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(Drum Formation), Missourian, Kansas, USA

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EVOLUTION AND DIAGENESIS OF AN OOLITIC LIMESTONE (DRUM FORMATION), MISSOURIAN, KANSAS, USA)

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ABSTRACT: The Drum limestone is an algal build-up and oolite complex (up to 21 m-thick) forming an E-W belt at a shelf edge of the Pennsylvanian north-american mid continent. The Drum formation lies on an erosive surface and formed in two depositional stages separated by an unconformity, resulting in a lower regressive and an upper transgressive unit. The diagenetic history of the Drum oolite is closely related to its depositional evolution. The main controls on the deposition and diagenesis of he Drum limestone were inherited topography, which controlled facies distribution and depositional sites, and relative sea level changes, influencing sedimentary processes.

INTRODUCTION

The Drum Formation is a limestone unit which includes an oolitic body that is an analog to many producing reservoirs in Kansas. The characteristics of this limestones unit, its extension, geometry, volume and connection between different bodies, as well as its porosity and permeability, are closely related to depositional and diagenetic factors. Determining what controlled the sedimentology and the diagenesis of the Drum limestones is therefore of interest for its understanding and evaluation, and the results may be applicable to other oolitic reservoirs in Kansas in the fossil record.

The study of the Drum limestone and associated sediments consisted of field work, core and well log analysis (neutron and gamma ray), and study of high resolution shallow seismic profiles. This work was complemented with diagenetic studies, including petrology, cathodoluminescence and fluorescence microscopy. Previous works in this unit include those of Stone (1979, 1985), Feldman and Franseen (1991) and Feldman et al. (1994).

GEOLOGICAL SETTING

During Pennsylvanian time, North America was located near the equator, in the intertropical zone, and rotated 43 degrees clockwise with respect to its present position (Walker et al., 1995). The studied area was part of a wide intracratonic basin located north of the equator (Fig.1), with the main winds (trade winds) blowing dominantly from the E-NE.

The Drum Formation (Missourian) is a discontinuous limestone body included in the Pennsylvanian Kansas City Group, characterized by alternating limestone and shale units. These units constitute a part of a Pennsylvanian cyclic series (cyclothem), which characterize the late Paleozoic Stratigraphy of North America.

The Drum limestone crops out in SE Kansas, near the locality of Independence. It lies unconformably on a distal carbonate shelf unit, the Cherryvale Formation, made up of marls and argillaceous limestones. It is overlain by the Nellie Bly Formation, a siliciclastic platform system, made up off sandstones and shales. The Drum Limestone forms an up to 40 km long and 30 km wide belt, characterized by a high dgree of variability in facies and thickness (Fig. 2 and 3). It includes an oolitic body that changes laterally (shelfward) to algal and bryozoan mounds. The thickness of the Drum Limestone varies from less than a meter to 24 m. It is wedge-shaped and pinches out in both shelfward and basinward directions. The Drum Limestone was deposited in two main sea level stages (Fig. 4), and its distribution evolution is closely related to that of the underlying unit.

PLATFORM EVOLUTION

Stage 1 (Lower Drum limestone)

The underlying Cherryvale Formation shows a facies succession that indicates a shallowing upward sequence in a distal carbonate platform with occasional storm deposits. This sequence culminates with an erosive surface which eroded up to 10m of the underlying sediments and has an angle of up to 3^{o}. The erosive surface is concave upwards and has an irregular distribution. It formed grooves elongated N-NE to S-SW, with a scale of several hundred meters across (Fig. 4a). Draping the erosive surface there is a lag which consists of intraclasts and algal oncolites; it constitutes the base of the Drum limestone and it is and excellent marker bed. Four sedimentary environments have been distinguished in the Lower Drum formation based on facies associations and sedimentological features (Fig. 3, Fig. 4b), from platform to basin: 1) Inner platform: stromatolites, algal mats, and tidal flat deposits, formed in restricted low energy environments. 2)

Outer platform: mud biostromes overlain by algal-bryozoan bioherms and interfingered oolitic grainstones. They formed in open, moderate to high energy, shallow marine environments. 3) Platform margin: oolites showing unimodal cross bedding basinward. They formed in high energy shallow water marine environments dominated by very continuous ebb tidal currents. 4) Distal platform: peloidal facies formed in low energy, open marine, deep water environments. The main oolitic body infilled the erosional grooves previously formed on the Cherryvale Formation, therefore showing notable thickness changes both along dip and along strike. The maximum thicknesses of the unit for this stage are at the platform margin, and depositional pinching out occurs platform and basinward.

At the end of this depositional stage an unconformity developed on top of the described facies. It resulted in very restricted conditions leading to local deposition of evaporitic facies in the outer platform, deposition of peloidal facies on the platform margin, and hard-ground development and minor resedimentation, as a fine oolitic breccia, in the basin. Some microscopic and megascopic features such as autobrecciation, circumgranular cracking and fractures with tapered ends (roots?) have been locally recognized on the proximal platform indicating subaerial exposure.

Stage 2 (Upper Drum Limestone)

Different types of facies were deposited for this stage on the previously described unconformity surface, depending on the position on the platform (Fig. 3, Fig. 4c): 1) Inner platform: oncolitic rudstones overlying stromatolites formed in the previous stage. They represent moderate energy restricted environments. Oolitic and bryozoan packstones and rudstones which change upwards to algal wackestones and boundstones. 2) Outer platform: oolitic-skeletal grainstones overlying previous algal bioherms indicating high energy. 3) Platform margin: oolitic skeletal grainstones occur as channel or barrier deposits with bimodal cross bedding both basin and shelfward. They are interpreted to have formed in a tide dominated, shallow marine, high energy open platform, with periods of inactivity during which highly diverse faunas thrived. Upward these facies are interbedded with shales, indicating periods of low energy and siliciclastic input to the area. 4) Distal platform: the oolitic bioclastic body thins and interfingers with shales of a prograding distal siliciclastic platform.

The sedimentary evolution of the Drum limestone indicates gradually shallower and more restricted environments upward, resulting in a shallowing upward sequence capped by an unconformity for stage one, followed by gradually more open marine and lower energy facies, indicating a transgressive trend, for stage two.

A recent analog showing some characteristics similar to that found in the Drum oolite is the Miami oolite, characterized by inner platform bryozoan facies and basinward cross-bedded oolites (i.e. Halley and Evans, 1983).

DIAGENESIS

The Drum limestone shows the following cement succession: 1) fine calcite rimming pores and grains, 2) fibrous calcite, 3) syntaxial and equant spar calcite, 4) dolomite and 5) silica. The deduced diagenetic sequence (Fig. 5) included early diagenesis in marine phreatic environments (rim calcite cements) followed by burial diagenesis (recrystalization and spar calcite cementation) which includes one stage of dissolution. The dissolution created a secondary oomoldic porosity which, as the remaining primary porosity, was infilled by late cements (equant spar and dolomite cements). The latest diagenetic stage consists of silica cement precipitation in remaining porosity and silicification affecting both sediments and older cements.

The Drum limestone shows a distribution of cements and porosity closely related to sedimentary facies. The lower part of the oolitic body (oolitic grainstones) is characterized by a strong early cementation and recrystalization of marine cements, a high oomoldic porosity, and little compaction. The upper part of the oolitic body (skeletal oolitic grainstones) shows a higher percent of spar and dolomitic cements, a lower moldic porosity and more compaction. Subtle subaerial diagenesis features (e.g. autobrecciation, circumgranular cracking, root traces) are locally recorded in the oolitic body and linked to the intra-Drum unconformity.

The diagenetic features observed in the Drum limestone can be compared to recent oolites from the Bahamas. These oolites have undergone shallow burial conditions, and show dissolution, recrystalization and cementation features similar to those of the Drum limestone (Melim et al. 1995, Eberly and Anzelmetti, pers. com.).

CONTROLS ON PLATFORM EVOLUTION. DISCUSSION

The main control on the evolution and change in depositional style between the lower and the upper part of the Drum limestone is the inherited topography, along with relative sea level. In the first stage the deposition of the Drum oolite occurred in erosive troughs on the Cherryvale Formation. In these grooves the ebb tidal currents were intensified, favored by the trade winds blowing from the NE. Moreover, a descending relative sea level induced basinward progradation of the oolitic sand body. The change in conditions resulting in the deposition of the upper Drum limestone may have been controlled by the change in the topography of the sea floor. Variabilty in the paleotopography was reduced after the initial troughs were infilled. This setting resulted in a wider oolitic system over the platform, formed in more open marine conditions. These conditions created a high faunal diversity and development of sub-environments of migrating bars, channels, shoals and intershoals. Alternating periods of high and low energy and zones in which the system was inactive also occurred. Increasing accommodation space, resulting from an ascending relative sea level, may also have favored the change in the sedimentary environment.

The main control on diagenetic changes in the oolitic body was the mineralogy, closely related to depositional facies. The Drum limestone oolites show a concentric texture, although they are very often partially recrystalized or dissolved. The concentric texture of oolites is related in modern environments with aragonitic composition. Moreover, recent geochemical analysis in the Drum Limestone oolites (Algeo and Watson, 1995) have documented their original aragonitic nature. On the other hand, the skeletal grains included in the oolite belong mainly to echinoderms, mollusks, brachiopods and some bryozoans, whose original shell consists of low magnesium calcite. The facies change from oolitic facies to skeletal oolitic facies from the lower to the upper Drum oolite implied therefore a mineralogical change, from aragonite dominated facies (ooids) to facies including a high low magnesium calcite percentage (skeletal grains). The aragonite, being unstable, is more prone to recrystalization and dissolution than the more stable low magnesian calcite, resulting in a more recrystalized and porous lower Drum oolite. Sedimentary facies controlled thus diagenesis, influencing porosity and cement distribution.

CONCLUSIONS

Erosion at the base of the Drum Formation created a sea floor topography with grooves oriented subperpendicularly to a platform margin. The topography, along with relative sea level trends, controlled the facies distribution of the Drum limestone, as well as its geometry. The porosity and its distribution is related to the diagenetic evolution of the unit, which was controlled by the mineralogy, aragonite or calcite, of the fossil components of facies, and therefore by depositional factors. These controls may be common to other oolites in the fossil record, and could help in the understanding of oolitic reservoirs in Kansas.

ACKNOWLEDGMENTS

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FIGURE CAPTIONS

FIG. 1. Paleogeography of the North American mid-continent in the Pennsylvanian. Note the proximity of the study area to the southern margin of the basin, which supplied siliciclastic sediments, while the northern margin is farther north. Carbonate deposition occurred at the southernmost end of the northern shelf. The symbol * indicates the study area.

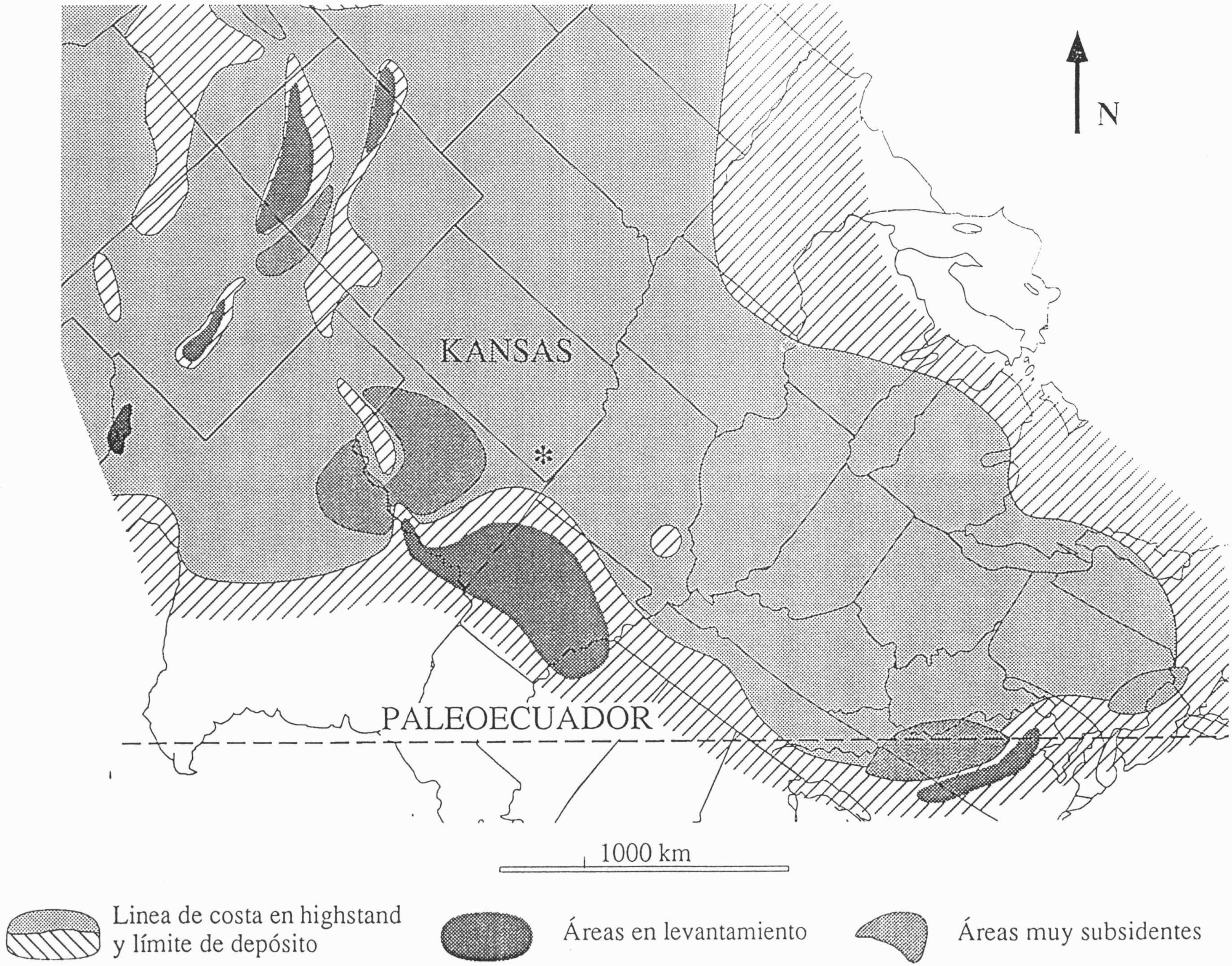
FIG. 2. Facies and thickness distribution for the Drum limestone. The study area is located on the Kansas geological map (left corner), which shows homoclinal series dipping to the east. A-A' corresponds to figure 3. Abbreviations correspond to field and core sections. Ch= Cherryvale, G=Gaddy, Lib=Liberty, F=Ferrel, B=Bredehoft, Cl=Clarkson, BJ=Big Jim, CQ=Cement Quarry, Br=Briedleman, MC=Mouse Creek, S=Sloop, W=White.

FIG. 3. Drum limestone cross section along dip, from platform to basin. Note its erosive base, the wedge shape, and the high facies and thickness variability. B) The same diagram with the vertical exaggeration reduced 40%.

FIG.4. Three-dimensional block diagrams showing sedimentary evolution of the study area. a) Situation preceding the deposition of the Drum limestone. b) First stage in the evolution of the Drum limestone. c) Second stage in the evolution of the Drum limestone.

FIG. 5. Diagenetic evolution of the Drum oolite. Diagram shows cement stratigraphy and diagenetic stages. Space is represented in axis Y, positive for primary porosity an negative for secondary porosity, as are cements infilling porosity. Time and diagenetic stages are represented in axis X. C=Calcite.

Figure 1


N
KANSAS
*
PALEOECUADOR
1000 km
Linea de costa en highstand
y límite de depósito
Áreas en levantamiento
Áreas muy subsidentes

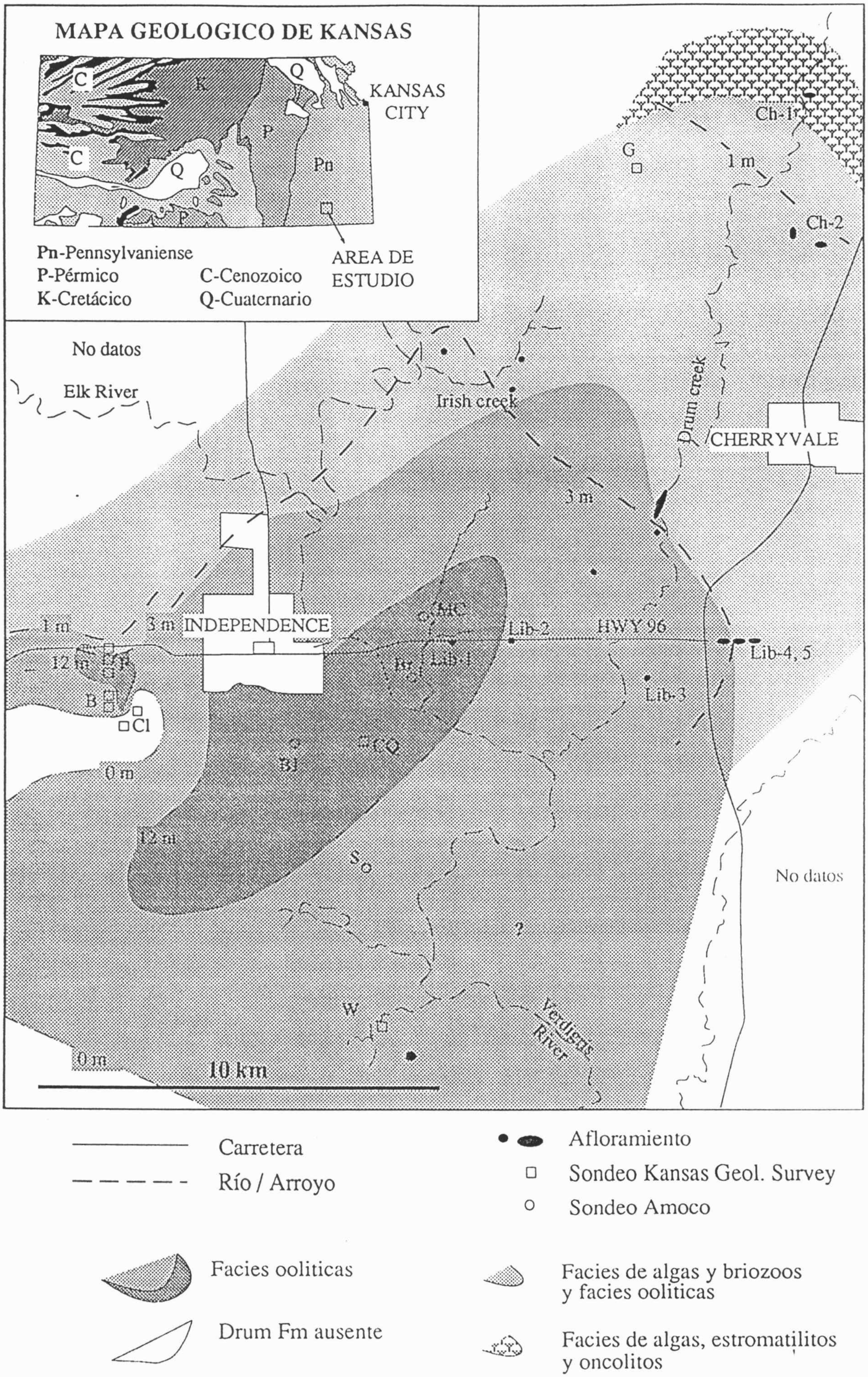

MAPA GEOLOGICO DE KANSAS
C
K
Q
KANSAS CITY
P
C
Q
Pn
P
Pn-Pennsylvaniense
P-Pérmico
K-Cretácico
C-Cenozoico
Q-Cuaternario
AREA DE ESTUDIO
No datos
Elk River
Irish creek
Drum creek
G
Ch-1
1 m
Ch-2
CHERRYVALE
3 m
MC
1 m
3 m
INDEPENDENCE
Lib-2
HWY 96
Lib-4, 5
12 m
Br
Lib-1
Lib-3
B
Cl
CQ
Bl
0 m
12 m
S
No datos
?
W
Verdigris River
0 m
10 km
Carretera
Río / Arroyo
Afloramiento
Sondeo Kansas Geol. Survey
Sondeo Amoco
Facies oolíticas
Drum Fm ausente
Facies de algas y briozoos y facies oolíticas
Facies de algas, estromatilitos y oncolitos

Figure 2

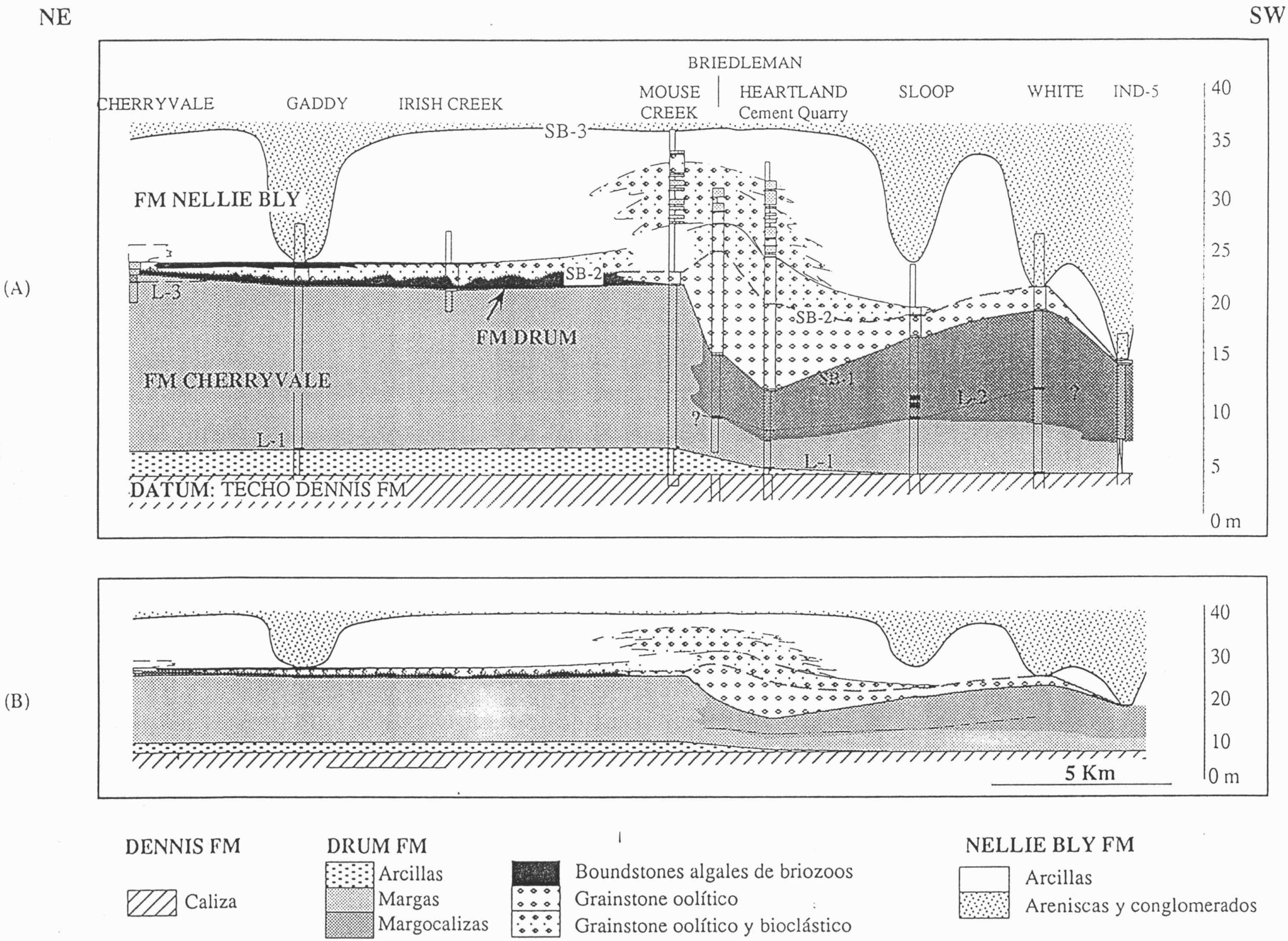

NE
SW
(A)
BRIEDLEMAN
CHERRYVALE
GADDY
IRISH CREEK
MOUSE CREEK
HEARTLAND Cement Quarry
SLOOP
WHITE
IND-5
SB-3
FM NELLIE BLY
SB-2
L-3
FM DRUM
FM CHERRYVALE
SB-1
L-2
L-1
?
DATUM: TECHO DENNIS FM
40
35
30
25
20
15
10
5
0 m
(B)
40
30
20
10
0 m
5 Km
DENNIS FM
Caliza
DRUM FM
Arcillas
Margas
Margocalizas
Boundstones algales de briozoos
Grainstone oolítico
Grainstone oolítico y bioclástico
NELLIE BLY FM
Arcillas
Areniscas y conglomerados

Figure 3

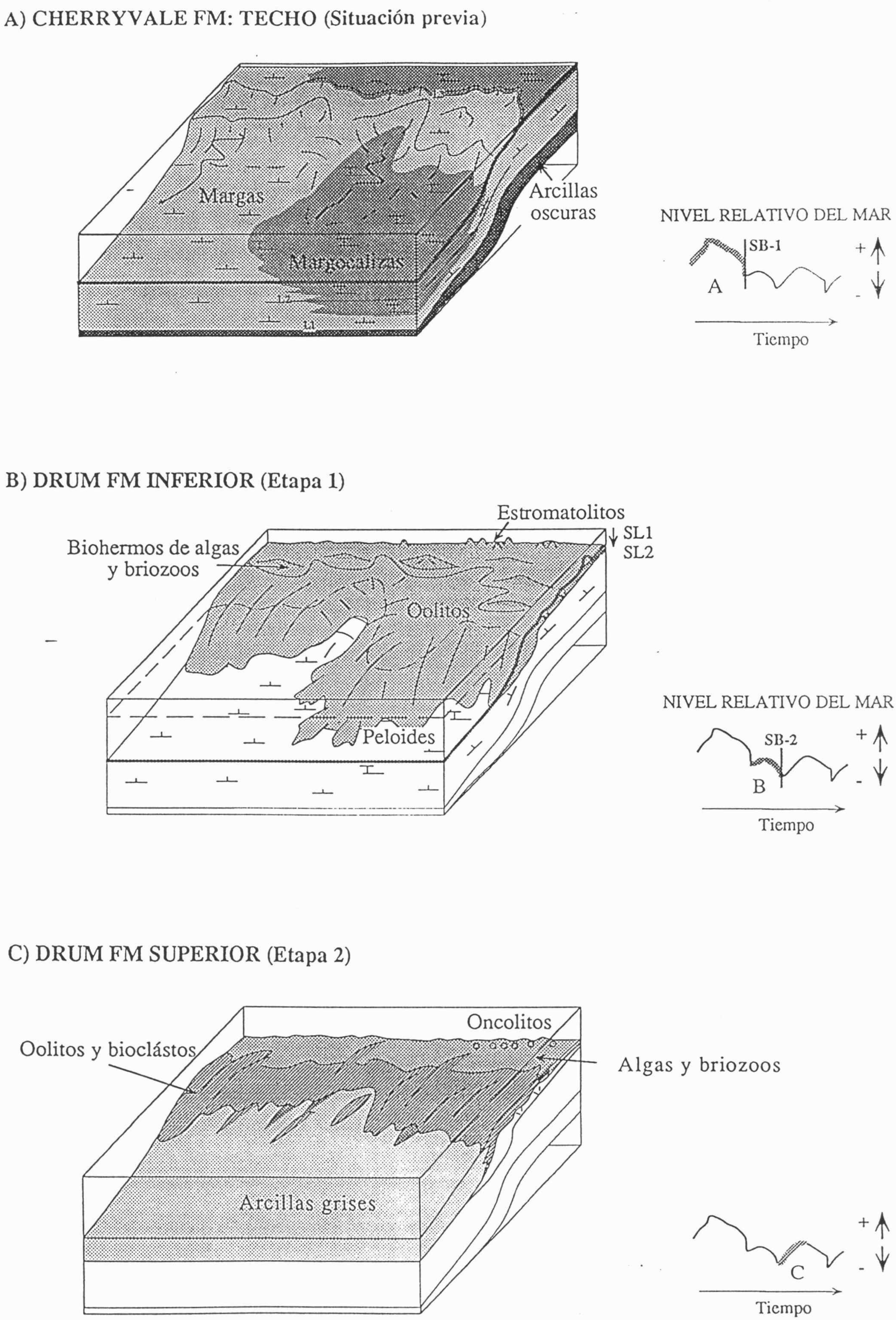

A) CHERRYVALE FM: TECHO (Situación previa)
Margas
Margocalizas
Arcillas oscuras
NIVEL RELATIVO DEL MAR
SB-1
A
+
-
Tiempo
B) DRUM FM INFERIOR (Etapa 1)
Estromatolitos
SL1
SL2
Biohermos de algas y briozoos
Oolitos
Peloides
NIVEL RELATIVO DEL MAR
SB-2
B
+
-
Tiempo
C) DRUM FM SUPERIOR (Etapa 2)
Oncolitos
Oolitos y bioclástos
Algas y briozoos
Arcillas grises
C
+
-
Tiempo

Figure 4

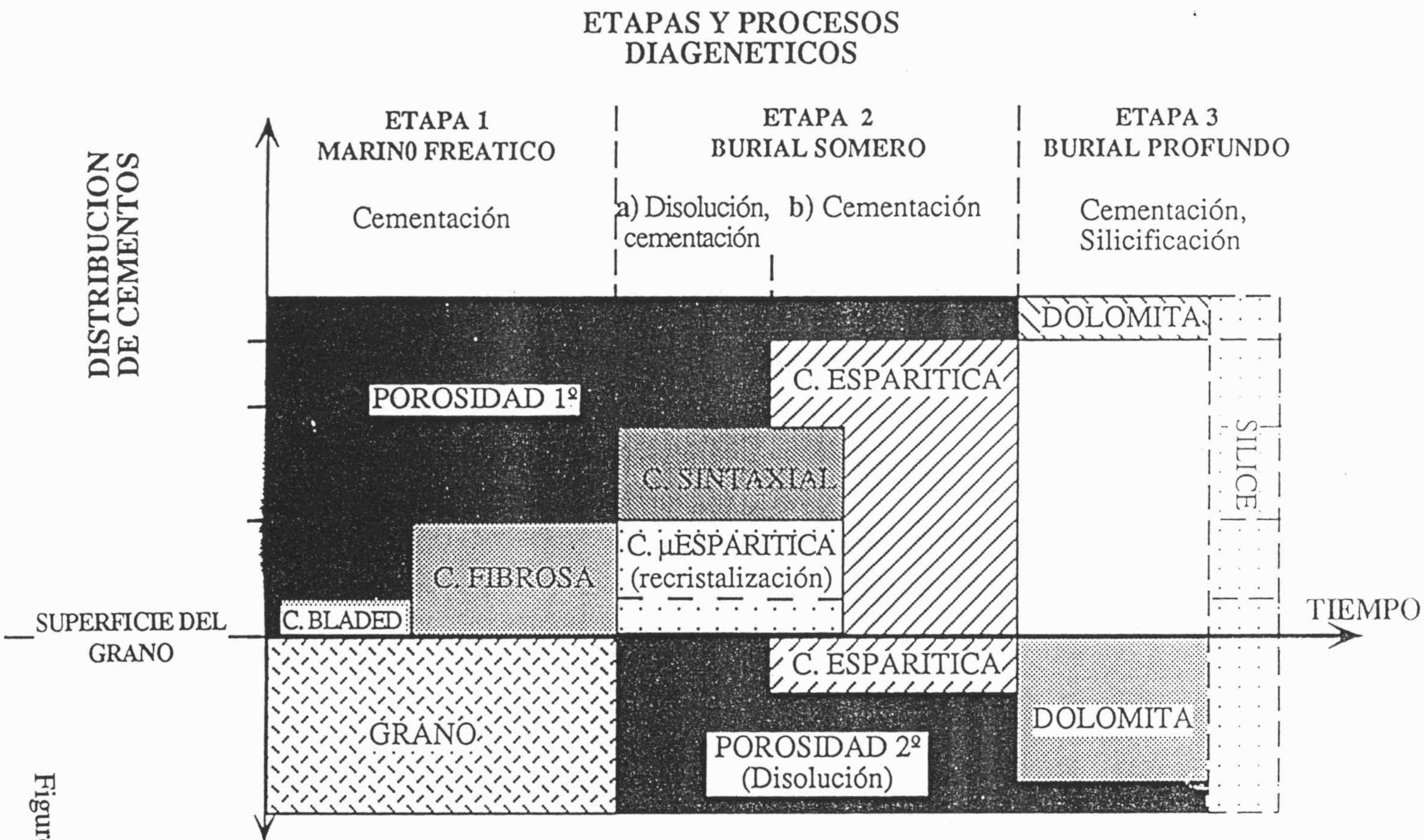

ETAPAS Y PROCESOS DIAGENETICOS
ETAPA 1
MARINO FREATICO
Cementación
ETAPA 2
BURIAL SOMERO
a) Disolución, cementación
b) Cementación
ETAPA 3
BURIAL PROFUNDO
Cementación, Silicificación
DISTRIBUCION DE CEMENTOS
POROSIDAD 1º
C. SINTAXIAL
C. ESPARITICA
DOLOMITA
SILICE
C. FIBROSA
C. µESPARITICA (recristalización)
C. BLADED
SUPERFICIE DEL GRANO
TIEMPO
GRANO
C. ESPARITICA
POROSIDAD 2º (Disolución)
DOLOMITA

Figure 5