Precise age and biostratigraphic significance of the Kinney Brick Quarry Lagerstätte, Pennsylvanian of New Mexico, USA

Spencer G. Lucas1, Bruce D. Allen2, Karl Krainer3, James Barrick4, Daniel Vachard5, Joerg W. Schneider6, William A. DiMichele7 and Arden R. Bashforth8

1New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, New Mexico, 87104, USA
e-mail: Spencer.lucas@state.nm.us
2New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, New Mexico, 87801, USA
e-mail: allenb@gis.nmt.edu
3Institute of Geology and Paleontology, University of Innsbruck, Innsbruck, A-6020, Austria
e-mail: Karl.Krainer@uibk.ac.at
4Department of Geosciences, Texas Tech University, Box 41053, Lubbock, Texas, 79409, USA
e-mail: Jim.Barrick@ttu.edu
5Université des Sciences et Technologies de Lille, UFR des Sciences de la Terre, UPRESA 8014 du CNRS, Laboratoire LP3, Bâtiment SN 5, F-59655 Villeneuve d’Ascq, Crèvecœur, France
e-mail: daniel.vachard@univ-lille1.fr
6TU Bergakademie Freiberg, Cottastasse 2, D-09596 Freiberg, Germany
e-mail: joerg.schneider@geo.tu-freiberg.de
7Department of Paleobiology, NMNH Smithsonian Institution, Washington, DC 20560
e-mail: DIMICHEL@si.edu
8Geological Museum, Natural History Museum of Denmark, University of Copenhagen, Øster Voldgade 5-7, 1350 Copenhagen K, Denmark
e-mail: bashforth@snm.ku.dk

ABSTRACT: The Kinney Brick Quarry is a world famous Late Pennsylvanian fossil Lagerstätte in central New Mexico, USA. The age assigned to the Kinney Brick Quarry (early-middle Virgilian) has long been based more on its inferred lithostratigraphic position than on biostratigraphic indicators at the quarry. We have developed three datasets — stratigraphic position, fusulinids and conodonts — that indicate the Kinney Brick Quarry is older, of middle Missourian (Kasimovian) age. Our detailed local lithostratigraphic studies coupled with regional stratigraphic investigations indicate the Kinney Brick Quarry is in the Tinajas Member of the Atrasado Formation, so it is stratigraphically lower than suggested by previously published maps. A laterally extensive fusulinid-bearing limestone a few meters below the level of the Kinney Brick Quarry yields an early-middle Missourian fusulinid assemblage consisting of Tumulotriticites cf. T. tumidus and species of Triticites: T. cf. T. planus, T. cf. T. myersi and T. ex gr. T. ohioensis. The Kinney conodont fauna is characterized by Idiognathodus corrugatus and I. cherryvalensis, which suggest an assignment to the Idiognathodus confragus Zone of the North America Midcontinent region (Dennis cyclothem; middle Missourian). Nonmarine biostratigraphic indicators at the Kinney Brick Quarry indicate either an imprecise age (Late Pennsylvanian: megaflora) or a slightly younger age (late Kasimovian-early Gzhelian: blattids) than do stratigraphic position and marine microfossils. The well-established age of Kinney on the marine timescale thus can be used to better calibrate the nonmarine biostratigraphy. So, the insect biozonation of the Euramerican continental basins, which was calibrated to the so-called regional West European Carboniferous stages by macrofloras and to the global marine scale by sparse, ambiguous isotopic ages, can now be linked directly to the marine conodont zonation.

INTRODUCTION

The Kinney Brick Quarry in the Manzanita Mountains of central New Mexico is a world-famous locality for Late Pennsylvanian fossil plants, invertebrates and vertebrates located ~ 12 km south-southeast of Tijeras, New Mexico in sec. 18, T9N, R6E, Bernalillo County, New Mexico (text-figs. 1-3). The quarry is actively mined for clay utilized to manufacture bricks by the Kinney Brick Company in Albuquerque, New Mexico.

A classic Konservat Lagerstätte, Kinney preserves soft tissues and other delicate structures of plants and animals not well known from correlative deposits (Lucas and Huber 1991; Kues and Lucas 1992). Fossils documented from the Kinney Brick Quarry are palynomorphs (Willard 1992), a diverse, conifer-rich megaflora (Mamay 1981, 1990; Ash and Tidwell 1982; Mamay and Mapes 1992), conchostracans (Kozur et al. 1992), ostracods (Kietzke and Kaesler 1992), ter-

stratigraphy, vol. 8, no. 1, text-figures 1-10, table 1, appendices 1-2, pp. 7-27, 2011
restrial arthropods, mostly diplopods and insects (Carpenter, 1970; Shear et al. 1992), conodonts (Krukowski 1992), a diverse assemblage of fishes, mostly acanthodians and palaeoniscoids (Zidek 1975, 1992b; Gottfried 1987a, b 1992; Bardack 1992; Huber 1992; Schulze 1992) and amphibians (Berman 1973; Hunt et al. 1992, 1996; Werneburg and Lucas, 2007), as well as coprolites (Hunt 1992) and “fish eggs” (Mamay 1994). The depositional setting of Kinney is interpreted to be that of an estuary fed by a river delta (Feldman et al. 1992; Lorenz et al. 1992).

The Kinney Brick Quarry is located in the Atrasado Formation, a lithostratigraphic unit of well-established Late Pennsylvanian age. However, the precise age of the Kinney Brick Quarry fossils has been difficult to determine, given that most of the fossils from the quarry are not precise age indicators. Indeed, the precise age long assigned to the Kinney Brick Quarry fossils—early-middle Virgilian—is based more on its previously inferred lithostratigraphic position than on any age indicators found at the quarry. Here, we present new data that not only alter the long-accepted lithostratigraphic position of the Kinney Brick Quarry fossils, but we also provide direct age determinations of the Kinney fossil assemblage based on fusulinids and conodonts. These data indicate that the Kinney fossils are of middle Missourian age, substantially older than previously thought. This newly determined age on the marine timescale can be used to better calibrate nonmarine biostratigraphic indicators from Kinney (plants and blattid insects) and may well explain the resemblance of Kinney to some other Pennsylvanian Lagerstätten.

PREVIOUS AGE DETERMINATIONS

Lucas and Huber (1991) and Kues and Lucas (1992) provided a detailed review of paleontological studies of the Kinney Brick Quarry Lagerstätte (KBQL) through 1992, when a comprehensive, edited volume brought together the state-of-the-art of knowledge of KBQL paleontology (Zidek 1992a). Little has appeared in print on Kinney paleontology since that volume (e.g., Mamay 1994; Hunt et al. 1996; Lucas et al. 1999; Werneburg and Lucas 2007). Here, we focus on the history of the study of the stratigraphic position and age determinations of the KBQL, which can be divided into three phases (text-fig. 4).

Students at the University of New Mexico initiated the first phase when they discovered the fossils at the KBQL in the early 1960s. Stukey (1967, p. 48-52) first determined the lithostratigraphic position of the KBQL as about 122m below the base of the Abo Formation in what he termed interval “S-1,” which is in the lower part of the “arkosic limestone member of the Madera limestone.” Based on fossil fishes (especially Acanthodes) and plants (especially Callipteris) from the KBQL, Stukey (1967) suggested a possible Permian age for the KBQL (text-fig. 4). Kelley and Northrop (1975, p. 47-49) essentially repeated this conclusion, but were more tentative about the
Permian age. They noted that the early report of *Callipteris* from the KBQL was not verifiable, but still considered it possible that the KBQL strata may be an equivalent of the lower Wolfcampian Bursum Formation.

During the 1960s, D. A. Myers of the U. S. Geological Survey began the second phase of study relevant to the age of the KBQL when he undertook an extensive two-decade-long study of the lithostratigraphy and fusulinid biostratigraphy of Pennsylvanian strata in the Manzano and Manzanita Mountains. This work appeared as a series of geologic maps (Myers 1966, 1967, 1969, 1977; Myers and McKay 1970, 1971, 1972, 1974, 1976; Myers et al. 1986) and reports (Myers 1973, 1982, 1988). Particularly significant is that Myers established a formal scheme of Pennsylvanian lithostratigraphy correlated by fusulinid biostratigraphy (text-fig. 4). In that scheme, Myers named strata formerly referred to as the “arkosic limestone member of the Madera limestone” the Wild Cow Formation, and established its age as Missourian-Virgilian based on fusulinids. Myers made no specific reference to the KBQL in his published work; only his geologic map of the area that encompasses the Kinney Brick quarry (Myers and McKay 1976) provided its stratigraphic position and age. Thus, Myers and McKay (1976) mapped the KBQL in the approximate middle of the Pine Shadow Member of the Wild Cow Formation, ~ 30m below the base of the La Casa Member (text-fig. 4). Myers (1988) reported no fusulinids from the area of the KBQL, but at Cedro Peak, ~ 6km to the north (text-fig. 2), he reported the fusulinids *Oketaella* sp., *Triticites* sp. and *T. cf. T. bensonensis* Ross and Tyrrell in strata he identified as the middle and upper parts of the Pine Shadow Member. This is an assemblage of early-middle Virgilian age, and subsequent workers (see the articles in Zidek 1992a) thus assigned an early-middle Virgilian age to the KBQL.

Phase three of the study of the stratigraphic position and age of the KBQL is the research reported here (text-fig. 4) and detailed below.

**AGE OF THE KINNEY BRICK QUARRY LAGERSTÄTTE**

Three lines of evidence can be used to determine the precise age of the KBQL: (1) lithostratigraphic position and, thereby, lithostratigraphic correlation with nearby, well-dated Pennsylvanian sections; (2) fusulinid biostratigraphy, based primarily on fusulinids newly discovered only a few meters below the stratigraphic level of the KBQL; and (3) conodont biostratigraphy, based on conodonts newly recovered from the basal fossiliferous beds of the KBQL. Here, we review these age data to show they all concur that the KBQL is of middle Missourian age.

**Lithostratigraphic position**

The Kinney Brick Quarry is developed in clastic strata that were originally assigned to the “arkosic limestone member of the Madera Formation” by Stukey (1967), who first studied the lithostratigraphic position of the quarry (also see Kelley and Northrop 1975, text-fig. 4). Stukey’s lithostratigraphic terminology was part of a generalized formation- and group-rank nomenclature developed during the first half of the 20th century for Pennsylvanian strata in central New Mexico, principally by workers of the U. S. Geological Survey (e.g., Herrick 1900; Gordon 1907; Darton 1922, 1928; Wilpolt et al. 1946; Read and Wood 1947).

All workers apply the term Sandia Formation to the lowest Pennsylvanian formation-rank stratigraphic unit in the Manzano-Manzanita Mountains (text-fig. 4)—a succession of siliciclastics (notably quartz sandstone and conglomerate) and carbonates (especially coarse-grained bioclastic wackestone) that yields fusulinids of Atokan age (Myers 1988). Similarly, all workers use the term Bursum Formation for the stratigraphically highest Pennsylvanian strata in the section (text-fig. 4)—a mixed succession of red-bed clastics and marine limestones (the Bursum was long regarded to be of earliest Permian age, but is now assigned to the latest Pennsylvanian) (e.g., Lucas and Krainer 2004; Krainer and Lucas 2009).

During the last decade, the terms Gray Mesa and Atrasado formations have been used for the strata in central New Mexico that had previously been termed Madera limestone (Formation or Group) by many workers (Kues 2001; Krainer and Lucas 2004; Lucas et al. 2009). Gray Mesa and Atrasado are the oldest mappable formation rank unit names formally proposed for these units (Kelley and Wood 1946; Krainer and Lucas 2004) and apply to mappable lithosomes across much of central New Mexico, from the Oscura Mountains through the Cerros de Amado, the Los Pinos, Manzano, Manzanita and Sandia Mountains and Lucero Mesa (text-fig. 1). They are formal terms for the lower gray limestone and upper arkosic limestone members, respectively, of the Madera limestone mapped by Wilpolt et al. (1946) and Wilpolt and Wanek (1951), among others, and first explicitly applied by Stukey (1967) to the strata exposed at the KBQL. The formation names Myers (1973) introduced for what he termed the Madera Group in the Manzano Mountains—Los Moyos and Wild Cow formations—are, as Kues (2001) first noted, obviously synonyms of the Gray Mesa and Atrasado formations of Kelley and Wood (1946). The names Los Moyos...
Formation and Wild Cow Formation thus have been abandoned and replaced by Gray Mesa Formation and Atrasado Formation, respectively (text-fig. 4).

Renewed mapping in the Manzanita Mountains beginning in the 1990s as part of the U.S. STATEMAP Program necessitated a re-evaluation of Myers’s work. Most of the geologists involved in this mapping effort (e.g., Karlstrom et al. 1994; Chamberlin et al. 1997; Read et al. 1998), working in areas previously mapped by Myers and McKay, found it difficult to apply Myers’s stratigraphic nomenclature, especially with respect to Myers’s member-level units of the Atrasado Formation (Sol se Mete, Pine Shadow, and La Casa members of Myers’s Wild Cow Formation). Further confusion arose from Myers’s (1988) statement that the Bursum Formation was not present in the Manzanita Mountains, despite the fact that the Bursum lithosome is well-exposed in outcrops near Interstate 40 east of Albuquerque (text-fig. 1). Myers and McKay (1976) included these strata in the La Casa Member of the Wild Cow Formation in their map of the area. STATEMAP mappers placed these strata in the Permian Abo Formation, but they are readily assigned to the Bursum Formation based on lithology.

The result of this renewed mapping effort was that, for the most part, Myers’s formal stratigraphic divisions were abandoned, and map-unit designations utilized by most STATEMAP mappers reverted to the mid-20th century nomenclature of the U.S. Geological Survey (i.e., “lower gray limestone” and “upper arkosic limestone” members of the “Madera Formation” text-fig. 4).

As part of the STATEMAP effort, one of us (BDA) attempted to retain Myers’s formation- and member-rank nomenclature (e.g., Allen 2002), recognizing that it was indeed possible to consistently divide the Atrasado Formation into three map-scale units based on the presence of two, relatively thick and laterally extensive limestone beds separated by siliciclastic (abundant shale and sandstone) intervals. We now assign these two limestone beds to the Amado and overlying Council Springs members of the Atrasado Formation (text-fig. 4; these units are discussed below). Thus, Allen assigned the Bartolo and Amado members of the Atrasado Formation to Myers’s Sol se Mete Member of the Wild Cow Formation, the overlying Tinajas and Council Springs members to Myers’s Pine Shadow Member, and all the overlying strata between the Council Springs Member and the Bursum Formation to Myers’s La Casa Member.

The primary reason for the mistaken stratigraphic position (and therefore the incorrect age) of the KBQL is the fact that Myers’s maps of the area are, in many places, incompatible with his own stratigraphy. A good example is on Cedro Peak just to the north of the KBQL, where Myers and McKay (1976) placed the contact between the Gray Mesa and Atrasado formations (their Los Moyos and Wild Cow formations) far up in the Atrasado Formation (near the top of the Amado Member). The reason for this may be that the Amado is a relatively thick, cherty, cliff-forming limestone, similar to the underlying Gray Mesa Formation in many respects. Nonetheless, our re-examination of Cedro Peak shows that the stratigraphic sequence there, despite subtle structural modifications (faults and landslides), is rather clear and incompatible with the mapping of Myers and McKay (1976).

In the immediate vicinity of the KBQL, Myers and McKay (1976) mapped the quarry as just below the base of their La Casa Member of the Wild Cow Formation. We now know that the quarry is in the lower part of the Tinajas Member of the Atrasado Formation, corresponding in reality to what we surmise they considered to be upper Sol se Mete or lower Pine Shadow in other parts of the mountain range. In short, it seems clear that the disconnect between Myers’s fusulinid-based, biostratigraphic units, actual mappable lithostratigraphic units, and what he and his colleagues mapped on the ground is so great in some areas that Myers’s member-rank nomenclature for the Atrasado Formation has to be abandoned (and much of the mapping redone). This is unfortunate, considering the large amount of good work that was done during Myers’s nearly two-decade long efforts in the Manzanos.

Thompson (1942) proposed a very detailed lithostratigraphic nomenclature for Pennsylvanian strata in central and southern New Mexico, and much of it has been used by those who have subsequently studied and/or mapped the Pennsylvanian rocks in Socorro and Valencia Counties, just to the south of the Manzano-Manzanita Mountains (e.g., Hambleton 1959, 1962; Kottlowski 1960; Rejas 1965; Maulsby 1981; Bauch 1982; Brown 1987; Cather and Colpitts 2005; Lucas and Krainer 2009; Lucas et al. 2009). Our recent work indicates that much of
this nomenclature can be applied to the Pennsylvanian section in the Manzano-Manzanita Mountains (Lucas and Krainer 2010), so that an older, member-level nomenclature exists that predates the terminology introduced by Myers (1973). We will present a more detailed treatment of Pennsylvanian lithostratigraphy in the Manzano-Manzanita Mountains elsewhere, but here we employ the member-level nomenclature of Thompson (1942) and Rejas (1965), as used by Lucas et al. (2009) in the Cerros de Amado of Socorro County, and correlate it with the member-level nomenclature of Myers (1973) (text-fig. 4).

Only about 55-60m of strata are well-exposed at the KBQL, and these clastic-dominated strata are certainly in the Atrasado Formation. Their precise lithostratigraphic position can be established by correlation with the section at Cedro Peak, where a complete section of the Atrasado Formation is exposed between the Gray Mesa Formation (below) and the Bursum Formation (above) (text-figs. 5-6) (Kelley and Northrop 1975; Myers and McKay 1976; Read et al. 1998). Our measured section of the Atrasado Formation at Cedro Peak consists of three overlapping segments that indicate total Atrasado thickness is ~ 200 m (text-fig. 5). We can divide this Atrasado Formation section into eight members (text-fig. 5):

1. The lower 40m of the Atrasado Formation is the Bartolo Member and consists of olive-gray micaceous sandy shale at the base, various limestones and a quartz-rich, crossbedded pebbly sandstone in the middle. Limestone ledges are 0.2-1.9m thick and include thin- to thick-bedded, locally cherty lime mudstone, crinoidal packstone and thin-bedded algal limestone near the top. Covered slopes, presumably shale, are up to 13.3m thick.
2. The overlying Amado Member is 14m thick and composed of limestone intervals 0.3-2.1m thick separated by shale (0.1-0.4m-thick) or thicker covered intervals up to 0.8m thick. The limestone types are mostly thin- to thick-bedded limestone that locally contain large chert nodules, cherty bioclastic wackestone containing brachiopods, and algal wackestone.

3. The Tinajas Member is 61m thick and begins with olive-gray, sandy micaceous shale, overlain by coarse-grained, crossbedded arkosic sandstone, followed by 0.2-0.4m-thick limestone beds (calcarenite and fusulinid wackestone). The thin limestone beds are separated by 1-5m thick covered intervals. In the middle of the section, green, laminated micaceous sandstone 0.2-2.1m thick alternates with mostly covered shale. The upper part consists of limestone ledges 0.3-1.9m thick, and three sandstone horizons 0.4-1.1m thick. The limestone ledges consist of lime mudstone and thin- to medium-bedded algal wackestone with brachiopods, locally containing some chert. The lowermost sandstone is massive, coarse grained and arkosic in composition. The middle sandstone is red, laminated and very micaceous. The uppermost sandstone is a massive, coarse-grained carbonate sandstone.

4. The Council Spring Member is about 7m thick and composed of algal limestone (wackestone), which is locally bioturbated and contains brachiopods and fusulinids near the base. This basal limestone is overlain by a 3m thick covered interval, followed by two limestone ledges, 1.8 and 0.6m thick. Both ledges are composed of algal wackestone and separated by a thin shale notch.

5. The Burrego Member is 47m thick and composed of four, fining-upward cycles. The basal 2.1m are not exposed and are overlain by cycle 1, which begins with 5.7m of pebbly, crossbedded sandstone containing hematized plant stems, overlain by fine-grained, micaceous sandstone with horizontal lamination and ripple lamination, followed by siltstone and olive-green shale. Cycle 2 starts with horizontal laminated and crossbedded sandstone, overlain by covered (shale) interval and green, thin-bedded micaceous sandstone with ripple lamination, followed by a thin algal limestone bed and a covered interval. Cycle 3 starts with coarse-grained, pebbly arkosic sandstone, followed by covered slope and a thin limestone bed (algal wackestone with brachiopods). Cycle 4 has a coarse, crossbedded arkosic sandstone at the base, overlain by covered slope and fine-grained micaceous sandstone with ripple lamination, followed by crinoidal and algal limestone with covered intervals.

6. The Story Member is 10.2m thick and consists of a lower (2m), middle (1.8m) and upper limestone interval (3.1m) separated by covered intervals (1.5 and 1.8m thick). The lower limestone is a fusulinid packstone at the base overlain by bioclastic wackestone containing bryozoans, fusulinids, brachiopods and oncoids. The middle limestone is cherty, bedded and contains crinoidal debris and brachiopods. The upper limestone is thick-bedded crinoidal wackestone containing brachiopods and algae.

7. The thickness of the Del Cuerto Member is 8.8m. In the lower part, a thin, fine-grained sandstone is exposed, within a covered slope and followed by shale with limestone nodules and nodular limestone containing brachiopods.

8. The Moya Member is about 4.9m of limestone ledges that are 0.3-1m thick, separated by covered intervals. Limestones consist of crinoidal wackestone and algal limestone containing large *Triticites*.

The stratigraphic section we measured at the KBQL is 56m thick and can be correlated with most of the Tinajas Member at Cedro Peak (text-fig. 6). Thick-bedded cherty limestone of the Amado Member is at the base of the KBQL section. The lower part of the overlying section is poorly exposed with thick covered intervals (shale), and one crossbedded sandstone bed near the base with a thin limestone bed composed of fusulinid wackestone on top. The fusulinid wackestone contains abundant fusulinid tests and rare larger shell fragments that float in fine bioclastic matrix. The matrix also contains abundant calcitellid foraminifers, subordinate ostracods, echinoderms, shell debris, rare brachiopod spines, *Tuberitina*, and peloids.

Above another covered interval, two thin limestone beds are exposed, separated by a covered interval. Each limestone bed is 0.3m thick. The lower bed is a fusulinid wackestone (the fusulinid marker bed in text-fig. 6), and the upper limestone contains many brachiopods and is unit 1 of the Kinney section of Kues and Lucas (1992, fig. 5). The upper limestone is a bioclastic wackestone, bioturbated and fine-grained with a few large skeletons. The fossil assemblage is composed of brachiopod shell fragments, many brachiopod spines, algae (?*Anthracoporella*), echinoderm fragments, bryozoans, ostracods, gastropods, a few smaller foraminifers (calciwettellids, *Globivalvula*, *Bradynia*), and recrystallized phylloid algae. The matrix is peloidal micrite, and locally the wackestone grades into packstone. The KBQL is in the shale immediately above this limestone, in the lower part of unit 4 of our measured section (text-fig. 6).

The overlying part of the Tinajas Member is very well exposed in the KBQL and is composed of greenish-gray shale with intercalated sandstone units (text-fig. 5). The lowermost sandstone unit (unit 5 of our measured section in text-fig. 6, which is unit 10 of the Kues and Lucas 1992 Kinney section) is 2.8m thick, displays crossbedding in the lower part, and horizontal and ripple lamination in the upper part. Fine-grained sandstone (0.1-0.2mm) is moderately sorted and indistinctly laminated by micas oriented parallel to lamination. Medium-grained sandstone (0.2-0.5mm, rarely up to 2mm) is poorly sorted. The most common grain type is monocrystalline quartz (13-24%), and there is subordinate polycrystalline quartz (12-20%). Detrital feldspar is abundant (10-17%) and is partially altered (unwinned K-Fsp, many polysynthetic feldspars). Rare fine-grained rock fragments composed of quartz and mica (metamorphic, < 1%) and rock fragments of quartz and feldspar (granitic, 6-18%) are present. Mica is common (1-10%), and is mostly biotite, with rare muscovite and chlorite. A few recrystallized detrital carbonate grains are present. Some quartz grains display authigenic overgrowths. The sandstone contains small amounts of matrix (4-7%), and locally coarse blocky calcite cement is present (up to 18%) replacing quartz and feldspars. Fossils include shell debris, echinoderms, echinoid spines, fusulinids, brachiopod spines and brachiopod shells.

Sandstone unit 7 (text-fig. 6) is crossbedded and is unit 17 of the Kues and Lucas (1992) Kinney section. Very coarse-grained sandstone is poorly sorted and composed of monocrystalline quartz (17-34%) and many polycrystalline quartz grains (20-47%), granitic rock.
TEXT-Figure 5
Composite measured stratigraphic section of Atrasado Formation at Cedro Peak.
fragments (quartz and feldspar; 10-14%), sedimentary rock fragments (recrystallized micritic carbonate grains, < 2%) and rare stretched metamorphic rock fragments (< 1%). Detrital feldspars are common (7-20%) and occur as large grains that are partly altered. Most feldspars are untwinned potassium feldspars; perthitic feldspars are subordinate, and polysynthetic twinned feldspar grains are very rare. Some of the feldspars are almost completely replaced by calcite. Detrital muscovite is rare (< 2%). A few fossils are present, mostly echinoderms and shell fragments, rare fusulinids, and bryozoans. Very rare reworked caliche carbonate grains are also present. Quartz grains display authigenic overgrowths. The grains are cemented by coarse, blocky calcite (6-11%), and some dark brown carbonate cement is also present.

This distinctive sandstone horizon is overlain by olive-gray shale with three micaceous sandstone beds intercalated (text-fig. 6, units 8-14). Each sandstone bed is 0.2m thick. The lower and upper bed are massive, and the middle bed displays ripple lamination and is mixed siliciclastic-carbonate, poorly sorted, and composed of mostly subangular to subrounded grains. The most abundant grain type is monocrystalline quartz (14-18%), and polycrystalline quartz is subordinate (4-11%). The sandstone contains many detrital feldspars (mostly potassium feldspars, 4-12%), which are partly altered. Some plagioclase grains are present. The sandstone also contains detrital muscovite (up to 4%), rare rock fragments of quartz and feldspar (up to 2%), and a few micritic carbonate grains (up to 3%). The sandstone contains many fossils, mostly phosphatic fish fragments (locally up to 21%), and other fossils (up to 17%), including shell fragments (brachiopods, mollusks), echinoderms, echinoid spines, bryozoans, smaller foraminifers (Globivalvulina, Climacocammina, Hedraites?), brachiopod spines, ostracods, and gastropods. Recrystallized micritic matrix constitutes 28-38%, and carbonate cement is up to 17% of the sandstone.

The upper 11m of the KBQL section (text-fig. 6) is gray, bedded limestone horizons 0.2-2.3m thick, separated by covered intervals 0.9-2.6m thick. Limestone is mostly bioclastic wackestone composed of abundant broken fragments of recrystallized phylloid algae, mollusk shells, gastropods, brachiopod shells, echinoderms, bryozoans, many brachiopod spines and ostracods. Small skeletons include bryozoans, ostracods, echinoderms, smaller foraminifers (Endothyra, Bradyina, Climacocammina, Eotuberitina, Tetrataxis, Tubitina, Spirelitina, Syzrania, calcivertellids), brachiopod spines, rare Tubiphytes (partly encrusting skeletons) and gastropods. A few skeletons are encrusted by cyanobacteria and calcivertellids. The matrix is recrystallized micrite. Phylloid algal floatstone is subordinate, grading into bioclastic wackestone/packstone.

The floatstone contains completely recrystallized fragmented thalli of phylloid algae up to 2 cm long. Skeletons of bryozoans, brachiopods, echinoderms, ostracods and very small Tubiphytes are rare and float in peloidal micrite.

Both sections, Cedro Peak and the KBQL, can be correlated primarily on a 0.3-m-thick fusulinid limestone that can be traced from the KBQL to Cedro Peak (text-fig. 6) and which produces a distinctive Missourian fusulinid assemblage described here (Appendix 2). Strata above and below this fusulinid bed include some beds that can be reasonably matched by lithostratigraphic correlation. Particularly significant is that the clastic-dominated
section at the KBQL closely resembles the clastic-dominated Tinajas Member section at Cedro Peak, especially the various beds of micaceous sandstone, which are very similar petrographically at both sections.

The correlation indicates that the KBQL is stratigraphically low in the Tinajas Member of the Atrasado Formation, about 10m above the local base of the member. In the regional stratigraphy (see above and Lucas and Krainer 2010), the lower part of the Tinajas Member is equivalent to the upper part of the Sol se Mete Member of the Wild Cow Formation of Myers (1973), so the KBQL is stratigraphically much lower than the mapping of Myers and McKay (1976) indicates (text-fig. 4). Indeed, our placement of the KBQL in the local Pennsylvania section is the same as that of Stukey (1967), that is, stratigraphically low in the Atrasado Formation.

Myers (1988) fusulinid biostratigraphy in the Manzano-Manzana Mountains assigns his upper part of the Sol se Mete Member to the Triticites ohiensis zone of “late Missourian” age. However, Douglas (1987) indicated that T. ohiensis and related species characterize the Brush Creek and Cambridge Members of the lower Conemaugh Formation in the Appalachian region. These units correlate with the middle Missourian Swope through Dewey cyclothems in the Midcontinent region on the basis of conodont faunas (Heckel and Weibel 1991; Heckel et al. 2007). Further south in New Mexico, in Socorro County, conodonts indicate a somewhat later Missourian age (Stanton cyclothem; Heckel et al. 2007) for the middle to upper part of the Tinajas Member (Lucas et al. 2009). Thus, the revised lithostratigraphic position of the KBQL combined with regional biostratigraphy suggest it is of middle Missourian age.

**Fusulinid biostratigraphy**

About 3m below the stratigraphic level of the KBQL, one of us (BDA) discovered a 0.3-m-thick fusulinid wackestone (text-fig. 6). This fusulinid-rich marker bed provided New Mexico Museum of Natural History (NMMNH) fossil localities 7874, 7875 and 7877 (Appendix 1) and can be traced from the area of the KBQL to Cedro Peak (text-figs. 5-6). In Appendix 2 to this article, we present a systematic paleontology of the fusulinids relevant to the KBQL assemblage of fusulinids that is somewhat similar to Ferganiites but different because they belong to two different lineages. Similarly, Thomspontites has no real equivalent in the Paleaeotethys. The second migration of schwagerinids to North America is represented by Pseudoschwagerina, and the third by Pseodus fusulina sensu lato.

**Conodont biostratigraphy**

Nearly all the conodonts from the KBQL were recovered from the basal marine limestone, unit 1, exposed in the Kinney Brick Quarry (text-fig 6). Three different sets of samples produced the same fauna, but with different numbers of elements per kilogram processed: (1) T. Lehman (Texas Tech) contributed 2.5 kg of brown limestone that had been obtained during collection of fish fossils; another sample of black limestone (0.9 kg; Unit 2?) produced only six small conodont elements and a small sample of the overlying shale was barren of conodonts; (2) J. Barrick collected 2.0 kg of Unit 1 during the 1991 GSA field trip to the Kinney Quarry; and (3) S. Lucas collected 5.8 kg of Unit 1 and a 2.6 kg sample of the overlying shale that produced no conodonts. Table 1 summarizes the conodont recovery.

Most of the Kinney conodonts can be assigned to the genus Idiognathodus (text-fig. 8). The taxonomy of Kasimovian to Gzhelian Idiognathodus species is not fully resolved and species ranges are not well known outside of the North American Midcontinent region (Barrick et al. 2004). Rosscoe and Barrick (2009) described the Idiognathodus fauna from the latest Moscovian and early Kasimovian (late Desmoinesian-early Missourian) in the Midcontinent region, but did not discuss species above the level of the Hertha cyclothem. Rosscoe (2008) revised the taxonomy of the species as high as the middle Kasimovian Dewey cyclothem, and his revision is followed here for the conodonts from the KBQL. His work emphasized conodonts from the deeper water core shales of cyclothems, and included fewer morphotypes from time equivalent shallower water facies.

Many P1 elements from the Kinney Quarry samples (text-figs. 8.6, 8.12-8.15) can be identified as possible examples of Idiognathodus corrigatus Gunnell 1933 (Rosscoe 2008). This form possesses the typical asymmetrical Idiognathodus platform outline, but the rostral lobe is reduced to a single node or is absent (Rosscoe 2008). The carina of the Kinney specimens is

<table>
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<tr>
<td><strong>Sample</strong></td>
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<td>Weight</td>
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<tr>
<td>Idiognathodus corrugatus?</td>
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<td>L. cherryvalensis?</td>
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<tr>
<td>L. confugurus?</td>
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<td>L. sp. aff. L. bilarus</td>
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Forke and Samankassou 2000: Montiparus prisicus Villa and Martínez-García 1989: Protrictites robustus Ueno 1991) and allows a correlation of the early/middle Missourian with the upper part of the early Kasimovian. Moreover, the first representatives of Schwageriniformis appear in the middle Kasimovian (Bensh 1972). Advanced Protrictites and Schwageriniformis constituted immigrants to North America, and the subsequent triticitids are relatively endemic. For example, true Triticites of North America corresponds to Rauwerites of the Old World. Kansanella is somewhat similar to Ferganiites but different because they belong to two different lineages. Similarly, Thomspontites has no real equivalent in the Palaeotethys. The second migration of schwagerinids to North America is represented by Pseudoschwagerina, and the third by Pseodus fusulina sensu lato.
longer than usual for Midcontinent I. corrugatus, which may represent a shallow water modification of the element. Krukowski (1992, fig. 1a-b) illustrated this form from the KBQL as Idiognathodus delicatus. A number of Kinney specimens are P1 elements with a long carina (25-50% of platform length), reduced lobes, coarse transverse ridges, and a tendency toward a slight depression on the oral surface (text-figs. 8.2-8.5). The outline of the platform is less asymmetrical than typical species of Idiognathodus. P1 elements with reduced lobes may be best assigned to I. confragus Gunnell 1933, as Rosscoe (2008) redescribed the species.

Similar P1 elements (text-figs. 8.7, 8.10-8.11) that possess a more slender platform outline and in which rostral and caudal lobes are absent can tentatively be assigned to I. cherryvalensis Gunnell 1933 (see Rosscoe 2008). The adcarinal ridges extend dorsally past the long carina and form high caudal and rostral margins to the platform, making the platform surface appear slightly depressed. Many of the numerous small P1 elements from Kinney appear to be juvenile examples of these two species. Only a few examples of another species were recovered from the Kinney Brick Quarry. The overall boat-like shape of the P1 element, lack of caudal and rostral lobes, and the long carina suggest the late Kasimovian-Gzhelian species Streptognathodus firmus Kozitskaya 1978. Barrick, in Mapes and Boardman (1992, p. 113), reported S. firmus from the Kinney Brick Quarry based on these forms, and Krukowski (1992, fig. 1c) illustrated a small specimen. The larger specimens (e.g., text-fig. 8.9) resemble the rare form Streptognathodus biliratus (Rosscoe 1933), as described by Rosscoe (2008), but too few specimens are available for confident species assignment.

The KBQL conodont fauna is early to middle Kasimovian in age, and provisional assignment is made to the Idiognathodus confragus Zone of the Midcontinent conodont zonation (Streptognathodus confragus Zone of Barrick et al. 2004). The KBQL fauna can be tentatively correlated with that of the Midcontinent Dennis cyclothem (Heckel et al. 2008). In the Midcontinent succession, Idiognathodus morphotypes with a long carina, including I. confragus and I. cherryvalensis, first appear in and characterize the Dennis cyclothem (Rosscoe 2008). Idiognathodus confragus and the rare I. biliratus range no higher than the Dennis cyclothem, and I. cherryvalensis ranges into the lower part of the Streptognathodus gracilis Zone of the overlying minor Hogshooter cyclothem. The other two Kinney species, I. corrugatus and Hindeodus minutus?, provide no additional constraints on the age of the fauna.

Absent from the Kinney Brick Quarry conodont fauna are representatives of two groups of idiognathodids characteristic of middle Kasimovian to Gzhelian faunas in North America. At the level of the Hogshooter cyclothem, multiple species of the genus Streptognathodus (senso stricto; e.g., Barrick et al. 2004; Rosscoe 2008) first appear, possibly evolving from I. cherryvalensis (Rosscoe 2008). From the Hogshooter cyclothem through the Gzhelian, Streptognathodus species are a common and characteristic part of the conodont faunas. In the late Kasimovian (shale of the Stanton cyclothem), the I. simul- tator lineage appears, which comprises strongly asymmetrically paired P1 elements that possess a well-defined eccentric groove on the platform surface (Barrick et al. 2008). This distinctive group of species ranges into the early Gzhelian. Note that Barrick (in Mapes and Boardman 1992, p. 113) incorrectly identified specimens of I. corrugatus from the Kinney Brick Quarry as the early Gzhelian species I. simulator.

**COMPARISON TO NONMARINE BIOSTRATIGRAPHY**

Some of the nonmarine fossils from the KBQL, specifically the megaflora and the blattid insects, have been used to determine the age of the deposit. Significantly, these correlations seemed to support the early-middle Virgilian age long assigned to the KBQL. Here, we re-evaluate this nonmarine biostratigraphy to demonstrate that it is imprecise and does not contradict the Missourian age of the KBQL based on marine microfossils.

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**TEXT-Figure 7**

Missourian fusulinids of the Tinajas Member of the Atrasado Formation at the Kinney Brick Quarry and Cedro Peak (New Mexico).

All scale bars = 1mm.


6 *T. (S.) aff. planus* Subaxial section with the chomata more extended to the poles. (NMMNH locality 7874).


Plant Biostratigraphy
A large megafloral assemblage was collected from the KBQL beginning with U.S. Geological Survey (USGS) geologists Charles B. Read and Sidney Ash in the early 1960s, and followed by Sergius H. Mamay and Arthur Watt in the late 1960s. These USGS collections are housed at the U.S. National Museum of Natural History; other collections are housed at the New Mexico Museum of Natural History and Science and the Carnegie Museum of Natural History. Mamay and Mapes (1992) first described and illustrated the full Kinney flora in detail. We undertake here a re-evaluation of the composition of the Kinney flora based on the USGS collections, and briefly assess the biostratigraphic implications.

Mamay and Mapes (1992) concluded that the KBQL flora was early Virgilian in age (= Late Pennsylvanian, early Gzhelian, Stephanian C, according to Davydov et al. 2010). They described a mixture of seemingly typical Late Pennsylvanian wetland elements and taxa more characteristically found as part of floras from seasonally dry habitats. The plants were collected from at least two different horizons. Palynological analyses at the site indicate considerable differences between samples from lower and higher parts of the exposed succession (Willard, 1992). Because of the sensitivity of plant distribution to climate, we conclude that the different floristic components of the KBQL megafloral assemblage actually represent at least two distinct species pools, probably reflective of some environmental changes during accumulation of the Kinney deposit.


We offer the following additional to the assemblage documented by Mamay and Mapes (1992). Found only in the non-illustrated collection are: Taeniopteris sp. (n=1), Neuropteris pseudobullisi (n=1), Alethopteris sp. cf. A. schneideri (n=1), cf. Neurocallipteris planchardi (n=2), Pseudomariopteris cordato-ovata (n=3), and several small frond fragments with foliage similar to that of an unnamed neuropterid described by Knaus and Lucas (2004) from Carrizo Arroyo, New Mexico, a Pennsylvanian-Permian boundary deposit. Among the population of larger Annularia specimens in the collection, there are several with ovoid, rather than round leaf whorls, with spatulate leaves and mucronate leaf tips. These may be referred to Annularia carinata (= A. mucronata).

In addition, we suggest the following revisions to the specimens illustrated by Mamay and Mapes (1992):

1. Text-figure 2D: This specimen was identified as Annularia radiata, a species typical of Middle Pennsylvanian strata. This material may instead belong to A. spicata, which is a characteristic Late Pennsylvanian species (Wagner and Álvarez-Vázquez 2010), although it is somewhat larger than typical representatives of that species.

2. Text-figure 2F: Annularia pseudostellata. Specimens in the collection indicate considerable morphological variation among Annularia with larger leaf whorls. Much of this material may belong to a single species, possibly A. stellata forma typica. Annularia stellata, at least as that name has come to be used in the United States, includes forms with spatulate leaves, as well as forms with somewhat more fusiform leaves, as illustrated by Mamay and Mapes (1992). The type form of Wood is fusiform in shape. At present we are inclined to recommend continued recognition of A. pseudostellata in this flora.

3. Text-figure 3E: Odontopteris sp. There is significantly more material of this taxon in the general collections. Ultimate pinnæ are generally short, and are characterized by a large, elongate or linguoid terminal pinnule that can be lobate near the base, ultimately dividing into small pinnules that are partly fused to the ultimate rachis. This taxon appears to be one of a complex of odontopterids that may belong to the fossil genus Mixoneura (sensu Wagner and Castro 1998). It most resembles Odontopteris subcrenulata and Odontopteris pseudoschlotheimii, which occur in Upper Pennsylvanian strata of the Saint-Etienne Basin, Massif Central (Doubinger et al. 1995).

4. Text-figure 4A, C-E: The identification of this material as Neuropteris ovata is probably correct. The pinnules are somewhat more rounded in overall shape than is typical and not notably auriculate. However, there are specimens with inflated terminal pinnules with fused, subjacent odontopterid pinnules immediately below the terminal. As others have noted, N. ovata may be in need of systematic revision given its long range and extensive geographic coverage.

5. Text-figure 4B. This tiny fragment cannot be assigned with confidence to Neuropteris heterophylla. It probably belongs to the neuropterid described by Knaus and Lucas (2004).

6. Text-figure 5D-E: These pinnæ probably do not represent Neuropteris macrophylla (incorrect gross shape, size and venation), but are rather more similar to Neurodontopteris auriculata. There is a considerable amount of this material in the collections. Pinnules are quite variable in size and shape, often with rounded, inflated bases and with dense, often irregular venation.

7. Text-figure 5H: Identified as comparable to Neuropteris obliqua, this specimen has very high angle veins, lobed bases, and other Odontopteris characteristics. It is likely part of the larger Odontopteris subcrenulata population described above. However, it shows some comparison with Odontopteris brandii (see Castro 2005, pl. III), whereas text-figure 5F could be the cyclopterid of the same species (see Castro 2005, pl. IV).

8. Text-figure 9E: Identified as “reminiscent of Rhacopteris.” We think that this identification should not be included in the floral list.

None of the newly identified or re-identified specimens are narrowly diagnostic stratigraphically. Plant taxa typical of seasonally dry habitats, in particular, are not good stratigraphic indicators because little is known about the details of their temporal distributions. Where such taxa have been used to infer young ages in the face of older ages inferred from wetland flora,
they invariably occur in paleoenvironmental settings suggestive of seasonally dry climates, and can significantly mislead biostratigraphic conclusions (e.g., Wagner and Lyons 1997; Falcon-Lang et al. 2011). The neuropteroid described by Knaus and Lucas (2004), for example, has been identified at several places in fragmentary preservation, but is rare enough and regionally localized enough not to be able to be used with confidence to specify an age. Overall, the flora is consistent with a Late Pennsylvanian age for the KBQL. It is not inconsistent with the early Virgilian age originally determined by Mamay and Mapes (1992). However, it also is in conformance with a Missourian age, as determined by other means in this paper, and this underscores the inherent imprecision of Late Pennsylvanian plant biostratigraphy.

Insect biostratigraphy
The KBQL has yielded various insect remains of different orders (Carpenter 1970, Shear et al. 1992), including cockroaches of the family Spiloblattinidae, which display distinctive color patterns on their wings (text figs. 9-10). Color patterns on the wings of blattids (cockroaches) show a directed development through time, which has been documented from the beginning of the Stephanian (Missourian) through the Sakmarian (middle Wolfcampian) and provides a basis for nonmarine biostratigraphic correlations in that interval (Schneider 1982; Schneider and Werneburg 2006). Based on these color patterns, three genera have been distinguished, each represented by one chronocline, which are the Sysciophlebia, the Spiloblattina and the Syscioblatta lineages. Each of these lineages is subdivided

**TEXT-Figure 8**
Conodonts of the Tinajas Member of the Atrasado Formation at the Kinney Brick Quarry. All x50.

1,8  *Idiognathodus* sp. indet., juvenile specimens.
2-5  *Idiognathodus confragus* Gunnell 1933?
6,12-15  *Idiognathodus corrugatus* Gunnell 1933?

9  *Idiognathodus biliratus* (Gunnell 1933)?
7,10,11  *Idiognathodus cherryvalensis* Gunnell 1933?
into several zonal species, but increasing data show that they form in reality a continuum or chronocline of successive biospecies in each lineage.

The time resolution of this blattid-based biostratigraphic tool for continental sediments is comparable to that for marine sediments using microfossils and ammonoids (Schneider and Werneburg 2006). However, there is no direct connection of the continental insect biostratigraphy to the marine biostratigraphy, although that will change now with data from the KBQL and from the Red Tanks Member of the Bursum Formation in central New Mexico (Schneider et al. 2004; Schneider and Werneburg 2006). Indeed, the link to marine standard sections, as shown, for example, in the correlation charts of Roscher and Schneider (2005) and Schneider and Werneburg (2006), is based only on some rare and often ambiguous isotopic ages from the latest Stephanian and the Lower Rotliegend (Gzhelian-Asselian) of Germany (Menning et al. 2006; \( L/c242 \)tzner et al. 2007). For most of the Pennsylvanian, isotopic ages are virtually unknown in either terrestrial or marine deposits (Ogg et al. 2008; Davydov et al. 2010). Therefore, the insect biostratigraphy has thus far mostly been calibrated by plant biostratigraphy. However, macroplant biostratigraphy and palynological biostratigraphy are primarily ecostratigraphy (see above), so time boundaries based on them can be very diachronous as shown, for example, in Hmich et al. (2005, 2006).

At the KBQL, species of the genera Syscioblatta and possibly Sysciophlebia are present. Best preserved are forewings of the genus Syscioblatta (text-fig. 9). Size and distribution of the light-colored areas of the wings are transitional between S. allegheniensis and S. lawrenceana, possibly a bit closer to the former and therefore designated here as S. allegheniensis form K. According to Carpenter (1934), S. allegheniensis comes from the Conemaugh Formation at Aspinwall, west side of Allegheny River, Appalachian basin, Pennsylvania. The type horizon is the Duquesne coal zone of the Casselman Formation of the Appalachian basin in Pennsylvania, strata of early Virgilian age (Barrick et al. 2008). The precursor species of S. allegheniensis is S. variegata. The type horizon of this species is the roof shale of the Ames Limestone (below the Duquesne coal zone) of the Appalachian basin in Ohio. Based on conodonts, the Ames was dated as early Gzhelian by Ritter (1995). Barrick et al. (2008) and Heckel et al. (2008) confirmed this based on the redescribed conodont Idiognathodus simulator, as they placed the base of the Gzhelian at the first appearance of I. simulator.

Comparing the color pattern and assuming a nearly constant rate of evolution, the time difference between S. variegata and S. allegheniensis is larger than that between S. allegheniensis and the subsequent S. lawrenceana. The latter co-occurs together with Sysciophlebia rubida in the Plouznice Horizon of the Semily Formation in the Krkonoše-Piedmont basin, Czech Republic, which is dated by macroplants as late Stephanian B, which is about early Gzhelian.

Significantly, at NMMNH locality 4629 in the Cerros de Amado of central New Mexico, the lower part of the Tinajas Member of the Atrasado Formation contains an ~ 7m thick unit of lacustrine to transitional brackish marine black shales (Lerner et al. 2009). Besides a variety of plants, invertebrate and fish fossils, some remains of Neorthroblattina as well as a spiloblattinid forewing fragment are known from this site, which is stratigraphically just below late Missourian conodonts (Lucas et al. 2009). This fragment has been determined by Schneider in Lerner et al. (2009) as Sysciophlebia cf. S. grata, which is in accordance with the age determination of the KBQL based on S. allegheniensis (see above). Sysciophlebia grata is known from the Hredle Member of the Slanž-Formation (lower to middle Stephanian B) of the Kladno basin of the Czech Republic (Schneider and Werneburg 2006), as well as from the upper Qued Issene Formation of the Souss basin in Morocco.
The Sysciophlebia grata zone is regarded as of Kasimovian to Gzhelian in age. These data indicate a stratigraphic range for the Syscioblatta specimens from the KBQL of approximately late Kasimovian to early Gzhelian, which is based on two interpretations (text-fig. 10). First, S. variegata is the precursor species of S. allegheniensis, and second, and most important, the Ames Limestone is earliest Gzhelian in age based on conodonts (Ritter 1995; Barrick et al. 2008; Heckel et al. 2008). However, the newly determined age of the KBQL presented here is early-middle Kasimovian, which is not completely congruent with the published insect biostratigraphy. Thus, the blattid insect biostratigraphy can now be in part recalibrated to the marine scale using the age of the KBQL (text-fig. 10). This indicates that at least part of the Sysciophlebia grata blattid zone is of early-middle Kasimovian age.

**COMPARISON TO OTHER LAGERSTÄTTEN**

The Missourian age of the KBQL indicates that it preserves a biota that lived during a time of seasonal moisture limitations (relatively dry) when sea level was low in the western equatorial tropics of Pangea (Bishop et al. 2010). Schultze and Maples (1992) used cluster analysis to compare the KBQL biota to other Pennsylvanian Lagerstätten. They found that Kinney is, overall, most similar to the Garnett, Kansas Lagerstätte, which is also the Lagerstätte closest in age to Kinney (both are Miss-
sourian, though note that Garnett is late Missourian, separated from the KBQL by most of three cyclothsms) of the Lagerstätte examined in the analysis. This may indicate that similarity in age, rather than similar paleoenvironment or taphonomy, best explains the similarity of the KBQL to the Garnett Lagerstätte.

ACKNOWLEDGMENTS

We thank Ralph Hoffman for permitting our work at the Kinney Brick Quarry. He, and the late Bob Jurgena, have made possible decades of scientific research at the Kinney Brick Quarry. We also thank Tom Lehman (Texas Tech) for contributing material for conodont processing from the KBQ, and Larry Rinehart for assistance in the field. Phil Heckel provided a detailed and very helpful review of the manuscript.

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APPENDIX 1

Fossil localities. All localities are in the Tinajas Member of the Atrasado Formation, Bernalillo County, New Mexico (text-figs. 4-5).

NMMNH locality 345 (Kinney Brick Quarry Lagerstätte) – UTM zone 13, 378414E, 3873814N, NAD 27.
NMMNH locality 345 (Kinney Brick Quarry Lagerstätte) – UTM zone 13, 378414E, 3873814N, NAD 27.
NMMNH locality 345 (Kinney Brick Quarry Lagerstätte) – UTM zone 13, 378414E, 3873814N, NAD 27.
NMMNH locality 345 (Kinney Brick Quarry Lagerstätte) – UTM zone 13, 378414E, 3873814N, NAD 27.

APPENDIX 2

Fusulinid identifications.

Genus *Tumulotriticites* Wilde, 2006

*Synonyms:* ?*Protriticites* (part.); ?*Eotriticites*.

*Diagnosis:* Test inflated fusiform; first whorls fusulinellin, last whorls schwagerinid; chomata mound-shaped; septa weakly folded; aperture terminal, simple.

*Composition:* Apparently monospecific.

*Occurrence:* Early/Middle Missourian of the Big Hatchet Mountains and Manzanita Mountains (New Mexico).

*Tumulotriticites* cf. *T. tumefactus* Wilde 2006

*Text-figure 7.1-2*

*Discussion:* All the characters of the species were observed: shape of test, wall microstructure, shape of tunnel and chomata, and weakness of septal folding. The population is a little smaller in all these parameter measurements than that reported by Wilde (2006): Diameter (D) = 0.840-0.870mm (versus 1.000mm); width (w) = 1.425-1.500mm (versus 2.770mm); w/D = 1.63-1.79 (versus 2.5); prolloculus diameter = 0.020-0.030mm (versus 0.073mm); wall thickness at the last whorl = 0.040-0.050mm; number of whorls = 5.5-6 (versus 6). The population may correspond to an immature set of *T. tumefactus*, to a subspecies, or to a microspherical generation (smaller prolloculi).

Genus *Triticites*

Subgenus *Schwageriniformis* Bensh in Rauzer-Chernousova et al 1996

*Type species:* *Triticites schwageriniformis* Rauzer-Chernousova 1938.

*Synonym:* *Triticites* (part.)

*Diagnosis:* Subgenus of *Triticites* characterized by plane to almost plane, small prolloculus and tight coiling (Leven and Davydov 2001).

*Occurrence:* Middle Kasimovian of Palaeotethys and Urals; rare in the Early/ Middle Missourian of North America

*Triticites (Schwageriniformis)* cf. *T. planus* Thompson and Thomas 1953

*Text-figure 7.3-5*

*Discussion:* Many characters of the species were observed: elongate fusiform shape of test and relative weakness of septal folding. The population is a little smaller than that reported by Wilde (2006) and measures: Width (w) = 2.140-3.540mm (versus 4.600-7.600mm); Diameter (D) = 0.800-1.150mm (versus 1.400-1.800mm) for less whorls (5-6 versus 6-7); but the w/D ratio is similar: 3.3-4.2 versus 3.5-4.5 = 1.63-1.79 (versus 2.5) as well as the prolloculus diameter = 0.060-0.130mm (versus 0.065-0.112mm). The wall thickness at the last whorl is 0.020-0.030mm; and the height of the last whorl, 0.145-0.185mm.

*Occurrence:* Casper Formation of Wyoming (U.S.A.); Upper Carboniferous of Fujian (China); Missourian of New Mexico.

*Triticites (Schwageriniformis)* aff. *T. planus* Thompson and Thomas 1953

*Text-fig. 7.6*

*Discussion:* The measurements are consistent with *T. planus* and *T. cf. T. planus*: w = 4.000mm ; D = 1.000mm ; w/D = 4.0; prolloculus diameter = 0.050mm; number of whorls: 5-6 ; but the chomata are lower and more elongate towards the poles.

*Subgenus Triticites*

*Triticites (Triticites)* cf. *T. myersi* Wilde 2006

*Text-fig. 7.7-8*

*Discussion:* The measurements are consistent with *T. myersi*: w = 4.090-5.000mm ; D = 1.000-1.250mm; w/D = 4.0-4.1; prolloculus diameter = 0.045mm; number of whorls: 5-6; but the specimens are a little deformed due to lithoclastic compaction, so exact identification is not possible.

*Triticites (T.) ex gr. *T. ohioensis* Thompson, 1936

*Text-fig. 7.9-10*

*Discussion:* Because of its massive chomata, as noted by Ross and Tyrell (1965), this elongate fusiform species is transitional between *T. ohioensis* and *Kansanella* Thompson, 1957. W = 4.210-5.130mm; D = 1.460-1.580; w/D = 2.9-3.8; number of whorls : 6.

*Occurrence:* Horquilla Formation of Whetstone Mountains (Arizona); Manzanita Mountains, New Mexico.