Plane polarized light, width of Fig. 1 - Fig. 4 = 6 mm, width of Fig. 5 - Fig. 7 = 4.3 mm. For position of the samples in the section see Fig. 3.

Fig. 1 - Grainstone, poorly sorted, containing abundant calcivertellid foraminifers and peloids, subordinate gastropods, ostracods and echinoderms and micritic intraclasts. Shalem Colony Formation, Section A, sample RM 50.

Fig. 2 - Fusulinid wackestone composed of abundant fusulinid tests (*Triticites*), subordinate are echinoderms, smaller foraminifers and ostracods. The matrix consists of micrite. Shalem Colony Formation, Section A, sample RM 28.

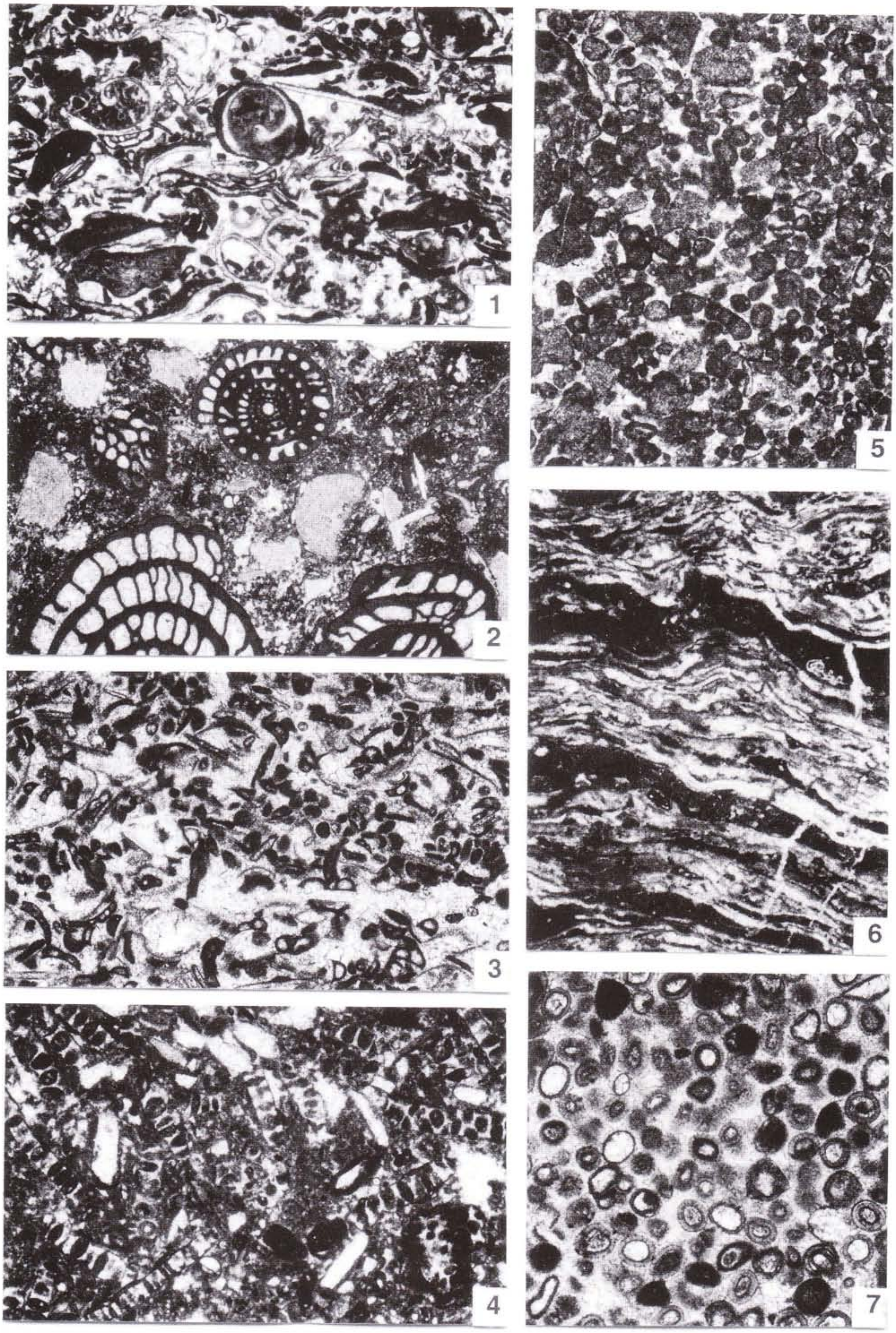
Fig. 3 - Grainstone composed of abundant peloids, calcivertellid foraminifers and calcite cement. Shalem Colony Formation, Section B, sample RM 22.

Fig. 4 - Algal wackestone/packstone composed of abundant fragments of *Epimastopora*. Some recrystallized phylloid algae also occur. The matrix is micrite. Shalem Colony Formation, Section B, sample RM 9.

Fig. 5 - Grainstone/packstone composed of abundant micritic intraclasts with dark gray micrite envelopes and rare bioclasts (ostracods). Shalem Colony Formation, Section B, sample RM 17.

Fig. 6 - Algal boundstone formed of algal crusts (*Archaeolithophyllum lamellosum*) and rare calcivertellid foraminifers. Shalem Colony Formation, Section A, sample RM 45.

Fig. 7 - Oolitic grainstone, well sorted, cemented by sparry calcite. Some ooids are micritized. Shalem Colony Formation, Section B, sample RM 5.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cemented by calcite. The limestones of this unit are composed of different microfacies, particularly wackestone, packstone and grainstone, and rarely of boundstone.

Bioclastic wackestone, locally grading into floatstone, is poorly sorted and contains a diverse fossil assemblage composed of large, recrystallized fragments derived from brachiopods, bivalves, gastropods, echinoderm remains, broken fragments of recrystallized phylloid algae, locally abundant small fragments of *Epimastopora alpina* and another species of *Epimastopora*, ostracods, echinoderm spines, trilobite fragments, and many smaller foraminifers (mostly calcivertellids). Many bioclasts are encrusted by cyanobacteria and *Palaeonubecularia*, forming oncoid-like clasts. The matrix consists of pelmicrite; locally, some calcite cement is present.

Algal wackestone is poorly sorted and consists of abundant fragments of *Epimastopora*, and subordinately of recrystallized phylloid algal plates, echinoderm remains, gastropods, fusulinids, ostracods, smaller foraminifers, and brachiopod fragments (Pl. 1, fig. 4).

Packstone consists of abundant shell fragments, gastropods, calcareous algae (rare *Epimastopora*), bryozoans, ostracods, smaller foraminifers and fusulinids, abundant rounded, recrystallized and micritic lithoclasts (intraclasts) with dark gray micrite envelopes, calcite cement, and a micritic matrix.

Different types of grainstone have been recognized (Pl. 1, figs. 1, 3, 5). One type is poorly sorted and composed of recrystallized ooids, micritic intraclasts, a few detrital quartz grains (mono- and polycrystalline quartz) and abundant bioclasts, including shell fragments, phylloid algae, *Epimastopora* (rare), echinoderms, gastropods, fusulinids, ostracods, echinoid spines, and bryozoans. The matrix is composed of sparry calcite cement, and locally of micrite and pelmicrite. Many clasts display micritic envelopes.

Oncolitic grainstone is also poorly sorted and consists of abundant oncoids (mostly 1 - 4 mm in diameter). The nuclei are formed of bioclasts, which are encrusted by cyanobacteria.

Bioclasts are shell fragments, echinoderms, gastropods, smaller foraminifers, ostracods, and bryozoans (almost all are encrusted to form oncoids). A few small detrital quartz grains are present, and rare, larger sedimentary chert fragments have also been observed.

Indistinctly bedded grainstone composed of alternating thin layers rich in bioclasts (cemented by calcite spar), peloids or smaller foraminifers (mostly calcivertellids and some tuberitinids) also occur (Pl. 1, fig. 1).

Intraclast grainstone/packstone, moderately to poorly sorted, cemented by calcite spar, and locally containing some micrite, is present (Pl. 1, fig. 5). Most lithoclasts are micritic to microsparitic in composition and display thin, dark gray micrite envelopes. Bioclasts are rare, and are mostly ostracod shells and a few other shell fragments. Some ooids are present. This microfacies is indistinctly bedded, with alternating coarser and finer grained layers.

Fine-grained, bioturbated peloidal grainstone composed mostly of peloids and smaller foraminifers (mostly sessile calcivertellid forms), ostracod shells and a few other shell fragments rarely occurs. A few micritic intraclasts are present, too.

The boundstone is composed of encrusting layers of cyanobacteria with a hemispheroidal growth form. Between the crusts, pelsparitic sediment is present. The boundstone is overlain by a grainstone composed of reworked crusts and peloids that are cemented by calcite.

The sandstone horizon consists of medium- and very coarse-grained, mixed siliciclastic and carbonate sandstone. Both sandstone types are composed of carbonate clasts (micritic intraclasts), ooids and bioclasts (shell fragments, echinoderm remains, rare algal fragments, fusulinids and smaller foraminifers). Siliciclastic grains are abundant polycrystalline quartz, including some stretched metamorphic quartz grains; monocrystalline quartz, sedimentary chert and rare detrital feldspars are subordinate. Siliciclastic grains are subangular to subrounded. The sandstone is indistinctly bedded, moderately sorted and cemented by calcite; diagenetic chert/microquartz cement is present.

Facies of the Robledo Mountains Formation and lower Apache Dam Formation near Picacho Peak

The Robledo Mountains Formation is 125 m thick and consists of limestones that are cyclically interbedded with siliciclastic sediments. The limestone facies of this formation was described in detail by Krainer & Lucas (1995); a detailed description of the clastic facies is presented by Mack and James (1986), and a summary is given by Lucas et al. (1998a, b).

According to Krainer & Lucas (1995), limestones of the Robledo Mountains Formation are mostly composed of different types of wackestone and packstone (ostracodal wackestone/packstone, foraminiferal wackestone/packstone, bioclastic wackestone/packstone), subordinate mudstone, bioclastic mudstone, grainstone (foraminiferal and bioclastic grainstone) and rare bindstone.

Limestones dominated by smaller foraminifers and ostracods are more abundant in the lower part, whereas limestones containing a more diverse fossil assemblage are predominant in the middle and upper parts. This reflects a trend from a shallow shelf environment with restricted circulation and, locally, a probable brackish water environment in the lower part to more

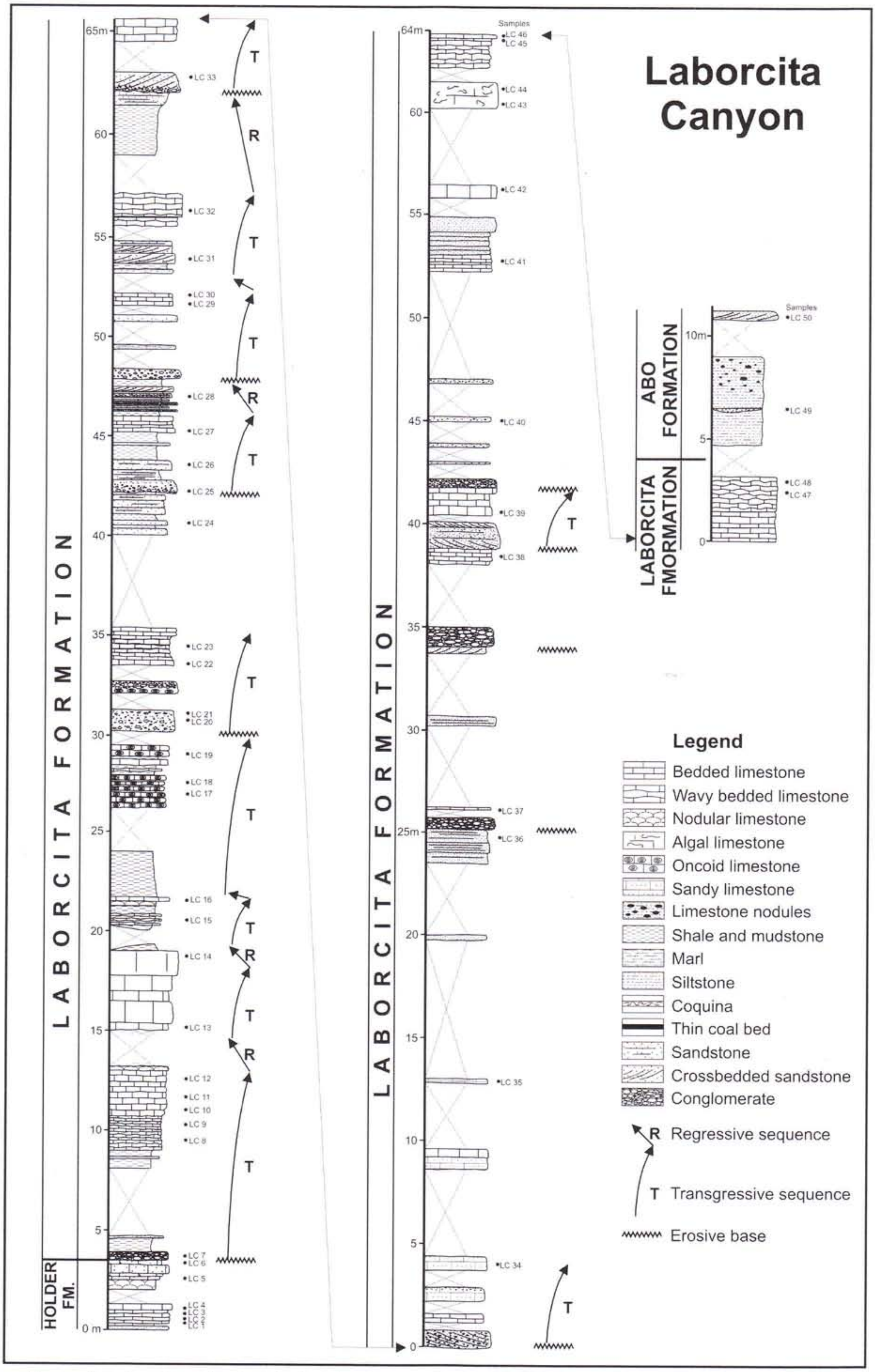


Fig. 4 - Measured stratigraphic section through the Laborcita Formation at Laborcita Canyon (type section; location see Fig. 1).

open marine conditions with normal salinity in the middle and upper parts of the formation. Siliciclastic red beds contain extensive invertebrate and vertebrate trace fossils, particularly tetrapod footprints, and represent a tidal flat environment (Lucas et al. 1995, 1998b). The overlying Apache Dam Formation is composed of shallow marine shelf limestones and siltstones.

We studied thin sections from limestones of the Robledo Mountains Formation and lower part of the Apache Dam Formation (sections A, B, and C of Lucas et al. 1995, 1998b; Krainer and Lucas 1995). Sample numbers in this paper refer to the sections of Krainer & Lucas (1995).

Laborcita Formation

The term Laborcita Formation was established by Otté (1959) for sedimentary rocks composed largely of gray and red mudstone, gray limestone, sandstone and conglomerate. The Laborcita Formation is exposed in the northern Sacramento Mountains, between the underlying Holder Formation and overlying red beds of the Abo Formation. At the type locality, the thickness is 146 m according to Otté (1959). The boundary between the Laborcita and Abo formations is drawn at the top of the highest marine limestone of the Laborcita Formation.

The different lithotypes of the Laborcita Formation are arranged to form alternating cycles of limestone and siliciclastic sedimentary rocks (Fig. 4). Otté (1959) pointed out that these lithologies change abruptly laterally and do not extend over long distances.

The Laborcita Formation is interpreted to consist of cyclic sequences of terrestrial to transitional marine siliciclastics and shallow marine carbonates that were deposited on a narrow shelf between the Orogrande basin to the west and the Pedernal landmass to the east during Early Permian time (Otté 1959; Delgado 1977; Fly 1986). Particularly well studied are the algal reefs (mounds), which occur in the middle member of the Laborcita Formation (Otté & Parks 1963; Cys & Mazullo 1977; Parks 1977; Mazullo & Cys 1979; Cross & Klosterman 1981; Bowsher 1986; Mazullo 1988). Like the Bursum Formation, the Laborcita Formation, which is composed of carbonate and clastic rocks, represents a transitional facies between the dominantly carbonate and marine strata of the underlying Holder Formation and the terrestrial red beds of the overlying Abo Formation.

The lower part of the Laborcita Formation at the type locality was considered late Virgilian in age by Otté (1959). He drew the base of the Wolfcampian at the base of the first limestone bed containing the fusulinid *Schwagerina* (probably *Thompsonites*), which is about 26 m above the base of the formation. Steiner & Williams (1968) restudied the fusulinid fauna, concluding that the Laborcita Formation is wholly Wolfcampian in age.

Rasbury et al. (1998) estimated the Pennsylvanian-Permian and Carboniferous-Permian boundaries within the Laborcita Formation of the Sacramento Mountains by U-Pb-dating of paleosols from the underlying Holder Formation (Goldstein 1988, 1991) and using classical linear least-squares fitting of sample age versus cycle number. They determined the Pennsylvanian-Permian boundary at 302 ± 2.4 Ma and the Carboniferous-Permian boundary at 301 ± 2 Ma. Rasbury et al. (1998) state that there is biostratigraphic control on the position of the boundaries, but they did not mention on which biostratigraphic zonation their estimations are based.

The Laborcita Formation at Laborcita Canyon (approximately 130 m thick according to our measurements; Fig. 4) and Fresnal Canyon (thickness of the measured section 106 m; Fig. 5) is composed of alternating carbonate and siliciclastic lithotypes. These lithotypes are arranged to form cycles recognizable in the lower part of both sections.

An ideal cycle begins with a conglomerate at the base, grades upward into alternating sandstone, siltstone and shale, and culminates in thin- and thick-bedded fossiliferous limestone, indicating a deepening upward trend (transgressive cycles). Grainstone on top of some limestones, overlain by greenish-gray shale, indicates the beginning of a regressional event, although shallowing upward (regressive) cycles are rare and very thin. Most cycles are composed of shale with intercalated sandstone and siltstone, overlain by thin, wavy to nodular bedded limestone, and thicker limestone beds on top.

Conglomerates are polymict, poorly sorted, clast supported and in most cases contain subrounded to rounded carbonate clasts, including reworked algal and fusulinid limestones, and siliciclastic grains, particularly pebbles of red jasper. At Fresnal Canyon, individual conglomerate layers form up to 2.5 m thick, laterally thinning channel fills that are incised up to 2 m deep into the underlying strata. At Laborcita Canyon, conglomerate layers are thinner and not so deeply incised, and frequently larger pebbles are floating in sandy, carbonate cemented matrix. In the upper part, a poorly sorted, angular to subangular conglomerate layer with a maximum clast size of 10 cm is present. Coarse-grained, locally pebbly sandstones form thicker units, particularly in the upper part of the sections, and appear as massive to indistinctly laminated or crossbedded ledges associated with conglomerates. Fine-grained sandstone and siltstone occur as thin beds intercalated in shale, and are massive or horizontally laminated; crossbedding and current ripples are rare.

Shale and silty shale intervals are mostly covered at Laborcita Canyon, but well exposed along the road cut at Fresnal Canyon. The rock color is either gray to greenish gray or reddish to pink. Locally, fossils occur in

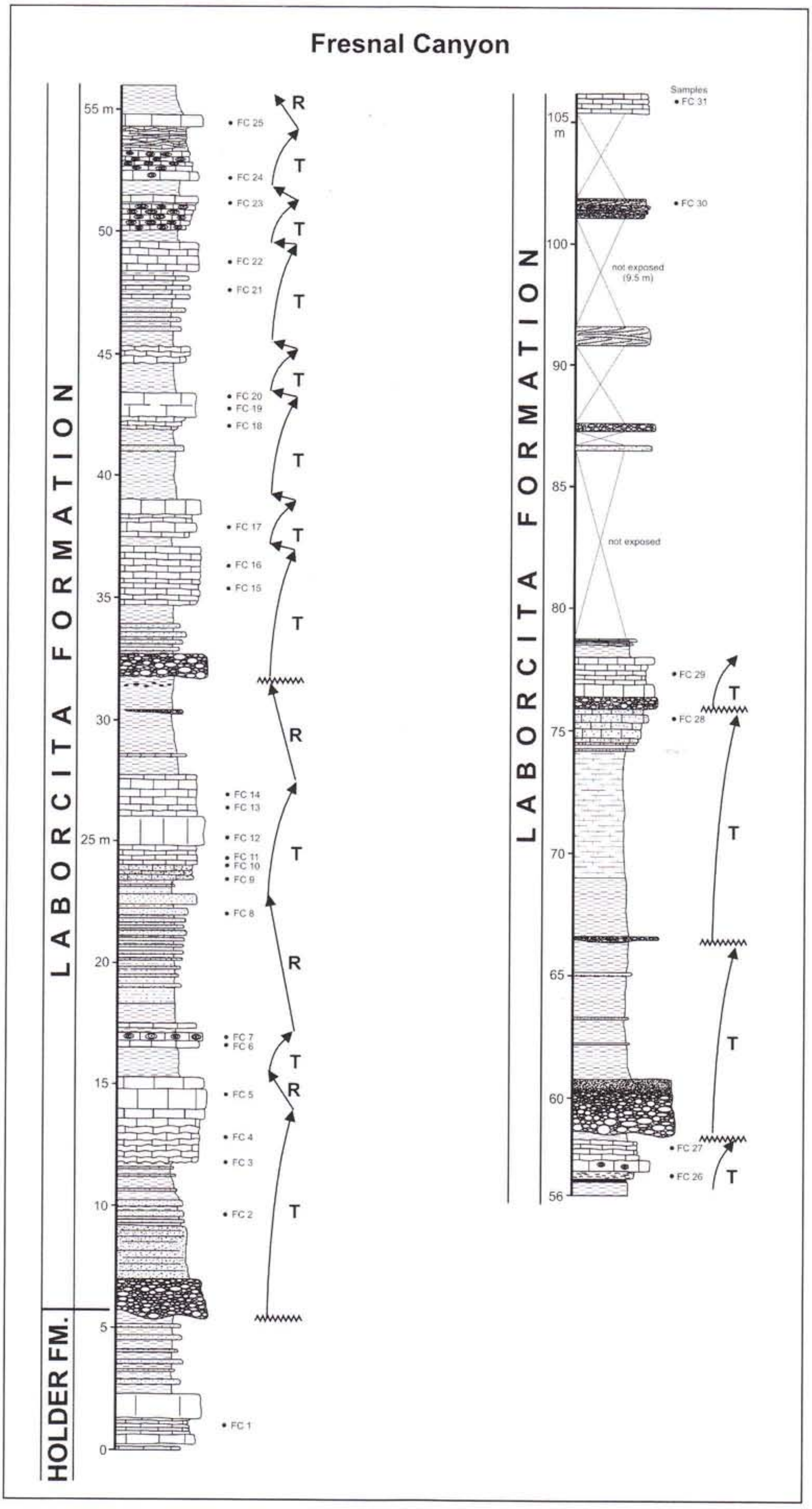


Fig. 5 - Measured stratigraphic section through the Laborcita Formation at Fresnal Canyon (location see Fig. 1).

greenish-gray shales.

In the field, the following lithotypes of limestone are recognized:

(a) Thin-bedded limestone with even to wavy bedding, bed thickness mostly 5 - 10 cm, and frequently with thin shale partings. These limestones are composed of different types of wackestones and packstones; grainstones are rare. The dominant microfacies is bioclastic wackestone/packstone; subordinate are algal wackestone, foraminiferal wackestone, fusulinid wackestone, oncoid wackestone, bioclastic mudstone, peloid/oncoid grainstone and grainstone/packstone.

(b) Thin-bedded limestones with wavy to nodular bedding, bed thickness mostly 5 - 20 cm and shale partings. The most frequent microfacies type is bioclastic wackestone; subordinate are bioclastic packstone/grainstone and fusulinid wackestone.

(c) Thick-bedded limestone with bed thickness > 20 cm and up to 125 cm thick. Common microfacies types are bioclastic wackestone/grainstone and algal wackestone; other observed microfacies are fusulinid wackestone, ooid wackestone and ooid/oncoid grainstone.

(d) At Fresnal Canyon, a thin carbonate bed occurs in a red silty shale unit that is of pedogenic origin.

Limestone Microfacies

In general, Laborcita Limestone microfacies are very similar to those of the Shalem Colony Formation. Bioclastic wackestones/packstones are characterized by a relatively high diverse biota (Pl. 2, fig. 5). In some wackestones, bioclasts are frequently encrusted by cyanobacteria (*Girvanella*), calcivertellids and rare *Archaeolithophyllum lamellosum*, *Palaeonubecularia*, *Claracrusta*, and *Eflugelia* to form oncoids up to several cm in diameter (oncoid wackestone), which are not observed in the Shalem Colony Formation. Bioclastic wackestone may grade into phylloid algal wackestone, fusulinid wackestone and foraminiferal wackestone/grainstone.

As in the Shalem Colony Formation, the most abundant bioclasts in algal wackestone/packstone are broken fragments of phylloid algae (mostly *Eugonophyllum*); also, locally, the dasycladaceans *Anthracoporella* and subordinate *Epimastopora* are present (Pl. 2, figs. 1, 2). Phylloid algal plates are frequently aligned parallel to the bedding and rarely found in growth position.

Foraminiferal wackestones/packstones are composed of abundant smaller foraminifers, mostly calcivertellids, and other bioclasts (Pl. 2, fig. 6).

Fusulinid wackestone is characterized by a relatively high taxonomic diversity compared to the other microfacies of the Laborcita Formation (Pl. 2, fig. 4); locally, fusulinid packstone occurs (Pl. 2, fig. 3).

Ooid wackestones are composed of well sorted, grain supported, locally matrix-supported ooids, mostly 0.2 - 0.3 mm in diameter. A few bioclasts, mostly echinoderm fragments, are present.

Oncoid wackestones/packstones contain elongate small oncoids, poorly sorted and locally densely packed, and some bioclasts (ostracods, echinoderm fragments, small gastropods) that are embedded in a matrix composed of peloidal micrite and small amounts of calcite cement. Oncoids are mostly 1-4 mm long, and the nuclei are commonly formed by bivalve shell fragments. A few angular to subangular detrital quartz grains are scattered throughout the rock. This facies, which is not observed in the Shalem Colony Formation, sharply overlies a fine-grained, quartz-rich sandstone.

Bioclastic mudstone is rare and consists of a gray,

PLATE 2

Thin section photomicrographs of characteristic microfacies types of the Laborcita Formation at Laborcita Canyon and Fresnal Canyon. Plane polarized light, width of Fig. 1 - Fig. 4 = 6 mm, width of Fig. 5 - Fig. 7 = 4.3 mm. For position of the samples in the section see Fig. 4 (Laborcita Canyon) and Fig. 5 (Fresnal Canyon).

Fig. 1 - Algal wackestone with abundant recrystallized fragments of phylloid algae (*Eugonophyllum*) and a few ostracods, embedded in dark gray micrite. Fresnal Canyon, sample FC 19.

Fig. 2 - Bioclastic packstone composed of recrystallized phylloid algae, shell debris, ostracods and brachiopod spines. Many bioclasts display micrite envelopes. The matrix consists of calcite cement. Fresnal Canyon, sample FC 4.

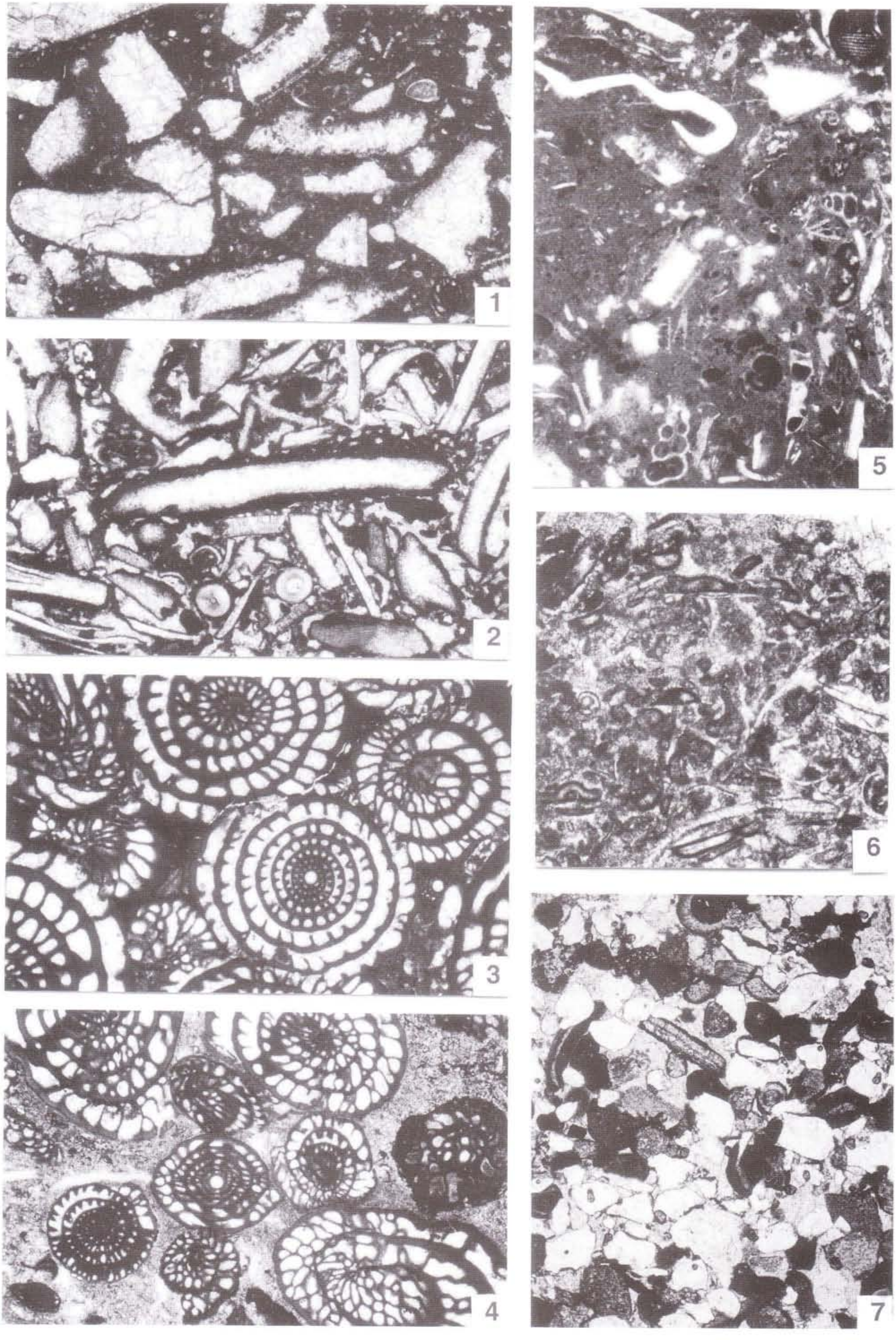
Fig. 3 - Fusulinid packstone showing densely packed fusulinid tests (*Triticites*) with pressure solution at their contacts. Some gray micritic matrix is present. Laborcita Canyon, sample LC 11.

Fig. 4 - Fusulinid wackestone containing abundant fusulinid tests (*Triticites*) embedded in recrystallized micritic matrix. Fresnal Canyon, sample FC 6

Fig. 5 - Bioclastic wackestone containing shell debris, echinoderms, algal fragments, gastropods, one trilobite fragment and ostracods, floating in gray micrite. Fresnal Canyon, sample FC 15.

Fig. 6 - Foraminiferal wackestone with abundant calcivertellid foraminifers, subordinate shell debris, small gastropods, ostracods, some peloids, recrystallized micrite and some calcite cement. Laborcita Canyon, sample LC 29.

Fig. 7 - Well sorted sandstone composed of subangular to rounded grains. Siliciclastic grains are mostly monocrystalline quartz. Abundant gray - dark gray micritic carbonate grains are also present. A few bioclasts occur. Laborcita Canyon, sample LC 26.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homogeneous to inhomogeneous (bioturbated) micrite with only a few peloids and rarely small bioclasts such as ostracods, small shell fragments, and a few foraminifers and echinoderm ossicles. Mudstone is composed of gray micrite containing a few caliche peloids/ooids and a few ostracods.

Grainstones are represented by coarse-grained oncoid grainstone layers alternating with fine-grained layers composed dominantly of ooids. Ooid grainstone layers and peloid/oncoid grainstone are composed of fine-grained laminae with mostly peloids and some small oncoids and coarse-grained laminae with mostly oncoids and larger peloids.

From outcrops north of Laborcita Canyon, Fly (1985) described foreset-bedded sandy grainstones, blue-green algal dismicrites, digitate algal stromatolites and phylloid algal bindstones, but those facies have not been recognized in sections examined for this study.

Sedimentary petrology of siliciclastics

Siltstones are mixed carbonate - siliciclastic - bioclastic in composition with varying amounts of siliciclastic grains (5 - 30%) and bioclasts. Carbonate grain types are mostly dark brownish and gray micritic intraclasts that may display dark micrite envelopes. Rarely, peloids are present. Siliciclastic grains are dominantly monocrystalline quartz, with subordinate polycrystalline detrital quartz. Detrital chert grains, micas and feldspars, the latter more or less altered and replaced by calcite, are less abundant.

Bioclasts are present in all studied siltstone samples in small amounts, including ostracods, echinoderm fragments, recrystallized shell fragments, locally large recrystallized phylloid algal plates, broken fusulinid tests, smaller foraminifers (calcivertellids, *Syzrania, Earlandia*) and unidentifiable recrystallized bioclasts. In one sample, a few large shell fragments, mostly derived from gastropods, are present. Some of these fragments are encrusted by *Palaeonubecularia* and cyanobacteria, forming oncoids with diameters up to several cm across.

Siltstones are moderately to well sorted, and in some samples poor sorting was observed. The matrix is mostly micrite or pelmicrite, although siltstones cemented by microsparite also are present.

Sandstones are composed of mixed siliciclastic and carbonate grain types. Only one sample was determined to be a pure quartz arenite. Angular to subrounded sand grains dominate, but in some medium and coarse-grained sandstones the sand grains are rounded to well rounded. Most sandstones are moderately sorted, although poorly and well sorted sandstones occur as well (Pl. 2, fig. 7). Lamination has not been observed in thin section. Commonly, siliciclastic grains are more abundant than carbonate lithoclasts, and small amounts of bioclasts are present in all studied samples.

The dominant siliciclastic grain type is quartz, mostly monocrystalline, and subordinately polycrystalline. Locally, quartz grains display authigenic overgrowths. Less abundant are opaque grains and chert grains, which rarely display ghost structures of radiolarians, spicules and very rare ostracod shells, indicating a sedimentary origin. Very rarely, detrital feldspars, altered and partly replaced by calcite, phyllitic grains and detrital micas occur. Most sandstones contain abundant recrystallized micritic carbonate grains (up to about 40%), and some contain small bioclasts such as shell fragments, echinoderms and fusulinids. Sandstones are frequently cemented by sparry calcite replacing quartz, feldspar and chert grains. Locally, recrystallized micrite (microsparite) is present.

Like the sandstones, the fine-grained conglomerates are mixed siliciclastic-carbonate in composition and poorly sorted. Siliciclastic grains are mostly represented by subangular quartz grains; subordinate are rounded, sedimentary chert grains. Detrital feldspars are very rare. Different types of rounded carbonate clasts are present in high amounts. Fine-grained conglomerates contain abundant bioclasts, particularly broken fusulinid tests, shell fragments, echinoderms, rare bryozoans and *Epimastopora*. The matrix consists of blocky calcite cement.

Depositional environment

The Hueco Limestone has been generally considered as a good example of an open shelf marine carbonate facies (Wilson & Jordan 1983). According to Wahlman & King (2002), the Lower Hueco Member (Shalem Colony Formation) is composed of predominantly offshore, normal marine, shallow shelf deposits with a general shallowing upward trend from a normal marine shelf environment in the lower part to mostly inner shelf, shallow water, restricted marine carbonates in the upper part.

Limestones of both the Shalem Colony Formation and the Laborcita Formation actually display a number of features that according to Wilson & Jordan (1983) are diagnostic of an open, well oxygenated shelf environment with mostly normal marine salinity, and below the normal wave base, but above storm wave base:

(a) Limestones of both formations are characterized by irregular bedding with bedding thicknesses ranging from less than 20 cm thick to thick bedded and massive limestones, locally including algal mounds (biostromes). Wavy bedding with thin shale partings is common, locally grading into nodular limestone.

(b) Muddy, frequently bioturbated carbonate textures predominate with normal marine bioclastic wackestone and packstone forming the bulk of the limestones, representing the SMF-Type 9 and 10 of Wilson (1975).

(c) Presence of different types of grainstones, representing SMF-Type 11, 12, 13, and 15 of Wilson (1975), is indicative of a high-energy shoal environment.

(d) Biota of high taxonomic diversity and including a normal marine fauna (stenohaline forms) such as brachiopods, bryozoans, crinoids, echinoids, fusulinids, some smaller foraminifers and trilobites.

(e) Presence of calcareous algae, particularly phylloid algae, and subordinate dasycladaceans and other algae, points to deposition within the photic zone with maximum water depths of a few tens of meters.

The limestones contain bioclastic remains of all major late Paleozoic biotic groups: shell fragments (brachiopods, bivalves, gastropods), echinoderms, bryozoans, calcareous algae (phylloid algae, *Epimastopora,* rare *Archaeolithoporella, Anthracoporella,* and *Eflugelia*), fusulinids, smaller foraminifers (mostly calcivertellid forms), ostracods, *Tubiphytes*, rare serpulids and trilobite fragments.

The phylloid algal wackestones that occur on top of algal boundstones in the upper part of section A show some similarities to the phylloid algal mounds ("Scorpion Mounds") of the Laborcita reef complex of the northern Sacramento Mountains.

All carbonate microfacies types that Wilson (1975) regarded as typical of late Paleozoic shelf and shelf margin limestones are present in the investigated sections, although they occur with some variation.

Low-energy sediments indicating a restricted shelf environment with reduced water circulation are rare and represented by mudstone and bioturbated bioclastic mudstone containing a restricted fauna with a relatively large number of organisms such as ostracods and certain species of smaller foraminifers (Laborcita Formation), and low-diversity intraclast/peloidal grainstone, which is locally laminated (Shalem Colony Formation).

According to Fly (1985), carbonate deposition of the Laborcita Formation was concentrated in shallow water marine embayments between fan-delta platforms. Terrigenous clastic sediments migrated towards these embayments.

The sandstone interval of section B of the Shalem Colony Formation, which contains various fossil fragments, is also of shallow marine origin, and was probably deposited during a relative sea-level lowstand with increased siliciclastic influx in an upper shoreface environment. The red marly shales containing limestone nodules in section A, display pedogenic features indicating subaerial exposure during relative sea-level lowstands. A general shallowing upward trend within the two investigated sections has not been observed.

Although the limestones of both the Shalem Colony Formation and Laborcita Formation are more or less equivalent and accumulated in a very similar shelf environment, the successions differ significantly, particularly in the following two points:

(a) The Laborcita Formation, which was deposited on the narrow eastern shelf of the Orogrande Basin, is composed of abundant siliciclastic sedimentary rocks, including shale, sandstone and conglomerate, alternating with fossiliferous limestones. Siliciclastic rocks are very rare in the Shalem Colony Formation.

(b) The Laborcita Formation is characterized by pronounced mixed siliciclastic-carbonate cycles, particularly in the lower part. Such cycles are absent in the Shalem Colony Formation.

Otté (1959) noted that in the lower part of the Laborcita Formation limestones and shales form cycles (cyclothems), that suggest increasing water depth during deposition. He stated that each cycle represents one complete transgression and regression. He also reported that the lower part of the Laborcita Formation was deposited mostly under normal marine conditions, and that towards the southeast and east the facies changes from marine to dominantly nonmarine facies. He interpreted all red conglomerates, sandstones and mudstones as terrestrial deposits, and gray and green mudstone locally containing abundant fossils as well as the limestones as marine. Fly (1986) interpreted the clastic sediments in the Coyote Canyon area as fan delta deposits, alternating with shallow marine limestones. Carr (1983) investigated a several meter thick clastic, coarsening upward sequence in the lower part of the Laborcita Formation, which he interpreted to have formed by progradation of a deltaic lobe. Carr (1983) stated that late Virgilian - early Wolfcampian sandstones of the northern Sacramento Mountains show evidence of both marine and fluvial influences on deposition.

We interpret the thick, coarse-grained conglomerates of the Fresnal Canyon section, which are deeply incised in the underlying strata, as fluvial channel-fill deposits. Conglomerates in the Laborcita Canyon section, which are thinner, fine-grained and not deeply incised, contain diverse bioclasts clearly indicating a shallow marine, nearshore depositional environment. All investigated sandstones and siltstones also contain marine fossils, pointing to a shallow marine origin. This is also the case for the greenish-gray shales in which fossils are found locally. Pink and reddish colored shales may indicate terrestrial conditions of a coastal plain. Generally, clastic sediments of the Laborcita Formation were deposited during relative sea-level lowstands and strong clastic influx. Fossiliferous limestones accumulated during relative sea-level highstands lacking siliciclastic influx.

Otté (1959) noted that many of the strata extend laterally only a few hundred meters and lense out or laterally grade into a different lithofacies. According to Otté (1959), Pray (1961), and Kottlowski (1963), there is evidence of tectonic activity in the northern Sacramento Mountains during the early Wolfcampian, indicating that the formation of cycles within the Laborcita Formation was strongly influenced by tectonic activity, and that glacioeustatic sea-level changes driven by the

Gondwana glaciation played only a minor role (see also Wilson 1975, Wilson & Jordan 1988). Lack of cycles and rarity of siliciclastic sediments within the Shalem Colony Formation may indicate that the Robledo Shelf on the western margin of the Orogrande Basin was tectonically more stable than the Laborcita Shelf on the eastern margin during early Wolfcampian time.

Paleontology (smaller foraminifers, pseudoalgae and algae)

The smaller foraminifers have been identified according to the criteria of Cushman & Waters 1928; Morozova 1949; Lipina 1949; Reitlinger 1950; Henbest 1963; Zolotova & Baryshnikov 1980; Baryshnikov et al. 1982; Davydov 1986; Groves & Wahlman 1997; Altiner & Savini 1997; Pinard & Mamet 1998; Groves & Boardman 1999; Groves 2000; Vachard & Krainer 2001a, b. Additional references for the algospongia are presented by Massa & Vachard 1979; Vachard 1980; Vachard & Montenat 1981; Groves 1983; Vachard et al. 1989; for *Nostocites*: Groves 1983; Perret et al. 1994 and for *Epimastopora* by Pia 1937 and Kochansky & Herak 1960.

Fossil assemblages

All determined fossils (algae, algal? microproblematica, algospongia and smaller foraminifers) are listed in Tables 1-4 with references to the figures on the plates (Pl. 3-8).

Smaller foraminifers of the Holder Formation (Virgilian) indicate a Gzhelian age. In Yucca Mound at Dry Canyon, a small association contains elements known from the latest Moscovian/early Kasimovian: *Brunsiella* cf. *densa* Reitlinger, 1950, *Glomospiroides* (?) sp. (= ?*Plummerinella*), hemigordiopsiid indet., and *Syzrania pulchra* Kireeva, 1958. At Laborcita Canyon, the Holder Formation contains at its top the characteristic fossil *Pseudovidalina* sp. (= *Raphconilia* sp.), a genus that appears in the Gzhelian (Groves 1997, fig. 1; Groves & Wahlman 1997, fig. 4-5). A Gzhelian age is also confirmed by unpublished fusulinids and conodonts (Wahlman, written comm.).

Limestones in the Scorpion Mound, intercalated in the Laborcita Formation northeast of Tularosa, contain *Nostocites vesiculosa* Maslov, 1929, a charophyte gyrogonite, *Eflugelia johnsoni* (Flügel, 1966) Vachard in Massa & Vachard, 1979; *Eotuberitina reitlingerae* (Mikhlukho-Maclay, 1958), *Quasilituotuba* (?) sp., *Endothyra* ex gr. *prisca* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova et al., 1936, *Vervilleina* cf. *bradyi* (Spandel, 1901), *Nodosinelloides* cf. *aequiampla* (Zolotova in Zolotova & Baryshnikov, 1980), *N.* cf. *longissima* (Suleimanov, 1949), and *N. netschajewi* (Cherdyntsev, 1914).

Limestones in the Laborcita Formation at Fresnal Canyon and Laborcita Canyon yielded a fossil assemblage that in general corresponds with the Auernig Formation, Carnizza Formation and Lower Pseudoschwagerina Limestone of the Carnic Alps (Vachard & Krainer 2001a, b), i.e., to the Orenburgian/early Asselian, or the "Bursumian" sensu Davydov. The lower parts of these sections (especially levels LC 18 and FC 24-25) are very similar to the Auernig Formation of the

Table 1: Algae, algal? microproblematica and algospongia	Holder Fm.	Scorpion Mound	Laborcita Fm. LC	Laborcita Fm. FC	Shalem Colony Fm.	Robledo Mt. Fm. A	Robledo Mt. Fm. C	Apache Dam Fm.
Algae								
Ortonella sp. 1 (Pl. 5, fig. 18)					●			
Ortonella sp. 2 (Pl. 8, fig. 21)								●
Ortonella sp. 3 (Pl. 8, fig. 29)								●
Anthracoporella spectabilis Pia, 1920 (Pl. 3, fig. 28)				●				
Mizzia cf. *cornuta* Kochansky-Devidé & Herak, 1960 (Pl. 7, fig. 10)						●		
Gyroporella sp. (Pl. 7, fig. 11)						●		
Epimastopora alpina (Kochansky-Devidé & Herak, 1960) sensu Kulik, 1978 (Pl. 5, fig. 7-8, 10, 17, 19)					●			
Epimastopora sp. (Pl. 5, fig. 34)					●			
Paraepimastopora ex gr. *kansasensis* (Johnson, 1946) Roux, 1989 (Pl. 4. fig. 30)			●					
Pseudoepimastopora sp. (Pl. 4, fig. 17, Pl. 6, fig. 21)			●			●		
dasyclad indet. (Pl. 5, fig. 26)					●			
Eugonophyllum (Pl. 3, fig. 31)				●				
Neoanchicodium catenoides Endo, 1954 (Pl. 6, fig. 31; Pl. 7, fig. 12; Pl. 8, fig.19)						●		●
Algal? microproblematica								
Nostocites vesiculosa Maslov, 1929 (Pl. 3, fig. 13; Pl. 5, fig. 3; not Pl. 6, fig. 8)		●			●			
Litostroma (?) sp. (Pl. 3, fig. 25; Pl. 4, fig. 13)				●				
Problematicum gen. 1 (Pl. 5, fig. 10, 13-15)					●			
Ellesmerella (?) sp. (Pl. 5, fig. 11)					●			
Tubiphytes sp. (Pl. 6, fig. 7)					●			
Algospongia								
Eflugelia johnsoni (Flügel, 1966) Vachard in Massa & Vachard, 1979 (Pl. 3, fig. 9, 17, 37; Pl. 5, fig. 20, 23-25; Pl. 6, fig. 13; Pl. 7, fig. 17)		●		●	●	●	●	
Claracrusta catenoides (Homann, 1972) Vachard, 1980 (Pl. 3, fig. 32)				●				
Claracrusta calamistrata Vachard, 1980 (Pl. 8, fig. 22)								●

Table 2: Smaller foraminifers Fusulinida	Holder Fm.	Scorpion Mound	Laborcita Fm. LC	Laborcita Fm. FC	Shalem Colony Fm.	Robledo Mt. Fm. A	Robledo Mt. Fm. C	Apache Dam Fm.
Eotuberitina reitlingerae (Mikhlukho-Maclay, 1958) (Pl. 3, fig. 8, 18, 27, 30, 31)		●		●				
Earlandia sp. (Pl. 7, fig. 29; Pl. 8, fig. 13, 27)							●	●
Spireitlina conspecta (Reitlinger, 1950) (Pl. 3, fig. 19; Pl. 4, fig. 42, 44)			●	●				
Spireitlina cf. *tokmovensis* (Reitlinger, 1961) (Pl. 5, fig. 16, 21)					●			
Endothyra ex gr. *bowmani* Phillips, 1846 emend. Brady, 1876 sensu China, 1965 (Pl. 4, fig. 18, 25)			●					
Endothyra ex gr. *prisca* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova et al., 1936 (Pl. 3, fig. 11; Pl. 4, fig. 24)		●	●					
Endothyra sp.				●				
Endothyranella ex gr. *minuta* (Waters, 1927) (Pl. 6, fig. 1)					●			
Endothyranella sp. (Pl. 3, fig. 35)				●				
Bradyina compressa Morozova, 1949 [= ? *B.* (?) *arctica* Pinard & Mamet, 1998] (Pl. 5, fig. 32; Pl. 6, fig. 2, 6)					●			
Bradyina lucida Morozova, 1949 (Pl. 3, fig. 14, 20, 26, 31; Pl. 4, fig. 52)			●	●				
Bradyina sp. (Pl. 3, fig. 34)				●				
Globivalvulina bulloides (Brady, 1876). (Pl. 7, fig. 3, 9, 15, 19, 22)						●	●	
Globivalvulina sp. (Pl. 3, fig. 36)				●				
Globivalvulina spp. (Pl. 6, fig. 18, 22-23, 28-29, 32; Pl. 8, fig. 1-2, 11-12, 15-16)						●		●
Palaeotextularia sp. (Pl. 3, fig. 31; Pl. 8, fig. 24)				●				●
Deckerella geyeri (Schwellien, 1898) (= *D. laheei* Cushman & Waters, 1928 sensu Vachard & Krainer, 2001a) (Pl. 3, fig. 16, 22-24)				●				
Tetrataxis sp. (Pl. 8, fig. 20)								●
Tetrataxis spp. (Pl. 3, fig. 38; Pl. 4, fig. 2)				●				
Polytaxis laheei Cushman & Waters, 1928 (Pl. 4, fig. 1, 17, 22)			●	●				
Pseudovidalina sp. (Pl. 5, fig. 28)	●			●	●			
Pseudovidalina spp. (Pl. 4, fig. 5-10, 19-20, 23, 26-28, (31-33, 36-39, 41, 45-47, 58, Pl. 5, fig. 28)			●	●	●			
Staffella sp. (Pl. 6, fig. 33)						●		
Pseudoreichelina ex gr. *darvasica* (Leven, 1970) (Pl. 7, fig. 23, 40)							●	
Eoschubertella sp. (Pl. 5, fig. 27)					●			
Schubertella sp. (Pl. 5, fig. 33)					●			

Carnic Alps, with *Pseudovidalina* spp. and *Nodosinelloides potievskayae*.

The Fresnal Canyon section yields *Anthracoporella spectabilis* Pia, 1920, *Eugonophyllum*, *Litostroma* (?) sp., *Claracrusta catenoides* (Homann, 1972) Vachard, 1980, *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979, *Eotuberitina reitlingerae* (Mikhlukho-Maclay, 1958), *Spireitlina conspecta* (Reitlinger, 1950), *Endothyra* sp., *Endothyranella* sp., *Bradyina lucida* Morozova, 1949, *Bradyina* sp., *Tetrataxis* spp., *Polytaxis laheei* Cushman & Waters, 1928, *Globivalvulina* sp., *Palaeotextularia* sp., *Deckerella geyeri* (Schellwien, 1898) (= *D. laheei* Cushman & Waters, 1928 sensu Vachard & Krainer, 2001a), Pseudovidalina spp., *Ammovertella inversa* (Schellwien, 1898), *A.* sp., *Palaeonubecularia fluxa* Reitlinger, 1950, "*Glomospira*" sp., *Syzrania* spp., *Nodosinelloides netschajewi* (Cherdyntsev, 1914), and *N. potievskayae* Mamet & Pinard, 1996.

The Laborcita Canyon section yields *Pseudoepimastopora* sp., *Paraepimastopora* ex gr. *kansasensis* (Johnson, 1946) Roux, 1989, *Spireitlina conspecta* (Reitlinger, 1950), *Quasilituotuba* (?) sp., *Endothyra* ex gr. *bowmani* Phillips, 1846 emend. Brady, 1876 sensu China, 1965, *E.* ex gr. *prisca* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova et al., 1936, *Bradyina lucida* Morozova, 1949, *Polytaxis laheei* Cushman & Waters, 1928, *Pseudovidalina* spp., "*Glomospira*" sp., *Syzrania* spp., *Protonodosaria praecursor* (Rauzer-Chernousova, 1949), *Nodosinelloides netschajewi* (Cherdyntsev, 1914), and *N. potievskayae* Mamet & Pinard, 1996.

Small oncoids of the the Shalem Colony Formation at Robledo Peak are principally composed of *Ellesmerella* (?) sp., *Ortonella* sp. 1, *Epimastopora alpina* (Kochansky-Devidé & Herak, 1960), *E.* sp., dasycladale indet., *Nostocites vesiculosa* Maslov, 1929, *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979, *Tubiphytes* sp., *Problematicum* gen. 1, *Spireitlina* cf. *tokmovensis* (Reitlinger, 1961), *Endothyranella* ex gr. *minuta* (Waters, 1927), *Bradyina compressa* Morozova, 1949 [= ? *B.* (?) *arctica* Pinard & Mamet, 1998], *Eoschubertella* sp., *Schubertella* sp., *Pseudovidalina* sp., *Cornuspira* sp., "*Glomospira*" sp., *Hemigordius harltoni* Cushman & Waters, 1928, *H. schlumbergeri* (Howchin, 1895), *Calcitornella* sp., *Syzrania minima* Stepanova, 1997, *Vervilleina* sp. 2, *Nodosinelloides netschajewi* (Cherdyntsev, 1914), and *N. potievskayae* Mamet & Pinard, 1996.

The Robledo Mountains Formation (section A) yields *Neoanchicodium catenoides* Endo, 1954, *Pseudoepimastopora* sp., *Gyroporella* sp., *Mizzia* cf. *cornuta* Kochansky-Devidé & Herak, 1960, *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979, *Globivalvulina bulloides* (Brady, 1876), *G.* spp., *Staffella* sp., *Ammovertella inversa* (Schellwien, 1898), *Calcivertella* (sensu stricto) sp., *Pseudovermiporella* sp. 1, *P.* sp. 2, *Hemigordius* sp. 3, *H.* sp. 4, *Neodiscus* (?) sp., *Nodosinelloides potievskayae* Mamet & Pinard, 1996, *N.* aff. *ronda* (Lipina, 1949), *Geinitzina postcarbonica* Spandel, 1901, and *Langella* (?) cf. *minima* Baryshnikov in Zolotova & Baryshnikov, 1980.

The Robledo Mountains Formation of section C contains: *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979, *Earlandia* sp., *Globivalvulina bulloides* (Brady, 1876), *Pseudoreichelina* ex gr. *darvasica* (Leven, 1970), *Ammovertella inversa* (Schellwien, 1898), "*Glomospira*" spp., *Nodosinelloides potievskayae* Mamet & Pinard, 1996, *Geinitzina postcarbonica* Spandel, 1901, *G.* (?) sp., and *Frondicularia* (?) spp.

The uppermost part of the Robledo Mountains Formation and lower Apache Dam Formation (section B) yield: *Ortonella* sp. 2, *O.* sp. 3, *Neoanchicodium catenoides* Endo, 1954, *Claracrusta calamistrata* Vachard, 1980, *Earlandia* sp., *Palaeotextularia* sp., *Tetrataxis* sp., *Globivavlvulina* spp., *Pseudovermiporella* sp. 3, *Hemigordius* (?) sp. 5, *Syzrania* sp., *Tezaquina* aff. *clivuli*

Table 3:

Smaller Foraminifers **Miliolida**	Holder Fm.	Scorpion Mound	Laborcita Fm. LC	Laborcita Fm. FC	Shalem Colony Fm.	Robledo Mt. Fm. A	Robledo Mt. Fm. C	Apache Dam Fm.
"*Glomospira*" sp. (Pl. 3, fig. 29; Pl. 4, fig. 21; Pl. 5, fig. 22)			●	●	●			
"*Glomospira*" spp. (Pl. 7, fig. 24, 27, 30, 38)							●	
Cornuspira sp. (Pl. 5, fig. 29)					●			
Brunsiella cf. *densa* Reitlinger, 1950 (Pl. 3, fig. 3)	●							
Hemigordius harltoni Cushman & Waters, 1928 (Pl. 5, fig. 30)					●			
Hemigordius schlumbergeri (Howchin, 1895) (Pl. 6, fig. 3)					●			
Hemigordius sp. 3 (Pl. 6, fig. 26)						●		
Hemigordius sp. 4 (Pl. 3, fig. 34)						●		
Hemigordius (?) sp. 5 (Pl. 8, fig. 3-6)								●
hemigordiopsiid indet. (Pl. 3, fig. 2)	●							
Calcitornella sp. (Pl. 5, fig. 12?; Pl. 6, fig. 5)					●			
Calcivertella (sensu stricto) sp. (Pl. 7, fig. 2)						●		
Ammovertella inversa (Schellwien, 1898) (Pl. 3, fig. 15; Pl. 6, fig. 30; Pl. 7, fig. 18				●		●	●	
Ammovertella (= *Calcivertella*) sp. (Pl. 4, fig. 11)				●				
Pseudovermiporella sp. 1 (Pl. 6, fig. 11-12)						●		
Pseudovermiporella sp. 2 (Pl. 7, fig. 1, 7)						●		
Pseudovermiporella sp. 3 (Pl. 8, fig. 7-8)								●
Palaeonubecularia fluxa Reitlinger, 1950 (Pl. 4, fig. 12)				●				
Quasilituotuba (?) sp. (Pl. 3, fig. 7; Pl. 4, fig. 35)		●	●					
Glomospiroides (?) sp. (= ? *Plummerinella*) (Pl. 3, fig. 1)	●							
Neodiscus (?) sp. (Pl. 6, fig. 34)						●		

Table 4:

Smaller foraminifers **Lagenida**	Holder Fm.	Scorpion Mound	Laborcita Fm. LC	Laborcita Fm. FC	Shalem Colony Fm.	Robledo Mt. Fm. A	Robledo Mt. Fm. C	Apache Dam Fm.
Syzrania minima Stepanova, 1997 (Pl. 6, fig. 4)					●			
Syzrania pulchra Kireeva, 1958 (Pl. 3, fig. 4)	●							
Syzrania sp. (Pl. 8, fig. 28)								●
Syzrania spp. (Pl. 3, fig. 21, 33; Pl. 4, fig. 14, 16, 34)			●	●				
Syzraniid indet. (Pl. 8, fig. 18)								●
Tezaquina aff. *clivuli* Vachard in Vachard & Montenat, 1981 (Pl. 8, fig. 25)								●
Vervilleina cf. *bradyi* (Spandel, 1901) (Pl. 3, fig. 6)		●						
Vervilleina sp. 2 (Pl. 5, fig. 2)					●			
Vervilleina sp. 3 (Pl. 8, fig. 23)								●
Nodosinelloides netschajewi (Cherdyntsev, 1914) (Pl. 3, fig. 12; Pl. 4, fig. 3, 40, 49-50, 55; Pl. 5, fig. 1; Pl. 6, fig. 9-10)		●	●	●	●			
Nodosinelloides potievskayae Mamet & Pinard, 1996 (Pl. 4, fig. 4, 29, 43, 48, 51, 53, 57?, 58; Pl. 5, fig. 4-6, 9?, 31; Pl. 6, fig. 19-20; Pl. 7, fig. 14, 26, 28, 31-33, 35, 37; Pl. 8, fig. 17)			●	●	●	●	●	●
Nodosinelloides cf. *aequiampla* (Zolotova in Zolotova & Baryshnikov, 1980) (Pl. 3, fig. 10)		●						
Nodosinelloides cf. *longissima* (Suleimanov, 1949) (Pl. 3, fig. 5)		●						
Nodosinelloides aff. *ronda* (Lipina, 1949) (Pl. 7, fig. 5)						●		
Nodosinelloides sp. (Pl. 8, fig. 9)								●
Protonodosaria praecursor (Rauzer-Chernousova, 1949) (Pl. 4, fig. 54, 56)			●					
Langella (?) cf. *minima* Baryshnikov in Zolotova & Baryshnikov, 1980 (Pl. 7, fig. 8, 13)						●		
Geinitzina postcarbonica Spandel, 1901 (Pl. 6, fig. 14-17, 25, 27; Pl. 7, fig. 4, 6, 34, 36, 39)						●	●	
Geinitzina sp. 1 (Pl. 8, fig. 10)								●
Geinitzina sp. 2. (Pl. 8, fig. 14)								●
Geinitzina (?) sp. (Pl. 7, fig. 25)							●	
Frondicularia (?) spp. (Pl. 7, fig. 16, 20-21)							●	
Pachyphloia sp. (Pl. 8, fig. 26)								●

PLATE 3

Microfossils from Yucca Mound (Holder Formation), Scorpion Mound and Fresnal Canyon (Laborcita Formation) (New Mexico). For the position of the samples FC (Fresnal Canyon) in the section see Fig. 5.

Fig. 1 - *Glomospiroides* (?) sp. Subaxial section. Yucca Mound. Holder Formation. Virgilian (Gzhelian). SampleY 1. x 78.

Fig. 2 - Hemigordiid indet. Oblique section. Yucca Mound. Holder Formation. Virgilian (Gzhelian). Sample Y 3. x 78.

Fig. 3 - *Brunsiella* cf. *densa* Reitlinger, 1950. Subaxial section. Yucca Mound. Holder Formation. Virgilian (Gzhelian). Sample Y 3. x 78.

Fig. 4 - *Syzrania pulchra* Kireeva, 1958. Axial section. Yucca Mound. Holder Formation. Virgilian (Gzhelian). Sample Y 3. x 78.

Fig. 5 - *Nodosinelloides* cf. *longissima* (Suleimanov, 1949). Longitudinal section. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM. x 78.

Fig. 6 - *Vervilleina* cf. *bradyi* (Spandel, 1901). Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM. x 78.

Fig. 7 - *Quasilituotuba* (?) sp. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM. x 78.

Fig. 8, 18, 27, 30 - *Eotuberitina reitlingerae* (Mikhlukho-Maclay, 1958). Four axial sections. Laborcita Formation. Early Wolfcampian (Orenburgian). Fig. 8 - Scorpion Mound Sample SM. x 78. Fig. 18, 27, 30 - Fresnal Canyon. Fig. 18 - Sample FC 6. x 78. Fig. 27 - Sample FC 12. x 32. Fig. 30 - Sample FC 13. x 78.

Fig. 9, 17, 37 - *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979. Fig. 9 - Longitudinal broken section. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian/Asselian). Sample SM 1. x 32. Fig. 17 - Longitudinal section partly filled with micrite (compare with Fig. 9). Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 3. x 78. Fig. 37 - Longitudinal section. This type of preservation partly filled (compare with Fig. 9, 17). Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 15. x 78.

Fig. 10 - *Nodosinelloides* cf. *aequiampla* (Zolotova in Zolotova & Baryshnikov, 1980). Longitudinal section. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM. x 140.

Fig. 11 - *Endothyra* ex gr. *prisca* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova et al., 1936. Axial section. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM. x 78.

Fig. 12 - *Nodosinelloides netschajewi* (Cherdyntsev, 1914). Longitudinal section. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM. x 78.

Fig. 13 - *Nostocites vesiculosa* Maslov, 1929. Scorpion Mound. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample SM 1. x 78.

Fig. 14, 20, 26, 31 - *Bradyina lucida* Morozova, 1949. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). x 32. Fig. 14 - Subaxial section. Sample FC1. Fig. 20 - Subtransverse section. Sample FC 7. Fig. 26 - Transverse section. Sample FC 1. Fig. 31 - Transverse section (right) with various sections of *Palaeotextularia* sp. (left), *Eotuberitina* and *Eugonophyllum* (center). Sample FC 13.

Fig. 15 - *Ammovertella inversa* (Schellwien, 1898). Sublongitudinal section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 6. x 32.

Fig. 16, 22-24 - *Deckerella geyeri* (Schellwien, 1898) (= *D. laheei* Cushman & Waters, 1928 sensu Vachard & Krainer, 2001a). Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). x 32. Fig. 16 - Oblique section. Sample FC7. Fig. 22 - Subaxial section. Sample FC 10. Fig. 23 - Subaxial section. Sample FC 7. Fig. 24 - Axial section. Sample FC 12.

Fig. 19 - *Spireitlina conspecta* (Reitlinger, 1950). Transverse section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 6. x 78.

Fig. 21, 33 - *Syzrania* spp. Two subaxial sections. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Fig. 21- Sample FC 1, x78. Fig. 33 - Sample FC 14. x140.

Fig. 25 - *Litostroma* (?) sp. Longitudinal section incrusted by a tolypamminid (?). Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 10. x 32.

Fig. 28 - *Anthracoporella spectabilis* Pia, 1920. Transverse section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 11. x 15.

Fig. 29 - "*Glomospira*" sp. Subaxial section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 12. x 78.

Fig. 32 - *Claracrusta catenoides* (Homann, 1972) Vachard, 1980. Longitudinal section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 13. x 32.

Fig. 34 - *Bradyina* sp. Subaxial section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 13. x 15.

Fig. 35 - *Endothyranella* sp. Subaxial section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 14. x 78.

Fig. 36 - *Globivalvulina* sp. Subaxial section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 14. x 78.

Fig. 38 - *Tetrataxis* sp. Axial section in life position. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 15. x 78.

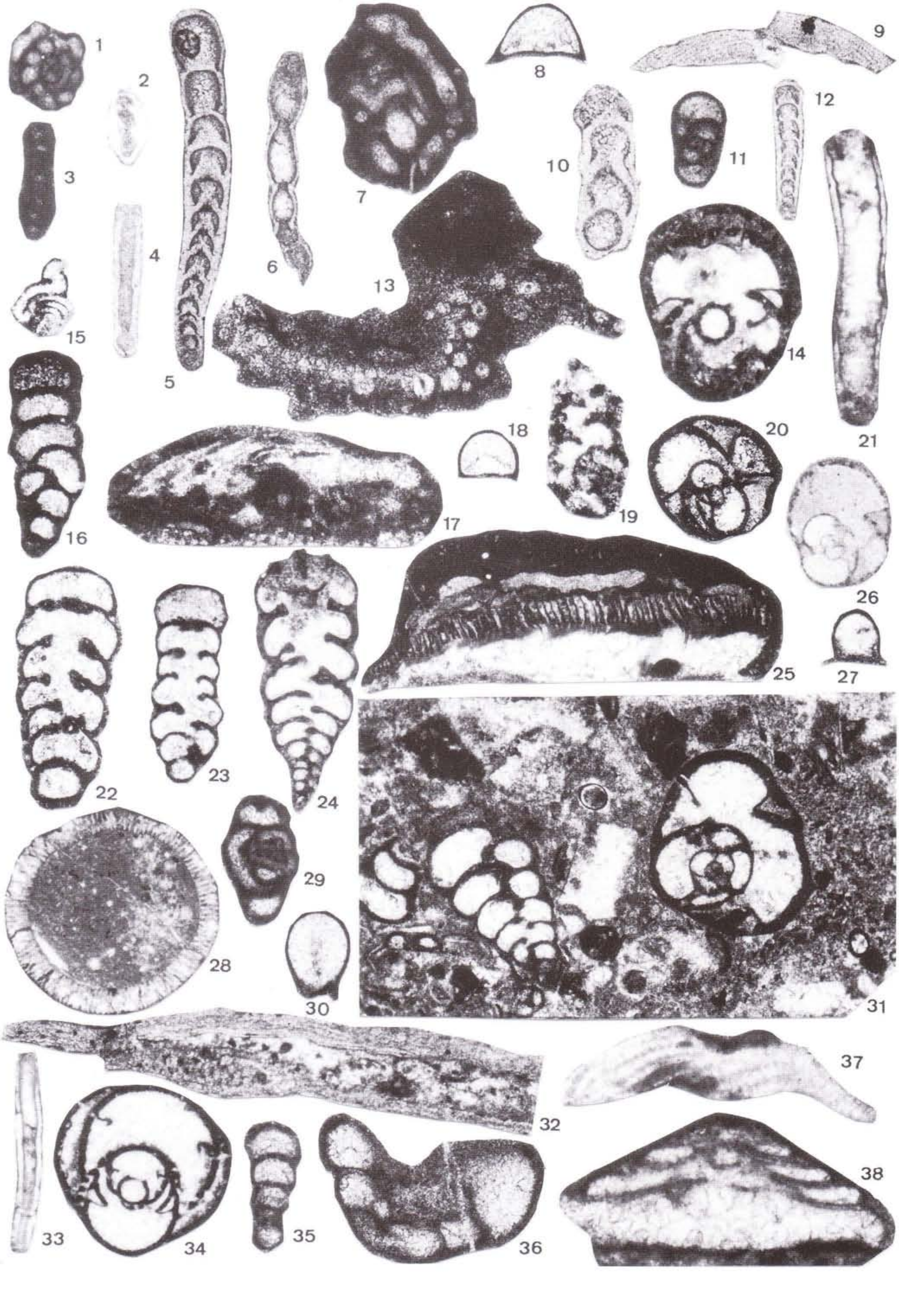
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PLATE 4

Fossil assemblages of the Laborcita Formation at Fresnal Canyon (continued) and Laborcita Canyon (New Mexico). For position of the samples in the sections see Fig. 4 (Laborcita Canyon, samples LC) and Fig. 5 (Fresnal Canyon, samples FC).

Fig. 1, 17, 22 - *Polytaxis laheei* Cushman & Waters, 1928. Three subaxial sections. Laborcita Formation. Early Wolfcampian (Orenburgian). x 32. Fig. 1 - Fresnal Canyon. Sample FC 22. Fig. 17 - Encrusting a *Pseudoepimastopora* thallus. Laborcita Canyon. Sample LC 2. Fig. 22 - Laborcita Canyon. Sample LC 9.

Fig. 2 - *Tetrataxis* sp. Subaxial section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 22. x 32.

Fig. 3, 40, 49-50, 55 - *Nodosinelloides netschajewi* (Cherdyntsev, 1914). Five longitudinal sections. Laborcita Formation. Early Wolfcampian (Orenburgian). x 78. Fig. 3 - Fresnal Canyon. Sample FC 18. Fig. 40, 49-50, 55 - Laborcita Canyon. Fig. 40 - Sample LC 18. Fig. 49-50 - Sample LC 44. Fig. 55 - LC 43.

Fig. 4, 29, 43, 48, 51, 53, 57? - *Nodosinelloides potievskaya*e Mamet & Pinard, 1996. Seven longitudinal sections. Laborcita Formation. Early Wolfcampian (Orenburgian). x 78. Fig. 4 - Fresnal Canyon. Sample FC 19. Fig. 29, 43, 48, 51, 53, 57? - Laborcita Canyon. Fig. 29 - Sample LC 15. Fig. 44, 48, 53 - Sample LC 18. Fig. 51 - LC 19. Fig. 57? - LC 44.

Fig. 5-10, 19-20, 23, 26-28, 31-33, 36-39, 41, 45-47, 58 - *Pseudovidalina* spp. [or several morphotypes of *P. recta* (Potievskaya, 1962)]. Twenty six axial and subaxial sections. Laborcita Formation. Early Wolfcampian (Orenburgian). x 78. Fig. 5-10 - Fresnal Canyon; the other ones: Laborcita Canyon. Fig. 5 - Sample FC 15. Fig. 6 - Sample FC 20. Fig. 7-8 - Sample FC 22. Fig. 9 - Sample FC 24. Fig. 10 - Sample FC 25. Laborcita Canyon: Fig. 19 - Sample LC 4. Fig. 20 - Sample LC 8. Fig. 23 - Sample LC 9. Fig. 26-27 - Sample LC 10. Fig. 28 - Sample LC 13. Fig. 31-33, 36-39, 41, 45-47, 58 - Sample LC 18. Fig. 58 shows the characteristic association of *Pseudovidalina recta* with *Nodosinelloides potievskayae*, specimen also reproduced in Fig. 48.

Fig. 11 - *Ammovertella* (= *Calcivertella*) sp. Sublongitudinal section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 27. x 78.

Fig. 12 - *Palaeonubecularia fluxa* Reitlinger, 1950. Transverse sections of tubules encrusting a bivalve shell. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 24. x 32.

Fig. 13 - *Litostroma* (?) sp. Longitudinal section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 27. x 32.

Fig. 14, 16, 34 - *Syzrania* spp. Laborcita Formation. Early Wolfcampian (Orenburgian). Three subaxial sections. Fig. 14 - Fresnal Canyon. Sample FC 19. x 78. Fig. 16, 34. Laborcita Canyon. Fig. 16 - Sample LC 2. x 78. Fig. 34 - Sample LC 18. x 32.

Fig. 15 - Charophyte gyrogonite. Sublongitudinal section. Fresnal Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample FC 31. x 78.

Fig. 18, 25 - *Endothyra* ex gr. *bowmani* Phillips, 1846 emend. Brady, 1876 sensu China, 1965. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). x 32. Fig. 18 - Transverse section. Sample LC 3. Fig. 25 - Axial section. Sample LC 9.

Fig. 21 - "*Glomospira*" sp. Subaxial section. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 9. x 32.

Fig. 24 - *Endothyra* ex gr. *prisca* Rauzer-Chernousova & Reitlinger in Rauzer-Chernousova et al., 1936. Axial section. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 9. x 78.

Fig. 30 - *Paraepimastopora* ex gr. *kansasensis* (Johnson, 1946) Roux, 1989. Longitudinal section. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 15. x 15.

Fig. 35 - *Quasilituotuba* (?) sp. - Subaxial section. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 17. x 32.

Fig. 42, 44 - *Spireitlina conspecta* (Reitlinger, 1950). Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 18. x 78. Fig. 42 - Tranverse oblique section. Fig. 44 - Subtransverse section.

Fig. 52 - *Bradyina lucida* Morozova, 1949. Subaxial section. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 18. x 32.

Fig. 54, 56 - *Protonodosaria praecursor* (Rauzer-Chernousova, 1949). Two subaxial sections. Laborcita Canyon. Laborcita Formation. Early Wolfcampian (Orenburgian). Sample LC 44. x 78.

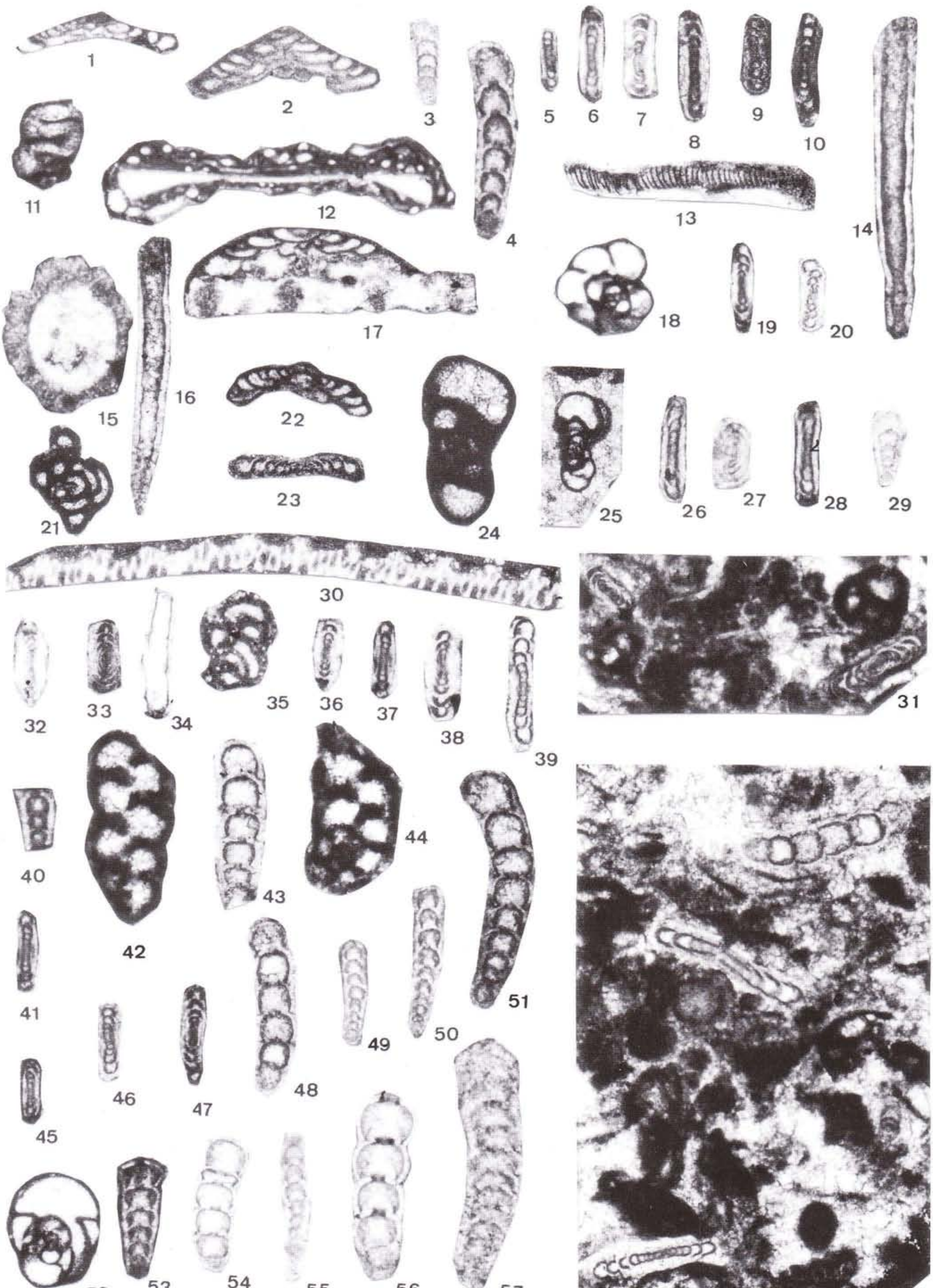
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PLATE 5

Fossil assemblages of the Shalem Colony Formation (Hueco Group) at Robledo Peak (New Mexico). For the position of the samples in the section see Fig. 3.

Fig. 1 - *Nodosinelloides netschajewi* (Cherdyntsev, 1914). Longitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 5. x 78.

Fig. 2 - *Vervilleina* sp. 2. Sublongitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 6. x 78.

Fig. 3 - *Nostocites vesiculosa* Maslov, 1929. Sublongitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 6. x 32.

Fig. 4-6, 9?, 31 - *Nodosinelloides potievskayae* Mamet & Pinard, 1996. Four longitudinal sections. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). x 78. Fig. 4 - Sample RM 7. Fig. 5-6 -Sample RM 8. Fig. 9? - Sample RM 14. Fig. 31 - Sample RM 31.

Fig. 7-8, 10, 17, 19 - *Epimastopora alpina* (Kochansky & Herak, 1960) sensu Kulik, 1978. Several sublongitudinal sections. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Fig. 7-8 - Sample RM 9. x 15. Fig. 10 - Sample RM 13 (bottom) with "*Problematicum* gen. 1" (top). x 32. Fig. 17 - Sample RM 15. x 32. Fig. 19 - Sample RM 23. x 78.

Fig. 11 - Oncoid of *Ellesmerella* (?) sp. (= "*Osagia*" sensu lato). Longitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 11. x 32.

Fig. 12 - *Calcitornella* (?) sp. Subtransverse section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 9. x 32.

Fig. 13-15 - Problematicum gen. 1. Various sections of an encrusting carbonate microproblematicum. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 14. x 32.

Fig. 16, 21 - *Spireitlina* cf. *tokmovensis* (Reitlinger, 1961). Two axial oblique sections. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). x 32. Fig. 16 - Sample RM 19. Fig. 21 - Sample RM 25.

Fig. 18 - *Ortonella* sp. 1. Longitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 16. x 15.

Fig. 20, 23-25 - *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/ Asselian). Fig. 20 - Oblique section converging with *Fourstonella* or *Stacheia*. Sample RM 23. x 78. Fig. 23-25 - Three oblique sections. Sample RM 25. x 32.

Fig. 22 - "*Glomospira*" sp. or young *Palaeonubecularia* sp. Sublongitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 24. x 32.

Fig. 26 - Dasyclad indet. Longitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 25. x 32.

Fig. 27 - *Eoschubertella* sp. Axial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 28. x 78.

Fig. 28 - *Pseudovidalina* sp. Subaxial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 29. x 78.

Fig. 29 - *Cornuspira* sp. Transverse section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 31. x 78.

Fig. 30 - *Hemigordius harltoni* Cushman & Waters, 1928. Subaxial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/ Asselian). Sample RM 31. x 78.

Fig. 32 - *Bradyina compressa* Morozova, 1949 [= ? *B* (?) *arctica* Pinard and Mamet, 1998]. Axial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 28. x 32.

Fig. 33 - *Schubertella* sp. Subaxial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 28. x 78.

Fig. 34 - *Epimastopora* sp. Longitudinal section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 28. x 15.

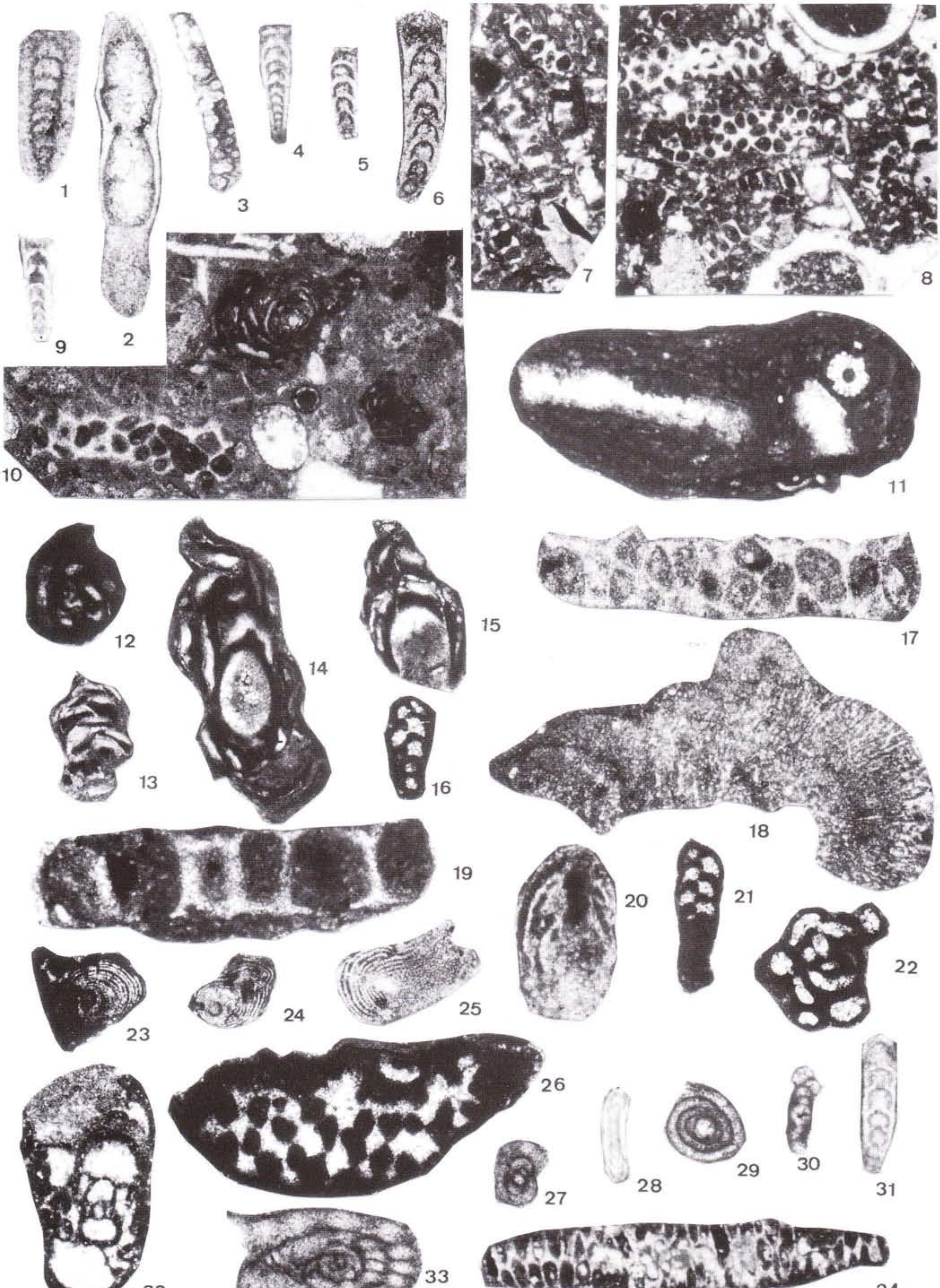
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PLATE 6

Fossil assemblages of the Shalem Colony Formation (samples RM, see Fig. 3) at Robledo Peak (continued) and the Robledo Mountains Formation (samples A from Section A of Krainer & Lucas 1995), Hueco Group (New Mexico).

Fig. 1 - *Endothyranella* ex gr. *minuta* (Waters, 1927). Axial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/ Asselian). Sample RM 31. x 78.

Fig. 2, 6 - *Bradyina compressa* Morozova, 1949. Two complementary sections. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). x 32. Fig. 2 - Subtransverse section. Sample RM 24. Fig. 6 - Axial section. Sample RM 46.

Fig. 3 - *Hemigordius schlumbergeri* (Howchin, 1895). Axial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/ Asselian). Sample RM 37. x 78.

Fig. 4 - *Syzrania minima* Stepanova, 1997. Axial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 44. x 140.

Fig. 5 - *Calcitornella* sp. Axial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 37. x 32.

Fig. 7 - *Tubiphytes* sp., whose morphology is intermediate between tolypamminid foraminifers and "true" *Tubiphytes*. Subaxial section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 35. x 32.

Fig. 8 - Hinge of a kirkbyid ostracod (not *Nostocites vesiculosa*). Tangential section. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 47. x 78.

Fig. 9-10 - *Nodosinelloides netschajewi* (Cherdyntsev, 1914).Two longitudinal sections. Robledo Mountains. Shalem Colony Formation. Early-middle Wolfcampian (Orenburgian/Asselian). Sample RM 48. x 78.

Fig. 11-12 - *Pseudovermiporella* sp. 1 (by its deep pits this species differs from *Hedraites*). Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). x 78. Fig. 11 - Atypical section, may be *Mendipsia*. Sample A 6c. Fig. 12 - Typical oblique section. Sample A 6e.

Fig. 13 - *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979. Oblique section filled with micrite. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 8c x 78.

Fig. 14-17, 25, 27 - *Geinitzina postcarbonica* Spandel, 1901. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). x 78. Fig. 14 -16 - Three sagittal sections. Sample A 8d. Fig. 17 - Frontal typical section. Sample A 8d. Fig. 25 - Sagittal section. Sample A 9. Fig. 27 - Oblique section. Sample A 9.

Fig. 18, 22-23, 28-29, 32 - *Globivalvulina* spp. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Fig. 18 - Subaxial section. Sample A 8e. x 32. Fig. 22 - Subtransverse section. Sample A 9. x 78. Fig. 23, 28-29 - Three subtransverse sections. Sample A 9. x 32. Fig. 32 - Subaxial section. Sample A 12. x 78.

Fig. 19-20 - *Nodosinelloides potievskayae* Mamet & Pinard, 1996. Two axial sections. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 9. x 78.

Fig. 21 - *Pseudoepimastopora* sp. Longitudinal section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 9. x 32.

Fig. 24 - *Neodiscus* (?) sp. Axial section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 9. x 32.

Fig. 26 - *Hemigordius* sp. 3. Axial section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 9. x 78.

Fig. 30 - *Ammovertella inversa* (Schellwien, 1898). Sublongitudinal section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 12. x 78.

Fig. 31 - *Neoanchicodium catenoides* Endo, 1954. Various sections. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 9. x 32.

Fig. 33 - *Staffella* sp. Subaxial section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 12. x 15.

Fig. 34 - *Hemigordius* sp. 4. Subaxial section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 12. x 78.


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PLATE 7

Fossil assemblages of the Robledo Mountains Formation (samples A refer to Section A and samples C to Section C of Krainer & Lucas 1995), Hueco Group (New Mexico).

Fig. 1, 7 - *Pseudovermiporella* sp. 2. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). x 32. Fig. 1 - Axial-tangential section. Sample A 12. Fig. 7 - Longitudinal section with "innermost tubes". Sample A 13.

Fig. 2 - *Calcivertella* (sensu stricto) sp. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 12. x 32.

Fig. 3, 9, 15, 19, 22 - *Globivalvulina bulloides* (Brady, 1876). Robledo Mountains (Sections A and C). Robledo Mountains Formation. Wolfcampian (Sakmarian/early Artinskian). x 32. Fig. 3 - Transverse section. Sample A 13. Fig. 9 - Axial section. Sample A 14c. Fig. 15 - Transverse section. Sample A 14c. Fig. 19 - Transverse section. Sample C 19f. Fig. 22 - Subtransverse section. Sample C 25.

Fig. 4, 6, 34, 36, 39 - *Geinitzina postcarbonica* Spandel, 1901. Robledo Mountains (Sections A and C). Robledo Mountains Formation. Wolfcampian (Sakmarian/early Artinskian). x 78. Fig. 4 - Frontal section. Sample A 14. Fig. 6 - Frontal section. Sample A 13. Fig. 34 - Sagittal section. Sample C 35b. Fig. 36, 39 - Two almost frontal sections. Sample C 35c.

Fig. 5 - *Nodosinelloides* aff. *ronda* (Lipina, 1949). Subaxial section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 13. x 78.

Fig. 8, 13 - *Langella* (?) cf. *minima* Baryshnikov in Zolotova & Baryshnikov, 1980. Two axial sections. - Robledo Mountains (Section A). Robledo Mountains Formation. Middle Wolfcampian (Asselian/Sakmarian). x 78, Fig. 8 - Sample A 13, Fig. 13 - Sample A 14b.

Fig. 10 - *Mizzia* cf. *cornuta* Kochansky-Devidé & Herak, 1960. Transverse section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 14b. x 32.

Fig. 11 - *Gyroporella* sp. Oblique section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 14b. x 32.

Fig. 12 - *Neoanchicodium catenoides* Endo, 1954. Longitudinal section. Robledo Mountains (Section A). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample A 14b. x 32.

Fig. 14, 26, 28, 31-33, 35, 37 - *Nodosinelloides potievskayae* Mamet & Pinard, 1996. Nine axial sections. Robledo Mountains (Sections A and C). Robledo Mountains Formation. Wolfcampian (Sakmarian/early Artinskian). x 78. Fig. 14 - Sample A 14e. Fig. 26 - Sample C 29. Fig. 28, 31-32 - Sample C 35a. Fig. 33, 35 - Sample C 35b. Fig. 37 - C 35c.

Fig. 16, 20-21 - *Frondicularia* (?) spp. Three subaxial sections. Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (Sakmarian). x 78. Fig. 16 - Sample C 1. Fig. 20 - 21 - Sample C 19f.

Fig. 17 - *Eflugelia johnsoni* (Flügel, 1966) Massa & Vachard, 1979. Longitudinal section. Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample C 19c. x 78.

Fig. 18 - *Ammovertella inversa* (Schellwien, 1898). Longitudinal section. Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (Sakmarian). Sample C 16d. x 78.

Fig. 23, 40 - *Pseudoreichelina* ex gr. *darvasica* (Leven, 1970). Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (early Artinskian). x 32. Fig. 23 - Subtransverse section Sample C 26. Fig. 40 - Axial section. Sample C 35c.

Fig. 24, 27, 30, 38 - "*Glomospira*" spp. Four subaxial to oblique sections. Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (early Artinskian). Fig. 24 - Sample C 26. x 78. Fig. 27 - Sample C 30. x 78. Fig. 30 - Sample C 35a. x 78. Fig. 38 - Sample C 35c. x 32.

Fig. 25 - *Geinitzina* (?) sp. Longitudinal section. Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample C 28 x 78.

Fig. 29 - *Earlandia* sp. Subaxial section. Robledo Mountains (Section C). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample C 35a x 78


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PLATE 8

Fossil assemblages of the Robledo Mountains Formation (samples B 3a, b, c) and lower Apache Dam Formation (samples B 8, 11, 13, 17) (Section B of Krainer & Lucas 1995), Hueco Group (New Mexico).

Fig. 1-2, 11-12, 15-16 - *Globivalvulina* spp. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Fig. 1-2 - Two subaxial sections. Sample B 3a. x 78. Fig. 11 - Transverse section. Sample B 3b. x 78. Fig. 12 - Subaxial section. Sample B 3b. x 32. Fig. 15 - Subtransverse section. Sample B 8. x 78. Fig. 16 - Subaxial section. Sample B 8. x 78.

Fig. 3-6 - *Hemigordius* (?) sp. 5. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Various sections. Sample B 3a. x 78.

Fig. 7-8 - *Pseudovermiporella* sp. 3. Two longitudinal sections. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 3a. x 78.

Fig. 9 - *Nodosinelloides* sp. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 3a. x 78.

Fig. 10 - *Geinitzina* sp. 1. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 3a. x 78.

Fig. 13, 27 - *Earlandia* sp. Two subaxial sections. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). x 78. Fig. 13 - Sample B 3b. Fig. 27 - Sample B 17.

Fig. 14 - *Geinitzina* sp. 2. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 3c. x 78.

Fig. 17 - *Nodosinelloides potievskayae* Mamet & Pinard, 1996. Axial section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 8. x 78.

Fig. 18 - Syzraniid indet. Subaxial section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 17. x 32.

Fig. 19 - *Neoanchicodium catenoides* Endo, 1954. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 8. x 32.

Fig. 20 - *Tetrataxis* sp. Subaxial section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 13. x 78.

Fig. 21 - *Ortonella* sp. 2. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (early Artinskian). Sample B 11. x 32.

Fig. 22 - *Claracrusta calamistrata* Vachard, 1980. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 13. x 32.

Fig. 23 - *Vervilleina* sp. 3. Sublongitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 13. x 78.

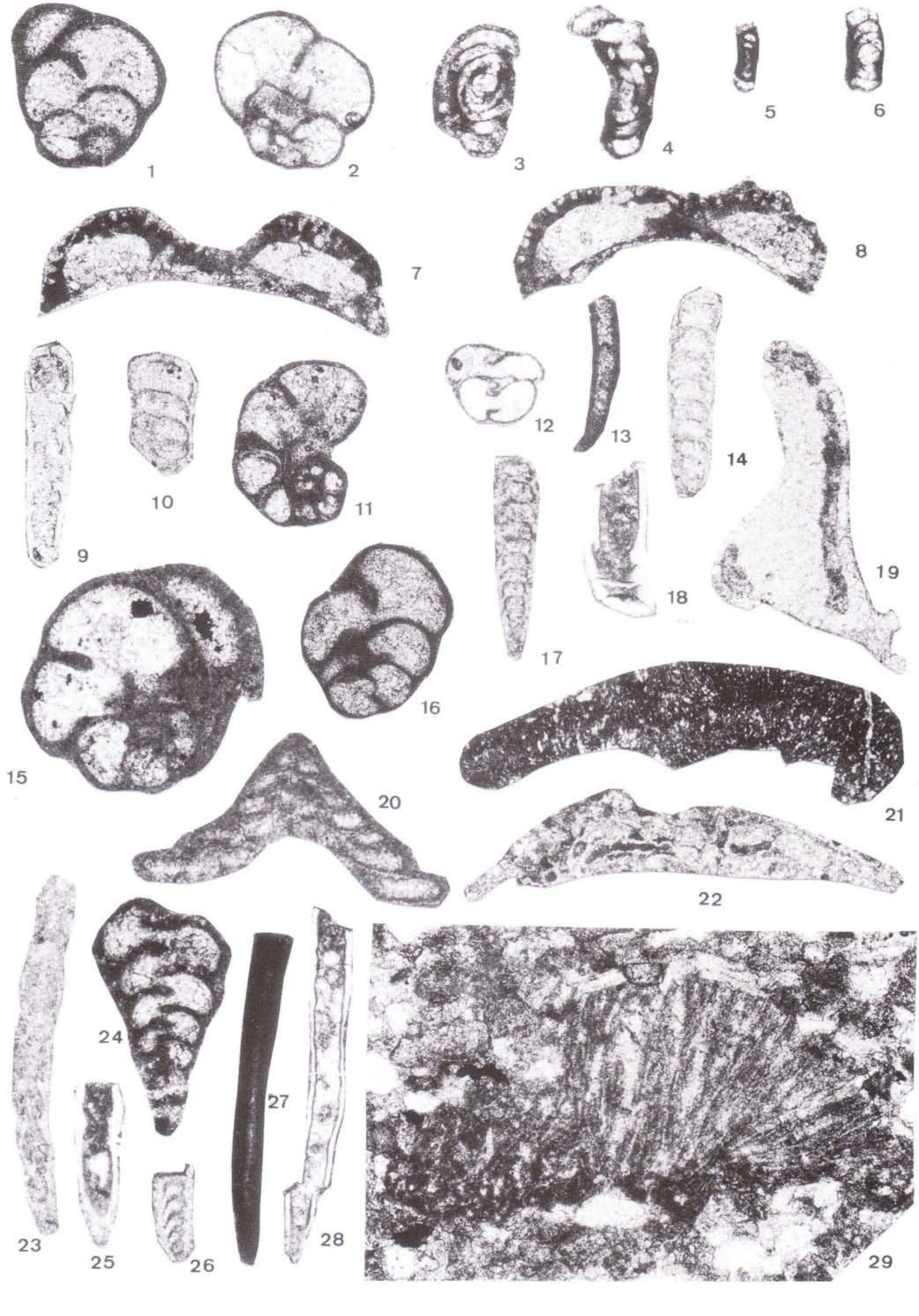
Fig. 24 - *Palaeotextularia* sp. Subaxial section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 17. x 78.

Fig. 25 - *Tezaquina* aff. *clivuli* Vachard in Montenat & Vachard, 1981. Oblique section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 17. x 32.

Fig. 26 - *Pachyphloia* sp. Axial section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 13. x 78.

Fig. 28 - *Syzrania* sp. Subaxial section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 17. x 32.

Fig. 29 - *Ortonella* sp. 3. Longitudinal section. Robledo Mountains (Section B). Robledo Mountains Formation. Wolfcampian (Artinskian). Sample B 11. x 78.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Vachard in Vachard & Montenat, 1981, syzraniid indet., *Vervilleina* sp. 3, *Nodosinelloides potievskayae* Mamet & Pinard, 1996, *N.* sp., *Geinitzina* sp. 1, G. sp. 2., and *Pachyphloia* sp.

Biostratigraphy

Although the smaller foraminiferal assemblages of the Laborcita Formation and Hueco Group are poor when compared to contemporaneous successions in the Carnic Alps, they allow a relatively precise and easy correlation because they are less endemic than the fusulinids, whose markers are, for instance in the Orenburgian, respectively restricted to North America (*Leptotriticites*) or some parts of the Paleotethys (*Bosbytauella*).

The assemblages of smaller foraminifers of the Laborcita Formation and Hueco Group are very similar to those recently reported from the upper Auernig Group and Rattendorf Group of the Carnic Alps (Austria/Italy) by Vachard & Krainer (2001a, b). Biostratigraphy of the Auernig and Rattendorf Groups is well established on the basis of fusulinids (e.g. Forke et al. 1998; Kahler & Krainer 1993; Krainer & Davydov 1998; Davydov & Krainer 1999).

Based on the assemblages of smaller foraminifers, the Holder Formation is of Gzhelian age at Laborcita Canyon but the foraminifers are not age diagnostic at Dry Canyon (Yucca Mound). The Laborcita Formation is typically Orenburgian in age at Laborcita and Fresnal Canyons, characterized by the occurrence of *Nodosinelloides potievskayae*, *N. netschajewi* and *Pseudovidalina* spp. The assemblage of the Shalem Colony Formation at Robledo Peak is less diverse and probably corresponds to the Asselian. Typical Sakmarian assemblages with *Geinitzina* and *Pseudovermiporella* appear in the Robledo Mountains Formation of section A. The Robledo Mountains Formation of section C is early Artinskian in age, as indicated by *Pseudoreichelina* ex gr. *darvasica*. Section B, comprising the uppermost Robledo Mountains Fomation and lower Apache Dam Formation, is probably late Artinskian in age, but clear evidence is lacking. Therefore, the correlations of Davydov (1996) are confirmed (see stratigraphic scheme, Fig. 2).

Conclusions

The uppermost part of the Holder Formation at Laborcita Canyon is of Gzhelian age due to the presence of *Pseudovidalina* (= *Raphconilia*). The foraminiferal assemblage of the Holder Formation at Dry Canyon (Yucca Mound) is less characteristic, containing *Glomospiroides* and *Brunsiella*. The Laborcita Formation at Fresnal Canyon and Laborcita Canyon exhibits in its lower part an Orenburgian foraminiferal assemblage that is very similar to that of the Auernig Formation of the Carnic Alps. The Shalem Colony Formation (Hueco Group) of the Robledo Mountains is more or less coeval, and may represent only the upper part of the "Bursumian" (Orenburgian) and Asselian. The foraminiferal assemblage of the Robledo Mountains Formation (section A) is late Asselian/Sakmarian in age and comparable with the Grenzland Formation and Upper Pseudoschwagerina Limestone of the Carnic Alps. The Robledo Mountains Formation of section C is clearly early Artinskian in age due to the biostratigraphic value of the staffelloid *Pseudoreichelina* ex gr. *darvasica*. It corresponds to the major part of the Trogkofel Group of the Carnic Alps. The uppermost Robledo Mountains Formation and lower Apache Dam Formation of section B is poorly dated but is probably equivalent to the the middle-late Artinskian (upper part of Trogkofel Group) (Fig. 2).

These data add support to the hypothesis of Davydov (1996) concerning the correlations of the North American stages with stages from the Urals and further contribute to the correlation of the New Mexican formations with those of the Carnic Alps. Only the stratigraphic gap of the middle Asselian, supposed by Davydov (1996) and Krainer & Davydov (1998), respectively, in North America and in the Carnic Alps, is not confirmed here. Finally, we correlate the "Bursumian" with the Orenburgian, and the Wolfcampian with the Asselian, Sakmarian and Artinskian.

The Laborcita Formation at Laborcita Canyon exhibits a complete "Bursumian" section and may be more complete than that of the Bursum stratotype (Lucas & Wilde 2000), especially for identifying the position of the Carboniferous/Permian boundary in North America. The microfauna of the Robledo Mountains Formation (section B) is also important for the correlation with the early Artinskian, because of the presence of *Pseudoreichelina* ex gr. *darvasica*.

Compared to the late Paleozoic succession (Auernig and Rattendorf Group) of the Carnic Alps, significant differences exist concerning the biotic constituents of limestones, particularly calcareous algae and smaller foraminifers. In limestones of the Auernig and Rattendorf Group, calcareous algae are the most frequent biotic constituent throughout the sequence, occurring in high diversity. In the Carnic Alps, algal wackestone is by far the most abundant microfacies. The most abundant algae are *Anthracoporella spectabilis*, *Archaeolithophyllum missouriense*, *Epimastopora*, and *Tubiphytes*/*Archaeolithoporella* in the uppermost part. All those taxa are rare in the Laborcita and Hueco limestones. Mounds in the Carnic Alps are composed dominantly of *Anthracoporella* (Krainer 1995; Forke et al. 1998; Samankassou 1998) or *Tubiphytes*/*Archaeolithoporella* (Flügel 1981), whereas in the Laborcita Formation and Hueco Group, phylloid algae are the dominant mound-building organisms.

Smaller foraminifers are also more abundant and display a higher taxonomic diversity in late Paleozoic limestones of the Carnic Alps (Vachard & Krainer 2001a, b). Although lower in diversity, the smaller foraminifers are less endemic than the fusulinids and allow relatively precise and easy correlations between New Mexico and Europe (Carnic Alps).

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