

GEOLOGY OF THE
BEACON HILL-COLOSSAL CAVE
AREA, PIMA COUNTY, ARIZONA

by

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Date

Section 2
Section 3
Section 4
References Cited

Page
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
34

TABLE OF CONTENTS

	Page
Abstract	iii
Introduction	1
Location of Area	1
Size of the Area	1
Purpose of Investigation	4
Method of Investigation	4
Acknowledgements	4
Geography	5
Structural Relationships of the Sedimentary and Igneous Rocks	7
General Stratigraphy	8
Sedimentary Rocks	9
Cambrian System	9
Bolsa quartzite	9
Abrigo formation	11
Mississippian System	16
Escabrosa limestone	16
Tertiary and Quaternary Systems	17
Tertiary (?) sandstone	17
Tertiary (?) red breccia	18
Tertiary (?) alluvium	19
Quaternary alluvium	20
Igneous Rocks	21
Rincon granite	21
Diabase	22
Altered peridotite	23
Structure	25
Geologic History	27
Pre-Cambrian time	27
Paleozoic	27
Mesozoic and Cenozoic times	28
Measured Sections	29
Section 1	29
Section 2	30
Section 3	31
Section 4	32
References Cited	34

ILLUSTRATIONS

	Page
Plate	
1. Geologic map of the Beacon Hill-Colossal Cave area , in pocket	
2. Cross-section through Beacon Hill-Colossal Cave area in pocket	
3. Index map showing location of the Beacon Hill-Colossal Cave area	2
4. A panoramic view of the area looking towards south and west	3
5. Fig. 1. The thick shale of lower member of the Abrigo formation	13
Fig. 2. A small fold in the lower member of the Abrigo .	13
6. Fig. 1. The quartzite member of the Abrigo formation .	14
Fig. 2. The cliff-forming Escabrosa limestone	14

INTRODUCTION

Location of Area

Colossal Cave, which lies in the northwest corner of the area, is twenty-nine miles southwest of Tucson, Arizona, and is easily accessible by two routes. The easier of the two is via U. S. Route 80 to Vail, turning north onto a good graded road leading to Colossal Cave; the more scenic route is via Broadway and the Old Spanish Trail which passes by Sahuaro National Monument. 32° North Latitude is about three miles north of the area and $110^{\circ}, 40'$ West Longitude passes through the area. The area of study is at the southern end of the Rincon Mountains and could conceivably be called part of the foothills. The area includes parts of Sections 1, 2, 11, and 12 of T.16S., R.17E. and is included in the Tucson, Arizona, Quadrangle published by the United States Geological Survey.

Size of the Area

The area is roughly one and a quarter miles square. The southern boundary is coincident with a graded road which leads to Colossal Cave; the western boundary runs along the western base of a series of hills; the northern boundary runs along the northern base of these same hills and extends east to just north of Colossal Cave; and the eastern boundary runs just east of Colossal Cave southward to the wash coming from Mountain Spring Canyon, then along the wash to a point just north of the Charles C. Day Ranch where the boundary goes east so as to exclude the ranch from the area.

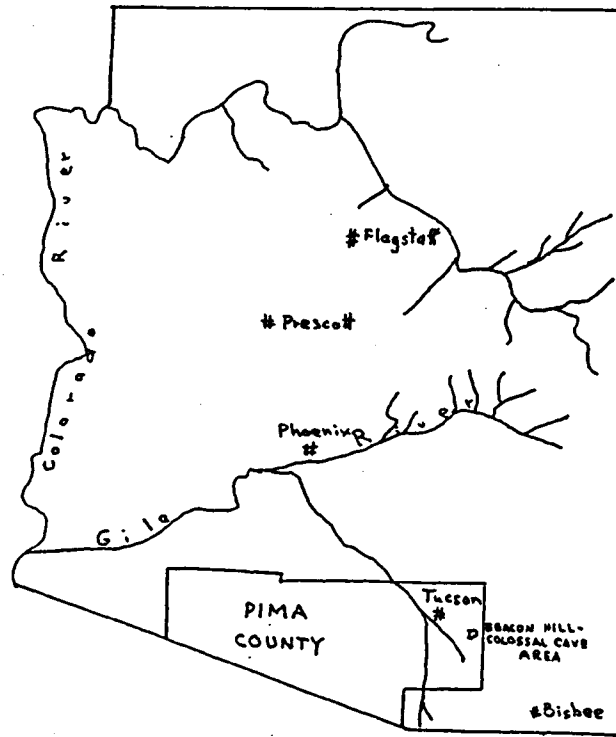


Plate 3. Index map showing location of the Beacon Hill-Colossal Cave area.

PLATE 4. A panoramic view of the area looking towards south and west. The high hill on the left is Quartzite Ridge, and the high hill on the right is Beacon Hill. In the foreground is the parking lot for Colossal Cave.



PLATE 4

Purpose of Investigation

The work was undertaken in order to fulfill partly the requirements for a degree of Master of Science at the University of Arizona. It is also hoped that the information will help in piecing together the complex geology of southeastern Arizona. No previous detailed study has ever been made except possibly by field classes from the University.

Method of Investigation

The geology was plotted on aerial photographs and transferred to a topographic map (scale: 1:6000) made by students of field courses. Brunton compass and cloth tape were used to measure sections and to obtain information in regard to structure. "Walking the outcrop" was difficult because much of the area is covered by detrital material from the Bolsa quartzite.

Laboratory work included microscopic investigation of a number of thin sections of representative rock types.

The field and laboratory work was done during the winter and spring of 1957.

Acknowledgements

The writer is grateful to the management of Colossal Cave and to Charles C. Day for granting me permission to study the area. Mr. John F. Sulik helped in the field when it was necessary to have more than one person. Special thanks are due to Dr. John Lance under whose direction this thesis was written, and to Dr. D. L. Bryant who furnished information on stratigraphy and paleontology.

GEOGRAPHY

The relief of the area is about 700 feet ranging from below 3400 feet to more than 4000 feet. The topography consists of a series of hills made of resistant sedimentary rocks lying above less resistant igneous and sedimentary rocks and alluvial material. The hills have been designated Beacon Hill (the highest and the one having a beacon at the top), Quartzite Ridge (an elongate ridge which is capped by quartzite and lies in the southeast corner of the area), and Hill 22 (so designated by students in field courses). The remainder of the hills have not been named.

The climate is semi-arid to arid and has an average annual rainfall of about eleven inches. Many small washes drain the area, but only during the torrential rains characteristic of the climate do any of the washes carry water. These washes drain into Pantano Wash which runs into the Santa Cruz River flowing into the Gila River.

Desert vegetation such as sahuaro, prickly pear, ocotillo, palo verde, and mesquite is common. The animal life consists of small reptiles, rodents, birds, and insects. Some deer and javelina can sometimes be seen.

Rock exposures are common but detrital quartzite covers much of the area.

The area has no economic importance besides Colossal Cave and cattle grazing at present and appears to have little more possi-

bility. Some prospects pits were made for uranium around 1952, but the amount of uranium was of such small value that no work was done past the prospecting stage.

STRUCTURAL RELATIONSHIPS OF THE SEDIMENTARY AND IGNEOUS ROCKS

The dominant feature of the area is a block of Paleozoic sediments thrust over quartz monzonite of either Late Cretaceous or Early Tertiary age. A diabase dike-sill associated with the thrust has been intruded into the thrust block; apophyses of the dike have also intruded along the thrust plane.

The Paleozoic sediments are overlain by a thin layer of quartz monzonite. The quartz monzonite is intruded by a diabase dike-sill which has been intruded into the thrust block; apophyses of the dike have also intruded along the thrust plane.

The quartz monzonite is intruded by a diabase dike-sill which has been intruded into the thrust block; apophyses of the dike have also intruded along the thrust plane. The Paleozoic sediments are overlain by a thin layer of quartz monzonite. The quartz monzonite is intruded by a diabase dike-sill which has been intruded into the thrust block; apophyses of the dike have also intruded along the thrust plane.

GENERAL STRATIGRAPHY

Sedimentary rocks of the area are confined to the Cambrian, Mississippian, Tertiary (?), and Quaternary. Cambrian Bolsa quartzite and Abrigo formation represent the greatest thickness of sedimentary rocks. More recent sediments, some of possible Tertiary age, are located in the topographically lower portions of the area.

Igneous rocks are restricted to intrusive bodies. Quartz monzonite surrounds most of the area and is the base that Cambrian sediments have been thrust over.

A diabase dike intrudes the Cambrian sediments and extends east and west across the area for about half a mile and probably has a maximum thickness about 600 feet. Many small apophyses extend from it and small outcrops are found throughout the area in the Abrigo, in the Bolsa, and along the contact between the quartz monzonite and the Bolsa. Between Quartzite Ridge and Beacon Hill a very dark rock composed of large crystals of hornblende forms a finger of the main dike.

SEDIMENTARY ROCKS

Cambrian System

Bolsa quartzite

The oldest known sedimentary rocks found at the Beacon Hill-Colossal Cave area are correlated on the basis of lithology and stratigraphic position with the Bolsa quartzite of Middle Cambrian age.

The Bolsa was originally described by Ransome (1904, p. 28) at Bisbee, Arizona. The section measured at Quartzite Ridge, where the greatest thickness of Bolsa appears, totals 779 feet. This abnormal thickness is likely the result of hidden structural complications (such as imbricate thrusting) not readily seen because much of the Bolsa is covered.

The Bolsa can be divided into three members on the basis of lithology and its weathering characteristics: the lower member which is composed of coarser-grained sediments and is generally covered, the middle member which forms the top of Quartzite Ridge and Beacon Hill and is composed of a fine-grained quartzite with many large quartz pebbles, and the upper member which is more shaly and is also generally covered.

The contact of the Bolsa quartzite with the quartz monzonite below it is generally covered but lithologic variations of the Bolsa can be noted at different locations along the contact. At Quartzite Ridge the Bolsa at the contact is a conglomerate made of white angular pebbles of quartz up to three inches across (similar to

lower member mentioned above), while at Beacon Hill it is generally a fine-grained purple quartzite with many larger rounded pebbles of quartz up to one-quarter inch in diameter (similar to middle member mentioned above). The contact of the middle member with the quartz monzonite is topographically higher than the contact of the lower member with the quartz monzonite (Plate 1). At a location between Quartzite Ridge and Beacon Hill the contact has been complicated by the intrusion of basic igneous rock. Similar complications occur in the northwestern part of the area.

The base of the lower member is a conglomerate composed of white angular pebbles of quartz up to three inches in diameter. Most of the member above the basal conglomerate is covered. The 66 feet that is exposed spottily on the south side of Quartzite Ridge is a quartzite but not as highly consolidated, thick-bedded, or competent as that of the quartzite of the middle member. Highly fractured zones filled with quartz stringers are quite prominent in the sparse outcrops. Iron and manganese mineralization has been more prevalent in this member than in the higher members. The fracturing and mineralization are used as indications that structural complications may exist that cannot be readily seen since much of this member is covered.

The middle member is found in the topographically higher portions of the area and is a highly consolidated fine-grained quartzite 155 feet thick. It has many large (up to one-quarter inch) rounded quartz pebbles throughout it. In the western part of the area below the beacon

on Beacon Hill this member of the Bolsa is in contact with the quartz monzonite. It ranges from almost white to brownish-red to purple and is quite thick-bedded, the beds ranging from two to ten feet. Banding is often found, some parallel to the bedding, some in the form of liesegang rings, some wavy, and some indicating cross-bedding. The banding is usually formed of finely alternating purple and white bands and is found most often where the larger quartz pebbles are not present.

The upper member of the formation is again not as consolidated, thick-bedded, and competent as the middle member. Exposures again are less common, but this is also because the slope of the hill is almost parallel to the dip of the quartzite. The best exposures of most of the upper member of the Bolsa is in a wash running parallel to the road west of Quartzite Ridge. Green shaly beds increase towards the top of the Bolsa. Also it becomes more calcareous with calcite and caliche often found in fractures. The color is generally darker ranging between brownish-red, purple, and green.

Abrigo formation

The Abrigo formation apparently lies conformably on the Bolsa quartzite. The Abrigo formation was defined by Ransome (1904, pp. 30-33) to include all of the Middle and Upper Cambrian deposits above the Bolsa quartzite. The total measured section in the Beacon Hill-Colossal Cave area is 732 feet, but this thickness is not considered

accurate because it was not possible to measure the entire thickness in one location and correlation of different locations was not easily done. Structural complications also hindered attempts to measure a more exact section.

Three fairly distinct lithologies are noted in the Abrigo formation and are divided as follows: 1) the lower shale and limestone member; 2) the middle quartzite member; and 3) the upper limestone member.

The lower 513 feet is composed of alternating shales and limestones. The shales are mostly green, though some are pink, are very thin-bedded, have crinkled bedding surfaces, and have a high mica and calcite (both in stringers and as cement) content. The thickest single section of shale is at the very top of the lowest member and has a thickness of 147 feet (Plate 5, Fig. 1).

The only fossils the writer was able to find in this member were fucoids of unknown origin and a cranidium of a trilobite even though the shale has been well exposed by the construction of a small earth dam north of Hill 22 (Plate 1).

The limestones in the lower member are generally thin and interbedded with shales. The thickness of the limestones are generally one or two feet, but immediately below the thick (147 feet) section of shale is a larger limestone layer. It measures sixteen feet just southwest of the dam and twenty-four feet in the wash running parallel to the road east of Quartzite Ridge. A large cavern, partially natural



Fig. 1. The thick shale of lower member of the Abrigo formation. Just west of dam.



Fig. 2. A small fold in the lower member of the Abrigo. Just east of dam.



Fig. 1. The quartzite member of the Abrigo formation. Just east of dam.



Fig. 2. The cliff-forming Escabrosa limestone. Northwest of Colossal Cave about 500 feet.

and partially man-made, is found in this limestone about 300 yards east of the road. This cavern is now used as a dump by Colossal Cave.

Three different types of limestones occur up through the member. In the lower portions the limestone is usually brown and very silty, which is indicative of the transition from the Bolsa quartzite below. Towards the center the limestone is generally green and has some of the lithologic characteristics of the green shale surrounding it. Higher the limestone becomes purer and is gray. An example is the thick limestone described above. The silt and shale are no longer as prevalent as they are lower down.

The lower member of the Abrigo is very incompetent and many small folds and breaks are present. An example is shown in Plate 5, Fig. 2. This is probably the result of forces applied when the thrusting occurred.

The middle quartzite member measures 44 feet and is gray to dark gray, medium- to coarse-grained, and is highly indurated. Bedding planes are from nine to fifteen inches apart and has some thin shale beds similar to those found in the lower member of the Abrigo. The amount of calcium carbonate is very high and only the higher amount of quartz keeps it from being a limestone. The resistant character of the quartzite is shown by the steep cliff it forms in the side of the wash near the dam (Plate 6, Fig. 1).

The upper member of the Abrigo is a coarse-grained limestone that becomes siltier towards the top. The silt is concentrated in zones parallel to the bedding. It is generally pink with some gray limestone. Because of its thin-bedded character it is not resistant enough to form cliffs in this area but it does form a steep slope. Dicellomus, a small brachiopod of Upper Cambrian age, was found towards the top of the exposed section.

Above the limestone the section is covered by debris from Bolsa quartzite and more recent deposits.

Stoyanow (1936, pp.466-467, 476) has described sections in the Santa Catalina Mountains and in the Whetstone Mountains similar to the Abrigo formation described here in the Beacon Hill-Colossal Cave area.

Mississippian System

Escabrosa limestone

The Escabrosa limestone (Plate 6, Fig. 2) is of Early Mississippian age and the youngest of the known Paleozoic sediments in the area. Only the lower (149 feet) portion of the formation occurs in the area since the northern boundary is arbitrarily placed at Colossal Cave.

The limestone is generally quite hard with the thick-bedded (4 to 6 feet) portions forming the only distinct cliffs in the area studied by the writer. The thinner-bedded (3 to 18 inches) limestones form steep slopes and benches between the cliff-forming limestones.

The textures vary from very fine- to coarse-grained. Chert is common but is most prevalent in the coarse-grained limestones. Numerous calcite stringers are found at the highest portion of the measured section, and local heavy concentrations of iron oxide are common about sixty feet up from the base of the section.

Fossils are quite common in the Escabrosa outside of the area, but none were found here. Guides at Colossal Cave (which has been formed in the Escabrosa by ground water activity) have informed the writer that they also have never seen any fossils here.

Tertiary and Quaternary Systems

Tertiary (?) sandstone

In the east central portion of the area a very friable, silty, calcareous sandstone is present. It varies from gray to light green to light purple and has a composition of about sixty percent quartz with silt and calcium carbonate holding the rounded, well-sorted quartz grains loosely together. It is quite thin-bedded and has an average strike about N10E and dips 35W. It has a maximum thickness of not over ten feet.

Brennan (1957, personal communication) has studied the Pantano formation (Miocene) farther to the south and indicates that the sandstone described above may be one of the members of the Pantano.

Tertiary (?) red breccia

In the eastern part of the area a formation of doubtful age and origin occurs lying apparently conformably on the Tertiary (?) sandstone in at least one place. It ranges from a very coarse breccia to a very siliceous rock. The breccia is composed of large angular to sub-rounded fragments (up to six inches across) of quartz monzonite, limestone, quartzite, and shales, and has zones that are fairly well-sorted and some that are not. The matrix is a fine-grained silica rich in iron oxide and has feldspar associated with it. The breccia fragments are absent in some zones and these zones are composed entirely of the fine-grained material. The unweathered portion is very hard and when fractured it breaks evenly across the larger fragments and matrix alike. The weathered rock becomes soft and crumbles easily. Manganese oxide stains the surface in many places.

In the southern portion the rock described above is associated with a very siliceous white rock capping the small hills. Chert is abundant in the lower portions of the siliceous rock and appears along the zone between the breccia and siliceous rock.

The bedding is poor and fracturing, such as joints, are irregular. It appears, however, that the dip of the formation is to the east at about 30 degrees, and the strike of the joints are approximately north-south and east-west.

This formation is probably associated with a chert formation that is found generally farther north. A 300-foot cliff of this material occurs above Colossal Cave to the northeast.

Clement Acker, who has studied this formation, informs the writer that he believes that it has been thrust from either the west or north and is derived from chert that has been forced from the cherty limestones prevalent in the region, possibly from the Horquilla formation, since a fusulinid of possible Pennsylvanian age has been found in a chert pebble.

The chert was probably the origin of the silica used to cement the breccia fragments together, and the siliceous rock was probably primarily formed from this same silica.

The age of the formation is considered to be post-Cretaceous because it has fragments of the quartz monzonite which was intruded sometime during Late Cretaceous or Early Tertiary (Moore & Tolman, 1945 (?), p. 11).

Tertiary (?) alluvium

Alluvium covers much of the area between Beacon Hill and Colossal Cave and forms small hills cut by many small washes. Two stages of deposition of alluvial material has taken place, one of Tertiary (?) age and the other of Quaternary age.

The earlier alluvium is a coarse conglomerate composed almost entirely of sub-rounded quartz monzonite fragments that give the formation a white color when viewed from a distance. Other constituents include some fragments of schist (which probably came from higher in the Rincon Mountains), limestone, and quartzite. Calcium carbonate cement is prevalent and accounts for a small amount of consolidation

in the formation. The almost complete lack of detrital material from the thrust sediments around it indicates that the formation was laid down before the thrusting occurred.

The formation dips in various directions ranging from almost north to almost south but always toward the west with dips ranging from 18 to 28 degrees and averaging about 20 degrees. The dip is considered to be the result of deposition and not because of any structural complications. The structural and stratigraphic relations to the thrust are not entirely clear.

Quaternary alluvium

Quaternary alluvium truncates the older alluvium and has a maximum thickness of only a few feet. Its most common occurrence is in washes cut into the older alluvium, and now it has been cut through to expose the older alluvium in many of the deeper washes.

It consists of fragments of all the older formations and is dark red in contrast to the white of the older Tertiary (?) alluvium. It has a conglomeratic texture made up of various shaped fragments. No consolidation has taken place.

IGNEOUS ROCKS

Rincon granite

Surrounding the area and forming a base for the thrustsed Paleozoic sediments is a quartz monzonite that has been termed erroneously the Rincon granite. Moore and Tolman (1945 (?), p. 11) have cited it as being either of Late Cretaceous or Early Tertiary age because it has intruded Cretaceous sediments elsewhere.

It is composed of:

feldspar: orthoclase (35%), oligoclase-albite (25%)—
subhedral to euhedral, large (up to 0.3 in.) but
varying size crystals, up to 25% has been altered
to sericite. (This presence of sericite makes it
difficult to distinguish the orthoclase from the
plagioclase. Consequently the percentage of
plagioclase may be higher.)

quartz (30%): subhedral, different size grains but smaller
(up to 0.1 in.) than the feldspar crystals.

hornblende (7%): euhedral, different size crystals (up to
0.2 in.).

biotite (2%): euhedral, associated with hornblende

opaque (magnetite) (1%): subhedral, generally small grains,
associated with hornblende.

Most of the quartz monzonite is coarse-grained (feldspar up to 0.3 inch across), but at certain small localities it is much finer-grained suggesting more than one phase of intrusion.

It weathers quite easily and can be broken easily by hand. It was difficult to find a specimen that was hard enough to make a thin section.

Diabase

Diabase intrusions in the forms of dikes and sills are prevalent in the area. The major intrusion is believed to be a dike because of the nature of fractures since no lineation could be found that could be used to determine the direction of intrusion. Fractures that were interpreted to be shear joints indicate that the intrusion was from the west and has a present dip of 70W (strike: N20W). It cuts through the Bolsa and the Abrigo and was definitely later than the Abrigo as shown by interfingering of Abrigo limestone and diabase.

Small diabase outcrops occur throughout the area, especially along the contact of the Bolsa and the quartz monzonite.

These small occurrences of diabase can be given a simple explanation, as follows: As the thrust moved over the quartz monzonite below it, tension fractures occurred through which the molten diabase flowed. A large tension fracture is now marked by the presence of the major dike. The fluid would naturally flow through the easiest channels, and the thrust plane would be one of these, thus accounting for the many outcrops found along the contact of the Bolsa and quartz monzonite.

This would make the time of intrusion about the same time or later than the thrusting.

The diabase is fine- to medium-grained, very dark green, and has the following constituents:

feldspar (70%): thin euhedral laths interlocking with one another, heavily altered to sericite.

hornblende (10%): euhedral, forms the largest crystals (up to 0.1 in.), edges altering to biotite.

biotite (10%): euhedral, associated with hornblende.

opaque (magnetite) (8%): euhedral, generally small crystals (but up to 0.1 in.), associated with hornblende.

quartz (2%): subhedral, small crystals.

The weathered diabase is easily crumbled and becomes earthy in appearance. It is not very resistant and therefore does not stand out in relief. Metamorphism was very slight along the contacts.

Altered peridotite

In one apophyse of the dike a differentiation of minerals occurred so that an altered peridotite has been formed in the diabase. It is very hard, black rock that is much more resistant than the diabase. The weathered rock looks like a pile of black popcorn; many large boulders are lying on the surface.

The constituents reflect the minerals of the Bowen reaction series and are as follows:

opaque (magnetite) (13%): subhedral to anhedral, both large (0.1 inch) and small crystals.

olivine (trace): euhedral

augite (15%): anhedral, localized, smaller crystals.

hornblende (40%): euhedral, large crystals (up to 1 in.),
edges altering to biotite.

biotite (30%): euhedral, strongly associated with hornblende.

chlorite (trace): euhedral

orthoclase (trace): subhedral to anhedral

quartz (2%): subhedral to anhedral, small grains.

STRUCTURE

A huge thrust of Paleozoic sediments over the quartz monzonite is the primary structure of the area and is probably the cause of the lesser structure which consists of large faults and fractures in the competent beds and smaller faults and fractures accompanied by small folds in the incompetent beds. The actual contact between the quartz monzonite and the overlying Bolsa quartzite is covered in almost all places. However, the sinuous pattern of the contact and the probable Late Cretaceous or Early Tertiary age of the quartz monzonite strongly suggests that the Cambrian sediments here were thrust into their present position.

Faults in the Bolsa quartzite have strikes that vary between N30-50E except one that has a strike of N40W. The Abrigo has many folds whose axes strike in the same direction as the majority of the faults in the Bolsa, and also has a few that have strikes similar to that of the N40W fault in the Bolsa. The axial plane of some of these folds are fractured and some displacement is noted in one. Joints are in three directions approximately N50W, N-S, N50W.

The Cambrian beds dip to the northeast (strike: N50W) in the eastern part of the area and swing around to the northeast so that they dip more to the east (strike: N20W) forming a broad syncline plunging northeast. The interpretation of this structure in relation to the thrusting is not certain; the folding may have occurred before or during the thrusting. If the syncline was formed

during thrusting, it might be explained by uniform forces acting from the southeast, or by forces from the south with the greater amount applied on the western side of the thrust block. Since trends of faults, folds, and joints vary, not enough evidence can be found to support any of the arguments substantially.

A second thrust in the eastern part of the area is possibly represented by a red breccia thought to be a thrust breccia derived from chert in the Pennsylvanian Horquilla formation. Not enough information from the area could be obtained to account for its presence here. This formation is discussed more thoroughly under **SEDIMENTARY ROCKS.**

GEOLOGIC HISTORY

Pre-Cambrian time

During most of pre-Cambrian time southeastern Arizona lay within a basin of deposition. The extent of sedimentation is unknown, but widespread outcrops of the Pinal schist and Apache group (neither of which appears in the Beacon Hill-Colossal Cave area) suggest that deposition occurred over nearly all of southeastern Arizona. At the close of pre-Cambrian time the land was uplifted and no deposition occurred again until Middle Cambrian time.

Paleozoic time

The stratigraphic hiatus between pre-Cambrian and the Middle Cambrian Bolsa quartzite is marked by an angular unconformity. The source of material for the Bolsa is not known. The succession from coarse clastic sediments in the Bolsa quartzite to the shales and limestones of the Abrigo formation indicate a transgressive sea. Also the succession of sediments probably indicate that the land mass supplying the sediments was wearing down to a surface of low relief. The alternating succession of shales and limestones indicates a sea that was shallow and somewhat oscillatory.

The Ordovician, Silurian, and Devonian are missing in the area, but since the Devonian Martin limestone is found a half mile east of Colossal Cave, it is concluded that the Martin is missing from the Beacon Hill-Colossal Cave area either because of structural complications or because it has been covered by later sediments. The

Ordovician and Silurian are not known in southeastern Arizona. The limestones of Devonian through Permian times show that southeastern Arizona was generally covered by seas. Small transgressions occurred during the early Pennsylvanian when conglomerates and shales were laid down and in the Permian when quartzites and gypsum were laid down.

Only part of the Mississippian Escabrosa is exposed in the Beacon Hill-Colossal Cave area. The remainder of the Escabrosa and the Pennsylvanian and Permian sediments are found farther north.

Mesozoic and Cenozoic times

No Mesozoic sediments are found in the area, but the quartz monzonite forming the base was intruded either in Late Cretaceous or Early Tertiary (Laramide) time. After this the area underwent erosion for a long time since it would take a great amount of time to uncover the quartz monzonite intrusion and to form the quartz monzonite alluvium.

Sometime in the Tertiary (?) large forces were being exerted that resulted in thrusts, one of which is the Beacon Hill-Colossal Cave area. About the same time, or shortly after, the diabase dike-sill complex was intruded into and under the thrust. Possibly about the same time the red thrust breccia was formed. The area since then has undergone continual erosion.

MEASURED SECTIONS

Section 1

Section was measured up the left side of the wash 500 feet northwest of Colossal Cave.

Mississippian:

	Escabrosa limestone: 149 feet.	Feet
	Top of cliff, additional Escabrosa not measured above.	
8.	Limestone: dark gray, fine-grained, weathers very dark gray, extremely cherty, numerous calcite stringers, forms cliff	20
7.	Limestone: dark gray, fine-grained, less chert than in 8, very thick-bedded, forms base of cliff	4
6.	Covered	12
5.	Limestone: light gray, very fine-grained, cherty but less than usual, forms cliff, very thick-bedded (4') . .	18
4.	Limestone: gray to white, cherty, forms bench between cliffs	7
3.	Limestone: gray to white, cherty, very thick-bedded (6'), forms cliff	23
2.	Limestone: dark gray, fairly coarse-grained, cherty, localized hematite concentrations, medium-bedded (3-18"), forms steeper slopes	15
1.	Covered, but dark gray, cherty limestone in float	50
	Bottom of wash.	

Section 2

Section was measured in wash at north base of Hill 22 near dam.

Cambrian:

	Feet
Abrigo formation: 488 feet.	
Covered	
6. Limestone: generally pink but grading to gray in zones, coarse-grained, thin-bedded, becomes more silty towards top, silt is concentrated more in zones and constitutes up to 40% of total composition, forms steep slope, <u>Dicellomus</u> found near top	175
5. Quartzite: dark gray to brown, medium-grained, calcareous (up to 50% limestone), highly indurated, medium-bedded (9-15"), some thin shale layers, forms steep side of wash	44
4. Shale: green and some purple, micaceous, crinkled bedding surfaces, some very thin ($\frac{1}{4}$ ") limestone lenses, calcareous, the upper 10' have been deformed by small folding and fracturing, exposed because of small earth dam having been dug here, fucoids of unknown origin, cranidium of trilobite found near top	147
3. Limestone: blue-gray, fine-grained, highly indurated, more shaly here than to the east	16
2. Interbedded limestones, siltstones, and shales: green to pink, limestones similar to 3, shales similar to 4, siltstones gradational between the two	39
1. Interbedded shales and siltstones: similar to 2 minus the limestone	67

Diabase

Section 3

Section was measured in wash running parallel to road east of Quartzite Ridge.

Cambrian:

	Feet
Abrigo formation: 468 feet.	
Distorted shales and limestones	
19. Interbedded limestones and shales: limestones—blue-gray to brown, fine- to medium-grained, highly indurated, silty; shales—green, micaceous, very thin-bedded, crinkled bedding surfaces. Correlated to 4 of Section 2	104
18. Limestone: blue-gray, fine-grained, highly indurated, cavern formed in this limestone 300 yds. to the east . .	24
17. Interbedded shale and limestone: similar to 19	116
16. Limestone: similar to 18	19
15. Shale: similar to 19 but with more limestone that is green, thin-bedded, and shaly	51
14. Limestone: similar to 18	1
13. Interbedded shale and limestone: shale—similar to 14; limestone—gray at top, similar to 18; green, thin-bedded, and shaly at center; brown, silty to very fine-grained sandy near base	108
12. Limestone: brown, very silty, medium-bedded (9-12"), prominent vertical jointing striking N15E and N70W, forms steep side of wash in a bend of the wash	6
11. Interbedded green and brown limestones: green—thin-bedded and shaly; brown—similar to 12	6
10. Covered, but probably similar to 19	15
9. Limestone: similar to 12	1
8. Shale: green, micaceous, crinkled bedding surfaces, 1" parting of beds, some green limestones	14

	Feet
7. Limestone: green (gray on some fresh surfaces), silty, thin-bedded	1
6. Limestone: brown, silty to very fine sandy, grading from Bolsa	4
Conformable and gradational contact with the Bolsa.	
Bolsa quartzite: 133 feet.	
5. Quartzite: purple to greenish-gray, medium to fine-grained, calcium carbonate in fractures, iron oxide on weathered surfaces	15
4. Quartzite: similar to 5 but with the addition of some green shaly members similar to the green shale found in the Abrigo	26
3. Quartzite: pale orange-brown to purple, very fine-grained, thin red and green shale interbeds, iron oxide prevalent	35
2. Quartzite: similar to 3 but banding is prominent	32
1. Covered	25
Diabase	

Section 4

Section was measured across the highest part of Quartzite Ridge.

Cambrian:

Bolsa quartzite: 779 feet.

Covered

14. Quartzite: gray to white, fine-grained, thick-bedded . .	66
13. Covered	50
12. Quartzite: gray, but red on weathered surface, not as highly indurated as other quartzite in the Bolsa, generally coarse-grained but a very fine-grained matrix is present, many white elliptical aggregates of fine-grained quartz grains	10

11.	Quartzite: white, fine-grained, some purple banding parallel to bedding, some cross-bedding noted, white rounded quartz pebbles up to $\frac{1}{2}$ " across are prevalent throughout but usually absent where banding occurs, thick-bedded (2-10'), forms the top of Quartzite Ridge .	155
10.	Quartzite: purple, medium-grained, finely banded, thick-bedded (3-6'), heavy manganese oxide staining, slightly friable	2
9.	Covered	20
8.	Conglomerate: purple, large (up to $\frac{1}{4}$ " white, fairly rounded quartz pebbles in manganese oxide-rich silica cement, medium-bedded (6-12")	12
7.	Covered; structural complications may result here that gives the great thickness of total Bolsa	250
6.	Quartzite: red (some very dark green), fine-grained, medium-bedded (1'), iron oxide and manganese oxide staining, quartz stringers	6
5.	Quartzite: gray, fine-grained, not as highly consolidated as other quartzite in the Bolsa, some bedding 6-12" apart, high manganese oxide content (up to 10%) usually restricted to long ovate forms parallel to bedding, some iron oxide staining, quartz stringers very common in fracture zone	60
4.	Covered; here also structural complications may have resulted, as in 7	110
3.	Quartzite: light gray to dark gray, coarse-grained, some large (up to $\frac{1}{2}$ " white quartz pebbles	8
2.	Quartzite: white to light gray, medium-grained, some large (up to $\frac{1}{2}$ " white quartz pebbles	15
1.	Conglomerate: white, angular quartz pebbles up to 3" across, iron oxide and manganese oxide spots, massive . .	15

Thrust fault.

Quartz monzonite.

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CROSS-SECTION A - A'

SAME SCALE AND LEGEND AS PLATE 1

GEOLOGIC MAP OF THE BEACON HILL-COLOSSAL CAVE AREA

LEGEND

SEDIMENTARY ROCKS

QUATERNARY-TERTIARY	QTal ALLUVIUM
	T(?)rb RED BRECCIA
	T(?)ss SANDSTONE
MISSISSIPPIAN	Ce ESCABROSA LIMESTONE
CAMBRIAN	Ca ABRIGO FORMATION
	Cb BOLSA QUARTZITE

IGNEOUS ROCKS

CRETACEOUS-TERTIARY	KTrg RINCON GRANITE
	Td DIABASE
	Tap ALTERED PERIDOTITE

SYMBOLS

	STRIKES AND DIPS
	FAULTS
	FORMATION CONTACTS
	ROADS
	DAM

750 0 500 1000 1500 FEET

CONTOUR INTERVAL 100 FEET



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