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1978, pp. 209-214. https://doi.org/10.56577/FFC-29.209

in:

Land of Cochise (Southeastern Arizona), Callender, J. F.; Wilt, J.; Clemons, R. E.; James, H. L.; [eds.], New Mexico Geological Society 29 th Annual Fall Field Conference Guidebook, 348 p. https://doi.org/10.56577/FFC-29

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THE GLANCE CONGLOMERATE, A LOWER CRETACEOUS SYNTECTONIC DEPOSIT IN SOUTHEASTERN ARIZONA

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INTRODUCTION

The middle Mesozoic tectonic environment of southeastern Arizona is poorly understood. Although recent regional syntheses by Drewes (1978) and Titley (1976) have added to our knowledge of the Mesozoic tectonic evolution of this region, much is still unclear. Titley (1976) recognized the presence of a major pre-Laramide, northwest-trending tectonic grain in southeastern Arizona and compiled evidence, primarily of an indirect nature, for vertical tectonic movements during the middle Mesozoic. The geologic structures that define this tectonic pattern are extremely discontinuous and obscure and require further investigation and documentation. Study of clastic sedimentary rocks deposited during this episode of crustal instability greatly clarifies the nature of these structural features and of the accompanying deformation. The most instructive clastic sedimentary deposit of middle Mesozoic age in the region is the Glance Conglomerate.

The Glance Conglomerate is a Lower Cretaceous alluvial fan deposit which provides a direct sedimentary record of extensive erosion associated with pronounced vertical displacements along various exposed and inferred normal faults. These relationships are especially well displayed in the southern Mule Mountains and in the Empire Mountains. In the Santa Rita Mountains, Drewes (1971, 1972) has also related the deposition of coarse conglomerate to Early Cretaceous normal faulting. The syntectonic nature of the Glance Conglomerate makes it a valuable key to understanding the mid-Mesozoic tectonic environment of southeastern Arizona.

GEOLOGIC SETTING

Sedimentary rocks of late Early Cretaceous age are widespread in southeastern Arizona, southwestern New Mexico and northern Mexico. These rocks comprise a thick sequence, over 3500 m, of shale, sandstone, conglomerate and limestone mapped as the Bisbee Group or various local units that are correlative with the Bisbee Group. The type section for the Lower Cretaceous is located in the Mule Mountains near the town of Bisbee. Ransome (1904) divided the strata into four units, the Glance Conglomerate at the base, the Morita Formation, the Mural Limestone, and the Cintura Formation at the top. Due to marked lateral facies changes within the Bisbee Group, Lower Cretaceous rocks exposed in mountain ranges to the north and west of Bisbee do not fit well into this classification scheme.

A major portion of the Bisbee Group in the southeastern part of the region is of marine origin and of Aptian to Albian age. The Mural Limestone is a relatively thick-bedded, fossiliferous, shallow marine limestone, and both the upper Morita and lower Cintura Formations contain marine sandstone and shale. Strata both above and below the marine interval are mainly fluvial. To the west and north the proportion of limestone decreases and to the northwest the only carbonates present are thin-bedded, silty, brackish water limestones. The sandstones of the Bisbee Group become more feldspathic or arkosic to the west (Hayes, 1970b). To the southeast in Mexico, Lower Cretaceous marine rocks increase in thickness and dominate the section (Cordoba and others, 1971; Greenwood and others, 1977).

The marine facies of the Bisbee Group represents the transgression and regression of an Early Cretaceous shallow marine sea which deepened to the southeast. This marine basin had a definite northwesterly linear trend; it received clastic and carbonate sediment in northern Mexico during the Late Jurassic before transgressing northwestward into southeastern Arizona in the late Early Cretaceous (Cordoba and others, 1971; deCserna, 1971; Hayes, 1970b; Beauvais and Stump, 1976).

The basal unit of the Bisbee Group, the Glance Conglomerate, is not directly related to the transgressive facies of this marine sea. The Glance Conglomerate is predominantly a coarse fanglomerate and was deposited on alluvial fans in local basins bounded on at least one side by normal faults. This synorogenic, unfossiliferous, nonmarine deposit is related to substantial vertical tectonic movements which preceded moderately stable crustal conditions and the transgression of the late Early Cretaceous shallow marine sea from the southeast.

Deposition of the Glance Conglomerate took place in a dramatically different tectonic as well as depositional environment from that of most of the overlying strata in the Bisbee Group. Analysis of the Glance Conglomerate both regionally and in detail at two well exposed localities allows for substantial insight into the mid-Mesozoic structural evolution of southeastern Arizona.

GENERAL STRATIGRAPHY

The Glance Conglomerate was first described by Dumble (1902) in the southern Mule Mountains. Recent work on the Glance Conglomerate (Hayes, 1970, 1970b; Drewes, 1971; Bilodeau, 1977, 1978) and extensive local and quadrangle mapping by university students, professors and most recently by U.S. Geological Survey geologists, has greatly expanded the knowledge of its distribution and character. Regionally the Glance Conglomerate varies widely in thickness, composition, texture, contact relationships and possibly even in age. The widely scattered outcrop distribution of this formation is shown in Figure 1.

The Glance Conglomerate was deposited with major unconformity on rocks ranging in age from Jurassic to Precambrian. Typically the Glance Conglomerate unconformably overlies late Paleozoic limestone at one locality, yet only a short distance away rests directly on Precambrian schist or granite. Locally it may overlie limited exposures of Triassic or Jurassic volcanic rocks and redbeds or Jurassic granite. The Glance also

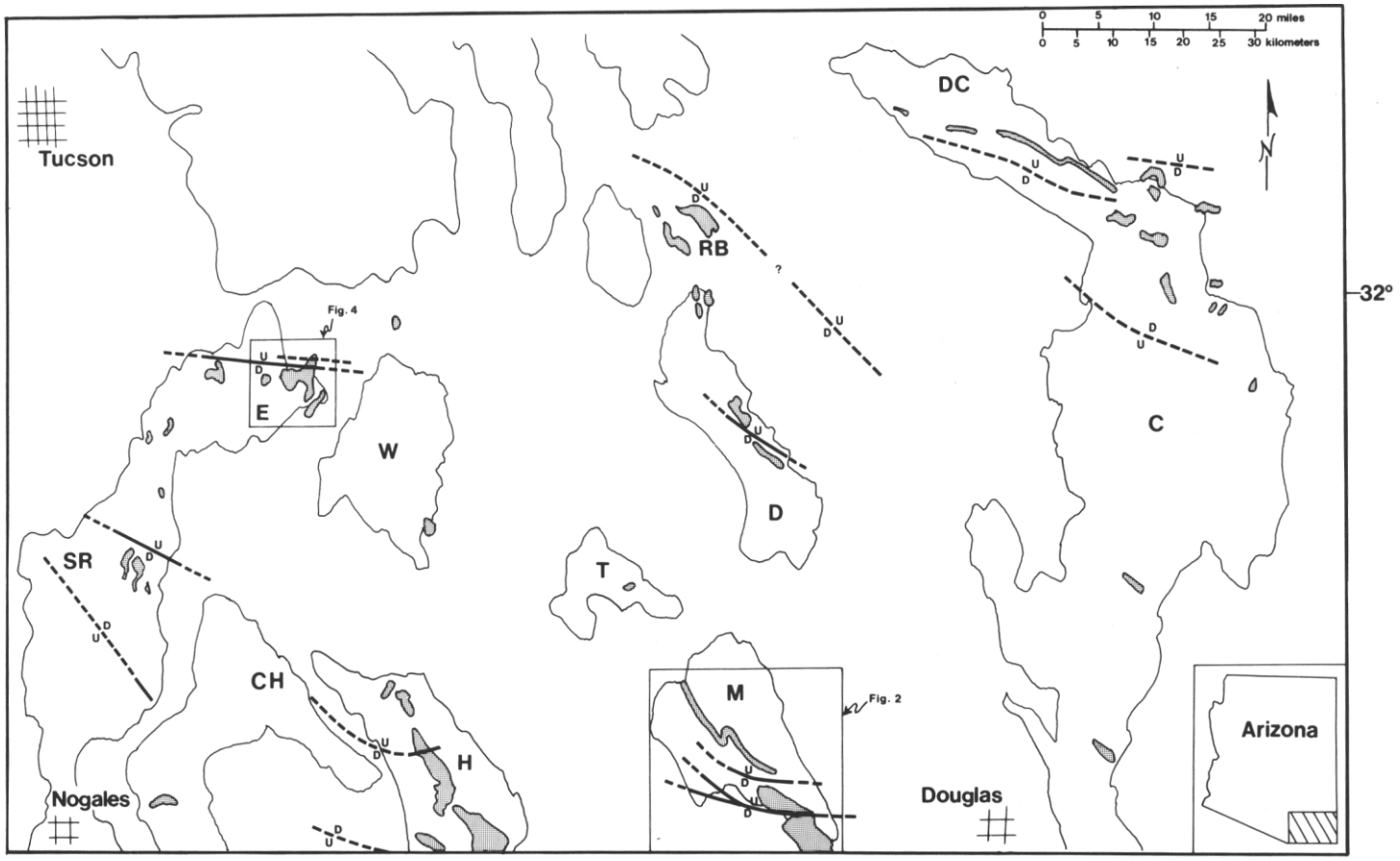


Figure 1. Distribution of Glance Conglomerate and equivalent rocks in southeastern Arizona. Also shown are the known and inferred faults associated syntectonically with these fanglomerate deposits. (SR) Santa Rita Mtns., (E) Empire Mtns., (W) Whetstone Mtns., (CH) Canelo Hills, (H) Huachuca Mtns., (T) Tombstone Hills, (M) Mule Mtns., (D) Dragoon Mtns., (RB) Red Bird Hills, (DC) Dos Cabezas Mtns., (C) Chiricahua Mtns.

ranges in thickness from less than one to over 1000 m, with large variations over short distances.

Compositionally, the Glance Conglomerate consists of poorly sorted and poorly rounded cobble to boulder conglomerate and breccia containing clasts of Paleozoic limestone and quartzite, Mesozoic volcanic rocks, Jurassic granite and Precambrian schist and granite. This assortment of clast types varies both regionally and within local outcrop areas. Where the Glance is thin (1-10 m), it is usually a monomictic conglomerate with a clast composition which reflects that of the underlying formation. Where relatively thick, it is a polymictic conglomerate with vertical variations in clast composition that define specific clast assemblages and frequently give the formation a locally consistent internal stratigraphy.

These various mappable lithofacies units are named for the composition of the most abundant clast type within the specific assemblage. Consequently, limestone, quartzite, volcanic, schist and granite-clast lithofacies are developed as well as some distinct lithofacies that contain two or more clast types. Locally the boundary between two lithofacies is sharp, although a gradational contact is much more common. The internal stratigraphy of lithofacies units consistently reflects the exposure and erosion of progressively older pre-Cretaceous formations within its source areas. The vertical sequence of clast assemblages thus presents an inverted stratigraphy of the eroded source terrane, typically involving the entire Paleozoic section and part of the Precambrian.

Texturally the Glance Conglomerate is highly variable. Textures ranging from very poorly sorted, matrix-supported, disorganized conglomerate to relatively well-sorted, though bimodal, clast-supported, well-bedded conglomerate are found. Typically the matrix-supported conglomerate contains angular to subangular clasts with a muddy matrix, is poorly sorted, poorly bedded and makes up a major part of the formation where it is relatively thick. Large boulders 1 to 2 m across are often found scattered throughout the section. Cut-and-fill channel structures are also found. Where the Glance Conglomerate is thin, the clasts are subrounded and have a clast-supported, commonly well ordered fabric. Similar beds are frequently interbedded with the matrix-supported conglomerate layers as well as with beds and stringers of sandstone.

ENVIRONMENT OF DEPOSITION

The poorly sorted, rather disorganized nature of the matrix-supported conglomerate, plus the large boulders, the fine-grained matrix, and the cut-and-fill channels suggest that these are debris-flow deposits. The better sorted, better rounded, clast-supported conglomerates with oriented fabric are examples of fluvial traction-flow deposits (Bull, 1972; Walker, 1975). The intimate association of these two types of deposits, along with the thickness variations and lithofacies changes suggest that the Glance Conglomerate was deposited subaerially on alluvial fans along actively rising mountain fronts. Paleo-

flow directions from clast imbrications, channel orientations and oriented clast fabrics support this interpretation.

Glance Conglomerate of the Mule Mountains

The Glance Conglomerate in the Mule Mountains is principally exposed in two broad outcrop bands southeast of Bisbee and in one long, thin band to the north (fig. 2). The three outcrop areas are restricted to discrete structural blocks separated by faults and have characteristics unique to the Glance Conglomerate of each particular block. The thickness of the formation is significantly different on each of the structural blocks, and differences in clast composition, subjacent rock type and degree of rounding of the clasts are also notable. The two essentially west-trending faults that separate these blocks are the Dividend fault on the north and the Abrigo-Bisbee-West fault complex to the south. 211

The Glance Conglomerate in the Mule Mountains can be divided into three gradational lithofacies units, a schist-clast facies, a limestone-clast facies and a mixed-clast facies. This internal stratigraphy is fully developed only in the southernmost structural block, while the schist-clast facies is the only lithofacies present in the central and northern blocks.

North of the Dividend fault the Glance Conglomerate unconformably overlies either Jurassic Juniper Flat Granite or Precambrian Pinal Schist. Nowhere within this northern structural block is the Glance more than 30 m thick, and locally it is absent. Compositionally, all of the Glance Conglomerate in this block is classified as schist-clast facies even though the number of pink granitic clasts is greater than Pinal Schist clasts where the formation directly overlies Juniper Flat Granite. The clasts are mostly subrounded cobbles and pebbles composing a clast-supported framework set in a reddish-brown sandy matrix.

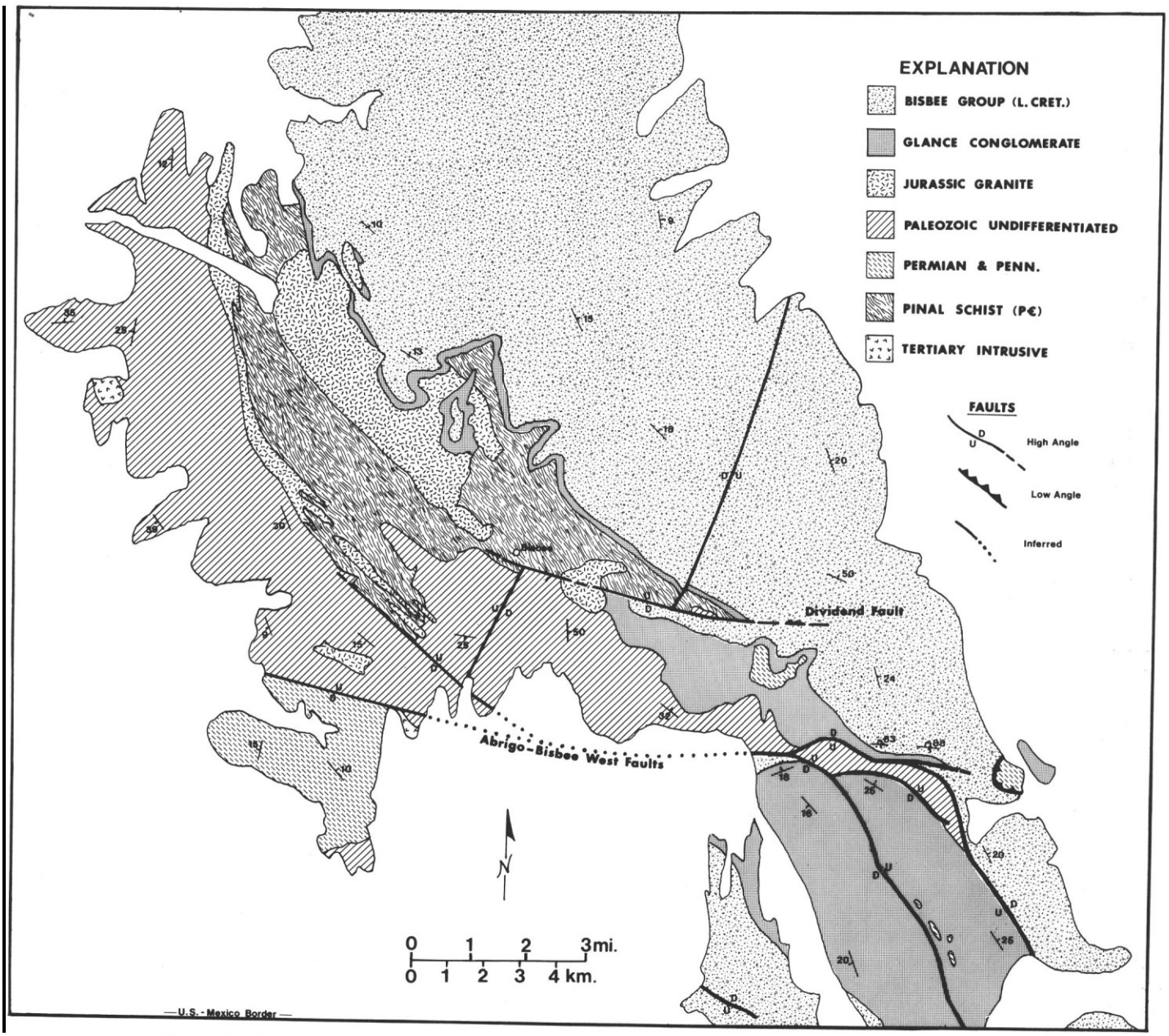


Figure 2. Geologic sketch map of the Mule Mountains (modified from Hayes and Landis, 1964).

South of the Dividend fault but north of the Abrigo-Bisbee-West faults, the Glance Conglomerate increases in thickness to 100-200 m and unconformably overlies late Paleozoic limestone. All of the Glance Conglomerate in this block also belongs to the schist-clast facies even though quartzite clasts become abundant in the lower half of the section. At the base of the section a thin limestone breccia grades up into schist-quartzite conglomerate. The Glance Conglomerate here has both matrix-supported and clast-supported zones with frequent large schist boulders.

In the southern structural block, south of the Abrigo-Bisbee-West faults, the Glance is at least 1000 m thick. This abrupt increase in thickness correlates with an increase in the diversity of clast types. Here three distinct lithofacies can be delineated. At the base of the section where the Glance rests unconformably on late Paleozoic limestone, a limestone-clast facies is developed. Minor, though locally abundant, clasts of red silicic volcanic rock, dolomite, chert and sandstone are found with the subangular to angular limestone clasts in this lithofacies. Gradationally above this unit is the mixed-clast facies where limestone clasts are of equal significance to quartzite and chert clasts. Quartzite clasts are subrounded and are derived primarily from Cambrian Bolsa Quartzite. Limestone and dolomite clasts come from a wide variety of Paleozoic formations, with cobbles from the Horquilla, Escabrosa and Martin Formations especially recognizable.

The mixed-clast facies grades vertically into schist-clast facies which is found in both structural blocks to the north. The transition zone is very thick and as is the case in the central structural block, there are abundant subrounded quartzite clasts present in the lower part of the schist-clast facies. Conglomerate beds of the schist-clast facies grade up into and interfinger laterally with sandstone and siltstone of the lower Morita Formation.

As shown in Figure 3, the lithofacies changes and the southward increase in thickness of the Glance Conglomerate clearly demonstrate that the Dividend fault and the Abrigo-Bisbee-West fault system were active during the time of Glance deposition. This interpretive cross-section has been greatly simplified, for reactivation of these faults and initiation of others during later Cretaceous and Tertiary deformation has complicated the present structural picture. Bryant and Metz (1966) were the first to note that the Dividend fault controlled much of the diversity found in the Glance Conglomerate and reported it to have normal displacement down to the south of 1500 m.

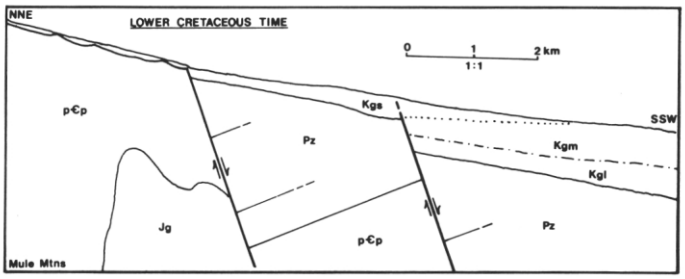


Figure 3. Schematic cross-section across the Dividend and Abrigo-Bisbee-West faults in the southern Mule Mountains showing the various lithofacies units within the Glance Conglomerate during Early Cretaceous time. (Kgs) Glance schist-clast lithofacies, (Kgm) Glance mixed-clast lithofacies, (Kgl) Glance limestone-clast lithofacies, (Pz) Paleozoic undifferentiated, (p€p) Precambrian Pinal Schist, (Jg) Jurassic Juniper Flat Granite.

Deposition of the Glance Conglomerate was by subaerial processes on alluvial fans that were built along the southern margin of a fault-block mountain range rising to the north. The complete Paleozoic section was eroded from this rising fault block and deposited in a subsiding graben-style basin to the south. The nature of the Glance Conglomerate and the low relief of the pre-Cretaceous unconformity north of the Dividend Fault suggest that a pediment was developed there before being covered by finer-grained, fluvial, lower Morita beds. Paleoflow data is in accord with this interpretation, showing consistent south to southwest flow directions.

Glance Conglomerate of the Empire Mountains

In the Empire Mountains the Glance Conglomerate is mainly exposed in the northeastern part of the mountain range. One outcrop belt runs along the east side of the range and another, somewhat less continuous band, across the northern side (fig. 4). The thickness varies from about 1000 m in northern exposures to less than 1 m or locally absent to the south. This gradual thinning southward is accompanied by lateral intertonguing of the Glance Conglomerate with overlying Willow Canyon Formation (Morita Formation equivalent).

Compositionally, the Glance Conglomerate can be separated into three lithofacies, a lower limestone-clast facies, a middle, transitional mixed-clast facies and an upper granitic-clast facies. The limestone-clast conglomerate facies consists of clast-supported subangular to subrounded cobbles and boulders of limestone, dolomite and minor chert bound in a

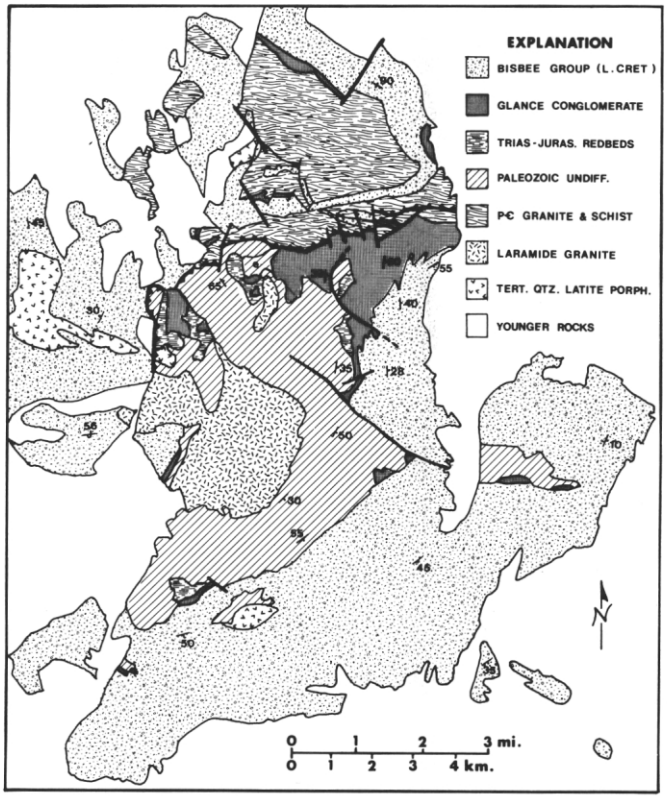


Figure 4. Geologic sketch map of the Empire Mountains (modified from Finnell, 1971).

matrix of reddish-brown to gray calcareous sandstone and siltstone. Boulders up to 3 m in diameter are common and large exotic blocks as much as 300 m long and 60 m wide of late Paleozoic limestone are found near the base of the unit. The limestone-clast facies ranges in thickness from less than 1 m to 120 m and rests unconformably upon late Paleozoic limestone or local exposures of redbeds of Triassic Gardner Canyon Formation or possible Triassic-Jurassic Canelo Hills Volcanics mapped by Finnell (1971).

The mixed-clast facies has a rather abrupt lower contact, formed by the sudden appearance of appreciable amounts of pink to light reddish-brown, angular to subangular Bolsa Quartzite fragments set in a matrix of reddish-brown sandstone and sandy mudstone. In the middle and upper sections of this facies granitic clasts become increasingly abundant. In general this mixed-clast facies is a quartzite-granite-limestone clast conglomerate and grades up into granitic-clast facies.

The granitic-clast lithofacies is restricted to the most northeastern section of the main outcrop area and scattered exposures of Glance Conglomerate further north. This facies rests either on the mixed-clast facies or unconformably on Precambrian granitic rocks. The lower part of this unit, where it overlies the mixed-clast facies, is gradational from a quartzite-granite clast conglomerate to a pure granitic-clast conglomerate composed primarily of Precambrian gneissic quartz diorite clasts set in a greenish-gray arkosic matrix. Where the granitic-clastic facies rests on Precambrian basement rocks, the composition is entirely Precambrian granitic fragments. The thickness of this facies ranges from 1 m to over 500 m.

These relationships are shown on the interpretive cross-section in Figure 5. Much local structural complexity has been simplified on this cross-section. Note that the geometry, inferred tectonic movements and syntectonic nature of the Glance Conglomerate are strikingly similar to that found in the Mule Mountains (fig. 3). The entire Paleozoic section, 2000 m of sedimentary rock, has been eroded off an uplifted northern block and the detritus deposited on alluvial fans and in a clastic basin to the south. Paleoflow determinations support this model, with consistent south to southwest flow directions. The intertonguing nature of the Glance Conglomerate and the basinal sandstones and siltstones of the Willow Canyon Formation suggest that normal faulting was active during most of the time of Willow Canyon (Morita equivalent) deposition. In the Mule Mountains, exposures suggest that normal faulting

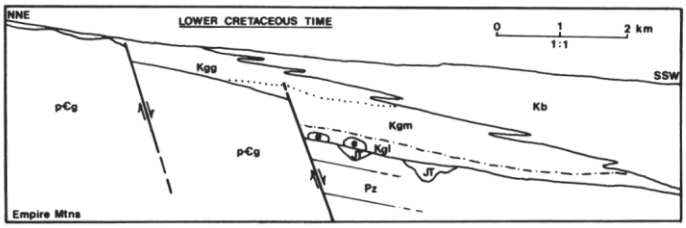


Figure 5. Schematic cross-section of the Empire Mountains in Early Cretaceous time showing Glance Conglomerate stratigraphy and syntectonic relationships. Note similiarities with Mule Mountains (fig. 3). (Kb) Bisbee Group, (Kgg) Glance granite-clast lithofacies, (Kgm) Glance mixed-clast lithofacies, (Kgl) Glance limestone-clast lithofacies, (JT) Jurassic-Triassic redbeds, (Pz) Paleozoic undifferentiated, (p€p) Precambrian granite and schists, (e) exotic landslide blocks of late Paleozoic limestone.

had ceased by that time, but the relationship between the Morita Formation and the Glance Conglomerate farther south is not known.

REGIONAL TECTONIC IMPLICATIONS

Regional studies of the Glance Conglomerate imply that similar depositional environments and syntectonic relationships as those found in the Mule and Empire mountains existed throughout southeastern Arizona during the Lower Cretaceous. The nature and contact relationships of the exposures of Lower Cretaceous fanglomerate in the Huachuca, Santa Rita, Dragoon, Dos Cabezas and Chiricahua mountains and in the Red Bird and Gunnison Hills suggest that the faults shown in Figure 1 were active during early Early Cretaceous time. Many of these faults are not exposed at present but are inferred to exist beneath Cenozoic cover in the approximate locations and orientations shown. Note that some of the inferred fault scarps faced to the northeast, whereas those related to the Glance Conglomerate exposures in the Mule and Empire mountains faced to the south-southwest. Source terranes to the southwest included exposures of Mesozoic volcanic rocks that gave rise to volcanic-bearing clast suites in some Glance and correlative conglomerates of the Huachuca, Santa Rita and Dos Cabezas mountains.

The regional pattern of Early Cretaceous faults suggests that southeastern Arizona was undergoing extensive vertical tectonic movements along northwest- and west-trending normal faults. Rotation of the fault blocks (shown in Figure 3) and comparison with other block-faulted regions indicate that this was also a zone of regional northeast-southwest extension. This zone of middle Mesozoic extensional deformation and syntectonic deposition extended south and southeast into Mexico to merge with the northwest-trending Chihuahua Trough, a major Mesozoic marine basin (Taliaferro, 1933; Imlay, 1939, 1944; Hayes, 1970b; Cordoba and others, 1971; Greenwood and others, 1977). The position, timing and extent of this episode of continental rifting indicates that it was a major event in the Mesozoic evolutionary development of the southern Cordillera.

ACKNOWLEDGMENTS

Research for this study was conducted as part of a Ph.D. dissertation at Stanford University. Financial support was provided by Geological Society of America Research Grant 2165-77, a Grant-in-Aid of Research from Sigma Xi, the Scientific Research Society of North America, and funds from the Shell Companies Foundation grant to Stanford University. I wish to thank William R. Dickinson whose comments helped in improving this manuscript.

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