Structure and Lithofacies of a Permian Carbonate Debris Flow Complex Apache Mountains, West Texas, U.S.A.

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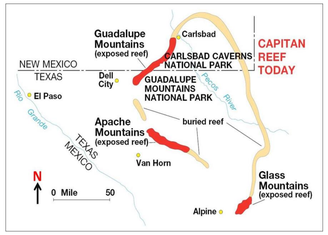
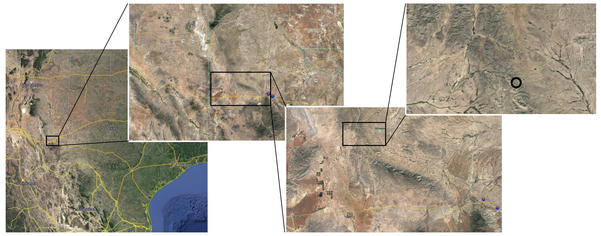
Introduction

A 10-12 m thick gravite (B debris) in the Bell Canyon Formation (Guadalupian) is well exposed in the lower part of the so-called B Section in a road cut on TX FM Road 2185 40 km NE of Van Horn, West Texas in the northwestern part of the Apache Mountains. This gravite is an amalgam of several thick and thin debris flows, each bearing carbonate clasts of distinct lithofacies. It disappears quickly to the east, but extends for several kms to the NNW into the southern Delaware Mountains where it covers an extensive area and forms prominent vertical cliff faces. Multiple beds of successively deposited debris have been identified in the B debris gravite complex. The B Section generally correlates with the Pinery Member of the Bell Canyon Formation of the Guadalupe Mountains area based on the presence in its upper part of the transition of the conodont species *Jinogondolella aserrata* to *J. postserrata*. The lower part under the B debris correlates with the Hegler Member of the Bell Canyon Formation. The B debris gravite contains a wide variety of shallow water carbonate lithofacies interbedded with normal basinal marine beds of deeper water carbonate sediments bearing radiolarians, foraminifers, and conodonts. Nine distinct gravite lithofacies have been identified, most of which appear to have been deposited in single events. The depositional sequence in this gravite complex is indicative of a shallow-water reef by-pass margin that is particularly common along block-faulted oceanic margins or at the structural hinge line where a basin is subsiding faster than the adjacent platform. The rapid subsidence of the Delaware basin during the middle to late Pennsylvanian could have created a submarine escarpment that led to the accumulation of these massive debris beds in the Permian. Fluctuating sea level and the cyclical build up and slope failures along this margin could explain not only the formation of the B-debris gravite complex, but also the periodic interruption of pelagic sedimentation.

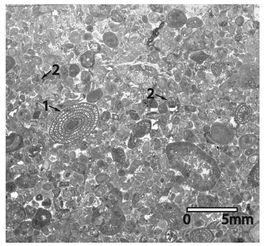
Site



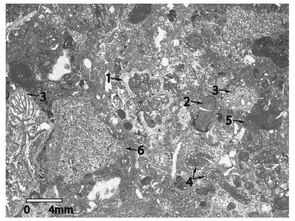
Location of the exposed Capitan Reef in the Guadalupe, Apache, and Glass Mountains, West Texas and New Mexico (Image is available via the Guadalupe Mountains National Park Service website www.nps.gov/gumo/naturescience/geologicformations.htm).



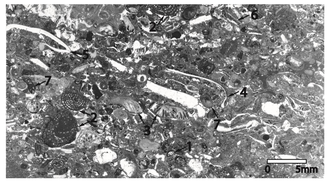
Lithofacies



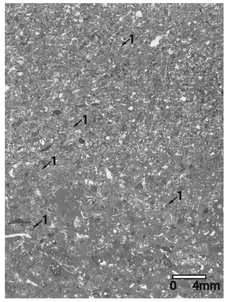
Lithofacies B-1 is found in a large boulder approximately 10 meters in diameter and exposed in the southeast road cut. Six samples were taken from this boulder vertically and laterally that show the same texture and fossil assemblage throughout. B-1 is a grainstone with variable sized well-rounded grains, the largest of which is approximately 5-6 mm in size. Some intergranular sparite is present, comprising approximately 5-10% in samples collected. B-1 contains small non-fusulinacean foraminifers and common fusulinacean fragments of likely *Parafusulina*, however no well-oriented specimens were recovered to aid in more precise identification. The boulder containing lithofacies B-1 does not appear to be the remnant of a fine grained subaqueous gravity flow, but a single fragment from what Dott (1963) would classify as resulting from a subaqueous rock fall and Gani (2004) would classify as a slide or slump deposit. (1 Fusulinacean, 2 Foraminifer)



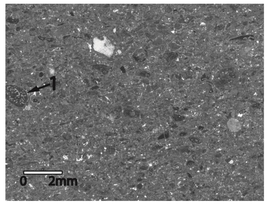
Lithofacies B-6 overlies B-5 across the majority of the northwest road cut and overlies B-4 on the southeast road cut forming the top of the B-section gravite complex for much of that side. The bed B-6 is as thick as 1 meter and extends laterally approximately 30 meters on the northwest road cut and approximately 20 meters on the southeast road cut. B-6 is a poorly sorted grainstone with variable sized sub-angular to sub-rounded grains, the largest of which are approximately 25 mm in size, and has approximately 10-15% intergranular micrite. B-6 contains primarily mudstone clasts which vary in color from light tan to dark brown with some grainstone clasts. Unlike B-5, the clasts that make up B-6 do not closely resemble any of the preceding lithofacies and contain a greater amount of fossil fragments as individual grains rather than present as clasts. B-6 also contains elongated grains which are generally oriented with the bedding. B-6 contains fusulinaceans, a variety of non-fusulinacean foraminifers, bryozoans, sponge spicules, and a brachiopod cross section. B-6 is a debrite after Gani (2004) and contains clasts originating probably in original depositional environment from a shallow shelf to a carbonate slope. (1 Brachiopod shell cross section, 2 *Tubiphytes*, 3 Bryozoan, 4 Fusulinacean (*Parafusulina* sp.), 5 Mudstone clast, 6 Grainstone clast)



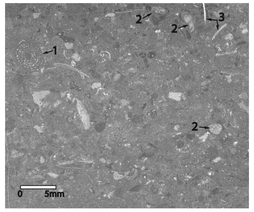
Lithofacies B-2 is exposed in a small wedge under the western edge of the boulder comprising lithofacies B-1. The exposure of lithofacies B-2 is approximately 1.5 meters laterally by 0.75 meters thick. The bed B-2 is a grainstone with variable sized well-rounded grains, the largest of which is approximately 4-5 mm in size and contains approximately 10% intergranular micrite. B-2 is a densite after Gani (2004) and contains a wide variety of fauna including a variety of non-fusulinacean foraminifers, fusulinaceans, bryozoans, bivalve shell fragments, trilobite fragments, sponge spicules and *Tubiphytes* indicating a shallow shelfful depositional environment. (1 Foraminifer, 2 Fusulinacean, 3 Bryozoan, 4 Bivalve fragment, 5 Trilobite fragment, 6 Sponge spicule, 7 *Tubiphytes*)



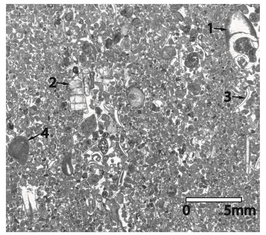
Lithofacies B-7 forms the top of the majority of the exposure of the B-section gravite complex on the northwest road cut and has found on only a small exposure on the top of the southeast road cut. B-7 was likely present over the entirety of the southeast road cut but has been eroded away as B-5 forms the top of the B-section gravite complex over much of the southeast road cut. The bed B-7 is as thick as 1 meter and extends laterally approximately 35 meters on the northwest road cut. B-7 is a poorly sorted grainstone with variable sized sub-rounded to rounded grains, the largest of which is approximately 1.5 mm in size, and has approximately 5% intergranular sparite. B-7 which appears at first as a mudstone is in actuality a grainstone made up of small, very fine grained carbonate mudstone clasts that fine upward in the bed. B-7 contains a variety of non-fusulinacean foraminifers (Figure 3.6.1). B-7 is a densite after Gani (2004) and contains clasts originating from a carbonate slope depositional environment. (1 Non-Fusulinacean Foraminifer)



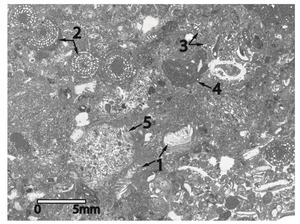
Lithofacies B-3 is the lowest portion of the B-section gravite complex on the northwest road cut and forms an erosive contact with the thickly bedded limestone directly beneath. The bed B-3 is exposed laterally on the northwest road cut for approximately 30 meters and ranges from approximately 20 to 40 cm in thickness. This lithofacies was not found on the opposite side of the road. B-3 is a carbonate mudstone that fines very slightly upward and has a maximum grain size of approximately 1 mm with mud content as high as 70-80%. B-3 contains scattered small foraminifers (including *Leella*, a fusulinacean) and trace sponge spicules. Lithofacies B-3 is a densite after Gani (2004) and is composed of carbonate shelf debris. [1 Fusulinacean (*Leella* sp.)]



Lithofacies B-8 forms the top of the southeast road cut as it disappears below ground level. B-8 is exposed laterally for approximately 10 meters and is as thick as 0.5 meters. B-8 is a carbonate wackestone that fines upward and has a maximum grain size of approximately 3 mm with mud content as high as 70-80%. B-3 contains fusulinaceans, bryozoans and sponge spicules. Lithofacies B-3 is a densite after Gani (2004) and is composed of carbonate shelf debris. (1 Fusulinacean, 2 Bryozoan, 3 Sponge spicule)



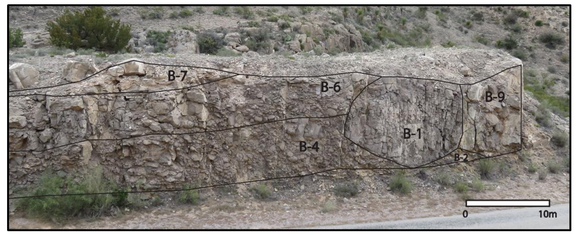
Lithofacies B-4 is situated directly above the bed of lithofacies B-3 on the northwest road cut and forms the base of the B-section gravite complex for much of the southeast road cut. The bed B-4 is exposed laterally on the northwest road cut for approximately 40 meters and on the southeast road cut for approximately 30 meters and is as thick as 4 meters. The bed B-4 is primarily a grainstone with variable sized well-rounded grains, the largest of which is approximately 2 mm in size. There is some variation in samples collected from lithofacies B-4. There are variations in intergranular sparite content with some specimens showing small amounts of intergranular micrite. Fusulinaceans are pervasive through the lithofacies with crinoids and *Tubiphytes* present in several specimens. Sponge spicules, gastropods and bryozoans are also present but in smaller quantities. Grain size also varies between specimens with some of the coarser grained material being above the finer grained. Several specimens of lithofacies B-4 contain large, very well-rounded, light colored, fine grained clasts ranging from 20 to 40 cm in diameter that appear to be debris themselves (Figure 3.3.3). B-4 most likely does not represent a singular event but a series of gravity flows originating from approximately the same location. Sediment that had originally been normally bedded may have, during the course of several small flow events beginning with the finer materials down to the coarser, caused the apparent reverse graded bedding which appears in the bed B-4. B-4 contains a variety of small non-fusulinacean foraminifers, fusulinaceans (*Parafusulina* sp.), sponge spicules, crinoid fragments, gastropods and *Tubiphytes* indicating an original shallow shelfful depositional environment. (1 Gastropod, 2 Crinoid fragment, 3 Sponge spicule, 4 *Tubiphytes*)



Lithofacies B-5 overlies lithofacies B-4 over the majority of the northwest road cut. The bed B-5 is, in places, almost 2 meters thick and extends laterally on the northwest road cut for at least 45 meters. Numerous samples were obtained of this lithofacies from the northwest road cut but only a single large clast was found on the opposite side of the road. B-5 is a poorly sorted grainstone with variable sized sub-angular to sub-rounded grains, the largest of which are approximately 40 mm in size, and has approximately 5-10% intergranular micrite. B-5 contains a wide variety of clasts. Extremely fine grained mudstone clasts are present (Figure 3.4.2), some of which closely resemble those in samples taken of lithofacies B-3. Grainstone clasts with intergranular sparite and grains as large as 2-3 mm are also present in lithofacies B-5 (Figure 3.4.3) with some being very similar to lithofacies B-1 in composition and others more closely resembling B-4. B-5 also contains many elongated grains oriented with the bedding. Fossil fragments are contained within some clasts and as individual particles in the debris. B-5 contains fusulinaceans, a variety of non-fusulinacean foraminifers, bryozoans and sponge spicules. Well healed fractures with sparite cement are pervasive throughout this lithofacies. These fractures regularly cut across grains indicating post lithification fracturing. B-5 is a debrite after Gani (2004) and appears to be a large flow that contains clasts varying in original depositional environment from a shallow shelf to carbonate slope. It seems likely that either the debris from this lithofacies originated from the same location as B-1, B-3 and B-4, or that fragments from the proximal end of those events were reworked into this gravity flow. (1 Bryozoan, 2 Fusulinacean (*Parafusulina* sp.), 3 Non-Fusulinacean Foraminifer, 4 Mudstone clast, 5 Grainstone clast)

Lithofacies B-9 is comprised of extremely resilient silicified reefal and slope deposits. The hardness of this lithofacies explains the prominence of the exposed cliff face of this complex of debris throughout this part of the Apache Mountains.

Several large and small clasts of bedded micritic limestone appear throughout the B Debris. Some are at the boundaries between different events, have maintained their original bedding structure, and appear to be independent of the main debris events.



A representation of lithofacies distribution across the southeastern road cut. The lithofacies distribution differs slightly from one side of the road to the other.

Conclusions

The B-Section gravite complex that can be correlated to the Pinery Member of the Bell Canyon Formation is composed of several smaller debris flow events. An effort has been made to organize the described lithofacies in the order that they have been deposited. Most lithofacies (B-1 to B-9) appear to have been laid down as a single event with the exception of lithofacies B-4 possibly made up of several smaller flow events explaining its apparent reverse bedding. It is difficult to define the boundaries between each named lithofacies because of stylolitization and solution along bedding contacts. The boundaries of each event are positioned between samples taken that represent each lithofacies or in rare instances where a sample was collected that contained two distinct lithofacies.

During initial inspection of the site and looking at previous research in the area, The B-section gravite complex could easily be described as a massive cliff derived breccia. There are indeed areas that do seem to fit this description, however, the majority of the complex appears to be composed of in-situ breccias that, due to rapid cementation and displacement and expansion of grain to grain distance, resulted in pervasive fracturing giving the impression of a massive cliff derived breccia. The appearance of many well rounded clasts entrained in these apparent large breccias suggest this interpretation as it is unlikely that these clasts could have been a part of two distinct slope failures, each one creating well rounded clasts, being re-lithified and then being entrained in a cliff derived breccia.

The majority of deposition in this gravite complex is indicative of a shallow-water reef by-pass margin (McIlreath, 1978). McIlreath states that a by-pass margin "is particularly common along block-faulted oceanic margins or at the structural hingeline where a basin is subsiding faster than the adjacent platform." The rapid subsidence of the Delaware basin during the middle to late Pennsylvanian could have created a submarine escarpment that led to the accumulation of these massive debris beds. Fluctuating sea level and the cyclical build up and slope failures along this margin could explain not only the formation of the B-section gravite complex but the periodic interruption of pelagic sedimentation with the multiple gravite beds in this portion of the Bell Canyon Formation. There is also deposition that more closely resemble a shallow-water reef depositional margin (McIlreath, 1978). The two models are not mutually exclusive and the angle of the slope may have fluctuated throughout this period of deposition explaining the sudden change between some of the described lithofacies and successive lithofacies. Massive escarpment failures causing coarse grained angular debris may have reduced the angle of the platform margin and allowed for subsequent fine grained carbonate mud and lime sand flows or periods of pelagic sedimentation.

References

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