

TECHNIQUES OF MOLLUSC ZONATION IN TEXAS CRETACEOUS

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ABSTRACT. The objective of the investigation, the kinds and numbers of fossils available, and the scale of the investigation all influence the type of zonation that will be used in any particular sequence of rocks. In an Edwards limestone study, the purpose being paleoecologic, the zones are based on sessile molluscs and are biosomal, but a single lithosome may be coextensive with more than one zone. No zones are coextensive with more than one lithosome; zonation is a technique with which to obtain data for further interpretation.

A study in the Georgetown limestone consists of a detailed correlation of appearances and disappearances of mutually overlapping ammonite teilzones. In this study the zones are those parts of teilzones that are or are not overlapped, arbitrarily depending on whether an appearance or a disappearance is more useful for the investigation.

Strata which can be correlated with the Austin chalk at Austin change rapidly from shale to chalk to limestone to black shale to flaggy limestone. The shale and limestone lithosomes contain ammonite sequences which are usually mutually exclusive. Within a single lithosome assemblage zones are useful and practical, but correlations from one lithosome to another is made only by the rare occurrences of single ammonites which seem to have been buried outside of their optimum environment. These single occurrences are neither index fossils nor guide fossils in the most recent interpretations.

None of the four techniques used above produce units that can be called zones in a chronostratigraphic sense. All of them are zones in the wider interpretation of that word, and the Edwards limestone zones also approach the meaning of the term zone as used by some ecologists.

INTRODUCTION

The objective of the investigation, the kinds and numbers of fossils available, and the scale of the investigation all influence the type of zonation that will be used in any particular sequence of rocks. If paleoecology is the objective of a particular study, then one will likely use benthonic animals that are tightly tied to the bottom and to a narrow depth, salinity, energy, or other range (e.g., stenohaline, stenobathic, etc., forms). On the other hand, the usual technique for long range interregional correlations is the use of planktonic or nektonic assemblages.

If one is interested in more detailed regional or even local work to emphasize local geological history, then more refined methods of zonation must be applied. These might include the use of single teilzones, or, preferably, the use of homotaxial arrangements of parts of a succession of overlapping teilzones.

If correlating between rocks that represent extremely different environments, it may be necessary to extrapolate from the rare accidental occurrence of a nektonic species that for some reason was buried outside of its optimum environment. Ammonites have long been considered by some as occurring outside of their optimum environment by the floating of conchs, but Reymont's (1958a) recent paper puts a different light on this subject, and agrees more closely with Spath's (1933) earlier speculations. Reymont's work indicates that conchs with the shape of *Nautilus pompilius* Linné could float for great distances, but that conchs that depart from this shape only as little as *N. umbilicatus* Lamarck would sink within only a few miles. Disk-shaped forms

and extremely tumid forms likewise, according to Reymont, would not float any great distance. It requires only a glance at any introductory paleontology text to observe that a shape of *N. pompilius* Linné is extremely rare among ammonites.

Four different techniques of mollusc zonation that have been applied with different degrees of success to rock sequences in the Cretaceous of Texas are as follows:

1. biosomal zonation
2. zonation of overlapping teilzones
3. assemblage zones
4. correlation by rare accidental occurrences.

In the following pages I will try to show that these different techniques meet the different demands of diverse investigations and the abundance or rarity of fossils in separate sequences of rocks.

BIOSOMAL ZONATION

Purpose.—The Edwards limestone of southern North-Texas consists largely of a persistent and resistant limestone unit, from 20 to 30 feet thick, containing fossil pachyodonts (rudistids and caprinids). To the west-southwest of Blum (fig. 1), on the south side of the Brazos River in Bosque and Johnson Counties, the Edwards limestone has been removed by erosion, except for scattered and incomplete outliers. To the east-north-east of Blum the Edwards interfingers with the Goodland limestone. It is overlain disconformably by the Kiamichi formation and underlain conformably by the Comanche Peak limestone.

The purpose and result of the particular study was paleoecological. Although the investigation was cursory, some of the questions to be answered were depth, salinity, energy, etc., of the water.

Technique.—Since the available fossils are pachyodonts, and since these were sessile molluscs, they are used for the zonation. The normal process of measuring detailed sections and identifying the fossils by position in the section is followed. The taxonomic problem is not great because the different zones turn out to be identifiable by genera, rather than species. There is a problem on how to draw the boundaries between the zones. The boundaries between the *Gryphaea* and *Cladophyllia* zones and between the *Cladophyllia* and *Monopleura-Toucasia* zones (fig. 2) are sharp and distinct. On the other hand the remaining zones are transitional from one to the next. The top of the *Monopleura-Toucasia* zone is drawn at that horizon at which *Caprinuloidea* becomes a more dominant fossil than the combination of *Monopleura* and *Toucasia*. This is a subjective choice, and the margin of error is probably plus or minus one and a half feet. In the same manner the top of the *Caprinuloidea* zone is placed at that horizon at which *Eoradiolites* becomes more abundant than *Caprinuloidea*. This boundary probably has an error of plus or minus two feet.

Terminology.—The use of zone for this particular technique is in the sense of widest latitude that can be given to the meaning of that term. According to Teichert (1958) a biostratigraphic zone should be restricted to world-

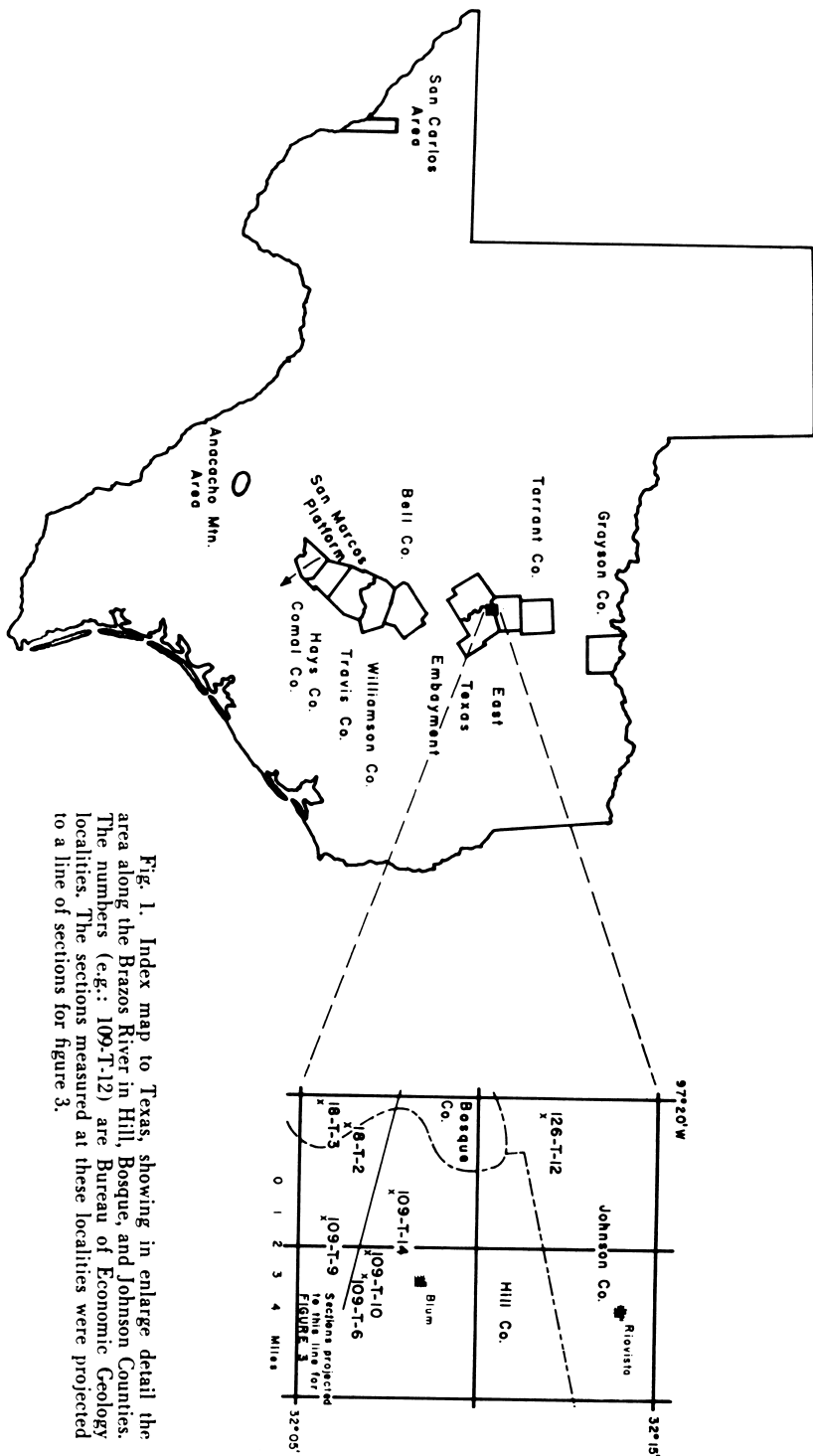
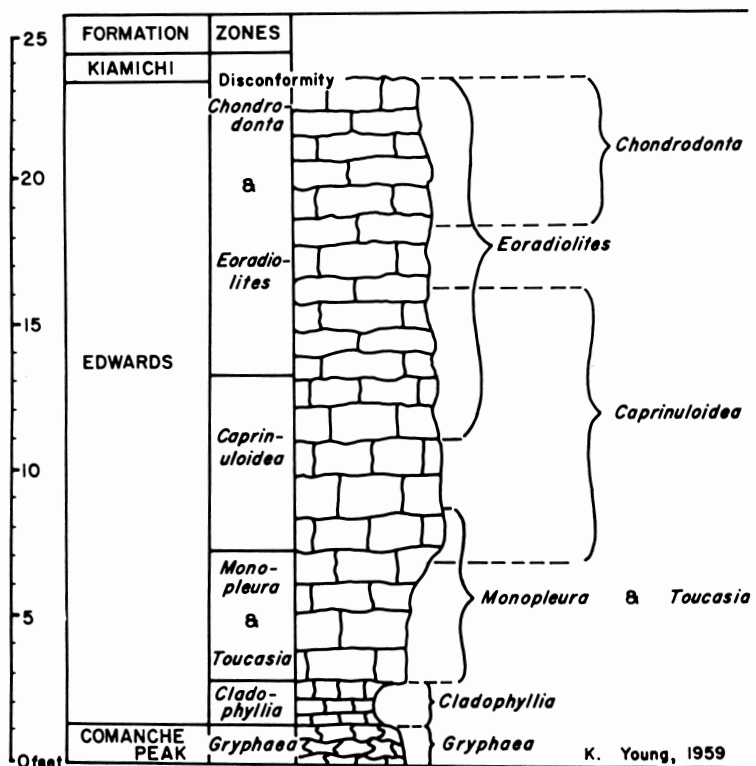


Fig. 1. Index map to Texas, showing in enlarge detail the area along the Brazos River in Hill, Bosque, and Johnson Counties. The numbers (e.g.: 109-T-12) are Bureau of Economic Geology localities. The sections measured at these localities were projected to a line of sections for figure 3.



Idealized Section of Edwards Limestone,
Northern Hill Co., Texas

Fig. 2. Idealized section of Edwards limestone, northern Hill County, Texas. The brackets on the right indicate the local range of the zone fossils; these ranges do not apply farther west, farther east, or to the south. Figure after Young (1959).

wide assemblages of fossils of which the chronologic significance can be empirically demonstrated. The use of zone in the present technique is obviously not the biostratigraphic zone of Teichert's interpretation. The pachyodont zones used here are almost equivalent to the biosomes of Wheeler (1958), except that in order to diagram them (fig. 3) it was necessary to simplify them. They are not, conceptually, the same as Wheeler's (1958) zones, because to me, if the fauna is recurrent, the zone is recurrent, and the arbitrary cut-off does not have to be used in biostratigraphy. The recurrence of a zone does not, automatically, presuppose faulting, or folding, as does the recurrence of a formation on a map.

I prefer, then, to keep the meaning of the word zone at its widest latitude, as does Hedberg (1958). If a term is really needed for the biostratigraphic zone of Teichert (1958)—if geochronology has advanced sufficiently that such a term is useful—then one should be proposed, the meaning of which is still

definite. Of course, there is always the question of whether to restrict a term to its original meaning, or to coin a new term. Generally terms, if allowed to evolve normally, will grow and their meaning change, as ideas change, even without the misuse of persons who do not know their original meaning. Restriction of meaning to original definitions, if followed rigidly, would not only stabilize the terminology, but would also stabilize thinking. Since this is impossible, restriction really would result in an even larger number of terms because every new idea could only be expressed by the definition of a new term. Arkell (1956) and Hedgpeth (1957a) also discuss this problem. In other words the biostratigraphical language needs a word with the meaning that zone has in its widest latitude. I think it more feasible to use the one that evolved to that meaning rather than to try to propose a new term of general meaning.

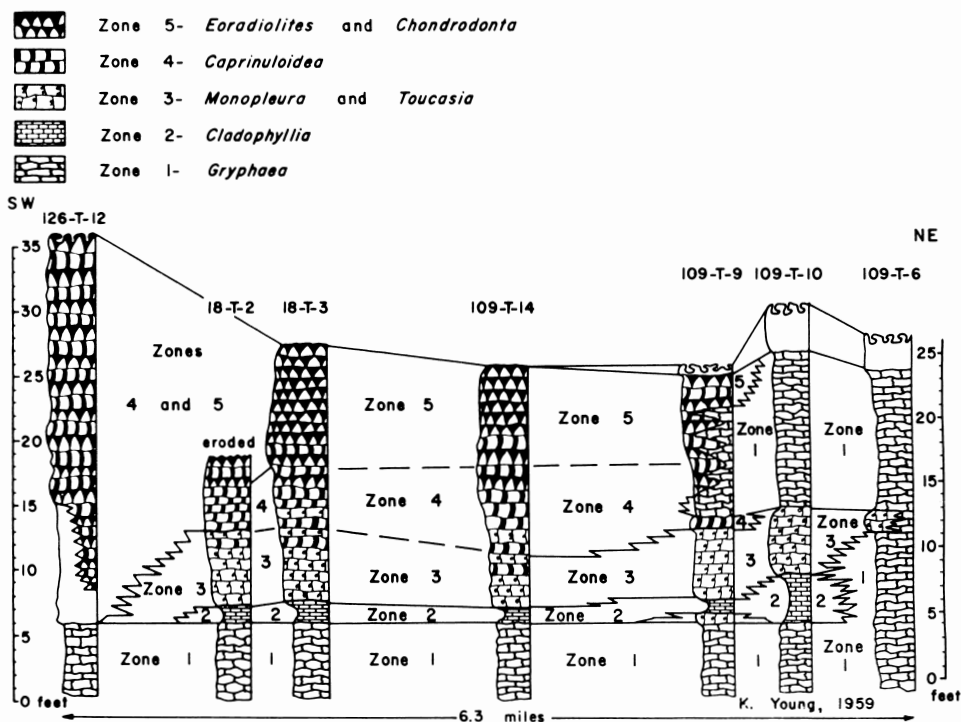


Fig. 3. Zonation of the Edwards limestone in Hill and Bosque Counties, Texas, modified after Young (1959). The patterned parts of the diagrammatic section denote areas in which sessile mollusks are still in growth positions. The different zones depict environments of different energies. The numbers at the tops of the sections are Bureau of Economic Geology locality numbers.

Further validation of this use for the pachyodont units of the Edwards limestone is that these zones represent the biologic units called zones by some ecologists (Hedgpeth in Ricketts and Calvin, 1952; Doty, 1957; Hedgpeth, 1957b; Wells, 1957), although to Thorson (1957) the zone appears to be the

interpretation applied to the community—the sublittoral zone, etc. For a classification similar to the Edwards limestone zonation described here, based on energy of the environment, Lowenstam (1957) uses stage, which seems even less adequate than zone.

Generally paleontologists have not used zone for ecological units, probably because of the prevailing association of a time concept with the biostratigraphic use of zone, and also because fossil zones, in the ecologic sense, are usually extremely difficult to determine.

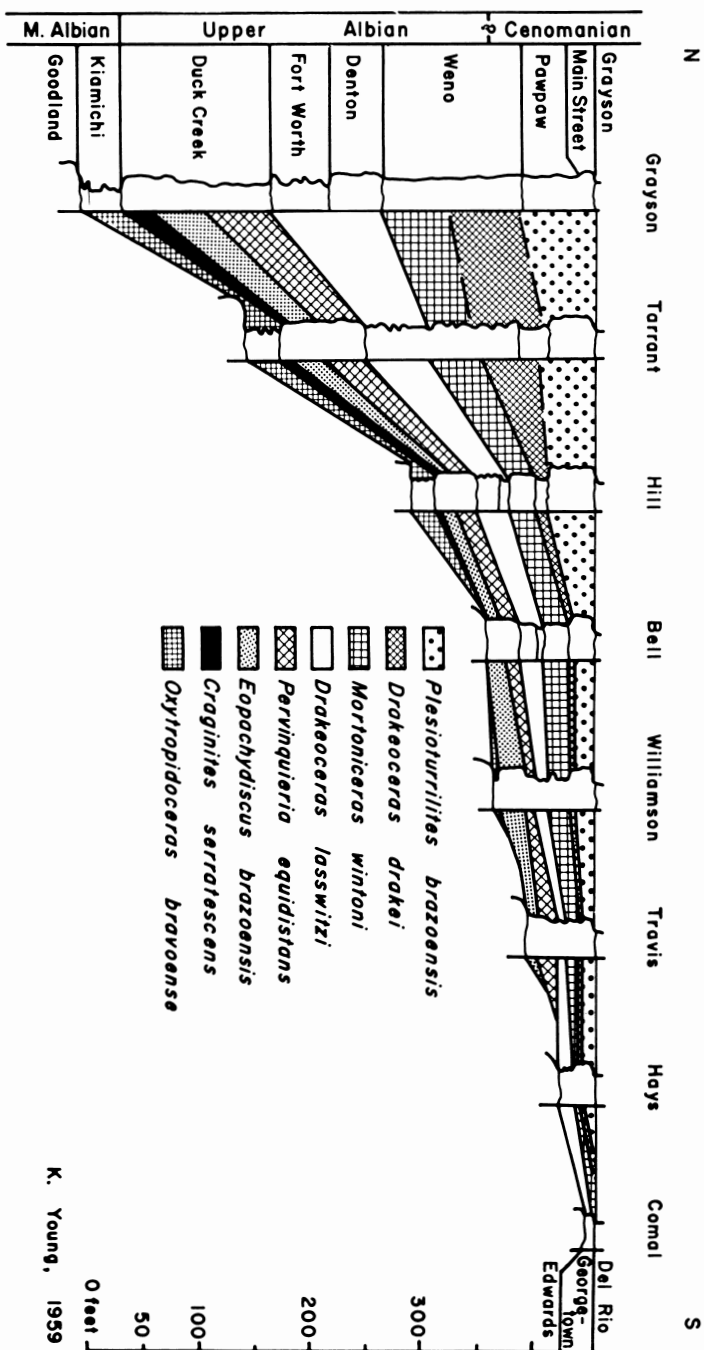
Results.—The results of the zonation have been published elsewhere (Young, 1959). The *Gryphaea* zone is restricted to the white nodular limestone of the Comanche Peak and Goodland formations. The *Cladophyllia* zone, the zone of a small ramose colonial scleractinian coral, and the only non-mollusk in the classification, is restricted to a pulverulitic bed overlying the Comanche Peak limestone.

The *Monopleura-Toucasia*, *Carpinuloidea*, and *Eoradiolites-Chondrodonta* zones make up the typical reef rock of Nelson (1959), and these are the dominant reef-building fossils that can now be identified. They compose one lithosome, but if one is familiar with the different patterns which the sections of the fossils give to the exposed surface of the rock, fossil identification is not difficult (Bonet, 1952, especially figs. 10, 11, 14, 17, 19). A petrographer could obtain about the same zonation from carbonate lithology, except hand specimen analyses would also be necessary because the fossils are too large for the identification of dominant species in thin section. In other words the zones reflect the environment of deposition so well that each zone or group of zones is coincident with a rock type. This is the reason I have labeled this “biosomal zonation”, stealing a term from Wheeler (1958) without his permission. The zones are the counterparts of deposition in zones as that term is used by some ecologists.

ZONATION BY OVERLAPPING TEILZONES

Purpose.—During the early part of a series of mapping projects along the Balcones Fault Zone it became desirable to understand the detailed stratigraphy of the Georgetown limestone and its equivalent formations along their strike. Figure 4 is a cross-section which leads diagonally out of the western margin of the East Texas Embayment, in the vicinity of Tarrant County, southward by slightly west onto the San Marcos Platform (Lozo and Stricklin, 1956), Comal County, Texas (fig. 1). Mapping had already indicated that some beds were being cut out at the base of the Georgetown formation, and consequently it was considered that Cuyler's (1929) diagram could be improved upon. The purpose of this project, in short, was to learn as much as possible by biostratigraphic methods of the details of the stratigraphic and tectonic history of the west side of the East Texas Embayment during the deposition of the Georgetown limestone and its equivalent formations to the North.

Technique.—The technique begins as all good stratigraphic techniques must, with the detailed measuring of sections and the recording of the positions of all of the fossils that might serve a useful zonation purpose. Since the



area is about 300 miles long, many sections were measured, and the most important selected for the illustrations. In addition to myself and the part time services of two assistants, some 15 graduate students have helped in building up the lithic and biostratigraphic grids. Kummel collected fossils in Hill and McLennan Counties, with excellent detail and accuracy; these are deposited in the Bureau of Economic Geology, and were very useful in this study. The collections of W. S. Adkins were also utilized, and that remarkable paper by Adkins and Winton (1920), "Paleontological Correlation of the Fredericksburg and Washita formations in north Texas", for which the stratigraphy and paleontology was done over 40 years ago, was done in such careful detail and with such accuracy that it is still useful for detailed studies such as the present one.

The fossils being recorded, it was then necessary to determine the teilzones for each section; an example is the section at Georgetown, Williamson County (fig. 5). The next step, if detail and refinement is desired, is to divide the sections into as many zones as desirable, or possible. The greatest number of zones can be obtained if the section is divided into segments arbitrarily selected on the appearances and disappearances of teilzones (fig. 6). Any zone is then named after the teilzone of which it is an effective segment. If further detail is desired the overlaps can also be recorded, but some other type of designation then becomes necessary because more units are being used than there are fossils. On the scale of the present diagrams it was impossible to record even all of the teilzones, and the teilzone of *Idiohamites fremonti* has been arbitrarily included in the three lower zones. It should be emphasized that unless fossils are extremely abundant this type of zonation is not possible.

Terminology.—Again the question of terminology arises. I have used teilzone in the manner of most American paleontologists, following the interpretation of Arkell (1933). Teichert (1958) points out that Arkell misinterpreted the original definition of teilzone, and that we should use, instead, Moore's (1957) topozone. If this is the desirable term, I have no objection to using topozone.

The zones resulting from the teilzones or topozones in the Washita group are not comparable to the biostratigraphic zones of Teichert (1958). They may be compared to Teichert's subzones, although I have not used them in any sense as subdivisions of zones. Perhaps they are so local that they should be called zonules, but again they in no way represent subdivisions of the ammonite zones that can be used for interregional correlation of the Upper Albian and Lower Cenomanian rocks. The zones here defined for a particular technique constitute a zonation devised for and applied to a specific problem.

Results.—The results of this study were presented (Young, 1956) at the

Fig. 4. Diagrammatic section illustrating a zonation of the Georgetown limestone and its North Texas equivalents. The extent of the diagram is from Grayson County on the north to Comal County on the south, paralleling approximately the western margin of the East Texas Embayment (fig. 1). The zones are based on overlapping homotaxial sequences of teilzones. All zones thin toward the San Marcos Platform (south-south-west), and each of the four lower zones is successively overlapped by the next younger zone. The line of section for figure 4 is from Grayson County through the counties illustrated on the map to Comal County on the southeast edge of the San Marcos Platform.

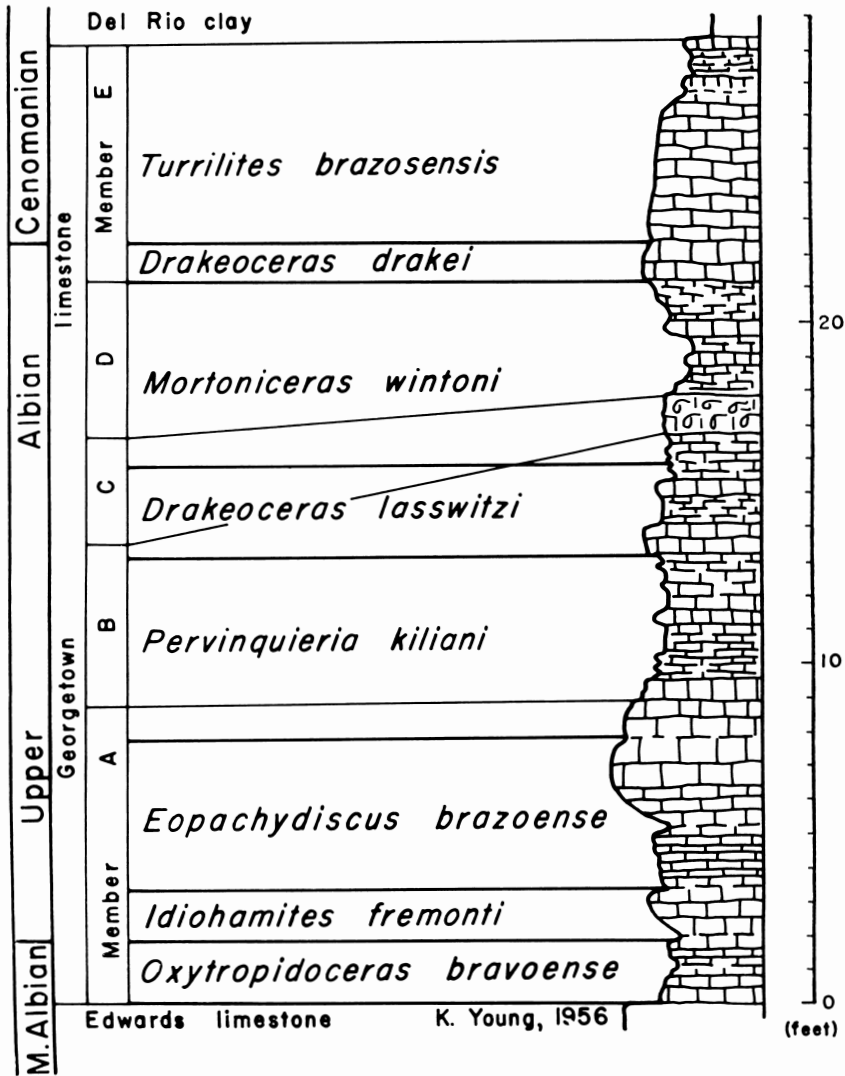
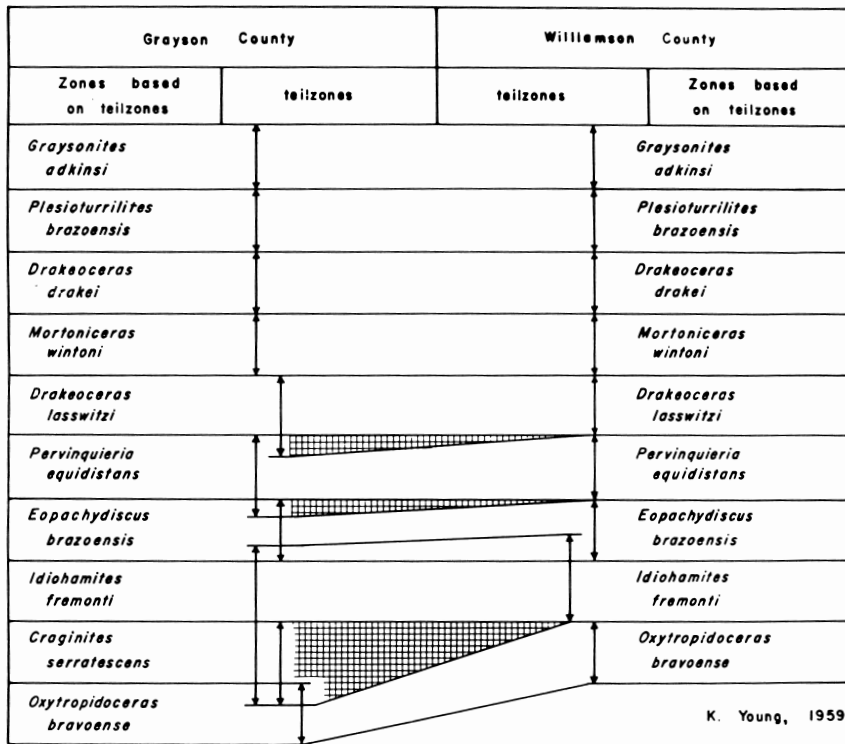


Fig. 5. Idealized control section for Williamson County; each zone is the teilzone for that species. It is only coincidence that the base of the *Drakeoceras drakei* zone is the same as the base of member E. There is otherwise no correspondence of zones and lithology.

20th International Congress, and should be published when the Cretaceous Symposium is eventually published. When the teilzones are redrafted as units, the diagram of the zonation of the Georgetown limestone and related formations appears as in figure 4. If the homotaxial sequence is consistent in all of the sections, there is something objective with which to correlate, although there is great room for argument as to its interpretation. In the Washita group



Comparison of Teilzones,
Grayson and Williamson Counties, Texas

Fig. 6. Diagram illustrating the relations of teilzones in Grayson County to the teilzones in Willemsen County. In the thin ($100 \pm$ feet) Williamson County section there is overlap of only the teilzones of *Idiohamites fremonti* and *Eopachydiscus brazoensis*. In the thicker (seven-fold) Grayson County section all of the lower teilzones overlap, but there is, as yet, no evidence of overlap of the younger teilzones. Shaded sections show biological relations in Grayson County which are absent in Williamson County.

this gives a picture of all zones thinning from the basin to the platform, and of the lower zones being successively overlapped.

ASSEMBLAGE ZONES

Purpose.—The purpose of this particular investigation is to learn as much as possible about the geologic history and biostratigraphic correlation of the various parts of the Austin chalk. Unfortunately ammonites are not nearly so abundant in the Austin group as they are in the Washita group. Consequently, the less refined method of assemblage zones is used, and as a result, less is known concerning the Austin group.

Technique.—The technique does not differ greatly from other techniques to start with, because some form of a lithic grid must be established into which to arrange the fossils. This means that either detailed sections must be meas-

ured or that the fossils must be tied into some horizon such as the disconformity at the base of the Dessau limestone (Durham, 1956). Because ammonites are not abundant in the Austin chalk, the information which leads to the zonation of the Austin chalk has accumulated slowly over a long period of years, and were it not for such dedicated collectors as Clarence Durham, Roy Hazard, W. S. Adkins, and Oscar Paulson, it is doubtful if enough Austin ammonites would have been collected to serve any useful purpose.

Some ammonites seem to have run in schools, at least they were buried in schools. Thus, in the Austin chalk it has been difficult to build up the assemblages, because one species of ammonite would be found at one locality, and another species at a second locality. Only occasionally were the representatives of two or more species found together so that the assemblages could be put together. Even then, were it not for the known superposition of genera in other parts of the world, so that the problem could be approached with some prejudice, I doubt if the results would be as complete as they are. Because the assemblages were put together in this fashion, and with a certain amount of intuition, they remain to some extent suspect, but they also are the best information that we have at the present time concerning the biostratigraphic units of the Austin chalk.

Terminology.—The assemblage zones of the Austin chalk, as used in this paper, may be subzones in the sense of Teichert (1958). Some elements of each zone are intercontinental, but whereas one element of the *Prionocycloceras* zone, for example, occurs in North Africa, another element occurs in Europe, and only in America are these two elements yet known to occur together with other species not reported from Africa or Europe. I cannot name all of the species at this time because many of them are undescribed; this is no place to introduce *nomina nuda*.

The assemblage zones I am using, if we believe in evolution, must be the result of past evolutionary processes, but the basis of their application is not evolution; it is that of empirical homotaxial arrangement. They are not based on phylogeny, because we do not know the phylogeny; at least there is no great agreement between Reyment (1958b), Wright (Arkell, Kummel and Wright, 1957), Matsumoto (1955), and Collingnon (1948). Spath (1934) points out that "if biological order does not agree with observed stratigraphic succession there can be no doubt that our views of what constitutes 'biological order' must be erroneous". The phylogenies of Reyment, Wright, Matsumoto, and Collingnon do not agree because the stratigraphical successions of Upper Cretaceous fossils in the different parts of the world are different. In other words collection failure results in short range zones and a horizontal classification; the taxa as now defined are polyphletic. Obviously, if there is so much disagreement, the phylogenies are not sufficiently well known to base the zonation on them. Furthermore, most of the present ideas concerning the phylogeny of these animals is based on their order of superposition. The empirical body of data concerning the superposition and homotaxial arrangements of these assemblages of ammonites is the only basis for their validity. This may be orthochronology in the interpretation of Teichert (1958), but evolution is not explicitly the basis for these assemblage zones.

Results.—In figure 7 I have shown only the upper part of the Austin group, for convenience, and more detailed information will be published in a forthcoming paper. Already the age interpretation of the upper part of the Austin chalk has been changed as a result of this study (Young, 1958). The Austin can be divided into about 8 ammonite zones: the lower is dominated by certain species of *Peroniceras*, the second is dominated by *Gauthiericeras* and

Substage	Central Texas	Anacacho Mtns.	San Carlos Area
Middle Campanian	<i>Delawarella</i> cf. <i>delawarensis</i>	<i>Delawarella</i> cf. <i>delawarensis</i>	<i>Submortoniceras</i> n. sp. <i>Delawarella</i> cf. <i>delawarensis</i>
Lower Campanian	<i>Submortoniceras</i> n. sp. aff. <i>tenuicostulatum</i>	?	<i>Submortoniceras</i> n. sp.
Lower Campanian?	<i>Bevahites</i> cf. <i>bevahensis</i>	<i>Bevahites</i> cf. <i>bevahensis</i>	<i>Bevahites</i> cf. <i>bevahensis</i>
Upper Santonian	<i>Texanites</i> <i>texanus gallicus</i>	<i>Texanites</i> <i>texanus gallicus</i>	
Lower Santonian	<i>Texanites</i> <i>stangeri</i> <i>densicostus</i>	?	

K. Young 1959

**Assemblage Zones of Central Texas & Anacacho Mtn. Area,
Compared with Accidental Indices of the San Carlos Area, Texas**

Fig. 7. Texanite assemblage zones of Central Texas and the Anacacho Mountain Area, compared with accidental indices of the San Carlos Area, Texas. The two or three individuals each of *Bevahites* cf. *bevahensis* and *Delawarella* cf. *delawarensis*, coupled with the reverse occurrence of *Placentoceras guadalupae* (one occurrence, see fig. 9) are a tenuous key to the correlation of the San Carlos beds with the Austin chalk, other criteria being absent.

Prionocycloceras, the third is the zone of *Texanites stangeri densicostus* (Spath), the fourth the zone of *Texanites texanus* (Römer), the fifth the zone of *Texanites texanus gallica* Collignon, the sixth the zone of *Bevahites* cfr. *B. bevahensis* Collignon, the seventh the zone of *Submortoniceras* sp. aff. *S. tenuicostulatum* Collignon, and the eighth is the zone of *Delawarella delawarensis* (Morton). These are ammonites that are the index species to the zones, but other species are just as indicative of the assemblage. Although

much more needs to be done, a reasonable zonation for the Austin chalk is being worked out, but it is not as refined as would be desirable for regional biostratigraphic purposes.

CORRELATION BY RARE ACCIDENTAL OCCURRENCES

The San Carlos area (fig. 1) is included in figure 7. The ammonites of the San Carlos beds were described by Hyatt (1903), and little has been done with them since. The fossils described by Hyatt were collected by R. T. Hill, T. W. Vaughan, and T. W. Stanton before 1900, and without the precision that is desirable in any more refined stratigraphic technique. There are about 5,000 ammonites now available from different horizons of the San Carlos beds. Nearly all of these are placenticerines or pseudoschloenbachiines. There are two assemblage zones, the upper one is the zone of *Placenticerias meeki*, with *P. meeki*, *P. guadalupae*, *P. sancarlosense*, *P. pseudosyrtae*, *P. planum*, *P. neuberryi*, and *Pseudoschloenbachia chispaensis*. The lower zone, the *Placenticerias guadalupae* zone, contains approximately the same assemblage except for the absence of *P. meeki*; the first appearance of *P. meeki* arbitrarily marks the base of the Campanian, by definition, when placenticerines are used for zonation purposes. Unfortunately *P. meeki* is practically unknown from the carbonate deposits. Although, as I shall try to show, the San Carlos beds are equivalent at least to the upper part of the middle Austin chalk and of the upper Austin chalk, Adkins (1929; 1933) considered them to be of Taylor age. Although we do not know why he reached this conclusion, there are probably three reasons: (1) he accepted the concept of a regional disconformity at the top of the Austin chalk (Adkins, 1936); (2) the San Carlos beds contain no ammonite assemblages in common with the Austin chalk; and (3) the ammonite assemblages of the Taylor were and are still unknown. Consequently, the age designation of the San Carlos beds was based on "negative correlation". These beds contained no Austin chalk ammonites, so they must be of some other age; "negative correlation" is always a danger when dealing with pelagic assemblages of different environments.

In deference to Adkins I should point out that the top of the Austin chalk had been considered as Lower Santonian because of misidentification by paleontologists usually other than Adkins, misidentifications that were still being made as late as 1952 (Young in Young and Marks, 1952).

Purpose.—The purpose of the investigation, now in progress, is to determine the biostratigraphic relationships, if any, of the Austin chalk and the San Carlos beds.

Technique.—The technique cannot be applied until a large number of ammonites have been obtained from the rocks representing each of the two contrasting environments. This is because, as Newell (1959) has pointed out, the probability of finding a particular fossil increases with the number of different and distinct periods of searching for it. In other words, the correlation of the rocks representing the black shales of the San Carlos beds and the light colored limestones of the Austin chalk depends on the accidental discovery of a fossil which was buried outside of its optimum environment. Here are a few examples to illustrate just how tenuous such a correlation is.

The only specimen of *P. guadalupae* known from the Austin chalk is the holotype, collected by Römer about 1846 and described by him in 1852. I can assure you that the type locality has been visited many times by many of us, and much of the Austin chalk has been searched, but not one individual of this species has been collected, to my knowledge, in the ensuing 100 years. The lithology of Römer's individual verifies the locality he lists; furthermore, he could not have ventured far enough west to collect from a locality where many of these fossils do occur because of first, the Comanche Indians and second, the Apache Indians. What are the odds that Römer, who spent all of six weeks on the outcrop of the Austin chalk, most of it on horseback, would find the only individual of *P. guadalupae* ever to be found east of the Pecos River? And this is the holotype! Rare individuals of *P. pseudosyrtae* and *P. planum* have been recovered from the Austin chalk, but no *P. sancarlosense* and no *P. newberryi*. The isolated occurrences of *P. pseudosyrtae* and *P. planum* in the Austin chalk have not been tied into the stratigraphic grid and do not mean much. Furthermore, rocks cannot be zoned as well by placenticerines as by texanitines (figs. 7 and 8).

The Austin chalk, on the other hand, is dominated by various texanitines, pachydiscines, and puzosiines. So far no pachydiscines have been collected from the San Carlos beds, only one puzosiine, and a few scattered texanitines, yet 5,000 or more ammonites are in the collections from these strata.

This means that correlation between the two areas can be only by texanitines, but unfortunately the Austin chalk and the San Carlos beds do not always contain the same species, and where a species is present in each area, it seems to be represented by different geographic subspecies. We know so little of the relation between subspecies and species that this situation throws doubt on the validity of any correlation made with them. In other words, a splitter would describe my presumed San Carlos and Austin texanitrine subspecies as different morphospecies; a lumpner would describe them as one biospecies.

The real reason for correlating the strata of these two areas is the apparent accidental occurrence of individual texanitines out of their optimum environment. A correlation on these may eventually help in a decision as to whether the use of subspecies in the texanitines of this area is valid or not.

Moon (1953) has collected one individual each of *P. guadalupae* and *P. sancarlosense* from the Fizzle Flat member in the Agua Fria quadrangle of the Big Bend area. Moon does not mention the fossils, but they are in his collections at The University of Texas. The Fizzle Flat member contains the Lower Santonian texanitines, *Paratexanites*, n. sp. and *Texanites stangeri*, which indicate that *Placenticeras guadalupae* ranges down into the Lower Santonian to a horizon below *T. texanus texanus*. The *P. meeki* zone of the San Carlos beds has yielded one or two individuals of *Delawarella* sp. cfr. *D. delawarensis* (Morton), plus the taxon that may prove to be a geographic subspecies of *D. delawarensis*. *D.* sp. cfr. *D. delawarensis* also occurs in the top of the Burditt marl (upper Austin chalk) below a Middle Campanian ammonite from the overlying Taylor, the latter related to *D. roedereri* Collignon. *D.* cfr. *delawarensis* has also been collected from the Gober chalk. This is a tenuous correlation based on less than half a dozen individual fossils. In the San Carlos

Substage	Central Texas	Anacacho Mtns.	San Carlos Area
Middle Campanian		<i>Placenticerus meeki</i>	<i>Placenticerus meeki</i>
Lower Campanian	<i>Placenticerus pseudosyrtae</i>		
Lower Campanian?			
Upper Santonian	<i>Placenticerus guadalupae</i>		<i>Placenticerus guadalupae</i>
Lower Santonian			

K. Young 1959

**Accidental Indices, Central Texas, & Anacacho Mtn. Area,
Compared with Assemblage Zones of San Carlos Area, Texas**

Fig. 8. Accidental indices, Central Texas and Anacacho Mountain Area, compared with assemblage zones of the San Carlos Area, Texas. In the right column are shown the two placenticerine assemblage zones of the San Carlos Area. The rocks of the other two areas are represented by rare finds of identifiable placenticerines, which have been dated by the texanitines with which they are associated. A correlation by placenticerines is impossible with the present data.

Area *Placenticerus guadalupae* ranges from Lower Santonian to Lower Campanian inclusive, if texanitines are used for zone fossils.

A new species of *Texanites* is found in the base of the Dessau formation with *Bevahites* sp. cfr. *B. bevahensis* Collignon. This most likely Upper Santonian species is also represented by 2 or 3 fragments from the *P. guadalupae* zone of the San Carlos area. One individual of the Santonian ? *Phlyctiocieras douvillei* (Grossouvre) is also known from the Austin chalk, from below the disconformity at the base of the Dessau, and another is known from below the *P. guadalupae* zone in the San Carlos area.

Results.—These few occurrences, then, indicate the equivalency of the San Carlos beds to the middle and upper Austin chalk, but in spite of all of the preceding discussion, they do not provide any refined method of correlation. These accidental occurrences of fossils deposited out of their optimum environment are not guide fossils or index fossils in any of the accepted definitions. I

have called this technique "correlation by rare accidental occurrences", but the technique is one that could, with other techniques, be included in the biozone or range-zone correlation of Hedberg (1958).

SUMMARY

In summary I will again emphasize that a theoretical system of zonation is not setup in the office, and then easily applied. Rather the fossils are collected, their geographic and stratigraphic occurrences recorded and studied, and a biostratigraphic grid (zonation) developed which best helps to solve the problem being investigated with the data available. If the zonation is to aid in ecologic studies one chooses benthonic fossils which most closely reflect the energy (or other) conditions of the environment. Such zones are biostratigraphic, but not chronostratigraphic. They probably represent the rocks deposited in a zone as that term is used by some ecologists; this is almost the biosome of Wheeler (1958).

If sufficient fossils are available then a refined system of zonation is possible, and it may be used in much the same way as subsurface geologists use the "key bed" technique. This involves tracing appearances, or disappearances, and naming the parts of the teilzones that best serve the purpose of the problem. This technique is only applicable in rocks in which particular zone fossils can be readily collected. It achieves validity only in homotaxial sequences when a body of empirical data indicates a high probability of finding the same homotaxial sequence the next time a section is measured or collected. The technique ceases to be valid when or where the homotaxial sequence breaks down. For this latter reason the technique is useful only locally.

Assemblage zones as a technique are unusually dangerous because most assemblages change as a result of an environmental change, and if the environment was transgressive, or regressive, as most environments were, so are the boundaries of the assemblage zones transgressive, or regressive. In the Austin chalk I have used assemblages of pelagic ammonites which are restricted to certain realms of the carbonate deposition. Assemblage zones are used because a better technique has not been discovered for this sequence of rocks.

In an attempt to correlate from the Austin chalk to the San Carlos beds, two sequences of strata which represent environments that were mutually exclusive of pelagic ammonites, even assemblage zones are impossible, and it is necessary to use only fossils that represent accidental burials outside of their normal environment. This is a technique of the last resort.

Again it should be emphasized that zonation techniques must be fitted to (1) the purpose of the investigation, (2) the degree of refinement or detail required by the investigation, and (3) the availability of the fossils that are to be used.

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