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CYCLIC SEDIMENTATION IN THE PERMIAN SYSTEM OF TASMANIA

By

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(WITH TWO TEXT FIGURES)

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ABSTRACT

Detailed stratigraphic sections of the Berriedale Limestone were measured in five quarries in the Derwent Valley. In these are thin beds of volcanic ash which is now altered to montmorillonite clay. These clay beds provide a means of precise correlation within the Berriedale. A study of the insoluble residues of the limestone beds indicates rhythmic and cyclic deposition and suggests deposition in relatively deep water. Glacial erratics seem to be concentrated in or near the clastic layers. The Berriedale cycles are probably Leonard in age.

Cyclic sedimentation of another type occurs in the lower Woodbridge Formation near Clifton Beach.

INTRODUCTION

During the winter of 1953 the writer measured in detail a number of stratigraphic sections of Permian strata. Five of these sections are of the Berriedale Limestone which is well exposed in quarries in the Derwent Valley north-west of Hobart. One is a section of the basal Woodbridge formation north of Clifton Beach. These exceptional exposures provide detailed information that can be obtained at few localities in the State. This paper is an interpretation of the sedimentary cycles that occur in these strata.

The writer wishes to thank the staff of the Geology Department of the University of Tasmania for the many courtesies shown to him during his stay. Special thanks are due to Mr. M. R. Banks of the Geology Department and to Mr. G. E. Hale of the Tasmanian Museum who shared freely their knowledge of the Permian and who guided the writer in the field on many occasions. Some of the insoluble residue studies were made at the Museum under the direction of Mr. Hale. The writer wishes to thank Dr. Harold Wanless and Mr. F. W. Booker, who were kind enough to read the manuscript.

BERRIEDALE LIMESTONE

Cyclic sediments: The Berriedale Limestone which was named for exposures near the village of Berriedale (Lewis, 1946), is widespread in eastern Tasmania (Banks in Hill, 1955). Typically it consists of beds of marine limestone interbedded with mudstone. Glacial erratics are scattered through the formation. It becomes less limy toward the south and south-east, where it interfingers with the Grange mudstone (Banks in Hill, 1955).

This paper deals primarily with the exposures in quarries in the Derwent Valley; however, excellent exposures occur on Maria Island and in the vicinity of St. Marys. At these two localities the lithology of the Berriedale is much like that in the Derwent Valley, but the writer was unable to make a bed for bed correlation.

No detailed section of the type Berriedale Limestone has been published; therefore a section is appended to this paper. This section was measured by the writer in Weily Quarry near Glenorchy. Although this is not the type locality of the Berriedale, it is only about three miles from the type and is a longer and better exposure.

Columnar sections of the Berriedale Limestone shown in Fig. 1 do not represent the total thickness of the formation, but illustrate only those portions well enough exposed to allow a detailed study to be made. Sections were measured in the following quarry faces:

1. Weily Quarry, at reservoir, about 2 miles south west of Glenorchy.
2. Abandoned quarry on Old Collinsvale Road, about 3 miles west of Berriedale.
3. Abandoned quarry about 1·5 miles airline west of Granton.
4. Rathbones Quarry about 3 miles west of Granton.
5. Abandoned quarry on east flank of Mt. Dromedary near station of Bundella.

In each columnar section it may be seen that (*a*) beds of impure limestone alternate with calcareous mudstone, (*b*) beds of limestone tend to be thicker than beds of mudstone, (*c*) limestone is more resistant to weathering. The repetition of such bedding indicates cyclic sedimentation.

In all sections the writer found thin beds of devitrified volcanic ash which has been altered to montmorillonite. These beds are associated with the mudstone layers. At least 13 beds of altered ash have been found in the Glenorchy section. Some of them can be traced through several sections. The most persistent bed is about an inch thick and is here referred to as the Lower Marker bed. Some 15 feet above this is another persistent layer called the Upper Marker bed. By means of these two markers, bed for bed correlation between sections is possible (Fig. 1). Although some beds of volcanic ash may be present in the Berriedale Limestone on Maria Island, it is not possible at the present time to correlate them with any of the beds in the Derwent Valley. No evidence of ash beds was found in the detailed section near St. Marys.

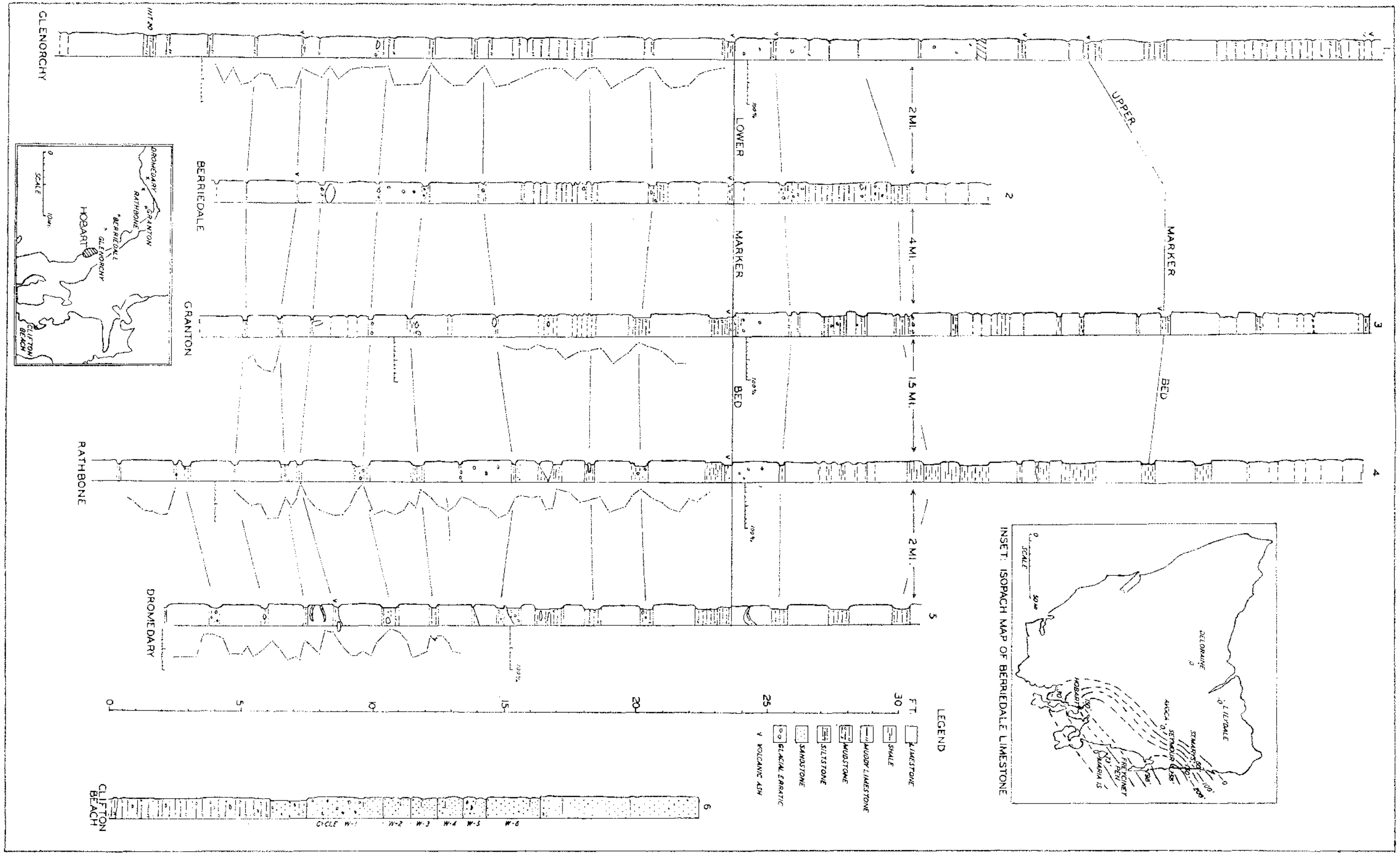

FIG. 1.—Columnar sections of Permian strata. Sections 1-5, parts of the Berriedale Limestone. Section 6, part of the lower Woodbridge Formation. The percentage of solubles is shown in the graph at the right of the section.

Pebbles and boulders composed of quartz, igneous and metamorphic rocks are scattered throughout the Berriedale. The largest observed is a granite boulder more than a foot in diameter in the quarry west of Berriedale. Figure 1 shows that the fragments tend to be more numerous in or near the mudstone layers. Concentrations of erratics occur in several cycles below the Lower Marker bed, namely, the top of cycle 4, the top of cycle 5, the top of cycle 6 and the base of cycle 6. It is assumed that these fragments are glacial erratics that have been rafted to their present position by icebergs; however, only one erratic out of several hundred examined by the writer showed striations.

In Fig. 1 solubility graphs are shown on the right side of several of the columnar sections. Series of chip samples provided data for these graphs. Samples of about 20 grams each were taken at about 4-inch intervals up the quarry face. Each sample was weighed dry, digested in acid, and the insoluble residue weighed dry. The per cent soluble matter thus obtained for each sample is plotted on the right side

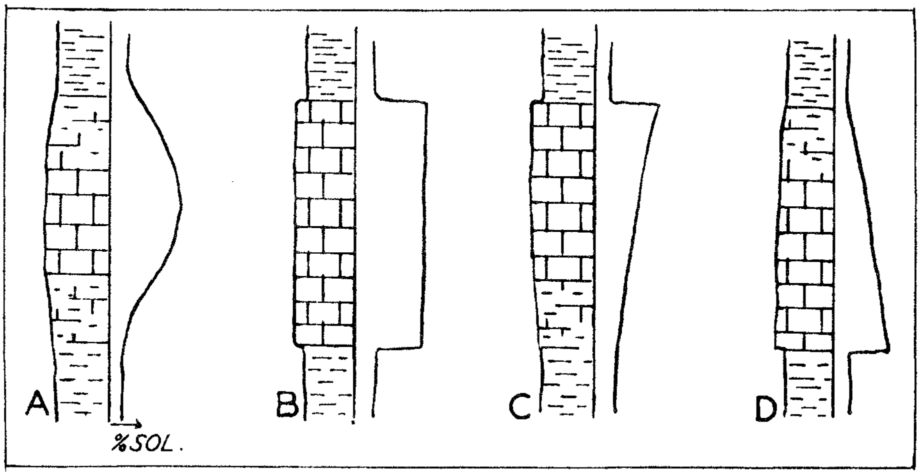

FIG. 2.—Four types of solubility curves in limestone beds.

A. Gradational contacts with beds above and below, typical of Berriedale Limestone, suggesting: relatively deep or quiet water below wave base, uniform cyclic fluctuation of sea level or supply of sediment.

B. Non-gradational contacts with beds above and below, typical of Warsaw formation (Lower Carboniferous) in St. Louis County, Missouri, suggesting: control by diastems, rapid vertical fluctuations of wave base, cycles interupted.

C. Gradational contact below, non-gradational above, a hypothetical case suggesting: a gradual increase in depth of water, decrease in clastic sediment, or chemical precipitation of limestone due to bacterial activity in underlying shale (Shrock, 1948, p. 31).

D. Gradational contact above, non-gradational below, a hypothetical case suggesting: gradual decrease in depth of water, increase in supply of clastic sediment.

of the columnar section. Although samples were not taken from all parts of each section, the solubility curve shows a repetitive pattern in each section and the gross features of it can be traced from one section to another. The typical cycle shows a maximum of mudstone deposition followed by a gradual decrease in clastic material until a maximum of limestone deposition is reached. This is followed by a gradual increase in mudstone deposition to the beginning of the next cycle. The greatest purity of the limestone beds occurs at or slightly above the middle in most beds. The graph seems to indicate that sedimentation is both cyclic and rhythmic (Moore, 1950, p. 6).

Four types of solubility curves that are possible for a limestone bed are shown in Fig. 2. Each curve suggests a different set of conditions under which the bed was deposited. The solubility curve that is characteristic of the Berriedale Limestone shows a gradual increase in insolubles at the top and bottom of the bed (Fig. 2A). This condition indicates continuous deposition with variation in the volume of clastic sediment. The lack of rapid changes in lithology between beds suggests deposition in relatively deep water unaffected by violent wave action. Angularity and freshness of mineral grains in the Permian was interpreted by Banks (1952, p. 72) as evidence of quiet water deposition. The presence of large numbers of productid brachiopods, pectenoid pelecypods and bryozoa in the Berriedale does not militate against the theory of moderately deep water. Barrell (1916, p. 803) states that marine mudstone seems to give the most favourable conditions for continuous record, and is well adapted especially where alternating with lime or silt beds to give a basis for the analysis of rhythms. In this respect the Berriedale Limestone seems to be an ideal formation for studying rhythms; however, the problem is complicated by three different types of sedimentation—glacial and sedimentary cycles and volcanic ash deposits.

The cause of rhythmic and cyclic sedimentation in the Berriedale is obscure. If it is due to eustatic changes in sea level, the problem is not unlike that of cyclothems in many parts of the world. The fact that thin beds of volcanic ash are associated with the mudstone beds and that commonly glacial erratics occur in or close to the mudstone beds suggests that all three may be related genetically.

Several hypotheses suggest themselves: (*a*) Volcanic outbursts in areas of glaciation may have increased glacial melting and thereby increased clastic deposition. (*b*) Volcanism may have increased precipitation on land and thereby increased discharge of streams and glacial flow. (*c*) The vertical movements of the sea floor may have resulted from earth movements associated with volcanism, in which case the presence of glacial deposits may have been entirely fortuitous. (*d*) Changes in the rate of sedimentation may reflect the waxing and waning of glaciers, in which case the presence of volcanic deposits may have been fortuitous.

Lithofacies. The isopach map (Inset, Fig. 1) indicates that the Berriedale Limestone thickens toward the north-east. Southward and south-eastward it interfingers with calcareous mudstone. The greatest thickness of limestone seems to be in the No. 4 Bore at Seymour (Voisey, 1938). Some of the generalizations on this map are borne out by more detailed information from the Berriedale in the Derwent Valley.

Detailed lithologic data are available for only a part of the Berriedale at all five localities. Table 1 shows the total thickness of each type of rock in each section for the 8 cycles below the Lower Marker bed.

TABLE 1

Section	Sandstone	Siltstone	Mudstone	Shale	Limestone
Glenorchy	....	....	1′ 9″	8″	17′ 6″
Berriedale	....	....	1′ 9″	4½″	17′ 4″
Granton	....	4″	1′ 3″	1′ 8″	17′ 1″
Rathbone	2″	5″	2″	3′ 2″	14′ 10″
Dromedary	....	6″	4′ 11″	1″	14′

These thicknesses indicate that the amount of clastic material increases toward the west. A greater number of beds bearing glacial erratics occur in the Dromedary and Granton sections, suggesting that the source of pebbles may have been to the west or north-west. More beds of volcanic ash occur in the Glenorchy section which may be significant as to source direction, or may indicate only deeper water. In the Glenorchy, Granton and Rathbone columnar sections lithologic data are available for the strata between the Lower Marker and Upper Marker beds. These also indicate that the amount of clastic sediment increases toward the west. Although comparative figures on lithofacies are available for only a portion of the Berriedale Limestone, they appear to be significant and consistent for this geographical area.

Age: The waxing and waning of ice sheets in the Southern Hemisphere has been suggested by Wanless and Shepard (1936, p. 1193) as a possible cause of cyclothems in Upper Carboniferous and Lower Permian strata in the United States. Moore (1950, p. 16), on the other hand, cites evidence to the contrary.

Although the Berriedale cycles may be related to fluctuations of glaciers, it is doubtful that they can be correlated with any known sedimentary cycles in the United States. Faunal studies of the Berriedale by Banks (1955) indicate that it contains *Lyroporella, Streblotrypa* and *Fenestella chapmani* which are also found in the Callytharra Limestone of the Carnarvon Basin in Western Australia. The Berriedale also contains *Taeniothaerus subquadratus* and *Neospirifer* cf. *moosakhailensis* which occur in the Wandagee Formation of the same area in Western Australia. According to Teichert (1949, p. 35) the Callytharra Limestone is very early Artinskian in age. Teichert (1942, p. 222) states that the Wandagee, although stratigraphically higher than the Callytharra, is also Artinskian. If these correlations are correct the Berriedale Limestone is approximately Leonard in age, and, therefore, younger than any of the well-known coal cyclothems in the United States.

WOODBRIDGE FORMATION

The Woodbridge Glacial Formation (Voisey, 1938) is younger than the Berriedale Limestone. Typically it consists of sparingly fossiliferous mudstone and sandstone with numerous glacial erratics. It thins toward the north-east, being about 200 feet thick in the Derwent Valley, about 55 feet thick on Freycinet Peninsula, about 25 feet thick in the No. 4 Bore at Seymour (Voisey, 1938), and 3 feet thick at Elephant Pass near St. Marys. In the three localities last mentioned it is glauconitic.

At least six sedimentary cycles occur in the basal Woodbridge Formation at the north end of Clifton Beach near Cape Deslac (Fig. 1). The lowest cycle begins in the cliff 104 feet above sea-level. The section above the sixth cycle is not exposed. Each cycle consists of two members. In the lowest cycle the lower member is a conglomerate of angular and subangular fragments of mudstone, porphyry and quartzite up to 8 inches in diameter. The lower members of the other cycles consist of coarse-grained quartz sandstone. The upper members of all cycles are finer-grained sandstone. In four of the six cycles the upper member is thinner than the lower. The lower member of one cycle contains a few fossils indicating that these sediments are marine.

These cycles may be a modification of the deltaic cyclothems of Wanless and Shepard (1936), and may have developed on a mildly unstable shelf near a source of glacial outwash. The members of the Woodbridge cycles are much thinner than any of those illustrated by Wanless and Shepard.

Good exposures of this particular part of the Woodbridge were not seen elsewhere in this area, therefore the areal extent of these cyclothems is not known. They do not seem to be present in the section along the New Norfolk road west of Rathbone quarry.

Sedimentary cycles have been recognized in the Tomago Coal Measures in New South Wales (Booker, et al, 1954, p. 147). It is doubtful that the Woodbridge cycles are related in age to those of the Tomago; however, they may be related genetically.

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APPENDIX

Detailed section of a part of the Berriedale Limestone in Weily's Quarry about 3 miles south of Glenorchy.

		Ft.	In.
Top of section:			
Grange Mudstone—			
65.	Mudstone weathers grayish-white, beds one foot to 18 inches thick, exposed in top of quarry	15	0
Berriedale Limestone—			
64.	Shale dusky yellow, very silty, laminated, perhaps metabentonite	0	0¼
63.	Mudstone weathers grayish-white, discontinuous shale band in middle of interval, a thin green shale band 8 inches above base; pectens, fenestellids	0	10
62.	Shale dusky yellow, laminated, waxy feel, metabentonite	0	4
61.	Mudstone gray, perhaps slightly limy, beds about 1 foot thick, prominent bedding plane 1 foot below top	4	6
60.	Limestone medium dark gray, massive, rounded fragment of schist 8 inches diameter near base, *Strophalosia*	3	1
59.	Mudstone olive gray, massive, numerous fenestellids give impression of laminae	0	8
58.	Shale dusky yellow, silty, perhaps metabentonite	0	0¼
57.	Limestone medium dark gray, muddy streaks, broken into thirds by two bedding planes; globular *Strophalosia* or *Taeniothaerus* in middle of interval	2	6
56.	Shale dusky yellow, silty, perhaps metabentonite	0	0¼
55.	Mudstone olive gray, slightly calcareous	0	9
54.	Shale dusky yellow, waxy feel, metabentonite	0	1
53.	Mudstone olive gray, slightly calcareous, one bed, laminae due to fenestellids	2	8
52.	Shale dusky yellow, soft	0	0¼
51.	Limestone medium dark gray, slightly muddy streaks, discontinuous shale (metabentonite?) 4 inches above base; *Strophalosia*, large *Stenopora*	1	8
50.	Shale dusky yellow, thin-bedded, soft, probably metabentonite	0	0¼
49.	Mudstone olive gray, calcareous streaks due to many fenestellids, silty, poorly bedded, bedding planes at 12, 23, 44, 56 inches above base	5	7
48.	Limestone medium dark gray, many muddy streaks and lenses, laminations due to fenestellids	2	0
47.	Mudstone olive gray, calcareous streaks, laminations due to fenestellids	0	10
	Overlying layers generally muddier than those below.		
46.	Limestone medium dark gray, slightly muddy, massive	1	8
45.	Mudstone olive gray, non-calcareous, laminations due to fenestellids	0	4
44.	Shale dusky yellow, waxy feel, thinly laminated, metabentonite. Upper marker bed	0	4
43.	Limestone medium gray, slightly muddy, upper 6 inches muddier, massive, prominent bedding plane 19 inches above base. Floor of upper bench	2	1
42.	Shale dusky yellow and dark greenish-gray, waxy feel, metabentonite	0	1
41.	Limestone medium dark gray, muddy near top, massive, small encrusting bryozoa	1	5
40.	Dolomite medium dark gray, muddy, laminae due to fenestellids	0	5
39.	Limestone medium dark gray, muddy and sandy streaks, scattered small pebbles, small black muddy nodules, containing bryozoa; many *Stenopora*, fenestellids, few spiriferids	2	1
38.	Mudstone dark gray, discontinuous bed	0	1
37.	Limestone medium dark gray, fetid odor, massive, but thin breaks of limy mudstone 11, 20, 33 inches above base; fenestellids, a few brachiopods	4	3

		Ft.	In.
36.	Limestone medium dark gray, slightly muddy, fetid odor, scattered rounded pebbles up to 2 inches diameter, many *Stenopora*	1	4
35.	Shale and mudstone interbedded; shale dusky yellow, perhaps metabentonite; mudstone gray	0	1
34.	Limestone medium dark gray, massive, slightly muddy, top 2 inches muddier, scattered small dark rounded pebbles; large *Stenopora* near middle of the bed	1	6
33.	Shale dusky yellow, thin-bedded, waxy feel, top silty, base without bedding, metabentonite. Lower marker bed	0	5
32.	Limestone medium gray, massive, scattered spiriferids and *Strophalosias* mainly smaller than in sections to the north; upper 2 inches muddier with abundant fenestellids	2	9
31.	Limestone dark gray with mudstone breaks, fenestellids, *Trigonotreta, Stenopora*	0	4
30.	Limestone medium dark gray, nearly a coquina at top of small *Strophalosia* and other small shell fragments	2	0
29.	Limestone medium dark gray, many thin muddy breaks; about one-third calcareous mudstone on fresh surface	2	5
28.	Limestone medium dark gray, muddy, one bed	1	11
27.	Limestone similar to Int. 25; thin muddy breaks in upper 3 inches	1	7
26.	Mudstone dark gray, thin-bedded, calcareous	0	3
25.	Limestone medium dark gray, slightly muddy, muddy breaks 3, 5 inches above base; numerous brachiopods	1	9
24.	Limestone medium dark gray, slightly muddy, massive; a 1-inch soft muddy streak 7 inches above base; coarse angular quartz and rock grains; subangular fragments of quartzite 5 inches diameter at top. Seems to be a thin metabentonite here	3	0
23.	Shale dusky yellow, waxy feel, thin-bedded, mixed with limestone, metabentonite	0	1
22.	Limestone medium dark gray, finely crystalline, 2-inch darker, more shaley band at base and 21 inches above; many spiriferids, *Eurydesma, Strophalosia,* composed of white calcite	3	7
21.	Limestone medium dark gray, muddy, fetid odor, 2-inch muddier band 5 inches above base; many fossils. Forms floor of 3rd bench in quarry, Cross small fault	2	0
20.	Mudstone dark gray, very limy, weathers brown at top; many *Strophalosia*	0	5
19.	Limestone dark grey, massive, fossiliferous beds with thin shale breaks at 21, 29, 36, 40, 43, 49, 53 inches above base. Large *Stenopora*, but spiriferids, *Strophalosia* smaller than farther north	7	4
18.	Mudstone dark gray, thin poor bedding, calcareous streaks; fenestellids, *Strophalosia*	0	4
17.	Limestone dark gray, many dark muddy streaks, many angular to rounded pebbles of quartzite, limestone and metamorphic rocks up to 4 inches diameter; many *Strophalosia* and spiriferids	2	9
16.	Limestone dark gray, very muddy, fetid odor, scattered *Stenopora, Strophalosia;* prominent bedding plane at top and bottom	0	5
15.	Limestone medium dark gray, dark muddy areas with brachiopods, fetid odor, scattered pebbles up to 2 inches diameter	1	8
14.	Limestone medium dark gray, thin bands and lenses of dark carbonaceous shale; bedding planes at 27, 46, 50 inches above base; many spiriferids, *Strophalosia* composed of white calcite, weathers cavernous, relatively pure bed. Floor of 2nd bench in quarry	4	6
13.	Shale and limestone; shale dusky yellow in two thin beds at top and bottom; limestone dark gray, muddy 1½ to 2 inches thick	0	3
12.	Limestone medium dark gray, weathers light gray, muddy, massive, prominent bedding planes at base and 32, 37, 42 inches above base, scattered subangular fragments of quartzite, dark metamorphic rocks up to 3 inches diameter	6	0

		Ft.	In.
11.	Limestone medium gray, massive, irregular muddy lenses a few mm. thick, streaks of sandstone, prominent bedding planes at base and 23, 49, 59 inches above base, subangular pebbles of quartzite and black argillite up to 1 inch in diameter especially in upper 1 inch	6	5
10.	Mudstone olive gray, silty, many fenestellids. Floor of quarry	0	2
9.	Shale dusky yellow, thin bedded, some may be slightly waxy, mainly silty, hard; weathers white like metabentonite	0	2
8.	Mudstone and limestone interbedded; mudstone olive gray, calcareous, silty, many fenestellids. Basal 1 inch contains flakes of metabentonite. Top of bed is three feet below access road	9	0
7.	Mudstone olive gray, hard, spiriferids and many fenestellids	2	0
6.	Mudstone olive gray, scattered angular quartz fragments, small clams and ostracodes	1	0
5.	Mudstone olive gray, silty, many fenestellids	1	8
4.	Shale dusky yellow, hard, silty	0	3
3.	Limestone olive gray, muddy, scattered sand grains, and lumps of gray mudstone	0	8
2.	Mudstone dark gray, weathers brown, slightly calcareous, numerous grains and pockets of quartz sand; pectens, spiriferids, small bryozoa, *Dielasma*	2	0
1.	Sandstone medium gray, muddy with limy spots, subangular pebbles up to 2 inches diameter; basal 1 foot partly covered	4	0
	Covered by dump.		