ORIGIN OF CONGLOMERATES IN SILURIAN RED MOUNTAIN FORMATION OF CENTRAL ALABAMA; THEIR PALEOGEOGRAPHIC AND TECTONIC SIGNIFICANCE

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Origin of Conglomerates in Silurian Red Mountain Formation of Central Alabama; Their Paleogeographic and Tectonic Significance[1]

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Abstract The Lower Silurian Red Mountain Formation in central Alabama consists of interbedded sandstone and siltstone and four prominent intervals of sedimentary iron formation. Conglomerates consisting of discoid limestone cobbles in sedimentary hematite ore matrix commonly are present in one or more beds within the formation. Elongate cobbles have preferred northeast and southeast orientations. Crossbedding within the conglomerate matrix suggests southwestward-directed paleocurrents. Cobbles are deformed by soft-sediment draping. Bioclastic limestone lenses within and directly below the conglomerate intervals were apparently the source material.

Although exposures of the Red Mountain Formation are insufficient to prove a beltlike distribution of the conglomerates, or the trend of such a belt, the conglomerates are known to be present along the strike of the southeastern limb of the Birmingham anticlinorium from Bessemer to Gadsden, Alabama, a distance of more than 70 mi. Width of the possible belt may be as much as 2 mi.

The Red Mountain Formation is absent in the Helena thrust block southeast of the Birmingham thrust block. Northwest of the Birmingham anticlinorium, the formation grades into calcareous shale and limestone.

Clay cobbles similar in size and shape to those in the Red Mountain Formation are forming at a site in the Mississippi Sound on the north coast of the Gulf of Mexico. The clay cobbles originate through the combined effects of desiccation and cracking of clay lenses in the intertidal zone and gentle wave abrasion.

It is suggested that during Early Silurian time a slowly rising arch at the site of the Birmingham anticlinorium separated land on the southeast from the open sea on the northwest. The cobbles originated in an intertidal zone on the arch. Southwest-oriented crossbedding foresets evidently resulted from back-bar longshore currents during tidal withdrawal. The arch never was sufficiently emergent to cause erosion during Early Silurian time, and during deposition of the greater part of the Red Mountain Formation the arch remained submerged. The conglomerate zones mark the times of maximum emergence. Basement involvement in the development of the Birmingham anticlinorium is suggested by this evidence of uplift early in the history of Paleozoic sedimentation.

INTRODUCTION

The Lower Silurian Red Mountain Formation in central Alabama ranges in thickness from 0 to 700 ft. The dominant lithology changes in a southeastward direction from limestone in northwestern Alabama (Jewell, 1967, p. 2) to siltstone and sandstone. At Birmingham the Red Mountain Formation is about 230 ft thick and consists of interbedded sandstone and siltstone and four prominent intervals of sedimentary iron formation (Thomas and Bearce, 1971). One or more conglomerates from a few inches to 5 ft thick are commonly present either within or adjacent to the sedimentary iron formation intervals. The conglomerates are composed of sandy, hematitic, discoid limestone cobbles in a sandy and calcareous hematite ore matrix. The conglomerates seem to be restricted to the southeast limb of the Birmingham anticlinorium (Fig. 1), and one or more intervals are found as far southwest as Bessemer and northeastward to the vicinity of Gadsden (Fig. 2). The northwest limb of the Birmingham anticlinorium is thrust faulted, and the Red Mountain Formation is poorly exposed there. Northwest of Birmingham, the formation thickens to as much as 500 ft in a northeast-trending narrow linear trough. The formation thins southeast of the trough, and it is absent because of erosion or nondeposition about 15 mi southeast of Birmingham (Fig. 2; Carrington, 1965, p. 19-21).

The conglomerate separating the two lowermost iron ore seams in the Red Mountain Formation, the Big seam and the Irondale seam (Fig. 3), is particularly well exposed in highway cuts and strip mines along the crest of Red Mountain on the southeast limb of the Birmingham anticlinorium. This conglomerate appears to be more persistent laterally than conglomerates at other stratigraphic positions and is present in all exposures of the Big and Irondale ore seams along the crest of Red Mountain from Bessemer to Irondale (Fig. 1). It has been used as a marker bed in separating the Big seam from the Irondale seam at locations where siltstone or some other intervening lithology is absent, and it is referred to as the "kidney seam" by mining companies because of the shape of many of the cobbles. Because of

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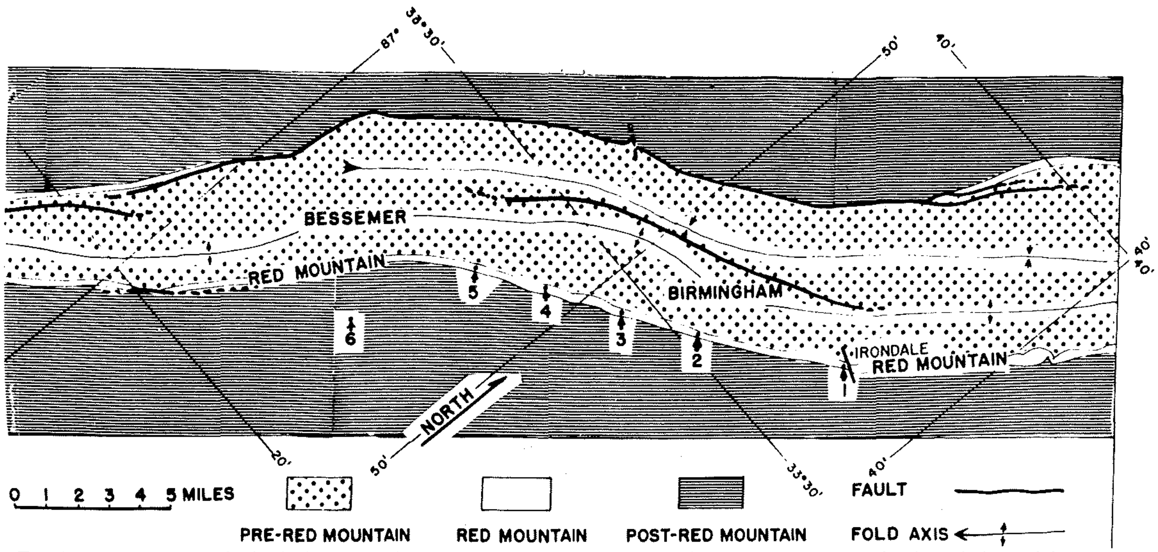

FIG. 1—Geologic map of Birmingham anticlinorium, Birmingham-Bessemer region. Conglomerate study sites, designated by numbers, are: (1) U.S. Highway 78 on Red Mountain at Irondale; (2) Red Mountain Expressway cut at Birmingham; (3) vicinity of Interstate Highway 65 South at Greensprings; (4) Ishkooda No. 11 mine on Red Mountain; (5) Wenonah Gap on Red Mountain; (6) Woodward Iron Company Pyne Mine (subsurface). Geology generalized from Burchard and Butts (1910, Pl. 2).

its persistence and its readily ascertainable location in the section, this conglomerate was selected for study.

The Red Mountain Formation conglomerates have been postulated to have been derived from an eroded highland southeast of the Birmingham anticlinorium, where the Red Mountain Formation is missing (Gray, 1965; Butts, 1926, p. 137). Clasts were postulated to have been derived mainly from beds lower in the Red Mountain Formation (Butts, 1926, p. 137), and some may have been derived from beds as old as Ordovician or Cambrian (Gray, 1965, p. 18). The present study of cobble orientation and matrix crossbed foreset orientation, lithology, and fauna had as its objective the determination of the origin, mode of transport, and environment of deposition of the cobbles. An examination of an apparently similar depositional environment on the northern coast of the Gulf of Mexico provides a modern analogue of cobble origin.

DESCRIPTION OF CONGLOMERATE

The locations of conglomerate study sites are shown in Figure 1. Although cobbles are present at all six sites, cobble lineation studies could be made only at sites 2, 3, and 4. Matrix crossbedding was analyzed at all except site 6 (Woodward Iron Company's Pyne Mine), where working conditions and exposures permitted only cobble size and conglomerate thickness to be determined.

The conglomerate separating the Big and Irondale seams commonly is less than 1 ft thick; however, at site 2 it occupies a 3-ft interval below the base of the Big seam. Scattered cobbles are abundant to a depth 5 ft below the Big seam and well into the Irondale seam (Fig. 4). Southwest of site 6, at a point where the Birmingham anticlinorium commences to plunge southwestward, the conglomerate pinches out (Fig. 1), and the Big seam is in contact with the Irondale seam (Gray, 1965, p. 17). Northeast of site 1, more than 20 ft of shale separates the Big and Irondale seams, and the conglomerate is absent (Butts, 1926, p. 137).

The conglomerate matrix is composed mainly of dark-red hematite, mostly in the form of pellets averaging 1–2 mm and rarely as large as 4 mm in longest dimension. Scattered, rounded quartz grains of the same size also are present. Discontinuous lenses of greenish-gray siltstone, generally less than 1 in. thick, are present but are not abundant (Fig. 5A). Lenses of coarsely crystalline, crossbedded, fossiliferous limestone containing abundant quartz grains and laminations of hematite pellets are common within and below the conglomerate interval (Fig. 5A, B).

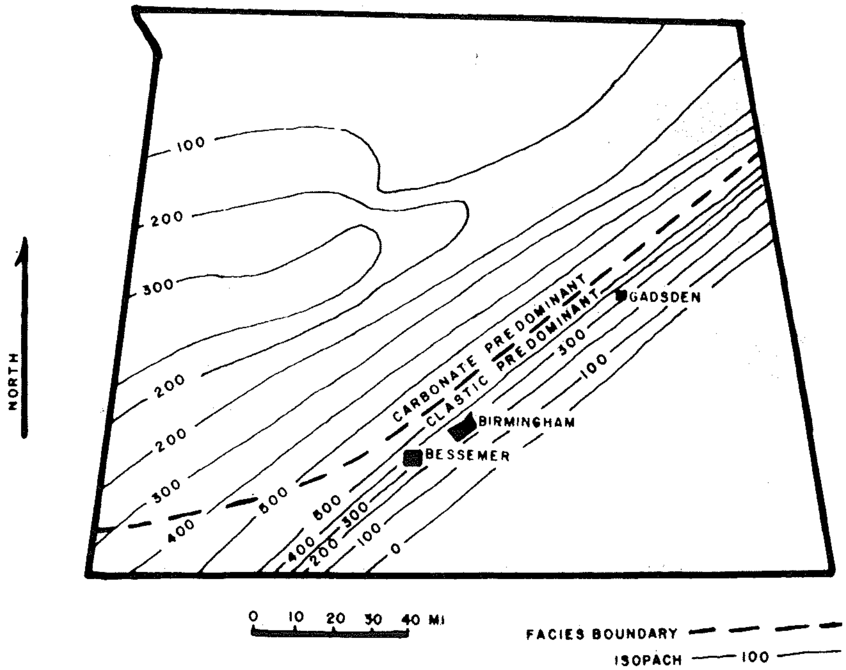

FIG. 2—Isopach and generalized facies map of Silurian Red Mountain Formation and equivalents in northern Alabama.

Cobbles commonly are discoid (Fig. 6A), flattened parallel with their internal bedding, and most lie with flat surface parallel with the bedding of the matrix which is in part crossbedded. Many of the cobbles are in contact with each other and are in part imbricated (Fig. 6B). Where most concentrated, cobbles make up about 40 percent of the total lithology. They range in size from 2 in. to almost 2 ft in longest dimension. Bedding texture is well defined on freshly broken cobble and lense surfaces as laminations of light-gray, coarsely crystalline, bioclastic limestone alternating with darker gray laminations in which hematite pellets are concentrated (Figs. 5A, B; 6A, B). Crossbedding is evident in the bedding texture of many of the cobbles, and their lithologic appearance is identical with that of the sandy, hematitic limestone lenses present in the matrix of the conglomerate.

Thin sections of cobbles taken from sites 2-4 (Fig. 1) all show essentially the same lithology, consisting of three main components: calcite, hematite pellets, and quartz grains. The predominant component, calcite, commonly is in the form of fossil fragments of horn and colonial corals, brachiopod shells, bryozoans, and trilobite carapace parts. Cobble thin-section photomicrographs (Figs. 7A, B; 8) show the character and distribution of the three components.

A study of cobble long-axis orientations at the three sites where such a study was possible showed only slight orientation preference, with the possible exception of cobbles at site 4, the Ishkooda 11 mine (Fig. 9). Long axes of 50 cobbles at site 4 show an orientation preference between N29E and N59E. Cobbles having length-width ratios of at least 3:2 were selected in hopes of dealing with definitely elongated bodies that would be most apt to show orientation preference from paleocurrent action. That a preferred orientation was not more strongly developed indicates that the transporting currents were weak or variable. Many of the largest cobbles have irregular prominences and appear to have been rounded in place, rather than in transit (Fig. 10).

Crossbedding is sporadically developed in the conglomerate matrix. Foreset-bed orientations of matrix crossbeds at sites 1-5 indicate a prevailing southwest current direction. Although only five crossbedding measurements were made at each station because of the scarcity and definition of crossbeds, all 25 indicated a southwesterly current (Fig. 17).

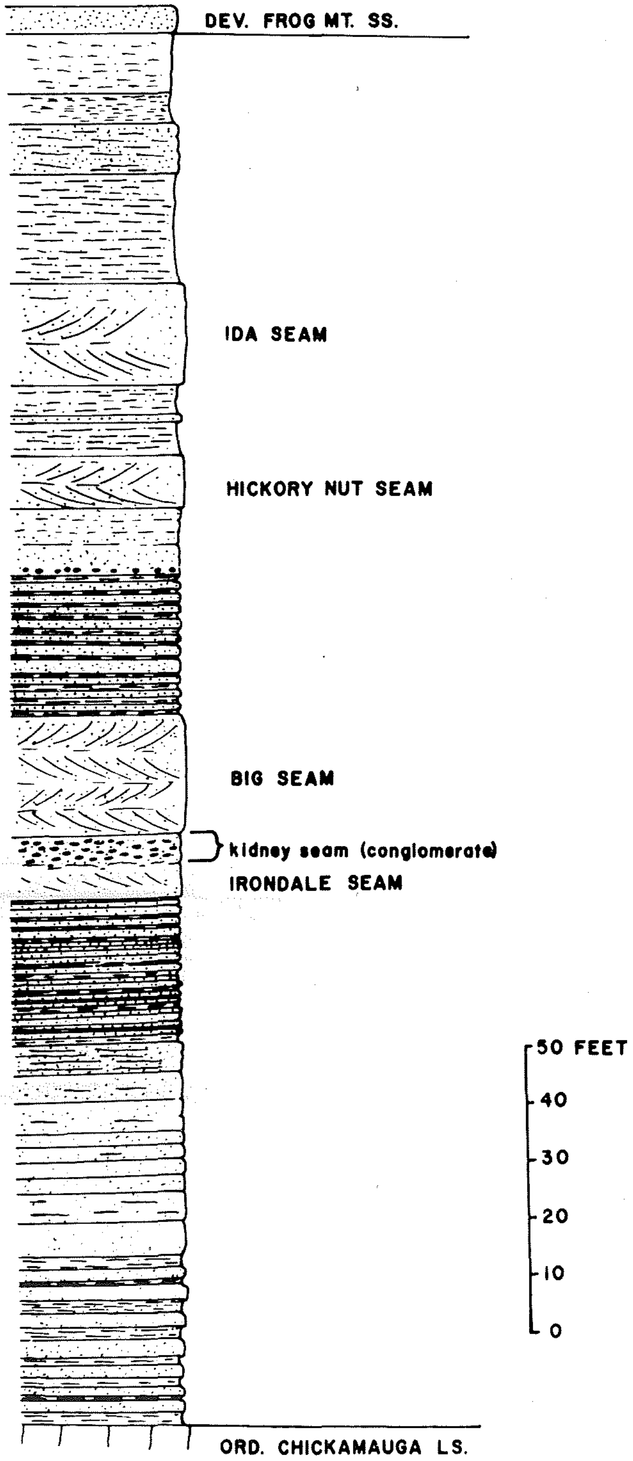

FIG. 3—Section of Silurian Red Mountain Formation at Red Mountain Expressway cut (site 2), Birmingham, Alabama.

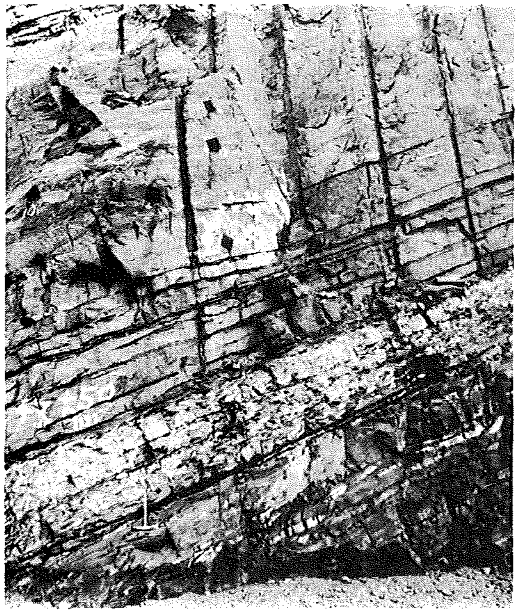

FIG. 4—Big Seam, conglomerate interval, and Irondale seam of Red Mountain Formation, Red Mountain Expressway cut, Birmingham, Alabama.

Cobbles and lenses of limestone at site 3 contain fragments of a new species of trilobite, *Acaste birminghamensis* (Norford, 1972). The presence of *Acaste birminghamensis* in both cobbles and limestone lenses within the conglomerate interval at site 3 corroborates the lithologic evidence that the cobbles were derived from the limestone lenses.

MODERN COBBLE-FORMING DEPOSITIONAL ENVIRONMENT

A depositional environment, perhaps similar to that in which the cobbles collected, exists at present on the north side of Mississippi Sound (Fig. 11). Mississippi Sound is separated from the Gulf of Mexico by Dauphin Island, a sand-barrier island. Water depth in the vicinity is about 3 ft at high tide.

A spoil pile, dredged in 1970 to deepen a channel to the University of Alabama Marine Research Station, lies about 300 ft offshore in Mississippi Sound. Figure 12 shows the dimensions of the spoil pile. The pile has been modified by wave action to appear to be a natural island (Fig. 13). It consists of sand and silty clay, and wave action has sorted this material to the extent that the part of the island exposed at high tide is mostly sand. A silty clay blanket, submerged at

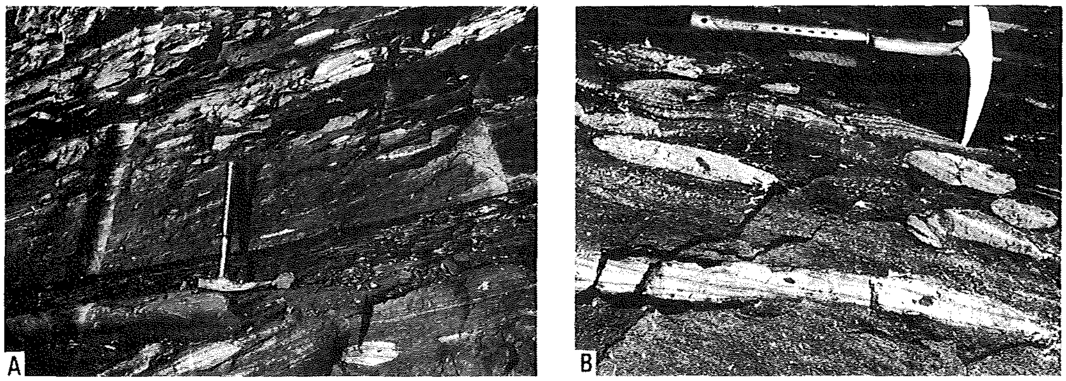

FIG. 5—**A.** Lenses of siltstone and crossbedded sandy limestone within and below conglomerate interval, Red Mountain Expressway cut (site 2). **B.** Freshly broken cobble and lense surfaces showing internal bedding detail.

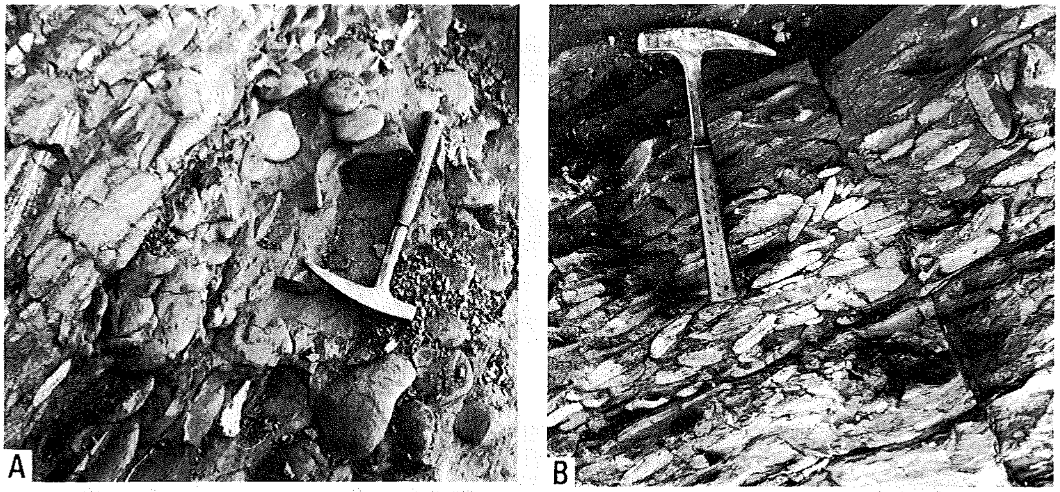

FIG. 6—**A.** Close-up of conglomerate interval, Red Mountain Expressway cut, showing plan view of cobbles. **B.** Close-up of conglomerate interval, Red Mountain Expressway cut, showing partial imbrication of cobbles.

high tide fringes the island and is widest on the southward side. The clay is mottled light-gray to light-brown (Fig. 14A), in contrast to the dark organic muck which forms the natural bottom of the sound. The sand that forms the supratidal part of the island appears to blanket the clay below. The sand thickens from zero at a point 6-20 ft laterally downslope from the high-tide line to a thickness of 2 ft at the center of the island, which is a few inches above the high-tide line. Tidal range is approximately 2 ft.

Clay cobbles, identical in size and shape with the limestone cobbles of the Red Mountain Formation, are distributed over the sand in belt-like clusters below the high-tide line and upslope from the blanket of clay spoil surrounding the island (Fig. 14B). The cobbles appear restricted to the soundward sides of the island where wave action is most intense. Cobble size and concentration decrease upslope from the margin of the clay-spoil blanket (the cobble parent material) and toward the northwesternmost (shoreward) side of the island (Fig. 14C). Cobble size ranges from 1 in. to a large average size of about 4 in., and shape varies from discoid to potato-shaped (Fig. 15).

Wave action has concentrated the cobbles in belts along the island shore, but the cobbles seem to acquire most of their ultimate shape while still part of the clay spoil blanket (Fig. 16). A large part of the clay blanket is exposed at low tide, and desiccation cracks develop in the clay during low tide. Sand, carried by backwash off the island and over the clay blanket, abrades the edges of the desiccation cracks, imparting the rounded-disc or potato-shaped character. The cobbles contain internal laminations of clay and clayey sand. The laminations were acquired as the original spoil pile was reworked by waves and probably serve as planes of weakness along which the abraded clumps are stripped from the upper surface of the clay layer and washed onto the island.

DISCUSSION AND CONCLUSIONS

Paleoenvironment

Similar lithologic character and faunal content of cobbles and associated limestone lenses, the homogeneous nature of the cobbles, the irregular shape of extremely large cobbles, and evidence of cobble deformation by mutual load compression during deposition, all indicate that the cobbles were formed from unlithified sediment—shelly, sandy, carbonate-mud lenses—and that little or no transportation of the cobbles took place during or after they were shaped. The modern clay-cobble-forming environment in Mississippi

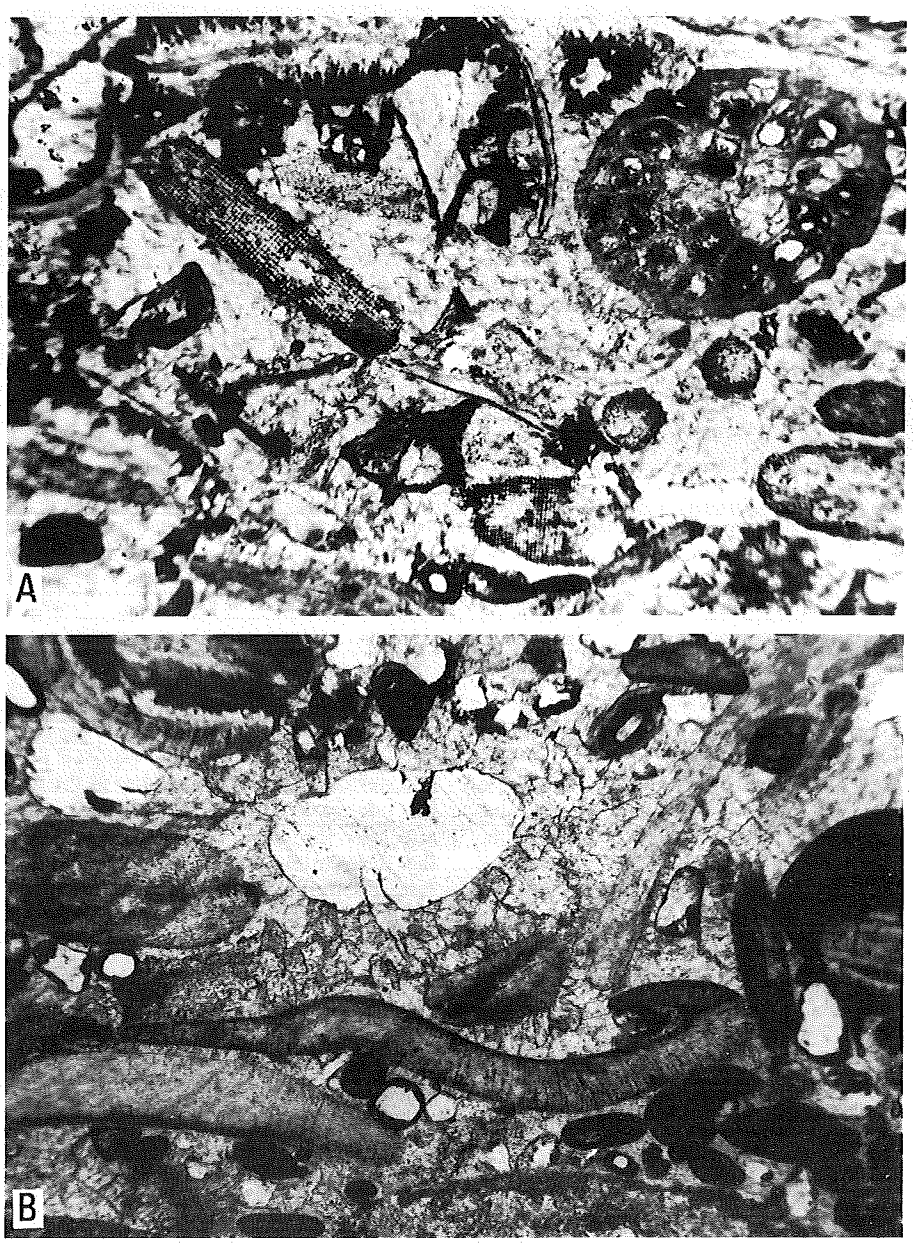

Fig. 7—**A.** Photomicrograph of cobble thin section showing calcite fossil fragment components, ×40. **B.** Photomicrograph of cobble thin section showing quartz grain characteristics, ×40.

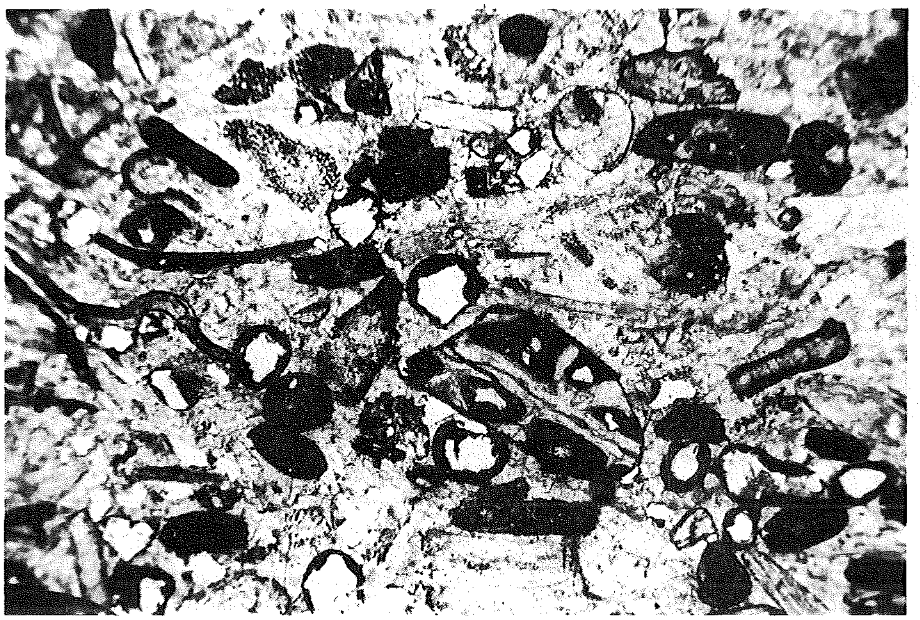

Fig. 8—Photomicrograph of cobble thin section showing varieties of hematite pellets, ×40.

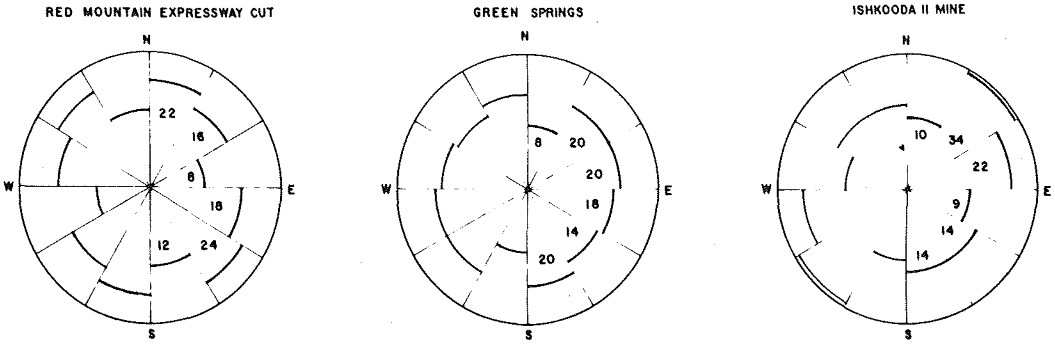

Fig. 9—Rose diagrams of percent distributions of cobble long-axis orientations based on 50 readings at each site.

FIG. 10—Plan view of large cobbles at site 4, Ishkooda No. 11 mine.

Sound shows that tidal fluctuation and the gentle wave action attending the rising and falling tide are sufficient to form cobbles from coherent soft sediment in a few months time. The cobbles so formed are distributed in belts paralleling the shoreline. So long as the environment persists, the cobble belts are almost entirely emergent at low tide and almost entirely submergent at high tide. On a coast exposed to open sea and strong wave action such cobbles, once formed, would probably not persist in great numbers.

The necessity of an environment sheltered from strong wave action for preservation of newly formed cobbles is of importance in a consideration of the paleoenvironment in which the cobbles of the Red Mountain Formation originated. The cobbles seem to be present only on the southeast flank of the Birmingham anticlinorium. At the time of cobble formation the main strand line of the Silurian sea lay several miles southeast. A barrier must have existed, then, at the site of the crest of the present Birmingham anticlinorium, protecting the cobble-forming sites from the wave action of the open sea on the northwest.

In a stratigraphic section the cobble belt will not only mark the trend of an ancient sheltered shoreline, but will pinpoint the exact position of the shoreline; that is, the intertidal zone. Similar conglomerates and scattered cobbles have been observed in sediments from early Paleozoic to Cenozoic age in the southeastern United States. These occurrences should be examined in outcrops and well cores to determine their distribution pattern and thus, perhaps, to locate precisely ancient strandlines with a likelihood of adjacent seaward arches and/or barrier bars in conjunction with petroleum exploration.

A beltlike expanse is probable for the cobble conglomerate between the Big and Irondale seams of the Red Mountain Formation, although exposures in mines and outcrops are insufficient to prove conclusively such a distribution. Likewise, the maximum width of the conglomerate downdip on the east limb of the anticline has not been determined, although the width is at least 2 mi locally, as deduced from the presence of the cobbles at site 6, approximately 2 mi downdip from the other sampling sites near the crest of Red Mountain (Fig. 1).

During Irondale-Big seam deposition a low arch evidently extended from the vicinity of Bessemer northeastward continuously, at least as far as Irondale; the crest of the arch coincided with the present crest of the Birmingham anticlinorium (Fig. 17). A sound, or lagoonal, type of environment, southeast of the arch, separated the latter from a more extensive land area 8-12 mi farther southeast. The crest of the arch may have been emergent during deposition of the Irondale seam; as a minimum, the arch had risen sufficiently by the time of conglomerate deposition that part of the southeast flank was within the range of tidal fluctuations. Although the distance between high- and low-tide lines may have been as much as 2 mi, it is just as likely that the arch continued to rise during cobble deposition so that the intertidal zone shifted southeastward. Longshore currents on the soundward (southeast) side of the arch probably were caused by tidal fluctuations and produced the southwest-oriented foreset bedding of the conglomerate matrix.

Tectonic Control

One concept of the mode of development of Appalachian Valley and Ridge province structural features—the thin-skin concept—is that the structures are primarily of *décollement* nature, formed independent of the basement.

One of the criteria used to support the thin-skin concept, the stripping of sedimentary layers from the basement and their independent folding, is an apparent lack of evidence, such as variations of sedimentary thickness and facies from anticlinal crest to synclinal trough, that highs and

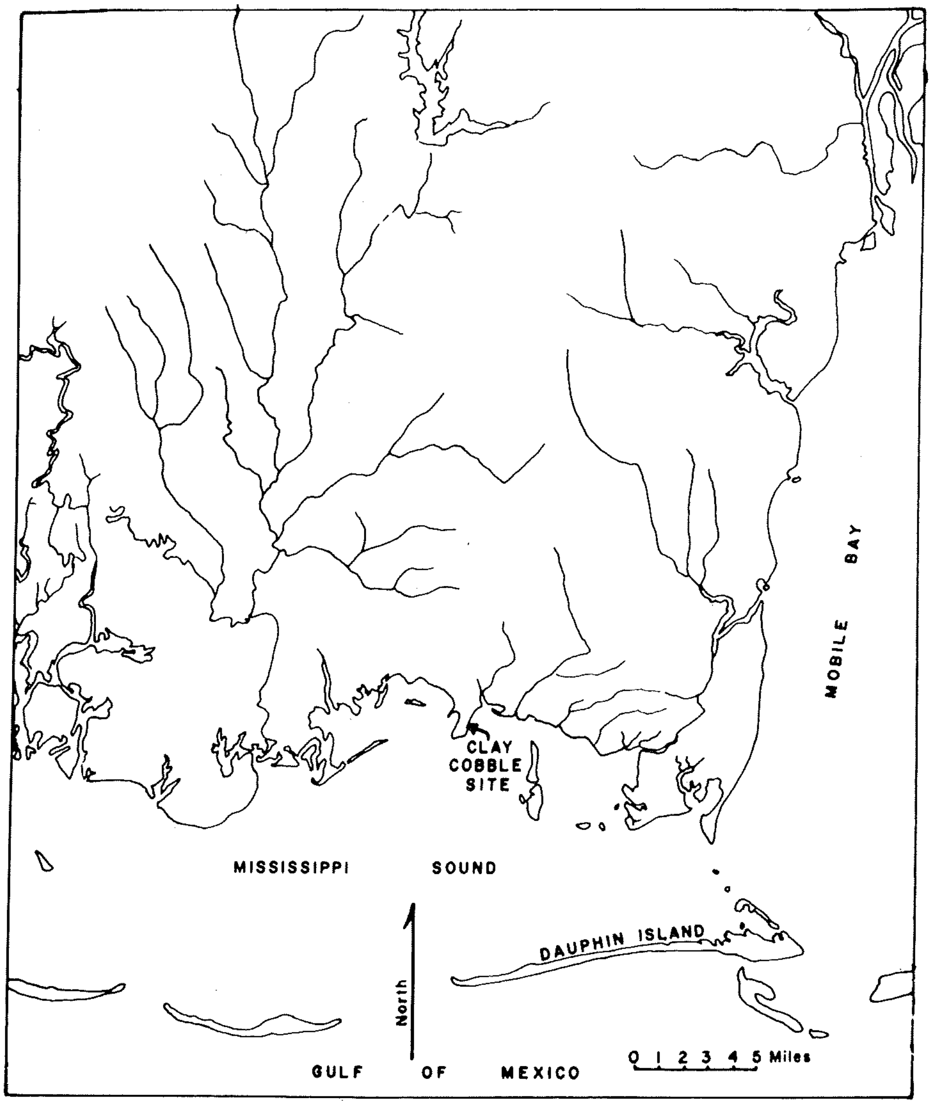

Fig. 11—Map showing clay-cobble site on north shore of Mississippi Sound.

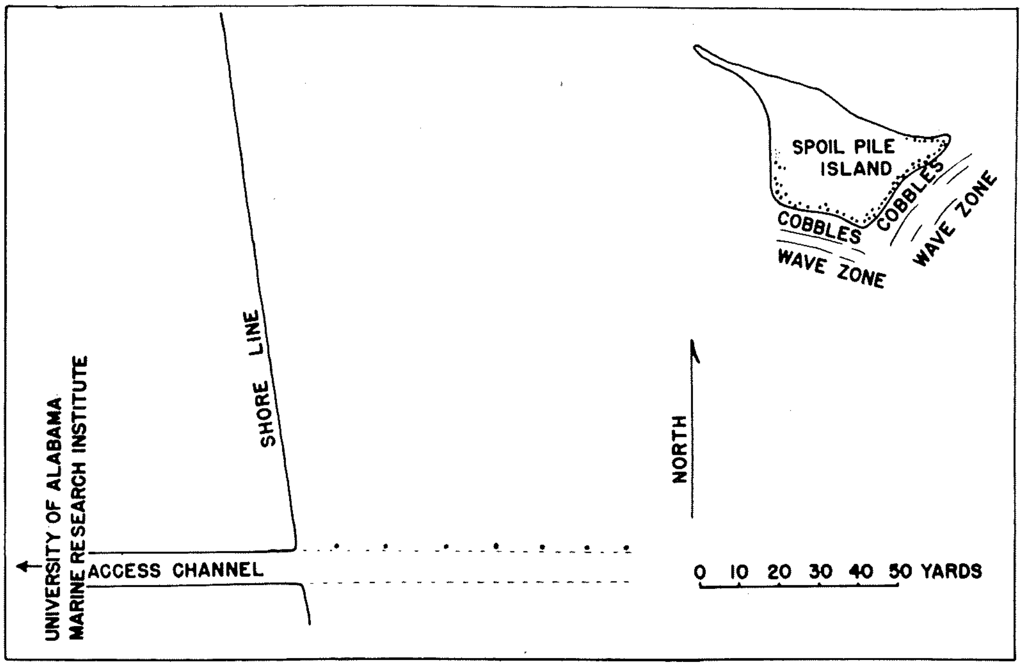

FIG. 12—Map of spoil-pile island and environs, showing relation of wave direction to cobble distribution.

lows coinciding with present structures existed while the sediments were being deposited.

An opposed concept, the thick-skin concept, is that shifting basement blocks were the controlling elements in the development of these structural features. The more extreme proponents of the thick-skin concept hold that almost any of the described Appalachian Valley and Ridge province structures could have developed by contemporaneous deformation of sediment deposited over shifting basement blocks. Evidence of contemporaneous tectonic activity, such as sedimentary thickness variations, sedimentary facies trends paralleling present structural trends, and folds and faults developed in unconsolidated sediments at different depths, is offered by thick-skin tectonic hypothesists as an indication of basement involvement.

Strata involved in folding of the Birmingham anticlinorium range in age from Cambrian to Pennsylvanian. The Red Mountain conglomerates, marking the site of a linear intertidal zone several miles from the nearest mainland on the southeast, indicate that a structural high of sufficient magnitude to provide a sheltered environment from the open sea on the northwest existed at the site of the Birmingham anticlinorium. Therefore the Birmingham anticlinorium commenced development at least as early as Silurian time. The existence of *décollements* as major features of Appalachian structures has been amply demonstrated. Nevertheless, where evidence at the site of a major positive fold indicates that uplift was occurring intermittently early in the history of deposition of the sediments involved in the folding, the possibility of basement involvement in the development of that structure should be considered.

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FIG. 13—View of spoil-pile island on north shore of Mississippi Sound, looking west.

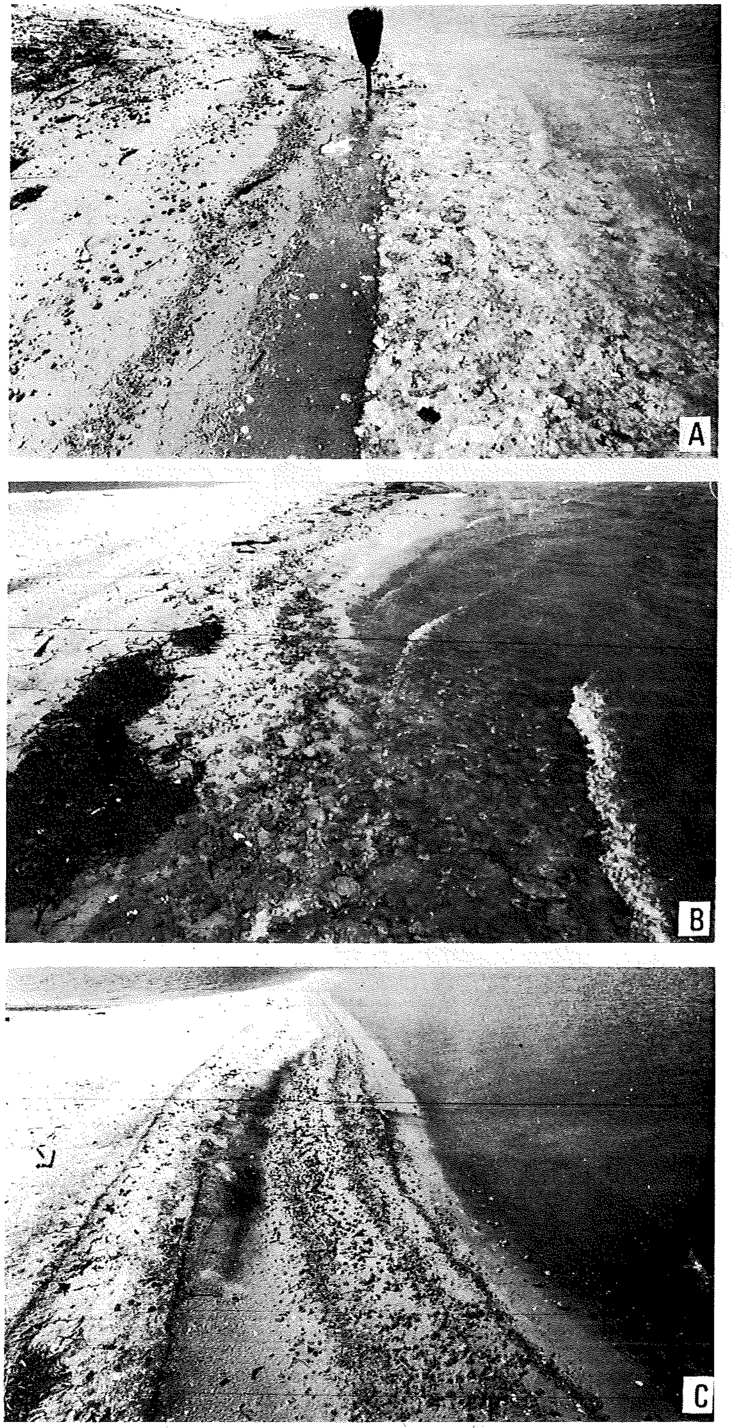

FIG. 14—**A.** Silty clay blanket, partly submerged, surrounding spoil-pile island. **B.** Clay-cobble belt fringing soundward side of island. **C.** Belts of clay cobbles decreasing in size and abundance northwestward toward mainland.

FIG. 15—Close-up of clay cobbles.

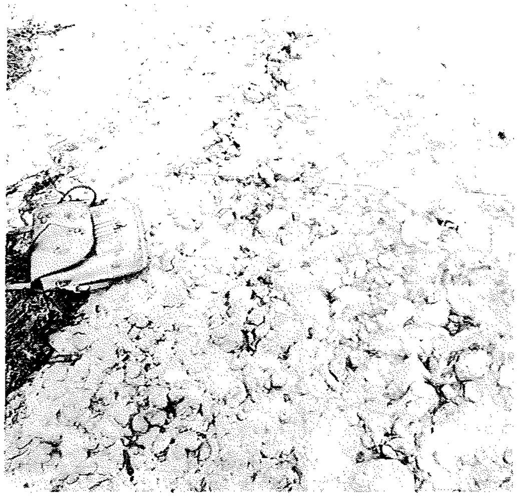

FIG. 16—Clay cobbles, shaped in place while still part of clay blanket.

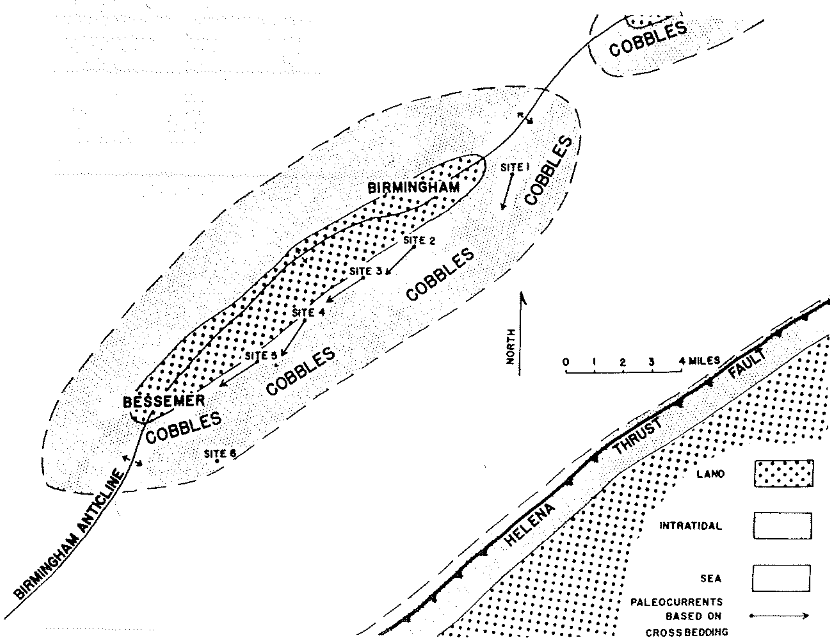

FIG. 17—Paleogeographic map of Birmingham-Bessemer region during Red Mountain Formation conglomerate deposition. Arrows at sites 1-5 show paleocurrent directions based on crossbedding studies. Present structural features (main anticlinal axis of Birmingham anticlinorium and Helena thrust fault, southeast of which Red Mountain Formation is absent) have been superimposed to emphasize relation between structure and paleogeography.

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