

THE KINNEY BRICK QUARRY LAGERSTÄTTE, LATE PENNSYLVANIAN OF NEW MEXICO, USA

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1. Introduction

In Europe and North America, Pennsylvanian strata contain several Lagerstätten, perhaps the best known being Mazon Creek in Illinois, USA. Other important Pennsylvanian Lagerstätten are Montceau-les-Mines in France, Nýřany in the Czech Republic, Linton in Ohio, USA, and Garnett, Robinson and Hamilton in Kansas, USA. The Kinney Brick Quarry in New Mexico, USA, is another significant Lagerstätte, and is the subject of a recently published collection of articles that present new discoveries and research at Kinney (Lucas et al., 2021a). Here, we offer a brief synopsis of the Kinney Lagerstätte based primarily on the research results just published. The Kinney Brick Quarry (Figs. 1-2), located in the Manzanita Mountains of central New Mexico, is a clay pit actively mined for the making of bricks at the Kinney Brick Company plant in Albuquerque, New Mexico. At Kinney, fossils come from deposits of a marine embayment of Late Pennsylvanian age and are remarkable for their diversity, abundance and quality of preservation, which includes the preservation in some cases of soft tissues that normally do not readily fossilize, and a variety of large and exceptionally complete plant remains not well known from correlative deposits. The quantity and quality of preservation have long been used to identify Kinney as a Lagerstätte (e. g., Lucas and Huber, 1991; Kues and Lucas, 1992; Zidek, 1992).

Scientifically significant fossils were discovered at Kinney by students at the University of New Mexico in the early 1960s. In 1992, the first 30 years of research at Kinney were brought together in an edited volume that detailed the stratigraphy, age, sedimentology and

paleontology, among other aspects, of the Lagerstätte (Zidek, 1992). The next two decades saw only sporadic research on the Kinney Lagerstätte. In 2009, renewed interest in the stratigraphic position and age of the Kinney deposit ultimately led to the first controlled excavation in April 2014. This renewed research interest and the controlled excavation produced a wealth of new data on the Kinney biota and its preservational environment recently published in the volume edited by Lucas et al. (2021a).

2. Stratigraphy and Age

Lucas et al. (2011, 2014, 2016, 2021b), Vachard et al. (2012, 2013) and Allen and Lucas (2018) restudied the Pennsylvanian stratigraphy and biostratigraphy in the Manzano and Manzanita mountains in central New Mexico. Their lithostratigraphy located Kinney in the lower part of the Tinajas Member of the Atrasado Formation (Fig. 1), strata of Missourian age to the south of the Manzano Mountains. Indeed, fusulinids from a bed a few meters below the stratigraphic level of the Kinney fossil deposit and conodonts from the fish bed at Kinney indicate an early Missourian age (Lucas et al., 2011).

The early Missourian is an important time period within the Late Paleozoic Ice Age. The Missourian begins with a major turnover in terrestrial tropical vegetation, specifically the loss of long-dominant wetland elements, such as several genera of arboreous lycopsids and numerous seed ferns, followed by the rise of a tree-fern-dominated wetland flora (Phillips et al., 1974; DiMichele and Phillips, 1996). These changes accompanied a major, long-term rise in sea-level (Heckel, 2008; Rygel et al., 2008), reflective of a significant loss of Southern Hemisphere terrestrial ice (Isbell et al., 2012). The biotic changes recorded in western Pangea differ from those that typify the coal-basins of the central part of the supercontinent. Thus, the Kinney flora and associated biota are a bench mark for those changes in the western parts of the tropical realm.

Barrick (in Lucas et al., 2011) documented conodonts from the fish bed at Kinney that are 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). Rosscoe and Barrick (2021) re-evaluated the Kinney conodont fauna based on a much larger sample than was previously available. Two conodont faunas were recovered; one from the fish bed at Kinney and one

from the stratigraphically lower fusulinid marker bed from nearby outcrops. Both faunas are characteristic of the lower part of the Missourian Stage (Kasimovian). The fusulinid marker bed conodont fauna correlates with the *Idiognathodus cancellosus* Zone of the Hushpuckney Shale from the Swope cyclothem in the Midcontinent Basin. Species of the fusulinid genus *Triticites* occur with the Swope-equivalent conodonts in the fusulinid marker bed, indicating that *Triticites* appeared in New Mexico very early in Missourian time. The Kinney Brick Quarry fish-bed conodont fauna correlates with the base of *I. confragus* Zone of the younger minor Mound Valley cyclothem.

The co-occurrence of marine index fossils together with blattoid insects at Kinney enables further calibrations of the insect zonation of purely continental basins as well as of the West-European Regional Stages with the Standard Global Chronostratigraphic Scale (Schneider et al., 2020, 2021b).

3. Depositional Environments

The Pennsylvanian strata at the Kinney Brick Quarry were deposited in the northeastern portion of the Orogrande basin, one of the depositional basins of the Ancestral Rocky Mountains in New Mexico. The depositional setting of Kinney has long been interpreted to be that of a shallow marine embayment (often referred to as an “estuary” or a “lagoon”) fed by a river delta (Archer and Clark, 1992; Feldman et al., 1992; Lorenz et al., 1992). Lorenz et al. (1992) identified several distinct depositional environments in the strata exposed at Kinney that make up a regressive sequence in which limestone grades up through prodelta and deltaic clastics to a capping delta-plain facies (Fig. 3). Schneider et al. (2021a) re-evaluated sedimentation at the Kinney Quarry.

The depositional environment of the brackish-marine laminated mudstones at Kinney was previously interpreted

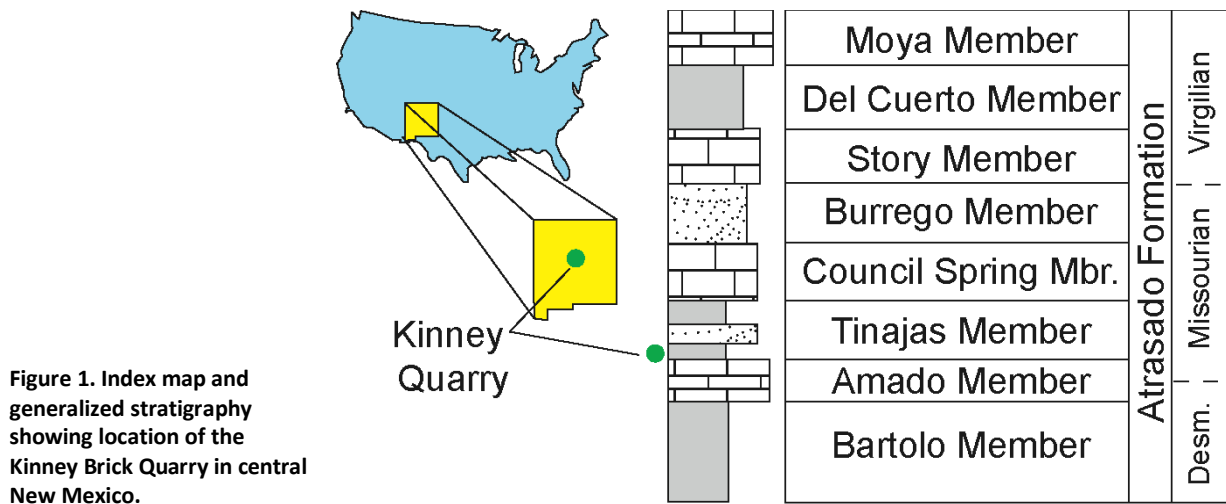


Figure 1. Index map and generalized stratigraphy showing location of the Kinney Brick Quarry in central New Mexico.



Figure 2. Photograph of part of the Kinney Brick Quarry in 2012. The floor of the quarry (lower right) exposes the basal limestone overlain by the primary fossil-producing interval of mostly dark gray shale. The higher wall of the quarry exposes delta-front and channel sandstones (compare to Figure 3).

as a tide-dominated estuary (Archer and Clark, 1992; Feldman et al., 1992) or as a non-tidally influenced prodelta (Huber, 1992). However, these interpretations imply rapid deposition of tidal deposits that contradicts some paleobiological and taphonomic observations. Instead, Schneider et al. (2021a) interpreted the depositional environment of the laminated mudstone at Kinney as a tidally modulated bayfill sequence controlled by several factors: (1) an embayed shoreline led to tidal amplification; (2) the embayed coastline protected the environment from storm-wave influence; (3) the prograding bayhead delta supplied nutrients to the embayment and resulted in increasingly brackish-water conditions; (4) restricted circulation, poor mixing and elevated bioproductivity resulted in dysoxic to anoxic bottom water conditions; and (5) the main sediment input occurred during seasonal river discharge into the embayment. At Kinney, two superimposed orders of lamination are observed in the mudstones. Thicker packages of laminae representing seasonal river discharge commonly exhibit internal laminae caused by waxing/waning flow related to tidal acceleration and deceleration of the river and the associated sediment plume entering the basin. Poorly oxygenated bottom water and the resulting lack of infaunal activity led to the unique preservation of both fossils and lamination structure in the Kinney Brick Quarry mudstones.

Thus, the stratigraphic sequence at the Kinney Brick Quarry mostly reflects shoreline progradation, created by the progressive construction (progradation) of a clastic delta (Fig. 3). Lateral shifts in the accumulation of sediments from the delta probably formed an embayment isolated from normal marine conditions as the clastic wedge developed and extended seaward. Clastic input in the embayment was initially restricted to clay-size particles. Eventually, the embayment was filled by silty shales from an advancing delta plain on which sand was later deposited.

4. Paleontology

Fossils documented from the Kinney Brick Quarry are palynomorphs, a diverse, macroflora consisting of plants typical of a range of substrate moisture, a shelly marine invertebrate assemblage that includes a few ammonoids but is dominated by brachiopods and the pectinacean bivalve *Dunbarella*, syncarid and hoplocarid crustaceans, conchostracans, ostracods, eurypterids, trilobites, terrestrial arthropods (mostly insects and diplopods), arachnids, conodonts, a diverse assemblage of fishes (mostly acanthodians and palaeoniscoids) and amphibians, as well as microbially induced sedimentary structures (MISS), insect and pathogen damage to vegetation, gastropod eggs and bromalites (mostly regurgitalites and coprolites). Most of the documentation of these fossils is published in Zidek (1992) and Lucas et al. (2021a). Publication of newly discovered fossils from Kinney continues with the

very recent articles of Stack et al. (2021), Braddy et al. (2021) and DiMichele et al. (2021).

5. Significance of the Kinney Lagerstätte

The Kinney Lagerstätte is significant in several ways. Perhaps foremost are the many taxa first discovered at Kinney and the exceptional preservation of many of its fossils that provide unique morphology not known otherwise. Recent work indicates that such discoveries will continue at Kinney and it will long remain an important source of new morphology and new taxa.

The Kinney flora consists of an intimately intermixed assemblage of plants typical of high soil moisture, tolerant of only short periods of drought, and forms that are considered drought-tolerant. Such a "mixed" assemblage is most likely to be drawn from a landscape characterized by habitat, even microhabitat, heterogeneity. The extremes of heterogeneity indicated by the Kinney flora would be unlikely to be found on a delta plain and associated floodplain under a humid climate, with relatively high rainfall, nearly equably distributed throughout the year. Rather, the regional climate almost certainly was strongly seasonal. The rationale for this interpretation is explained in detail in papers by DiMichele et al. (2020) and Bashforth et al. (2021). Seasonal drought magnifies microhabitat differences that would be masked under a higher volume, more equably distributed rainfall regime. In a nearshore to shoreline setting, like the Kinney Quarry, the opportunity for the close proximity of standing water and better drained microhabitats is great. We suggest, therefore, that the parent plants of the fossil flora populated a complex, spatially and environmentally heterogeneous terrestrial environment, and lived within close proximity of one another. The animal fossils at Kinney are a mixture of taxa that lived in the embayment (most of the invertebrates and fishes), those washed in from terrestrial/freshwater environments (the insects diplopods, arachnids, conchostracans and amphibians) and marine visitors to the estuary (the sharks). If these fossils fully capture the diversity that lived in the Late Pennsylvanian embayment, then that diversity was low compared to modern analogues (e.g., Williams and Lucas, 2013), either a result of taphonomic bias and/or a Pennsylvanian biota of lower diversity than the Modern world.

Kinney provides an important tiepoint between marine and nonmarine Pennsylvanian biostratigraphy. Thus, Kinney contains and is stratigraphically proximate to marine index fossils (fusulinids, conodonts) and contains diverse nonmarine fossils, some of which are useful in nonmarine biostratigraphy (plants, insects, conchostracans). It thus is important to integrating the marine and nonmarine chronology of part of a significant interval of Pennsylvanian time (Schneider et al., 2020, 2021c).

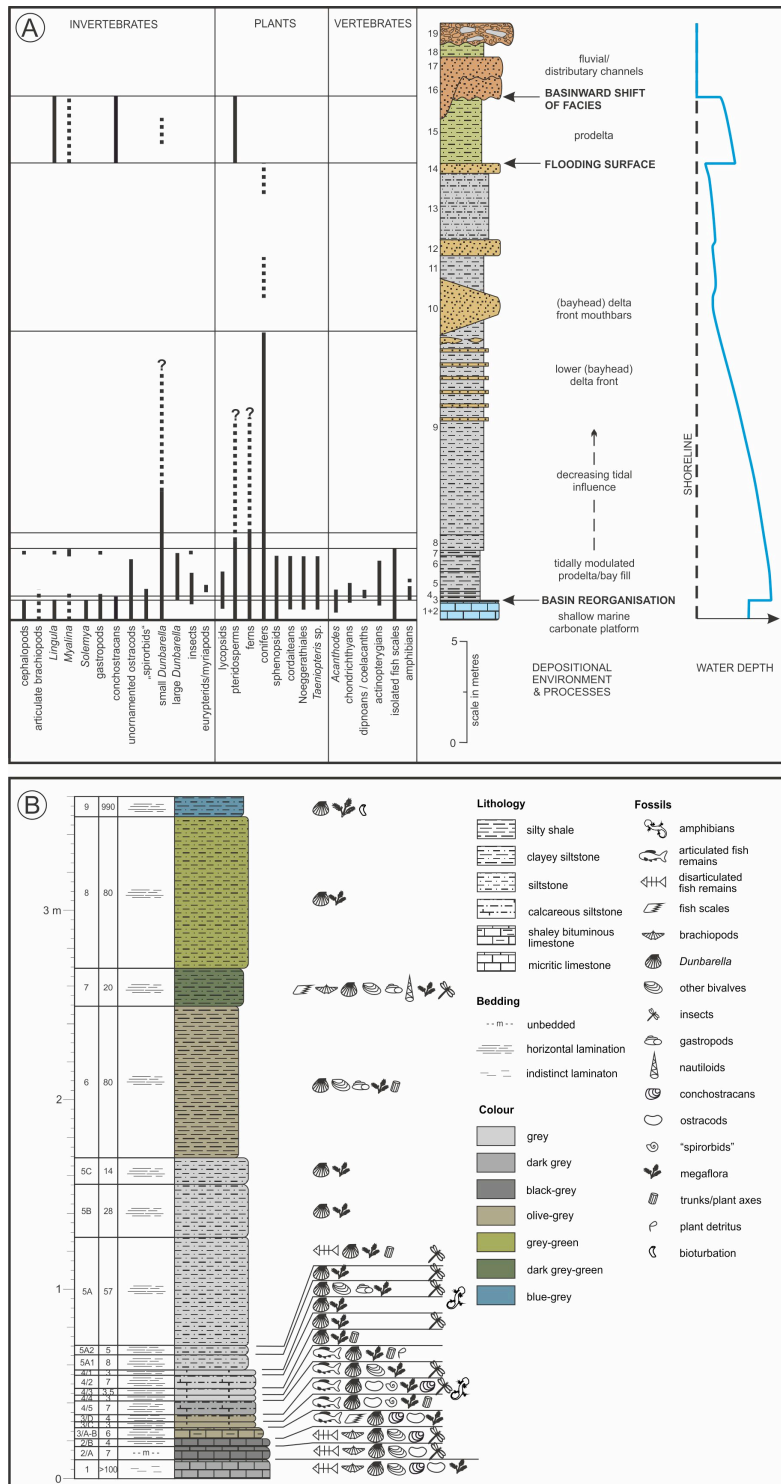


Figure 3. Summary diagram of the paleontology, stratigraphy, depositional environments and sea-level changes at the Kinney Brick Quarry (from Scholze et al., 2021).

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