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HESSIAN (LEONARDIAN, MIDDLE LOWER PERMIAN) DEPOSITIONAL SEQUENCES AND THEIR FUSULINID ZONES, WEST TEXAS

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INTRODUCTION

The lower Leonardian (Lower Permian) Hess Limestone in the eastern part of the Glass Mountains, West Texas, forms a high, well-exposed escarpment of repetitious, shallow-water, platform limestone facies for about 35 km. The strike of the outcrops cuts the strike of depositional facies at relatively low angle so that the actual width of the carbonate platform, from its marginal rim to shore facies, was probably less than 10 km (Figs. 1, 2). At the platform margin, the Hess Limestone passes abruptly into coarse, conglomeratic slope deposits that form the Skinner Ranch Formation. The pebbles, cobbles, boulders, (some the size of a small house) and other clastic debris in this facies include both reworked limestones from older Paleozoic formations and redeposited penecomptemporaneous carbonate blocks and pieces from the outer margin and rim facies of the Hess platform. Many previously described fossils faunas attributed to the Skinner Ranch Formation include a mixture of reworked older faunas (especially from the Lenox Hills, Neal Ranch, and Gaptank Formations), penecontemporaneous fossils redeposited from the Hess platform and rim, and in situ faunas of the Skinner Ranch slope facies. The foraminifers of the platform are relatively common, but they have a low species diversity. Those of the slope facies are more diverse, however, as with the other faunas, the foraminifers include a mix of platform, margin and rim species, upper slope species, and a large number of reworked specimens from older deposits, both in cobbles and pebbles and as individual specimens reworked from shales. To the west, the Skinner Ranch facies thins within a short distance, less than 2 or 3 kilometers, and passes into a thin, dark, turbiditic basinal facies. Similar platform, slope, and basin lithologic facies and topographic depositional relief are common in strata of equivalent age around the margin of most of the Permian Basin in western Texas and southeastern New Mexico (Mazzullo and Reid, 1989; Reid and others, 1989).

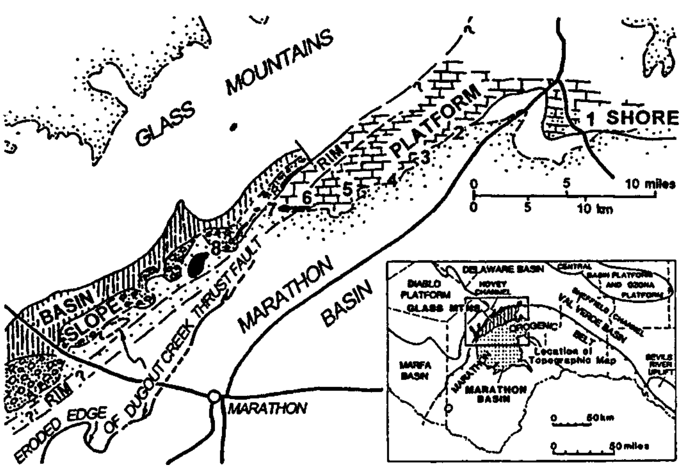

Figure 1.–Outcrop distribution of the different lithologic facies of Hessian strata, Glass Mountains, West Texas.

HESS LIMESTONE STRATIGRAPHY

The Hess Limestone reach a thickness of more than 550 m (1800 feet). In its lower part, lithologies are repetitious silty, commonly dolomitic, lime mudstones, fossiliferous mudstones, wackestones, sponge mounds, and only minor packstones and almost no grainstones, These lithologies display well-developed meter-scale cycles. Parasequence sets of five to more than ten of these meter-scale cycles are grouped together and are separated from similar parasequence sets of cycles by depositional unconformities that can be traced across the width of the platform. The surfaces of these unconformities commonly are immediately overlain by thin, sheet-like layers of sandstone, siltstone, and non-marine clastic redbeds that have been to various degrees resedimented by the succeeding marine transgression. The beds beneath the unconformities usally show indications of subaerial weathering, including various carbonate cement changes, micritization of fossil shells, and mickrokarst features (and at some unconformities, even karst features). Using the features associated with these unconformities, we divide the Hess Limestone into seven main depositional sequences based on the inferred duration of the exposure at these unconformities. Internally, each of these depositional sequences is complex.

Depositional sequence 1 (Fig. 3) includes four well-defined parasequence sets in the inner platform and near-shore facies. Well-preserved foraminifers (Ross, 1960, 1962) are common to abundant, but not diverse, in the lower three parasequence sets, and include *Schwagerina crassitectoria* and *S. guembeli* which are the only common fusulinids. *S. crassitectoria* ranges from parasequence 1A into parasequence 1B where it is considerably smaller in size. It has not been reported from higher parts of this depositional sequence. *Schwagerina guembeli* ranges as high as parasequence 1C and shows morphological changes throughout its range in both parasequence sets 1B and 1C. The upper parasequence set 1D is very dolomitic, apparently the result of a more deeply weathered unconformity at its top, and identifiable fusulinids were not collected from this parasequence.

Depositional sequence 2 is generally more shaly and silty than depositional sequence 1 and, in eastern exposures, parasequence sets of shale/carbonate meter-scale cycles are common and in a few parts of the succession alternate with parasequence sets of carbonate/shale cycles. Toward the platform margin, the shaly fraction declines. Again, the upper

1997. *in* C. A. Ross, J. R. P. Ross, and P. L. Brenckle, editors, Late Paleozoic Foraminifera; their biostratigraphy, evolution, and paleoecology; and the Mid-Carboniferous boundary, Cushman Foundation for Foraminiferal Research, Special Publication 36.

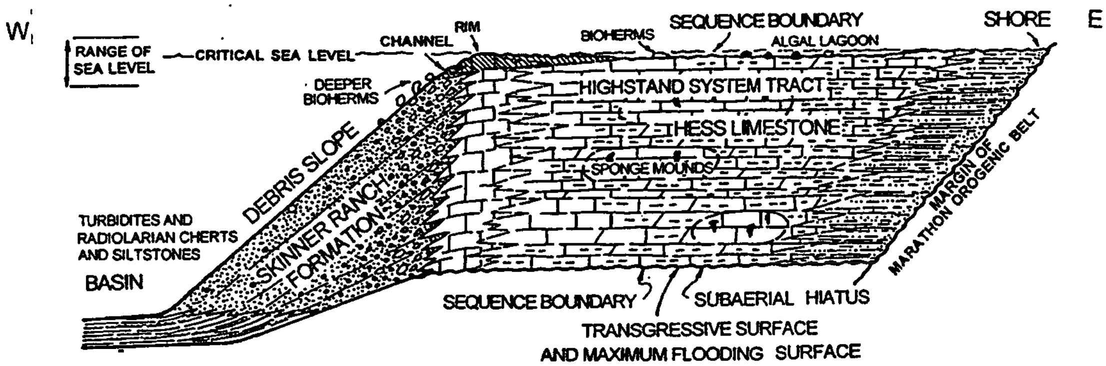

Figure 2.–Rimmed platform model of a lower Hessian carbonate-dominated depositional sequence shows range of sea-level fluctuation and the critical level at which the platform will be either flooded or exposed. Channels which cross the rim facies act as point sources for large amounts of debris washed from the platform during storms. Some blocks of living penecontemporaneous debris transported from the platform may become established as biohermal mounds on the upper part of the debris slope. The highstand systems tracts form nearly all the sedimentary deposits and the transgressive systems tracts are either minor or missing.

parasequence set (2C) is more dolomitized than the lower two (2A, 2B). *Parafusulina allisonensis* is abundant in this depositional sequence and is dominant in the platform facies.

Depositional sequence 3 (Fig. 4) includes considerable sandy siltstones, sandy shales, dolomitic limestones, and silty limy dolostones in meter-scale cycles in the inner platform and near-shore facies. Its upper surface and the upper several meters are dolomitized, and in the near-shore facies are dolomitized and silicified. *Parafusulina deltoides* is the predominant species in the platform facies of this depositional sequence.

Sequence 4 is composed of predominately sandy siltstones and sandy dolomitic siltstones in the middle and inner platform facies and sandstone with thin carbonates in the near-shore facies. Two unidentified species of *Parafusulina* are present, however, they are micritized and poorly preserved. Also present are a few specimens of *Pseudoreichelina* sp. This depositional sequence shows evidence of exposure, weathering, diagenesis, and erosion at its upper surface. The platform margin of this depositional sequence is more than 120 m thick whereas the near-shore facies is less than 25 m thick, indicating considerable erosion and weathering at this surface. Within a few tens of meters along strike, erosion at the unconformity between depositional sequences 4 and 5, has cut several meters into the underlying beds. Lenses of sandstone and conglomerate, several meters thick, are common on this irregular surface and appear to be fluvial deposits.

Above this unconformity, marine transgressive deposits in the lower part of depositional sequence 5 form the 'Hess fossil beds', or the Taylor Ranch Member of the Hess Limestone, and include a diverse and abundant megafossil fauna. These beds, in contrast to the those below, are sandy, dolomitic, and porous grainstones and packstones, which pass higher into a parasequence cycle set of stacked fusulinid grainstone banks, each 3 to 5 meters thick, with large off-lapping cross-beds of grainstones that are pock-marked by thousands of empty fusulinid molds. They suggest a more open marine environment than those of the lower Hess sequences. *Parafusulina spissisepta* is the dominant fusulinid and is abundant in these banks across the upper part of the Hess escarpment.

Depositional sequence 6 has relatively pure, medium-bedded limestones in 10 to 15 m parasequence sets that are separated by thinner bedded (about 1 m), silty and sandy darker limestones. Near the top of the sequence, two species of *Parafusulina, P. vidriensis* and *P. brookensis,* are abundant in the eastern part of the Glass Mountains. To the west, beds of this depositional sequence were removed by erosion at the unconformity at base of the Cathedral Mountain Formation.

In the eastern Glass Mountains, stratigraphically higher but still within the Hess Limestone, a thin, persistent sandstone lies at an unconformity at the base of depositional sequence 7. The overlying limestones are largely recrystallized and relatively few original fossil shells are preserved. No identifiable fusulinids were recovered from this interval. In a stratigraphic section half a kilometer to the northeast (not shown in Fig. 3), an additional thin sandstone overlying an unconformity and a higher succession of limestones similar to those in sequence 7, suggest an eighth sequence may be present in this part of the Glass Mountains. The unconformity at the top of the Hess Limestone cuts down through the Hess platform strata such that the Hess rim and platform margin facies are deeply eroded, as deep as depositional sequence 5 (Taylor Ranch Member) at the western edge of the Hess platform and as high as depositional sequence 7 (or even depositional sequence 8) in the easternmost outcrops.

FUSULINID SEQUENCE EVOLUTION

Many of the fusulinacean species are restricted in their stratigraphic distribution to one depositional (third-order) sequence, or to a few parasequence sets within a depositional sequence. This has permited detailed correlation of individual sequences within paleobiogeographic regions (Ross and Ross, 1987a, 1987b). Further, the occurrences of particular species are closely associated with specific depositional facies within a depositional sequence (Ross and Ross, 1995). In the late Paleozoic, many of these facies were in highstand systems tracts. As a result, phylogenetic lineages of species in shelfal strata are stratigraphically discontinuously preserved and represent only a fraction of the actual duration of the depositional cycle. Thus, the geological record of most evolutionary lineages of fossil species is very discontinuous so that we have only glimpses of what were commonly rapidly evolving species lineages separated by long intervals reflecting depositional breaks and unfavorable facies when the lineages were not recorded. This discontinuous stratigraphic distribution is common in several fossil groups including fossils common and widespread in the shallower-water carbonate facies of the highstand systems tracts, such as calcareous foraminifers and corals, and those common in the fine-grained, darker, condensed stratigraphic units associated with maximum sea-level flooding, such as cephalopods and conodonts. Repeated changes in sea levels and the associated changes in depositional facies have resulted in an apparent episodic record of species evolution and species extinction. We use the terms 'sequence evolution' and 'sequence extinction' to describe these patterns and to call attention to the importance of the gaps in interpreting the fossil record of species lineages (Ross and Ross, 1995). Many of these breaks, or gaps, in deposition and in environmental facies result from fluctuations in sea levels.

Modern evolutionary theory recognizes the broad and varied ways that eukaryotic organisms usually adapt to 'geologically' rapid changes in environmental conditions. Morphological changes in species in the fossil record are dynamic and continuous throughout the stratigraphic record. These changes are often masked by the taxonomic classification of species which is centered around the concept of a morphological range of variation within a species. Breaks in the continuous pattern of morphological changes, caused by breaks in deposition, such as depositional sequence boundaries resulting from regressions and transgressions, have commonly been used as the basis for establishing a new species. These major morphological changes have commonly been used to support the idea that changes took place rapidly, or even abruptly, instead of taking into account the relatively long hiatuses in the geologic record between depositional sequences, . The sequence boundary is, in itself, an indication of an environmental change, and hence an indication that selection and adaptation pressures may even accelerate morphological shifts. Because much of the stratigraphic record is made up of well-developed depositional sequences, much of the fossil record exhibits this phenomenon, or appearance, of 'sequence evolution' and 'sequence extinction'. 'Sequence evolution' and 'sequence extinction' may explain the abrupt appearances of new species within phylogenetic lineages and the disappearance of earlier species as recorded in succeeding depositional sequences. Because each successive depositional sequence usually repeats similar depositional environments, they commonly are characterized by successively younger (later) species in those lineages that survive extinction. These survivors continue to evolve at the species level in the time and sedimentary framework of depositional sequences — their apparent 'tempo' and 'mode' of evolution.

DURATION OF SEDIMENTATION AND TIME RELATIONS

During most of the Pennsylvanian and the Early Permian Wolfcampian, sea-level fluctuations, particularly large sea-level rises, were too rapid for carbonate-producing faunas to keep up (Kendall and Schlager, 1982). This resulted in 'meter scale' carbonate cyclicity being poorly developed. Starting with Hessian deposition, parasequences and meter-scale cyclicity did keep-up and was well-developed. Although complicated by several major hiatuses of unknown duration, more than a hundred small, meter-scale sedimentary cycles comprise almost 300 m in Hessian sequences 1 through 4. If, as we suspect, these are 20,000-year cycles, then the duration for this early part of the Hessian is at least 2 million years. The upper part of the Hess Limestone has eighty or more well-developed parasequences, which are about 1.3 to 1.5 meters thick, and we estimate a duration of about 1.6 million years for their accumlation. Thus, deposition of the Hess Limestone took approximately 3.5 million years.

CONCLUSIONS

The Hess Limestone platform facies in the eastern part of the Glass Mountains was deposited in a paleotropical or paleosubtropical region and includes at least seven, and possibly eight, well-developed third-order depositional sequences. Meter-scale carbonate parasequences and parasequence sets are well developed. Significant erosion, implying long exposure, occurred both at the base of the Taylor Ranch Member and at the top of the Hess Limestone. The upper unconformity has karst features. The stratigraphic distribution of fusulinacean species provides a robust record that permits detailed stratigraphic correlation of each of the third-order sequences and, in some cases, even some parasequences sets. The duration of Hess deposition is estimated as 3.5 million years or more based on the number of parasequence cycles.

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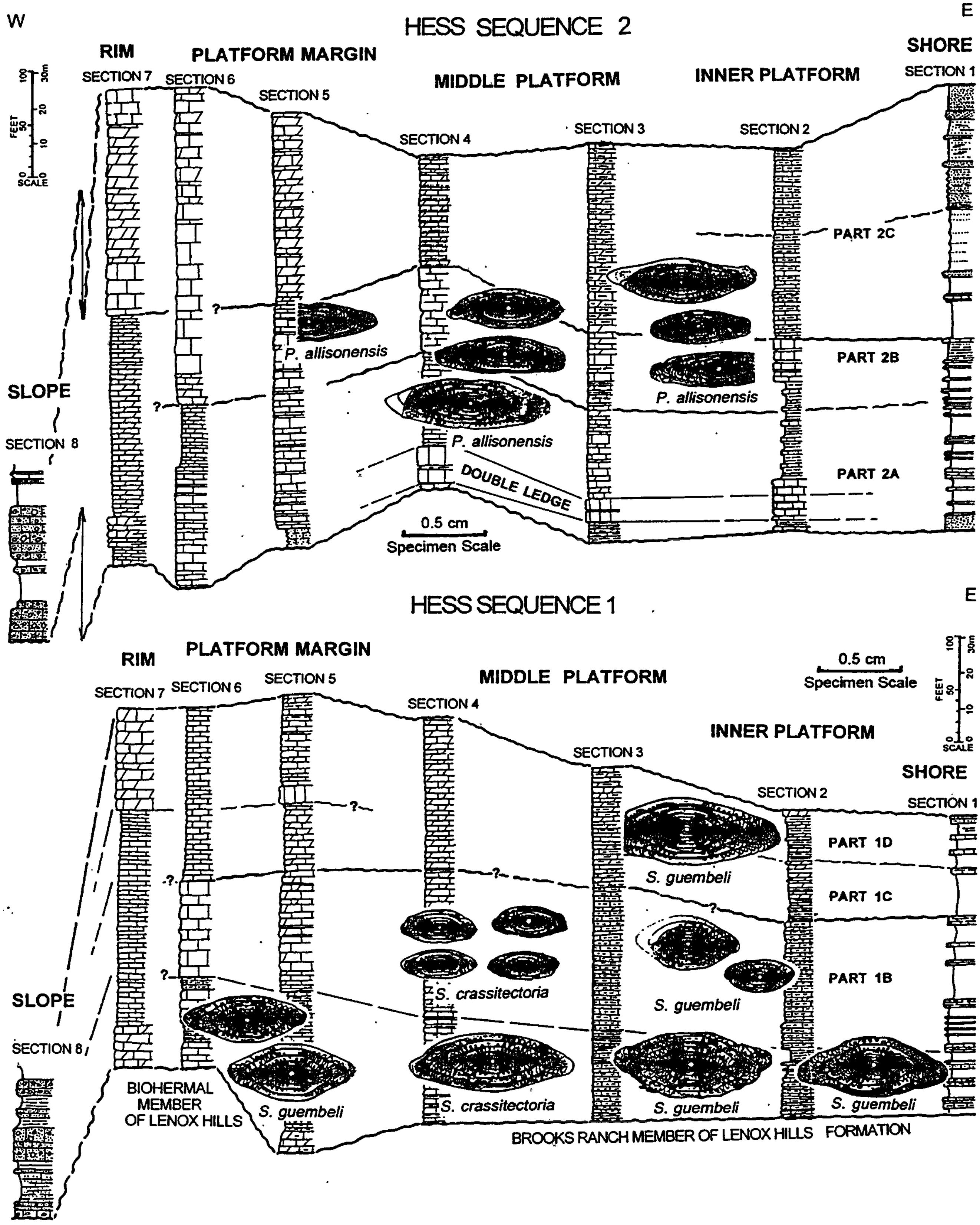


Figure 3.–Hessian depositional sequences 1 and 2 from near-shore facies across the platform into rim and slope facies and representative fusulinaceans. Sequence 1 includes four parasequence sets that are traceable across the platform. The 'double ledge' forms a prominent set of sponge-biohermal ledges near the base of sequence 2. Sequence 2 includes three parasequence sets.

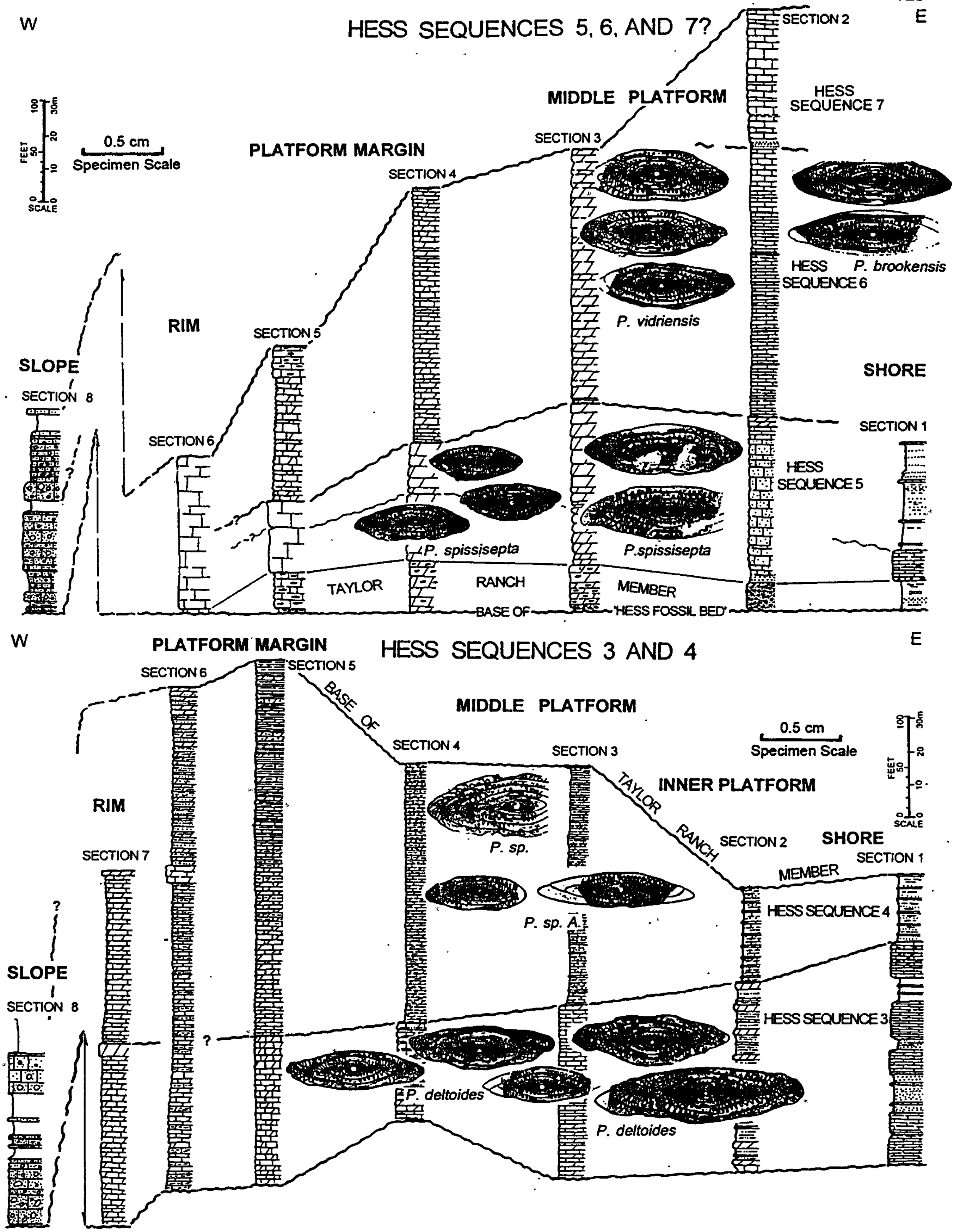
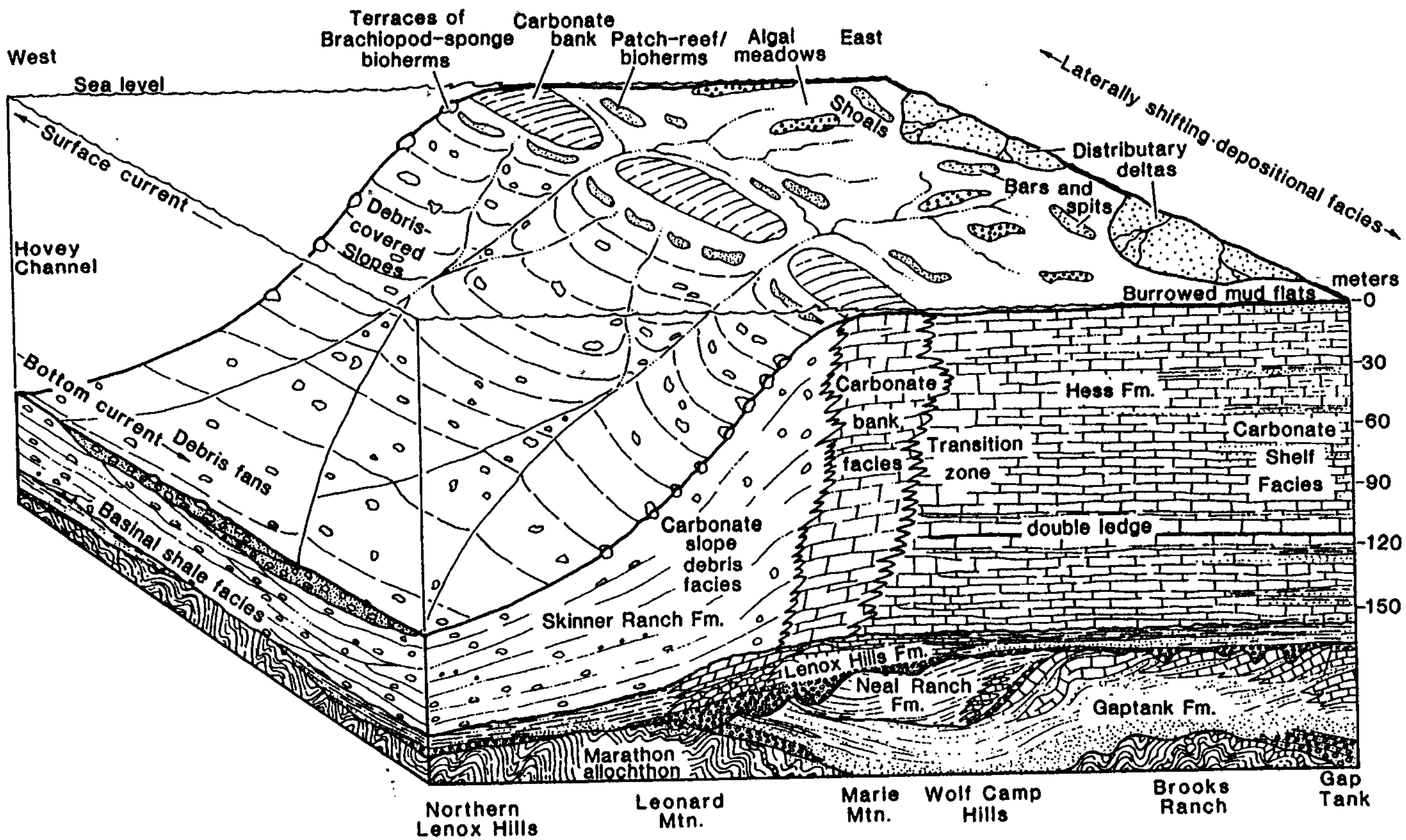


Figure 4.–Hessian depositional sequences 3 to 7 showing representative fusulinaceans. The top of sequence 4 is deeply weathered and very dolomitic, and about 40 m of beds appear to be truncated in the eastern (shoreward) facies. Upper part of the Hess Limestone shows Hess depositional sequences 5, 6, and 7. The Taylor Ranch Member probably was deposited on a surface of low relief with shallow channels developed on the eroded surface of sequence 4 below. After deposition of sequencé 7 and 8?, the western edge of the platform was more deeply eroded than the central and eastern parts of the platform.



Block diagram of depositional facies during the Hessian (Early Leonardian).
From C. A. Ross, 1987, Leonardian Series (Permian), Glass Mountains, West Texas: Permian Basin Section, Society of Economic Paleontologists and Mineralogists, Publication 87-27, Fig. 3.