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Anatomy and origin of large scale foreset beds in the Capitan Formation, Glass Mountain, Texas

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ABSTRACT: *Large scale foreset beds occur in the Capitan Formation of the Glass Mountains, west Texas. These beds are clinoforms of basinward dipping, massive, partially to completely dolomitized beds that interfinger with slope and basinal facies of the time-equivalent Altuda Formation. The foreset beds represent deposition of reef and backreef derived, allochthonous sediments shed off of the Capitan shelf-edge in shelf-to-basin slope transition. On the basis of lithology, texture and bedforms, various subaqueous gravity flow processes are recognized, including debris flow, grain flow and submarine slide and slump blocks. High energy conditions along with sea level fluctuations on the Capitan shelf-edge produced carbonate debris that moved under the influence of gravity and were deposited on the foreslope as multiple debris sheets.*

INTRODUCTION

The Permian (Guadalupian) stratigraphic sequence in the Glass Mountains is represented by Gilliam and Capitan Formation and Altuda Formation in a shelf-to-basin transition (Haneef et al., 1991). The Capitan Formation crops out in a narrow, laterally discontinuous carbonate belt along the rim of the Delaware basin (Pray, 1989). Along the entire extent of exposure only the Guadalupe Mountains, at the northwestern shelf of the Delaware basin have been the focus of extensive sedimentological studies in the past six decades. In the Glass Mountains, the Capitan Formation fringes the southern shelf and has largely been ignored.

Most of the previous work in the Glass Mountains deals with stratigraphic and biostratigraphic relationships. Emerging from the Capitan Formation (Guadalupian) are clinoforms of steeply dipping, massive beds that extend downslope and interfinger with gently inclined Altuda beds (Figs. 1, 2). King (1931) noticed this peculiar feature along the east face of the Old Blue Mountain which he referred to as Upper Massive (Capitan) foreset beds. The purpose of the present study is to document the nature and origin of these beds on Old Blue Mountain in the Glass Mountains (Fig. 3).

FIELD RELATIONS

The Capitan foreset beds display light to dark gray to olive colour on the weathered surfaces and white to cream colour on fresh surfaces. In outcrop, the majority of the beds are fractured and jointed marked by honeycombed weathering and wavy, non-sutured to sutured microstylolites with brownish iron residue seams. Most of the fractures are irregular and filled with coarse spray calcite. The beds are generally hard and display resistant outcrop profile. Internally they are massive with obscure bedding and contain irregular vuggy porosity, coarse spar-filled cavities, brownish chert layers/lenses or isola-

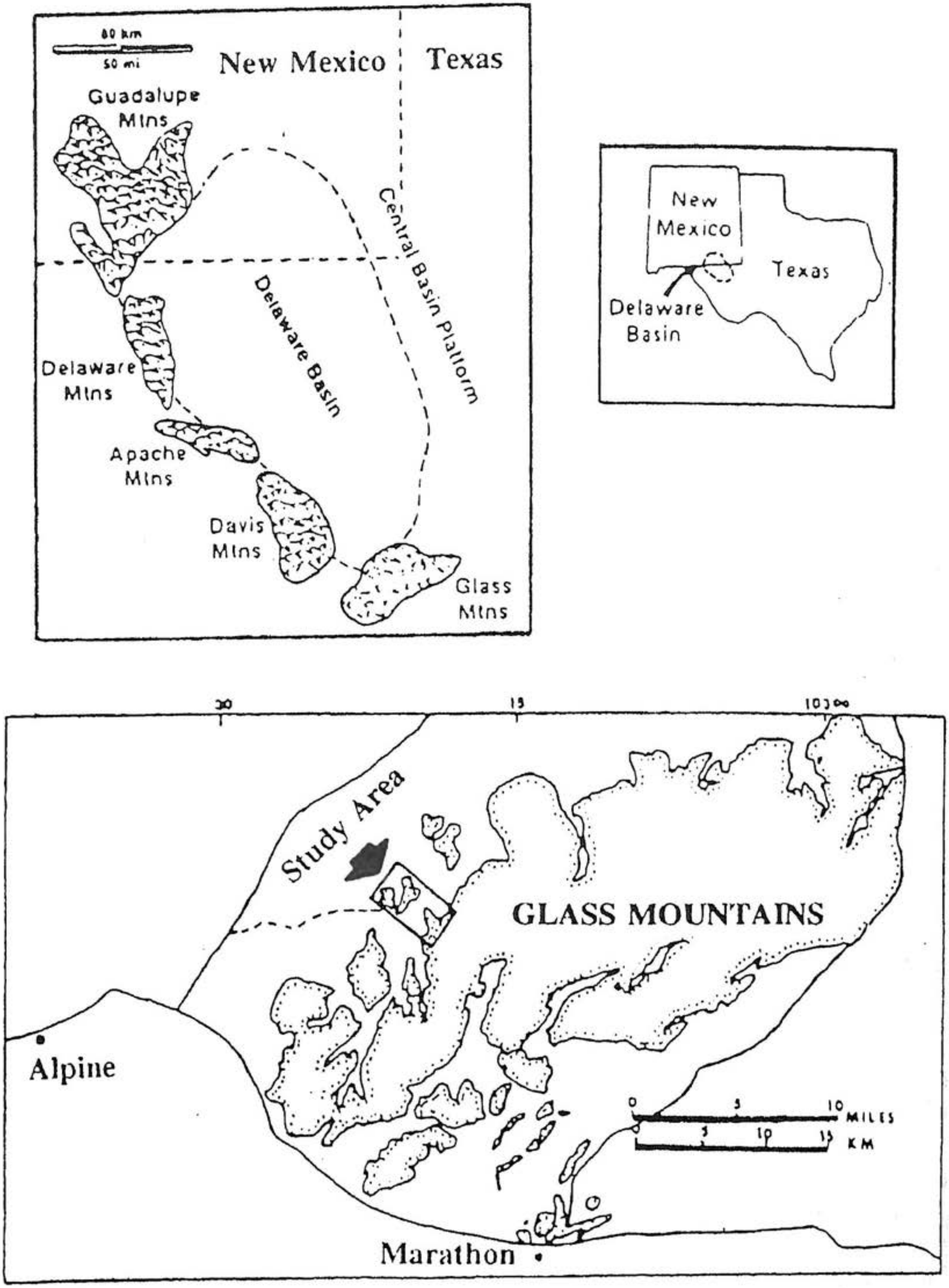

Fig. 1. Index map of study area.

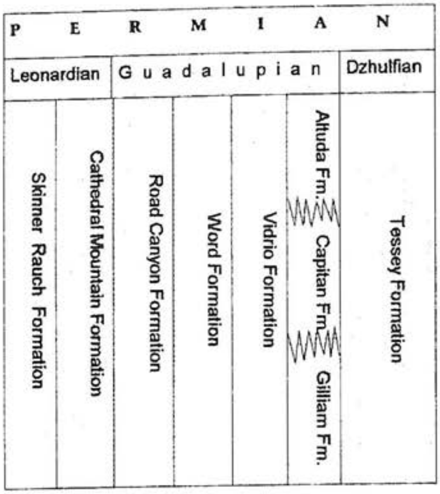

Fig. 2. Permian stratigraphic column of the Glass Mountains, Texas, U.S.A.

ted pods, partially to completely recrystalized internal fabric, and are sparsely bioclastic. Lithoclasts and intraclasts of various shapes, sizes and compositions are present in the majority of the foresets but are difficult to recognize on weathered surfaces because of chaotic internal structure and dolomitized fabric. The foresets typically weather to large irregular to semicircular blocks which litter the lower slopes around the mountain.

The foreset beds form resistant ledges and can be differentiated from the recessive, slope-forming, bedded Altuda Formation in which they occur. The foreset beds display a variety of bedforms including, irregular (hummocky), wavy, channelized and planar bedding surfaces (Figs. 4A, 4B, and 4C). The thickness of the foreset beds ranges from a few centimeters to more than 8 meters. The beds display pinch and swell structures and generally exhibit a decrease in thickness along dip and die out within a few kilometers down dip. The massive beds also display variation in depositional dip from low angle (8-10) in the upper reaches of the outcrop where they seem to emerge, to as steep as 25 (in the lower slopes of the outcrop at the terminating end of the beds. The beds below the foreset are characterized by planar, abruptly truncated, drag-folded contact relationships (Fig. 4D), and at places these are marked by squeezing upwards (injection) of Altuda beds into the massive foreset

Fig. 3. Panoramic view of the east face of Old Blue Mountain. The Capitan Formation is represented by massive, resistant beds at the top. The recessive weathering profile is Altuda Formation. Note eastward-dipping thick, massive wedge shaped foreset beds, interfingering Altuda Formation.

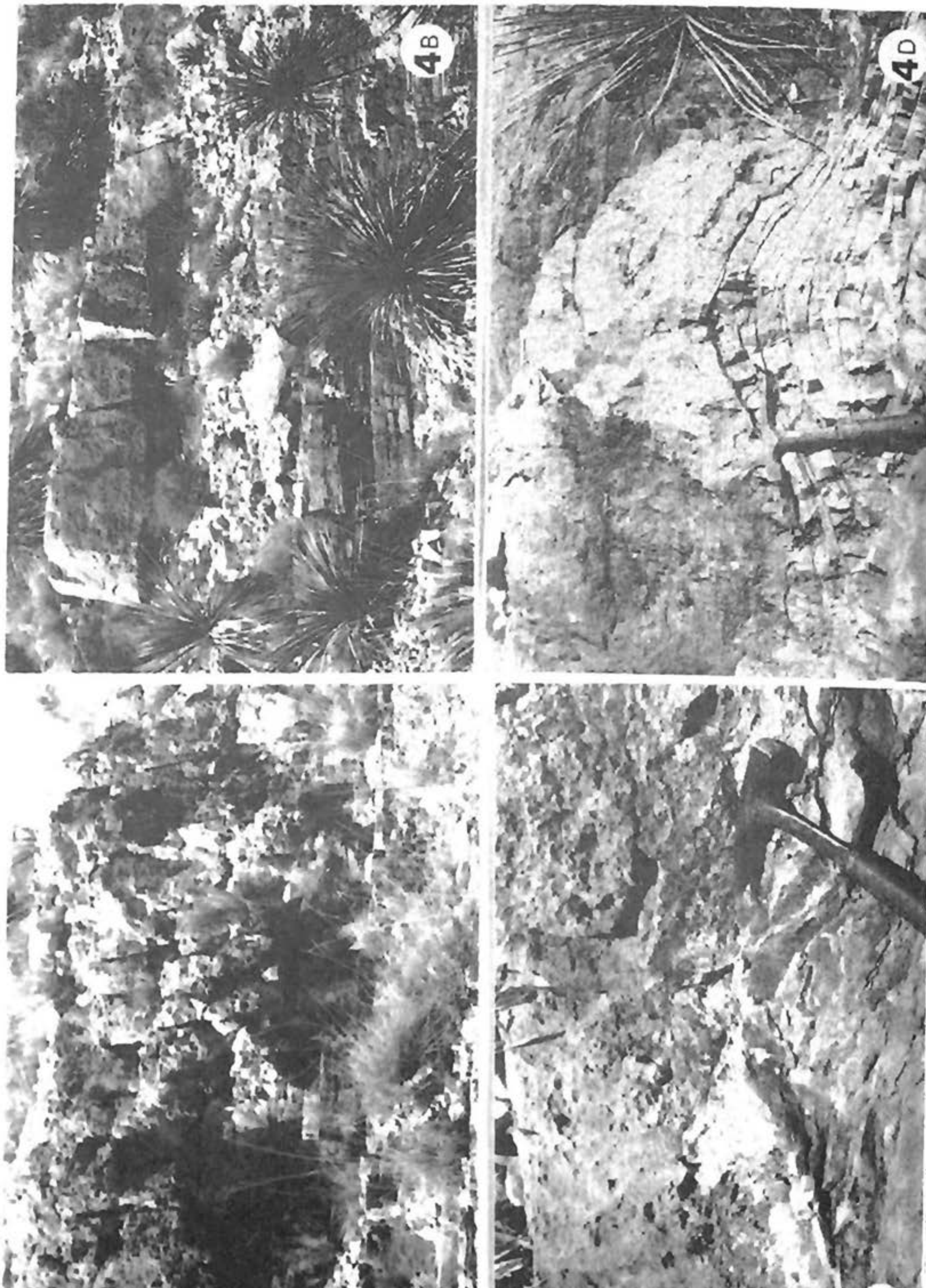

Fig. 4

beds (Fig. 5A) and by ball and pillow structures (Figs. 5B & 5C).

LITHOLOGICAL CHARACTERISTICS

In the study area more than ten foreset beds occur within the Altuda Formation, though only five of these foresets are mappable and can be traced laterally. Detailed field observations, petrographic examinations of polished slabs and thin sections of these beds reveal a wide spectrum of lithologies, textures and fabric variations with genetic implications. The variation in sedimentary parameters has bearing on the mode and mechanism of transportation, paleotopography and source which can be explained in terms of the sedimentary processes and finally related to environments of deposition. The following lithological and fabric types are recognized in the foreset beds.

Matrix supported dolo-breccia

The matrix as well as clast lithology of these beds is predominantly dolomudstone (Fig. 5D). The clasts range in size from few millimeters to more than three centimeters. The shape of the clasts varies from irregular sharp edged to subangular. The clasts are composed of fine dolomudstone with rare siltstone, sandstone, chert, and micritized bioclasts. Angular, fine, quartz silt occurs scattered in dolomudstone matrix. In some cases localized disruption and brecciation of original bedding can be inferred on the basis of similarity of clast lithology and parallel orientation. The rocks display irregular fractures and solution vugs filled with clear, coarse cavity-filling spray calcite. Microstylolitic seams mark the boundaries of the grains. The clast to matrix ratio of these beds is generally three to one.

Clast-supported, lithoclastic, bioclastic floatstone

The lithology is represented by angular to subrounded clasts exhibiting a mixture of rectangular, tabular, elongate , and irregular shapes. The clast lithologies include dolomudstone, intraclasts and lithoclasts of siltstone, silty spiculitic dolomudstone, and detrital chert fragments (Figs. 6A and 6B). The matrix of these beds is dolomudstone with quartz silt, fine sand and micritized skeletal debris. The bioclasts are represented by brachiopods, bryozoans, echinoderms, Archaeolithoporella sp., Tubiphytes, dasycladacean algae and sponge spicules. The rocks display a variety of internal structures varying from chaotic internal structure to faint normal to reverse grading. The upper and lower contacts with the Altuda beds vary from planar, irregular, wavy, undulatory to channelized (Figs. 6C, 6D, and 7A).

Fig. 4. A) Jointed and complexly fractured massive foreset bed with undulatory base and top. The massive bed is vuggy, lithoclastic, sparsely bioclastic, dolo-floatstone. The foreset is characterized by large (cm size), irregular coarse spar-filled cavities/fractures and brownish chert nodules. The planar beds beneath the foreset are Altuda silty spiculitic dolomudstone. Field note book is 18 centimeters in length. B) Vuggy, recrystalized skeletal dolomud /wackestone beds of Capitan foreset. The lower contact of the foreset bed is wavy (hummocky) with thin-bedded Altuda Formation. Note truncation of beds near the hammer. The foresets exhibit downslope decrease in thickness and die out within a short distance. C) Irregular base of Capitan foreset. The foreset bed display pinch and swell bedforms. Note abrupt truncation of underlying thin, graded Altuda beds. D) Symmetrical folding in thin bedded Altuda formed by the drag created by overriding debris flow bed of the Capitan foreset. Also visible in the photograph are recumbent folds outlined by brownish cherty layers within the massive, matrix-supported foreset bed. Hammer length in B, C, and D is 28.5 cm

Truncation and injection of underlying Altuda sandstone and siltstone beds is present in some beds.

Lithoclastic, intraclastic, bioclastic rudstone

The foresets characterized by rudstone texture are dominantly clast-supported with clast to matrix ratio of six to one. The matrix is lime mud with varying admixtures of quartz silt, fine sand, skeletal debris and chert fragments. Irregular microstylolite swarms are abundant and exhibit compacted fabric (fitted lens response of Walness, 1979). The clasts are marked by irregular interpenetrating stylolitic grain boundaries. Dolomite rhombs and brownish iron oxide residue occur along the stylolitic boundaries. The irregular, non parallel orientation of stylolites indicate compacted grain fabric. These beds are characterized by large clast sizes generally in the centimeter range. The lithology is dominated by broken to whole shells of brachiopods and bivalves. Other bioclasts include, sponges, echinoderms, encrusting algae, Tubiphytes and Archaeo-lithoporelia sp., sponge spicules, solitary corals, and foraminifers. Chert occurs as replaced bioclasts, cavity fill, and nodules. The intraclasts are subround to rounded in shape and contain bivalves and peloids in a lime mudstone-dolomudstone matrix. The lithoclast (rip-up, non-carbonate clasts) constitute 10-15% of the rudstone fabric and are represented by laminated siltstone, spiculitic siltstone and non fossiliferous sandstone clasts (Figs. 7B and 7C). The rocks do not show any preferred orientation of the clasts. The beds are characterized by chao-tic to crude normal to reverse graded bedding.

Recrystalized, dolomudstone-wackestone

The recrystalized dolomudstone-wackestone lithology represents the majority of the foreset beds. The thinner foreset beds are composed exclusively of this lithology. These beds are 30 cm to less than 1 meter thick and display planar bedding surfaces. Spar-filled vugs and fractures are the only similarity these beds show with the other types of foresets. The rocks are extensively dolomitized with complete obliteration of the depositional fabric. Rarely some silicified echinoderms, sponges, solitary corals, brachiopods and bryozoans are visible on the outcrop surface. The beds are massive internally. The lower and upper contacts of these foresets with the Altuda Formation are planar. Some of the foresets have broad wavy (hummocky), non channelized bedforms. The foresets of this lithology appear to extend farther into the basin and the decrease in thickness is more gradual than those of the other lithologies. Chert accentuated slump structures and recumbent folding are commonly associated (though not restricted) with this lithology. The trend of all the deformational features found in the foreset indicate basinward

Fig. 5. A) Sedimentary dike formed by the squeezing up (injection) of thin bedded Altuda sandstone beds into Capitan debris foreset. The foreset is interpreted as grain flow deposit. B&C), ball and pillow structures within matrix-supported, sandy debris flow beds of Capitan foreset. The parallel alignment of the subrounded sandstone clasts indicate pull-apart structure as a result of compaction of a modified gravity flow. The same foreset bed (Fig. 5C) about 100 meters down slope exhibiting nodular fabric. The clasts are subrounded to rounded and include, chert-coated sandstone clasts, large silicified sponges and chert nodules. The foreset bed do not show any appreciable decrease in thickness. Apparently the gravity flow commenced as a matrix-supported debris flow tongue and later converted into grain flow in the later stages of flow. D) Polished slab of 1 meter thick foreset bed. Note monomict clast lithology represented by resedimented clasts of dolomudstone and dolowackestone. The bed display poorly sorted, subangular to subrounded clasts with rare echinoderm fragments. The foreset show grain flow to debris flow fabric indicating multiple, episodic deposition of material derived from the shelf and shelf-edge.

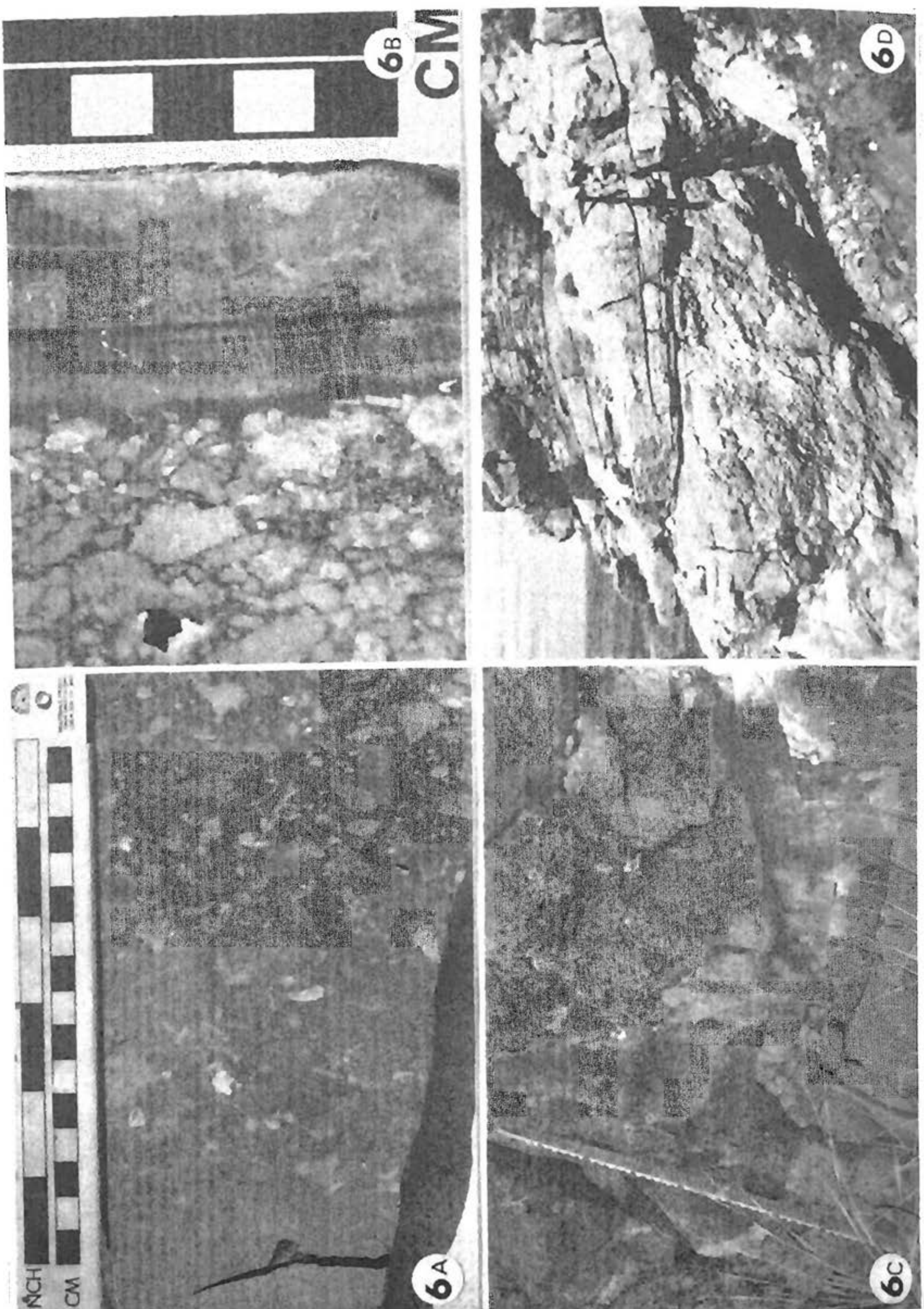

Fig. 6

movement. The beds beneath the foresets mimic the bedforms of the foresets and exhibit load and drag deformation without any evidence of truncation.

Carbonate slide block

Interbedded with thin sandstone and siltstone beds of the Altuda Formation on the south side of Old Blue Mountain is a large carbonate block composed of sponge, bioclastic wacke-packstone. The block is about 10 meters long and 0.5 - 5 meters wide. The block has a lenticular shape with an updip tapering end. The colour of the block is olive gray on weathered and pink on fresh surfaces. The block is internally massive and lacks any discernable bedding. The bioclasts include calcareous sponges, fenestrate bryozoans, brachiopods, dasycladacean algae, echinoderms and bivalves. The rock contains abundant spar-filled irregular cavities. The basal part of the block is composed of a mixture of clasts of sandstone, siltstone and skeletal fragments. The lower contact of the block with underlying Altuda Formation is undulatory and the upper contact is covered with alluvium. The geopetal fabric indicate right-side up without any rotation.

Detached breccia block

An isolated large semicircular block of lithoclastic breccia overlies thin- to medium-bedded dolomudstone beds of Altuda Formation (Fig. 7D). The block contains boulder to pebble-size, angular to subangular clasts of dolomudstone, silty dolomudstone and fine sandstone. The block displays chaotic internal structure with crudely inclined bedding and slump features in the center. The top of the block is irregular with outwards-projecting clasts. The block contains coarse spar-filled irregular cavities and fractures.

INTERPRETATIONS

King (1931) described these foreset beds as reef- derived "material poured" over the slope. He also observed similar features on the slopes of Guadalupe Mountains and regarded it as part of the Capitan forereef facies. Newell (1957) believed the foresets are composed of reef-derived material but did not agree with the notion that it represents part of the reef itself. The detailed study of these rocks reveal that they are composed of shelf, back shelf and shelf-edge-derived allochthonous material. Garber et al. (1989) in their study

Fig. 6. A & B) Polished slabs of the Capitan foreset displaying clast-supported fabric interpreted as grain flow deposit. The grain flow bed has irregular (scoured) contact with the laminated spiculitic mud-wackestone beds of the Altuda slope facies. The clasts are represented by intraclasts, lithoclasts of siltstone and sandstone and bioclasts of echinoderms, solitary corals, fenestrate bryozoans, dasycladacean algae, Tubiphytes, Archaeolithoporella sp., and disarticulated bivalves. The foreset bed is poorly sorted and exhibit clast size variation from few mm to more than 4 cm. Note reverse grading and slight alignment of the clasts. C) cross sectional view of massive Capitan debris flow foreset. The foreset bed is more than 2 meters thick and has an irregular channelized base truncating the Altuda beds below. The debris flow forms channel 4 m wide and 2 m deep. The beds below display truncation and compactional deformation. The debris flow is characterized by jointed and brecciated lithoclastic, vuggy, recrystallized, sparsely skeletal, cherty dolomitic floatstone texture. The lithoclasts include vaguely skeletal, dolowackestone and laminated to non laminated dolomudstone. The rock possesses irregular coarse calcite-filled cavities and fractures. The stadia rod scale is about 1 m long. D) Capitan debris flow bed displaying lithoclastic, bioclastic dolomitic floatstone-rudstone fabric. The lower contact of the foreset is channelized into Altuda thin-bedded dolomudstone. The debris flow bed shows slight alignment of clasts parallel to flow direction. The upper contact of the debris flow with Altuda silty, spiculitic, laminated dolomudstone beds is planar. Hammer length is 28.5 cm.

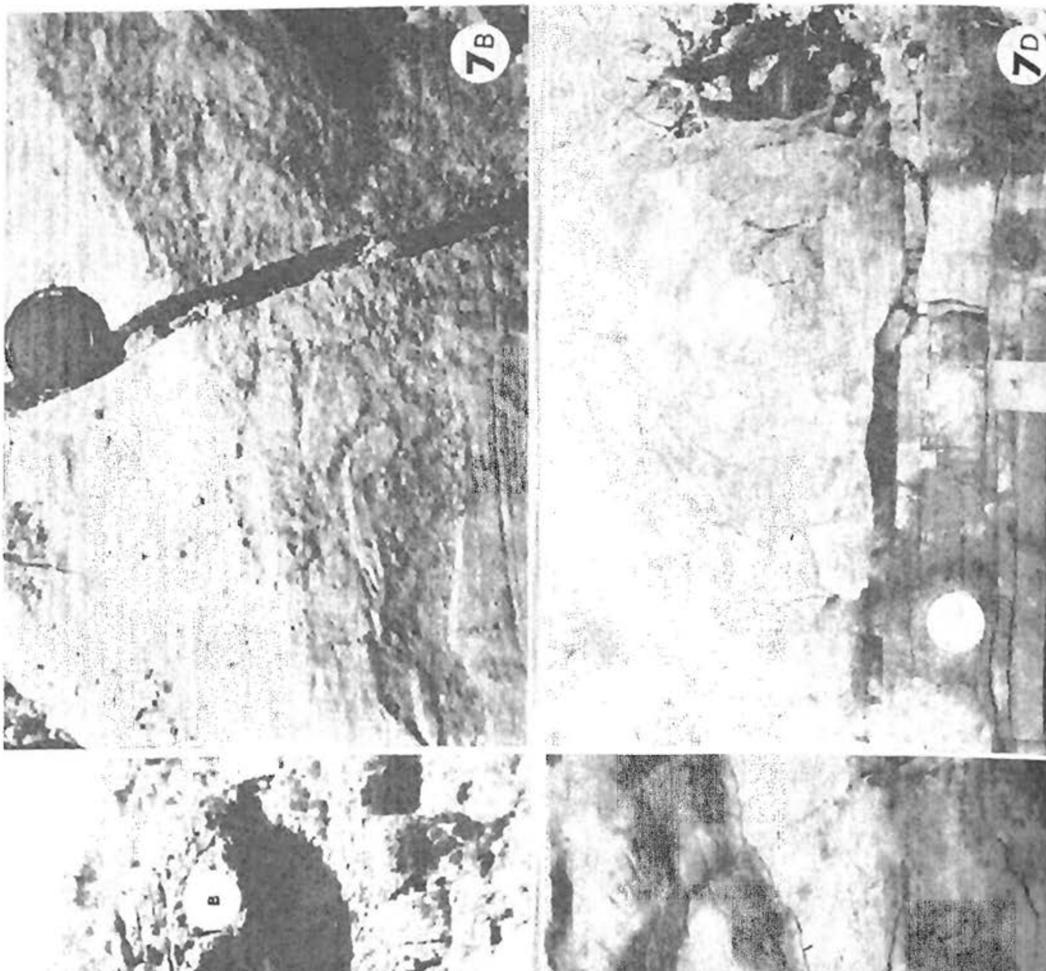

Fig. 7

of Capitan foreslope facies in the Guadalupe Mountains concluded that similar clinoforms are shelf-derived allochthonous carbonate debris deposited on the Capitan foreslope. Carbonate breccia deposited around the seaward margin of carbonate shelves and buildups is known from many places in the geologic record (Hopkin, 1977).

The Capitan foreset beds in the Glass Mountains, Texas, display features diagnostic of subaqueous gravity flow deposits. The presence of poor sorting, grading, variation in sizes and compositions of clasts, lack of distinct internal structure, slump folding, truncation of underlying beds, wavy, channelized and planar bedforms, slide and slump blocks, and basinward inclined, laterally thinning wedges favor this interpretation. This interpretation also best fits the overall shelf-to-basin transition for the Guad-alupian sequence in the Glass Mountains (Haneef et al., 1991; Rohr et. al., 1991). The variations in texture, fabric and bedforms within Capitan foresets represent a variety of transport and depositional mechanisms. The following gravity flow types are recognized in the study area.

Debris flow deposits

The foreset beds characterized by matrix-supported dolo breccia and recrystallized dolo mud-wackestone lithology are interpreted as debris flow deposits. The matrix support, angular clasts and hummocky to planar bedforms indicate coherent, non-turbulent movements of the mass on a gently sloping surface. The classifications of debris flow deposits by Dott (1963), Carter (1975), Middleton and Hampton (1976), Nardin et al. (1979), and Lowe (1976, 1979) recognize rheological behaviour, grain matrix ratio, angle of slope, shear stress, viscosity and yield strength as the main factors influencing the nature and lateral extent of the gravity flow deposits. According to these workers the matrix in a debris flow serve several purposes, including lubrication of clasts, buoyant support for denser clasts, and elevated pore pressure to overcome frictional resistance to flow. The presence of slump/recumbent folding restricted only to some foresets beds indicate a lack of intragranular support, steeper slopes and rapid rate of deposition of these foresets (Figs. 8A and 8B). The drag and distortion produced

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Fig. 7. A) Channelized bedforms displayed by Capitan foreset beds. The rocks are massive, cherty, lithoclastic, recrystalized bioclastic floatstone. Note multiple shifting shallow channels labelled A and B within the bed. The Altuda beds below the debris flow are truncated along the channel floor. B & C) Upper part of the Capitan foreset. The debris flow bed is 1.5 m thick at this locality. The foreset shows pinch and swell bedforms throughout its extent. The foreset is characterized by a basal zone of shearing followed upwards by clast-supported, poorly sorted, randomly oriented, outward projecting, subangular to rounded clasts of colour fine quartzose sandstone and laminated siltstone clasts. The clast size in this foreset is exceptionally large as compared to other foreset in the study area. The similarity of the clasts to the Altuda sandstone beds of the slope facies suggest that these clasts are probably rip-up clasts of the underlying bed incorporated into the debris flow. The lack of sandstone clasts within the basal part of the foreset indicate dispersive pressure and buoyancy effects within the debris flow. Camera lens cap is 5.5 cm in diameter. C) Close up view of the same area. Hammer is 28.5 centimeters in length. D) Rotated slump block of Capitan foreset within thin- to medium- bedded Altuda dolomudstone. The block displays slump deformation outlined by inclined disrupted bedding in the middle of the photograph. The basal part of the block contains boulder-size angular clasts of dolomudstone and silty dolomudstone. Note brecciated internal fabric and spar-filled fractures and cavities. Field note book is 19 cm.

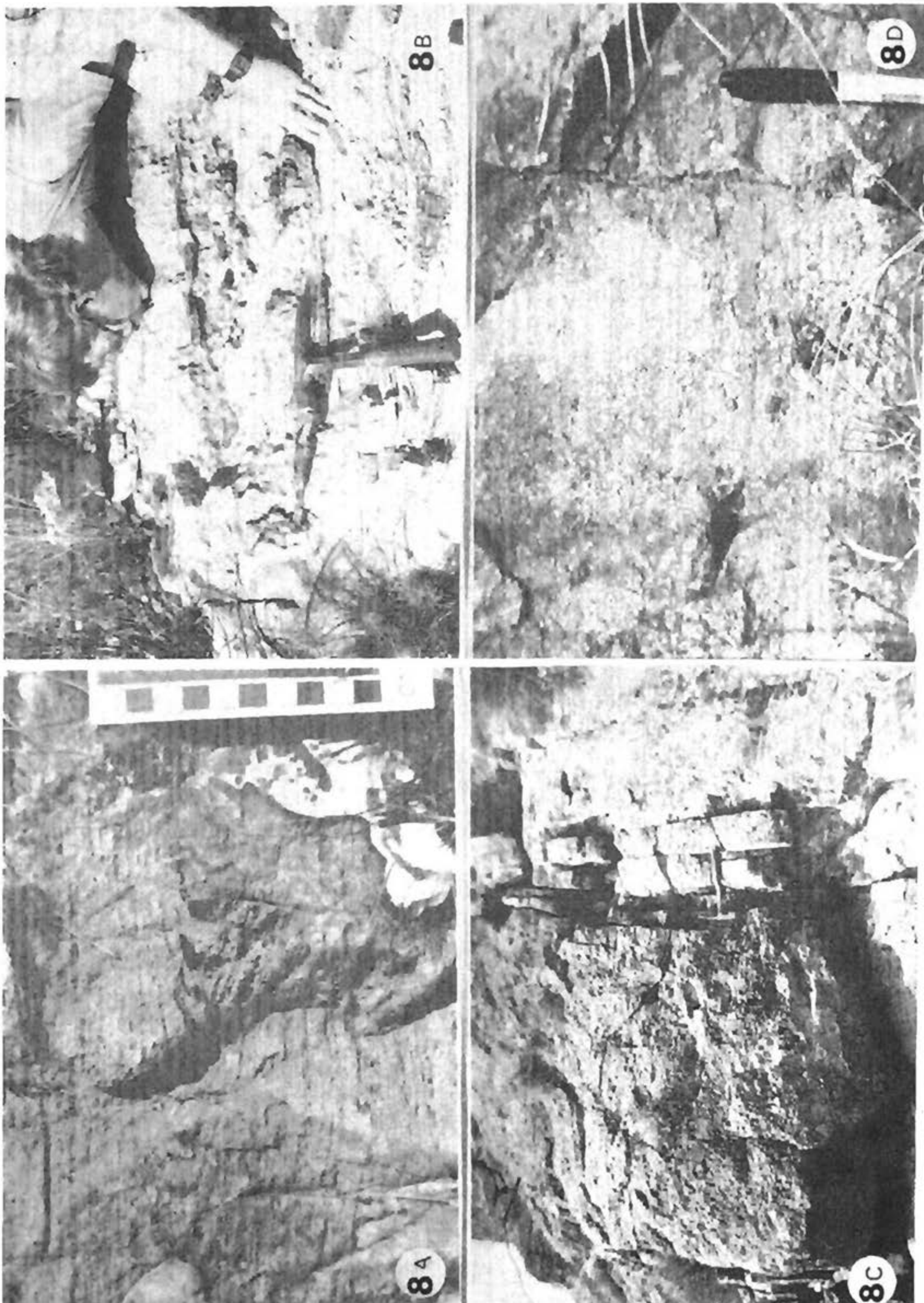

Fig. 8

in the underlying beds by overriding debris flow tongues illustrate the cohesive nature of these flows.

Grain flow deposits

Foreset beds dominated by clast supported floatstone and rudstone fabric are interpreted as grain flow deposits. The clasts in these beds were derived from the shelf and shelf edge environments (Figs. 8C and 8D). Some of the clasts are similar to the Altuda slope facies, probably representing rip-up clasts incorporated during flow. The high grain to matrix ratio and reverse grading indicate that grain interaction in these beds was the main transporting mechanism resulting in upward movement of larger clasts.

Submarine slide and slump blocks

The large carbonate block and detached brecciated block are believed to be submarine slide and rockfall deposits derived from the shelf edge and slope environments. The carbonate slide block exhibits lithological characteristics similar to the massive facies of the Capitan reef. The block appears to have been detached by waves and currents on the seaward side of the reef and slid downslope under the influence of gravity without any significant rotation. The block displays similar lithology to the Capitan foreset beds.

The isolated breccia block in Fig. 8D exhibit brecciated and deformed internal structure. The rotation of the block is evident from tilted geopetal fabric. It probably represent a detached segment of the debris flow tongue during flow.

CONCLUSIONS

The Capitan foreset beds in the Glass Mountains were formed by subaqueous gravity flow processes. Figure 9 shows the proposed depositional setting of the Capitan foreset beds. The high energy conditions on the seaward side of the reef along with sea level fluctuations produced carbonate debris on the shelf-edge. The material thus formed moved downslope under the influence of gravity and was deposited on the foreslope. A lack of deep submarine channels and associated features suggest that the sediment movement was predominantly in the form of widespread debris sheets with few shallow and rare deep channels.

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Fig. 8. A& B) Penecontemporaneous slump deformation and contortion accentuated by dark brown cherty layers (A) within Capitan foreset beds formed as a consequence of downslope en masse movement of matrix supported debris flow. B) Photo shows predominantly sandy matrix. C) Close up field photograph of weathered surface of one of the Capitan foreset bed exhibiting clast-supported texture. The stylolitic compacted fabric and predominantly sandy, cherty matrix clearly display the internal fabric not visible in most of the Capitan foreset beds. The clasts are angular to subrounded and represent mixture of lithologies, shape and sizes. The foreset is interpreted as grain flow deposit. The pen length is 10 cm D) Outcrop photograph of clast-supported Capitan foreset, grain flow deposit. The foreset is 1.2 m thick and has flat top and bottom with the, superjacent Altuda silty dolomudstone beds. The lower contact contain brownish iron oxide coated thin chert layer. The foreset lacks any grading and is composed of poorly sorted dolomudstone breccia.

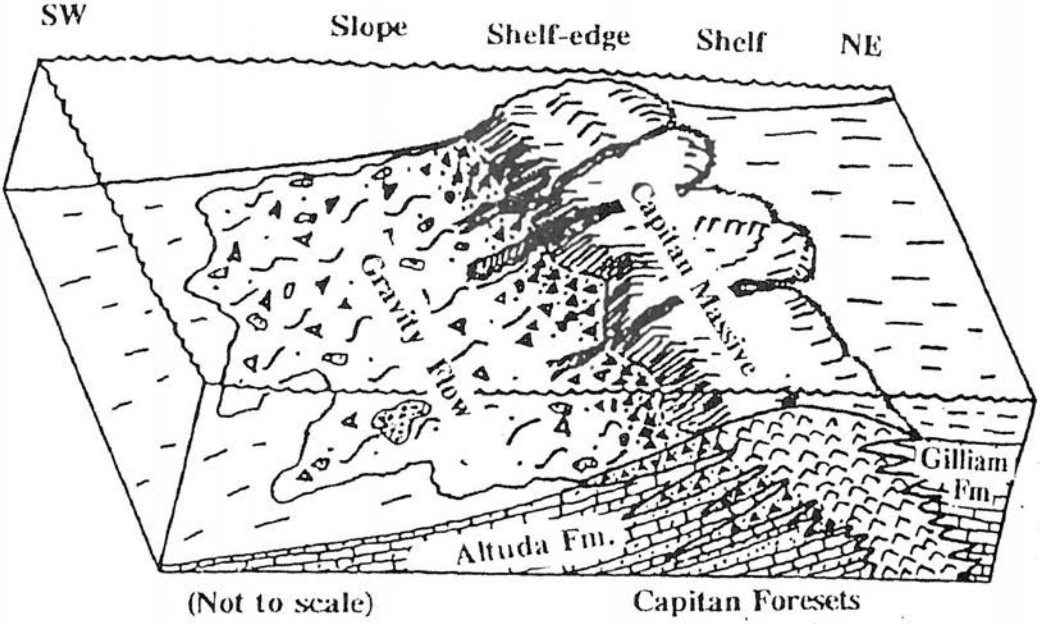

Fig. 9. Block diagram showing proposed depositional setting of Capitan foreset beds in the Glass Mountains.

REFERENCES

Carter, R. M., 1975. A discussion and classification of subaqueous mass transport with particular application to grain-flow, slurry-flow and fluxo-turbidites. Earth Sci. Rev., 11, 145-177.

Dott, R. J., 1963. Dynamics of subaqueous gravity depositional processes. Amer. Assoc. Petrol. Geologists, Memoir, 1, 104-121.

Garber, R. A., Grover, G. A., & Harris, P. M., 1989. Geology of the Capitan shelf margin-subsurface data from the northern Delaware Basin. In: Subsurface and outcrop Examination of the Capitan Shelf Margin, Northern Delaware Basin (P. M. Harris & G.A. Grover eds.). Soc. Eco. Paleontologists & Mineralogists, Core Workshop, 13, 3-269.

Haneef, M., Rudine, S. F., & Wardiaw, B. R., 1991. Shelf to Basin Transition in the Capitanian (Permian) Deposition in the Glass Mountains, West Texas. Geol. Soc. Amer., Abstracts with Programs, 22, A46.

Hopkin, J. C., 1977. Production of foreslope breccia by differential submarine cementation and downslope displacement of carbonate sands, Miette and Ancient Wall Buildups, Devonian, Canada. In: Deep Water Carbonate Environments (H.E. Cook, & P. Enos, eds.). Soc. Eco. Paleontologists and Mineralogists, Spec. Publ., 25, 155-170.

King, P. B., 1931. The Geology of the Glass Mountains, Texas, Part 1, Descritive Geology: University of Texas Bull., 3038, 167 p.

Lowe, D. R., 1976. Grain flow and grain flow deposits: Jour. Sed. Petrol., 46. 188-199.

Lowe, D. R., 1979. Sediment gravity flows, their classification and some problems of application to natural flows and deposits: Soc. Eco. Paleontologists and Mineralogists, Spec. Publ., 27, 75-82.

Middleton, G. V., & Hampton, M. A., 1976. Subaqueous sediment transport and deposition by gravity flows: In: Marine sediment transport and environmental management (D.J. Stanley, & D.J.P. Swift, eds.). John Wiley, New York, 197-218.

Nardin, T. R., Hein, F. J., Gorsiine, D. S., & Edwards, B. D., 1979. A review of mass movement processes, sediment and acoustic characteristics, and contrasts in slope and base-of-slope systems versus canyon-fan-basin floor systems: Soc. Eco. Paleontologists & Mineralogists, Spec. Publ., 27, p. 61-73.

Newell, N. D., 1957. Paleoecology of Permian reefs in the Guadalupe Mountains area. In :Treatise on marine ecology and paleoecology, v.2 (H.S. Ladd, ed.). Geol. Soc. Amer., Memoir 67, 407-436.

Pray, L. C., 1989. Lateral variability of the Capitan Reef Complex, west Texas and New Mexico, In: Subsurface and outcrop examination of the Capitan Shelf Margin, Northern Delaware Basin (P.M. Harris,& G.A. Grover, eds.). Soc. Eco. Paleontologists & Mineralogists, Core Workshop 13, 273-278.

Rohr, D. M., Wardlaw, B. R., Rudine, S. F., Haneef, M., Hall, J. A., & Grant, R. E., 1991. Guidebook to the Guadalupian Symposium. In: Proceedings of the Guadalupian Symposium (B. R. Wardlaw, R.E. Grant & D. M. Rohr eds.). Sul Ross State University, Alpine, Tx., 18-111.

Walness, H. R., 1979. Limestone response to stress, pressure solution and dolomitization. Jour. Sed. Petrol., 49, 437-462.