Chapter 3 Jurassic: Great Estuarine Series

General description

The following table gives details of the succession in the Great Estuarine Series in Skye and Raasay.

N. Skye (after Anderson 1948)	S.-E. Skye (Wedd in Peach and others 1910, p. 121) Hudson 1962, p. 150)	Raasay (Lee 1920; Hudson 1962, p. 147)
Belemnite Sands 25 ft Contain a marine fauna and appear to be of Kellaways age	Black Sandstone	Absent?
Upper `*Ostrea*' Beds 35 ft Probably a lenticular shell-bed of Cornbrash age	Absent	Absent?
Mottled Clays 43 ft No fauna but plant fragments. Possibly of Cornbrash age	Blue shaly marl up to 30–40 ft	Sandy limestone
Ostracod Limestones 90 ft	Taludina' scotica Limestones 37 ft Shales and thin limestones 40 ft?	Limestones and Shales
Lower 'Ostrea' Beds 60 ft	'*Ostrea*' *hebridica* Beds 17 ft	'Ostrea' *hebridica* Beds ?
Concretionary Sandstones 240 ft	'Cyrena' Limestones 70ft	Calcareous Sandstones at least 120 ft
'*Estheria*' Shales 120 ft	'Cyrena' Shales 200 ft	'Cyrena' Shales and Sandstones 100 ft
White Sandstone 30–100 ft	White Sandstone 50 ft	White Sandstone 50 ft
Oil-Shale 10 ft	Oil-Shale 10 ft	Oil-Shale 8–10 ft

In Skye as in Scotland generally, the Great Oolite epoch was one during which estuarine conditions prevailed; fully marine conditions were re-established in the Cornbrash. The deposits laid down during this period were originally known as the Loch Staffin Beds after Staffin Bay where they were examined by Murchison (1829) who believed them to be fresh-water sediments of Wealden or Purbeck age. This name can, however, only be applied to the uppermost beds i.e. the Upper '*Ostrea*' Beds and Belemnite Sands which are exposed in Staffin Bay and, as Anderson and Cox (1948) have shown, contain a fauna of predominantly marine species.

In 1878, Judd introduced the term Great Estuarine Series, by which name these have been known ever since.

In Raasay where the series is badly exposed Lee (1920) was unable to recognize the Skye subdivisions and followed H. B. Woodward in thinking that only the lower part of the Great Estuarine Series was present in that island. There is reason to believe however, (Anderson in Richey and others, 1961) that the succession in Raasay is not very different from that in N. Skye.

In 1934 MacGregor described the upper part of the Concretionary Sandstones as exposed near Rubha Garbhaig. More recently Hudson (1962, 1963, 1963a) has studied the stratigraphy and fauna of the Great Estuarine Series in the Hebrides including Skye.

In the Great Estuarine Series of North Skye a great variety of sediments is represented, comprising sandstones, frequently with calcareous doggers, limestones, cementstones, marls and shales. Cyclic sedimentation is evident throughout. The *Garantiana* Clay at the top of the Inferior Oolite passes upwards into a bituminous shale at the base of the Great Estuarine Series. The lowest 7 ft form a true oil-shale whilst the uppermost 3 ft are sandy. Northwards the oil-shale passes into a black sandstone. In Skye this bed has only yielded Protomiodon and plants, but according to Forsyth (1959), in Raasay a quarter of a mile northeast of Storav's Grave it contains a marine fauna. The White Sandstone overlies the Oil-Shale.

Wedd (in Peach and others 1910, p. 117), in Strathaird grouped this sandstone with the Inferior Oolite on the grounds of its similarity to the sandstones below and because of its gradual downward passage into the shale. Lee, however, (1920) included the Oil-Shale and White Sandstone in the Great Estuarine Series. Since no diagnostic fossils have yet been

found in either stratum it is not possible to settle the question. Wedd's argument that there may have been some oscillation between marine and estuarine conditions in the highest Inferior Oolite has a degree of support from the field evidence. Certainly the three major sedimentary changes in this part of the succession are: 1. Upper Lias Shales 2. *Garantiana* Clay 3. '*Estheria*' Shales.

Above the White Sandstone the '*Estheria*' Shales consist of numerous shalelimestone-sandstone rhythms. The Concretionary Sandstones provide five repetitions of a shale-sandstone rhythm, the Ostracod Limestones show a coarser grained repetition of the '*Estheria*' Shales and finally the Mottled Clays-Belemnite Sands cycle occurs before the oncoming of the characteristic shale-calcareous mudstone rhythm of the Oxford Clay—Corallian—Kimmeridge Clay sequence (Figure 4).

Though fossils are frequently abundant, they are usually badly preserved and the number of species represented is few. Except for the two uppermost subdivisions the freshwater and brackish-water faunas appear to be the same throughout so that no zonal subdivision seems possible unless by the use of ostracods.

Many sections of the Great Estuarine Series are recorded in detail on the six-inch maps and also by Anderson (1948) and Anderson and Cox (1948). In Anderson's paper are sketch-maps giving details of the occurrence of particular beds and especially the development of algal horizons in the '*Estheria*' Shales, in the Lower '*Ostrea*' Beds and in the Mottled Clays.

Details

Oil-shale

The Oil-shale reaches sea-level at Inver Tote, where there are two black sandstones separated by 2 in of shale. The upper Sandstone is the lateral development of the Oil-shale and the lower, which contains marine fossils, of the underlying *Garantiana* Clay of the Inferior Oolite. The clay and shale are eroded back to form a conspicuous ledge between the Bearreraig Grit and the White Sandstone above.

Lee (1920, p. 56) thought that southwards from Portree the Oil-shale became an impure coal, but the coal (lignite) seen at Camastianavaig is in the Tertiary plant beds at the base of the Palagonite Tuffs and the Oil-shale is cut out by the Tertiary overstep before Camastianavaig is reached.

White Sandstone

The White Sandstone in Strathaird is slightly calcareous and includes a few seams of quartz pebbles. In North Skye it is poorly exposed but at Port a'Bhata is a soft white, somewhat greenish, often waterlogged sandstone composed of angular quartz grains and virtually without cement. At Portree and again at Holm it is 100 ft thick (Figure 5) but thins northwards gradually until where last seen at Inver Tote it is only 30 ft thick (Figure 6). Southwards, it is rapidly overstepped by the Palagonite Tuffs which at Camastianavaig rest on the lower beds of the Inferior Oolite.

The upper two thirds of the White Sandstone is well seen in Rigg Burn.

Section in Rigg Burn

	feet
Dolerite Sill	2½
'*Estheria*' Shales, black shale	9
White Sandstone, soft sandstone	10
Shaly sandstone	10
Sandstone with doggers	10
Hard, irony sandstone	1½
Dark, sandy, calcareous shale	5
Hard, irony sandstone	1½
Dark, sandy calcareous shales	5

Irregular, irony, calcareous sandstone	2½
Black, sandy, calcareous shales	20
Hard sandstone causing waterfall	2
Shaly sandstone with hard bands	

'*Estheria*' Shales

The White Sandstone is succeeded abruptly by dark calcareous shales. The junction is best seen in the Lealt River where, in the lower gorge, these shales are seen to rest on a coarse grit 2 ft 8 in thick at the top of the White Sandstone. Here they are thin papery shales with thin dark limestone ribs, bands of 'beef ' (fibrous calcium carbonate) and layers of crushed shells usually *Neomiodon* ('Cyrena') spp. Some bedding planes are literally covered with a multitude of *Euestheria* carapaces, or, less frequently, with ostracods.

In 1948 Anderson and Cox described the lamellibranch *Mytilus* (*Praemytilus*) *strathairdensis* from the '*Estheria*' Shales in Strathaird but the species was not known from Northern Skye. Since then J. D. Hudson (1963) has recorded it in the *Mytilus* Shales (the lower part of the '*Estheria*' Shales of the present memoir) of Eigg and Raasay. From the '*Estheria*' Shales (upper part of the '*Estheria*' Shales of the present memoir) of Skye, Raasay and Eigg, Hudson (1963) has also recorded *Cuspidaria ibbetsoni* (Morris), *Modiolus* cf. *imbricatus* (J. de C. Sowerby), *Placunopsis socialis* Morris and Lycett, *Procerithium* spp., cf. *Quenstedtia* sp., *Tornus praecursor* (Tate) as well as the ubiquitous *Euestheria murchisonae* (Jones) and *Liostrea hebridica* (Forbes). A few yards upstream from the road-bridge, the shales include a group of limestones rather thicker than usual. One of these, a dark brecciated bed 9 in thick, contains *Charophyte gyrogonites* and indeterminate algal growths (Anderson, 1948). Hudson (1963) has recently investigated the fauna of the 'Estheria' Shales in Eigg, Skye and Raasay and has recorded several molluscan species in addition to the *Mytilus strathairdensis* first found by Anderson in Strathaird (Anderson and Cox 1948).

Section in the Lealt River

	feet	inches
Base of Concretionary Sandstones		
15. 'Cyrena' (*Neomiodon*) shales and limestones, poorly exposed, about	20	
Gap of 90 ft—probably shales		
14. Black shale	3	
13. Dark shaly limestone		3½
12. Paper shale with *Neomiodon*	1	10
11. Dark shaly limestone		3
10. Black paper shales	2	4
9. Dark shaly limestone		2½
8. Black paper shales	2	7
7. Limestone with *Neomiodon*	1	2
6. Black shale	1	0
5. Dark brecciated limestone with cementstone pebbles and algal concretions. *Chara*		9
4. Dark shales, *Euestheria*, *Neomiodon* sp., ostracods	30	0
Dolerite sill	about 150	0
3. Dark shales with *Euestheria* and *Neomiodon* sp	21	0
Dolerite sill	7	0
2. Dark shales with *Euestheria* and *Neomiodon* sp	15	0
Dolerite sill	1 ft 6 in to 2	9

1. Dark shales with *Euestheria*	24	0
Coarse Grit, top of White Sandstone	2	8

In Trotternish the '*Estheria*' Shales are overlapped by the Tertiary lavas at Sithean Bealaich Chumhaing and are not seen south of this point until they reappear inStrathaird. To the north for just over two miles they crop out as a wide flat bench in the cliff with the White Sandstone scarp below and with a 25-ft thick dolerite sill forming a low steep bluff at the back. Exposures are few and poor but it is evident that only about 40 ft are exposed whereas at Inver Tote they are not less than 120 ft thick (Figure 6).

At the latitude of Armishader the 'Estheria' Shales outcrop turns inland under a tongue of sill and gives rise to a wide marshy flat at the southern end of Loch Leathan. They underlie the western half of the loch and again passing beneath a leaf of sill follow the cliff top northwards as far as Rigg Burn. They are exposed in two unnamed streams one ■ miles and the other 1¼ miles south of Rigg. At the most northerly of these two localities about 50 ft of shale are exposed containing a 2½-in thick '*Ostrea*' limestone, cementstones and a line of septarian nodules. A thousand yards north along the strike of the shales they are again seen in the southern tributary of Rigg Burn. Here two thin leaves of sill, the upper 1 ft 9 in and the lower 2 ft 0 in thick, cause a waterfall in the stream. They are separated by 1 ft 3 in of shale and about 3 ft of shale is exposed below them. Twenty yards further north the two leaves of sill have joined and again produce a waterfall. Black shales with many thin limestones, some composed almost entirely of *Neomiodon* shells, and layers of 'beef' are exposed at intervals in the stream above the fall.

In an unnamed stream 1000 yd north of Rigg this same leaf of sill, here about 50 ft thick and resting directly on the White Sandstone, causes another waterfall. Above it the '*Estheria*' Shales are exposed in the burn for about 500 yd. Two dykes cross this section and 150 yd to the south of the more westerly dyke about 10 ft of indurated '*Estheria*' Shales crop out below a higher leaf of the sill.

From here northwards the shales are covered by peat and boulder clay as far as the section in the Lealt River, already described.

Between Inver Tote and Port Earlish the sediments are dislocated by a plexus of faults, none with a very large throw, but sufficient to cause considerable irregularity in the outcrop. The only section of the beds lying above the sill is that seen in Lonfearn Burn but it is difficult to interpret:

Section in Lonfearn Burn

		feet	inches
'*Estheria*' Shales:	Thin hard platy shales (indurated) 70 yds upstream from waterfall	10	0
	Olivine-dolerite sill		
	Fault		
Concretionary Sandstones:	Well-bedded sandstones about	12	0
	Soft sandstone with doggers about	10	0
	Platy sandstone	10	0
	Gap in section		
	Calcareous sandstone and sandy shale	5	0
'*Estheria*' Shales:	Black shales	5	0
	Sandy *Neomiodon* limestone	1	6
	Calcareous sandstone	3	6
	Limestone and shales	2	6
	Black paper shales	4	0

Shale with hard grey *Neomiodon* limestone	5	0
Black paper shales	4	3
Hard grey limestone		6
Hard *Neomiodon* limestone and thin shales	2	0
Black paper shales	5	0
Hard limestone		1 in to 2
Black paper shales	3	0
Dolerite sills about	6	0
Neomiodon shales and shell beds	5	0
Grey shales	5	0
Sandy *Neomiodon* limestone		2 in to 10
Grey shales	3	0

The '*Estheria*' Shales disappear below sea-level just north of the Sgeir Gharbh and are not seen again in N. Trotternish.

The only other locality in N. Skye where the '*Estheria*' Shales are exposed is in the extreme west of Duirinish in the promontory lying between Oisgill Bay and Moonen Bay.

The shales are found in a faulted block which makes a platform roughly square in outline, sloping gently to the east and known as Mointeach nan Tarbh. At its south-west corner the long narrow promontory of Eist juts out to sea, on the east a shallow basin contains Loch Mor and lies at the foot of a lava scrap which rises to over 900 ft. On the south side the bay Camas nan Sithean lies between the promontory of Eist and Waterstein Head.

At the north-west in Oisgill Burn for some 300 yd upstream from the mouth about 60 ft of black shales are exposed. On the beach they can be seen resting on a leaf of sill and are indurated by it. Southwards the sediments are concealed by scree as far as Eist Fhiadhaich (Oisgill Bay). Here about 40 ft of dark grey shale with lighter calcareous bands is seen resting on sill. Southwards there is some small scale faulting and then the sill rises steeply into a high sharp rib (Figure 14). South of this again is a patch of about 25 ft of yellow, grey and dark limy shales lying almost horizontally against the plunging sill. On the eastern side of the promontory up to 40 ft of dark calcareous shales with thin bands of very fossiliferous *Neomiodon* limestone and occasional sandy beds also containing *Neomiodon*, lie between two sills and are exposed for about 400 yd before the sills come together and pinch out the sediments. Some 250 yd to the east the shales again appear resting on sill. They include several thin sills and are dipping southeastwards, finally disappearing below sea-level a little beyond An Stac at the foot of Waterstein Head.

Inland and due north of An Stac fragments of the Lower '*Ostrea*' Beds are found scattered in the landslip below the lava scarp. The base of the lavas at Waterstein Head is estimated to be at about 350 ft above sea-level so that there is ample room for a full development of the Concretionary Sandstones and the Lower '*Ostrea*' Beds above the '*Estheria*' Shales at this locality.

The abrupt transgressions of the lower leaf of the sill cause remarkable contortions in the '*Estheria*' Shales. These can be seen very well on the west side of the Eist promontory immediately to the south of the 'rib' of sill and also against a transgression of the sill on the east side also under the cliff of Mointeach nan Tarbh (Figure 14), p. 130.

Concretionary Sandstones

The Concretionary Sandstones are made up of five repetitions of the cycle, shales and limestones below, sandstone with doggers above. This sequence of cycles can be traced over the whole area though the composition of each unit may vary considerably in detail. *Neomiodon* and *Viviparus*, often very abundant, are virtually the only fossils found in this subdivision.

The most southerly section of the Concretionary Sandstones is that in Lon Druiseach 2½ miles N.N.E. of Portree, where however, only the lower beds are exposed :

Section in Lon Druiseach

	feet	inches
Cycle 2		
12. Soft sandstone with calcareous bands	14	0
Gap of 15 ft		
11. *Neomiodon* limestone		8
10. *Neomiodon* shale	2	6
9. Sandy limestone with *Neomiodon*	3	0
Cycle 1		
8. Calcareous grit with *Neomiodon*	1	4
7. Soft sandstone with calcareous bands and doggers	6	0
6. Hard calcareous sandstone with *Neomiodon*	2	6
5. Grey shale	1	0
4. Soft shaly sandstone	6	0
3. Grey shale	2	0
2. Sandy *Neomiodon* limestone	1	0
1. Sandy shale with *Neomiodon*	1	6

Eastwards the upper beds of this section are cut out by the overlap of the lavas so that in a small gully on the south side of Lon Druiseach the base of the Tertiary rests on bed 9 of the above section and in the sea-cliff, on bed 8.

In the area ½-mile west of Sithean Bhealaich Chumhaing and 1½–2 ½ miles north of Portree along the Portree-Staffin road are thin bands of sediments enclosed in a dolerite sill. A small exposure in Lon a'Ghlinne, 450 yd east of the road shows sill resting on about 8 ft of soft grey sandstone. Where this band of sediment crosses Lon an t-Sithein 500 yd further north, about 8 ft of soft sandstones and *Neomiodon* limestone are exposed. A second band of sediment crops out 500 yd north of Lon a'Ghlinne and 150 vd east of the road. The section here is:

	feet	inches
Sill — very irregular and including fragments of a coarse gritty *Neomiodion* limestone		
6. Plae carbonaceous sandstone with doggers in uppermost 3 feet	13	4
5. Shale, black and sandy	1	4
4. Hard calcareous band		2
3. Shale, black and sandy		4
2. Hard calcareous band		2
1. Shale, black and sandy	2	2

West of the road and below the lava scarp the abundance of fragments of Jurassic sediments indicates the presence of other sedimentary bands in the sill. The whole of this area forms a long triangular segment bounded by faults which throw down the beds on all sides. These sediments are certainly part of the Concretionary Sandstones and most probably belong to one of the lower cycles.

In the sea-cliff between Craig Ulatota and Fuirnean occasional exposures of sandstone and *Neomiodon* limestones indicate the course of the Concretionary Sandstones outcrop. Inland, both east and west of Loch Fada and for a third of a mile to the south there are numerous small exposures of the Sandstones. In a small stream entering the loch from the

east a section showing dark limestones and shales and probably at the top of the '*Estheria*' Shales gives an approximate position for the base of the Concretionary Sandstones.

Outcrops of the Lower '*Ostrea*' Beds just west of the road and loch mark the top of the Sandstones which is seen in small exposures of sandstones and shales on the western shore of the loch. North of Loch Fada the Concretionary Sandstones are obscured by peat and drift but the base must follow closely the western shore of Loch Leathan whilst the Lower '*Ostrea*' Beds above are seen at intervals about 500 yd west of the loch.

The most extensive of these sections is that exposed in Lon Coire na h'Airidh:

	feet	inches
7. Platy green shaly shell bed; masses of *Neomiodon*	2	0
6. Light grey shale with *Neomiodon*		9
Gap of 4 ft, probably shales		
5. Sandy limestone, abundant *Neomiodon*	2	3
4. Sandy shell bed crowded with *Neomiodon*	1	0
3. Thin white flaggy sandstone	3	6
2.Hard calcareous sandstone	2	0
1. Thin white flaggy sandstone	2	0
The top of this section is about 12ft. below the '*Ostrea*' Beds.		

North of Loch Leathan the landslip extends from The Storr to within 200 yd of the cliff top and sections are rare. But 1500 yd N.E. of the Old Man of Storr a *Neomiodon* limestone is exposed in a small stream and 100 yd further west the Lower '*Ostrea*' Beds.

A mile further north sediments belonging to the middle cycles of the Concretionary Sandstones are exposed below a leaf of sill, 160 yd west of the road and 200 yd north of Rigg Burn:

	feet	inches
12. Grey shales	1	6
11. *Neomiodon* shell bed		6
10. Dark limestone with *Neomiodon*	2	6
9. Calcareous shale with *Neomiodon*		8
8. Sandy limestone	2	0
7. Grey shales		9
6. *Neomiodon* shell bed		3
5. Sandy, flaggy, limestone	1	5
4. Calcareous shales	1	9
3. Sandy limestone	1	0
2. Shales with *Neomiodon*	1	0
Gap of a few feet		
White sandstone with doggers	10	0

A little further north, a roadside quarry, due west of Rigg, shows beds in the lower part of the Concretionary Sandstones:

	feet	inches
11. Sandy shales, very sandy at base Black shale	4	0
10. Black shale		4
9. Black sandstone with *Neomiodon*	2	3

8. Brown sandstone	6	0
7. White and yellowish-green sandstone	12	0
Dolerite sill		
6. Brown sandstone		8
5. Yellow sandstone		9
Dolerite sill		
4. White shaly sandstone	1	7
3. Yellow shaly sandstone with *Neomiodon*	5	3
2. Limestone crowded with *Neomiodon*		8
1. Brown shales		

The Concretionary Sandstones are not again exposed until the Lealt River where the three lower cycles and part of the fourth are exposed in the stream, from the ford for a distance of about 1000 yd upstream.

Section in the Lealt River

		feet	inches
Cycle 5 (part)			
30.	Grey calcareous sandstone		
	Gap of about 35 ft—largely sandstone?		
Cycle 4 (part)			
29.	Grey limestone with *Neomiodon*	7	0+
28.	Grey sandy limestone	1	4
27.	Brown calcareous sandstone	1	6
26.	Dark shaly and sandy limestone		9
25.	Yellow calcareous sandstone		6
24.	Blue sandy limestone		5
23.	Green-grey sandy shale with *Neomiodon*	5	0
22.	Grey sandy limestone with *Neomiodon*	4	6
Cycle 3			
21.	Sandstone with irregular doggers	5	0
20.	Green-grey sandy shale with *Neomiodon*	5	0
19.	Blue-grey shelly limestone	5	0
18.	Grey sandy shales	10	0
17.	Limestones with *Neomiodon*	12	0
16.	Coarse calcareous grit	1	4
15.	Sandy, shelly limestone	1	8
Cycle 2			
14.	Soft grey sandstone with doggers, very calcareous in uppermost 3 ft	22	0
13.	Thin, blue-grey sandstone	1	10
12.	Thin, sandy and shaly beds		10
11.	Sandy limestone with *Neomiodon*		6

10.	Soft, green-grey sandstone		11
9.	*Neomiodon* shales and limestones with a very rich 4-in shell bed near the middle and a bed full of *Viviparus* (*Bathonella*) at the base	13	0
Cycle 1			
8.	Green-grey, shaly sandstone	2	0
7.	Dark shale		8
6.	Green-grey, shaly sandstone		8
5.	Hard grey limestone		1
4.	Soft sandstone with doggers, very irregular 3 ft	to 6	0
3.	Grey, sandy clay	4	8
2.	Green-grey, sandy clay	3	0
	Gap of about 20 ft (?sandstone)		
1.	*Neomiodon* limestone ('*Estheria*' shales)		9+

North of the Lealt River the Concretionary Sandstones are to be seen in several fragmentary exposures beneath the Grealin Sill and in the district round Culnaknock and as far north as Loch Mealt but the irregular behaviour of the associated intrusions and extensive faulting in this area make it impossible to identify individual cycles with any certainty. From Port Earlish northwards, however, the Concretionary Sandstones form part of the sea-cliff and extensive sections can be examined in detail. Typical of the sequence hereabouts is that seen at Valtos.

Cliff Section at Valtos

		feet	inches
	Olivine-dolerite sill		
Cycle 4			
36.	Flaggy sandstones	2	0
35.	Hard, massive sandstone	2	0
34.	Flaggy sandstones	2	0
33.	Hard, massive sandstone	6	0
32.	Thin, shaly sandstone		3
31.	Soft, yellow sandstone with doggers	2	6
30.	Calcareous sandstone	1	0
29.	Thin, shaly sandstones and sandy shales	3	0
28.	Shale and *Neomiodon*	7	0
27.	Limestone with *Neomiodon*	2	0
26.	Shale with *Neomiodon*	7	0
25.	Limestone with *Neomiodon*		6
24.	Shale with *Neomiodon*		3
Cycle 3			
23.	Hard calcareous sandstone	3	0
22.	Soft, yellow sandstone with doggers	6	0
21.	Thin sandstones and shales	4	0
20.	Sandstone	l	6
19.	Thin, shaly sandstones	2	0

18.	Thin, calcareous sandstones	1	6
17.	Soft, yellow sandstone with doggers	1	0
16.	Thin, calcareous sandstones	2	0
15.	Hard sandstone	1	6
14.	Thin sandstones and shales	6	0
13.	Irregular, sandy limestone with *Neomiodon*	1 ft to 2	6
12.	Soft, yellow sandstone with doggers	7	0
11.	Soft, grey shales with *Neomiodon*	5	0
10.	Limestone with *Neomiodon*	2 ft 8 in to 4	0
9.	Sandy shale with *Neomiodon*	4	6
8.	Limestone with *Neomiodon*	2	6
7.	Sandy shale		6
6.	Calcareous sandstone		6
5.	Shale with *Neomiodon*	1	0
4.	Sandy, grey-green shale	2	0
Cycle 2 (part)			
3.	Calcareous grit	1 ft to 3	0
2.	Soft yellow sandstone with doggers	18	0
1.	Hard calcareous sandstone	3	0

At Dun Dearg the later cycles of the Concretionary Sandstones are incorporated in the sea-cliff together with the Lower '*Ostrea*' Beds. The sediments exposed in the cliff between Dun Dearg and the Kilt Rock measured at various points where accessible, are shown in the following section see (Figure 7).

Strata between Dun Dearg and the Kilt Rock

		feet	inches
	Dolerite Sill		
	Concretionary Sandstones		
Cycle 5 (part)			
44.	Calcareous sandstone or sandy limestone	1 ft to 3	0
43.	Coarse grained calcareous pebbly grit	1	0
42.	Very calcareous sandstone with thin calcareous shales at the base	15	0
41.	Soft sandstone with doggers	15	0
40.	Sandy shale with thin, sandy limestones	2	0
39.	Grey, sandy shale	5	0
38.	Hard, sandy limestone	8	0
37.	Hard, sandy limestone	4	0
36.	Grey shale	5	0
35.	Hard, sandy limestone	8	0
34.	Grey shales	2 ft to 3	0
Cycle 4			
33.	Thin, flaggy sandstones	2	0

32.	Hard, massive sandstone	2	0
31.	Thin, flaggy sandstones	2	0
30.	Hard, massive sandstone	6	0
29.	Thin, shaly sandstones		3
28.	Soft, yellow sandstone with doggers	2	6
27.	Hard, calcareous sandstone	1	0
26.	Thin, sandy and shaly beds	3	0
25.	Dark shales with *Neomiodon* spp.	7	0
24.	Grey limestone with *Neomiodon*	2	0
23.	Dark shales with *Neomiodon*	7	0
22.	Grey limestone with *Neomiodon*		6
21.	Dark shale with *Neomiodon*		3
Cycle 3			
20.	Hard, calcareous sandstone with *Neomiodon*	3	0
19.	Soft sandstone with doggers	6	0
18.	Thin sandstones and shales	4	0
17.	Sandstone	1	6
16.	Thin, shaly sandstones		0
15.	Hard, calcareous sandstone in platy, 3-in concretionary layers with thin partings of shale and in the middle a 1-ft bed of soft sandstone with small doggers	4	0
14.	Hard, calcareous sandstone	1	6
13.	Thin sandstones and shales	6	0
12.	Hard, very irregular, sandy limestone	1 ft to 2	6
11.	Soft sandstone with large doggers	7	0
10.	Soft grey shales with *Neomiodon*	5	0
9.	Hard grey limestone with *Neomiodon* and *Hybodus*	2 ft 8 in to 4	0
8.	Sandy shale with *Neomiodon*	4	6
7.	Grey limestone with *Neomiodon*	2	6
6.	Sandy shale full of worm casts		6
5.	Calcareous sandstone, ripple-marked and sun-cracked		6
4.	Grey shale with *Neomiodon*	1	0
3.	Sandy, grey-green shale with coprolites	2	0
Cycle 2 (part)			0
2.	Calcareous grit	1 ft to 3	0

1.	Soft sandstone with doggers	18	0

The best section of the higher beds of the Concretionary Sandstones is seen ¾ mile south of Rubha Garbhaig.

Section in the Cliff ¾ mile S.E. of Rubha Garbhaig

		feet	inches
	Dolerite sill		
	Ostracod Limestones		
46.	Yellowish, hard baked marl with crushed *Neomiodon*	2	0
45.	Yellow, fine-grained, thin-bedded calcareous sandstone with crushed *Viviparus*, *Neomiodon* and Ostracoda	2	0
44.	Yellowish, sandy marl	3	9
43.	Very dark brown, greasy clay with *Neomiodon*, *'Euestheria'*, and *Ostracoda*	3	0
Lower '*Ostrea*' Beds			
42.	Hard grey limestone crowded with *Liostrea hebridica* Forbes	4	0
41.	Black rusty shale with small *Neomiodon* spp.	4	6
40.	Hard grey limestone	1	1
39.	Grey shale crowded with *Liostrea hebridica*	1	5
38.	Hard, grey limestone		11
37.	Grey shale crowded with *Liostrea hebridica*	7	0
36.	Rusty shales with *Neomiodon* spp.	8	0
35.	Dark, shaly sandstone	4	0
34.	Fairly hard, calcareous sandstone	15	0
33.	Hard, calcareous sandstone	2	0
32.	Sandy shale	1	9
31.	Sandy limestone		4
30.	Dark shale with *Liostrea hebridica*		6
29.	Grey limestone with *Liostrea hebridica*		4
28.	Sandy shales	1	6
27.	Pale brown, sandy and pyritous, fragmental shell limestone with *Neomiodon* spp.	1	0
26.	Sandy limestone		8
25.	Sandy shale		9
24.	Rusty shale with *Neomiodon* spp.	3	6

	Concretionary Sandstones (Cycle 5)		
23.	Hard, concretionary, calcareous sandstone with doggers attached to base	4	0
22.	Soft, white, fine-grained calcareous sandstone with large doggers	13	0
21.	Hard, calcareous sandstone		4
20.	Soft, white sandstone	2	0
19.	Hard, calcareous sandstone		6
18.	Soft, white sandstone		9
17.	Hard, calcareous sandstone		8
16.	Sandy shale	3	6
15.	Hard, sandy limestone		4
14.	Grey, sandy shale	5	6
13.	Grey, micaceous, calcareous sandstone with *Neomiodon* spp.	2	7
12.	Black shale	2	6
11.	Hard, grey, sandy limestone		8
10.	Black shale	4	0
9.	Light grey, fine-grained, calcareous sandstone	4	3
8.	Bands of dark grey, sandy and shaly limestone and sandy, calcareous shale	1	1
7.	Black paper shales	9	2
6.	Hard, dark grey, impure, sandy and gritty limestone with small greenish patches and bands of *Neomiodon* spp.	4	0
	Current bedded. The basal 2–3 in is marly and weathers fawn colour		
5.	Dark grey, sandy and Shelly limestone with *Neomiodon cunninghami* (Forbes)	1	2
4.	Dark grey, fine-grained, shaly and streaky sandstone with some *Neomiodon cunninghami*		10
3.	Dark grey, shaly, fine-grained sandstone with *Neomiodon cunninghami*	1	6
2.	Light grey, calcareous sandstone with abundant *Neomiodon cunninghami*	2	4
1.	Grey, crystalline limestone with numerous shell fragments. Baked by underlying sill	3	0

Dolerite sill.

The lowest bed in this section rests on a leaf of sill and is in places partly incorporated in it. The degree of alteration induced by the intrusion varies from place to place. Generally the limestone has become saccharoidal, but in some cases the alteration has gone further and small groups of dark calcite crystals have developed giving the rock a spotted appearance. Pockets in the top of the sill are often filled with masses of black calcite.

The beds 1 to 23 inclusive in the above section represent the uppermost strata of the Concretionary Sandstones. It will be seen that the lower 47 ft consist of shales and sandy limestones with *Neomiodon cunninghami* whilst above is a massive bed of sandstone 21 ft thick with thin calcareous bands and large calcareous doggers. These doggers are hard flattened-spheroidal calcareous concretions ranging from 3 ft to 15 ft in diameter. It is clear that the concretions were formed secondarily in situ for the current bedding of the sandstone continues without break through them. The uppermost 4 ft of the sandstone is a hard, concretionary band formed by the growing together of a number of adjacent doggers. On the underside the doggers are to be seen apparently suspended from it and in all stages of emergence. This seems to suggest that the formation of the concretions was penecontemporaneous and that at this level the amount of calcium carbonate available was not enough to allow of the doggers developing sufficiently large to fuse laterally and to form a continuous band as they did immediately above.

In Eigg the division is more sandy and exhibits the phenomena peculiar to these beds even more markedly. The doggers are here very conspicuous features and were described in graphic terms by Hugh Miller (1858, pp. 56–7). As in Skye the quartz grains comprising these sandstones are fairly uniform in size and on weathering give rise to 'musical sands' which are especially well developed in Camas Sgiotaig in Eigg and on the northern shore of Loch Leathan in Skye.

In Strathaird the Concretionary Sandstones are represented by the subdivision 'II (Cyrena Limestones)' described as 'massive blue sandy and often crystalline limestones and calcareous sandstones' (Peach and others 1910, p. 121). The thickness is here only 70 ft so that there has been a great reduction in the amount of coarse detrital material between North Trotternish and Strathaird. Apparently the sandstone unit in each sedimentary cycle has thinned out southwards so that at Strathaird only the calcareous-argillaceous unit is left, for if the sandstones be removed from the North Trotternish succession then the remainder of the Concretionary Sandstones approximates in thickness to the Cyrena Limestones of Strathaird.

Northwards from the section given above, most of the sediments are hidden by scree but there are small patches of the lowest beds (limestones and shales with *Neomiodon*) to be seen resting on the top of the sill as far as Rubha Garbhaig. Here the beds are thrown down to the north by a N.N.W. fault and the sandstones with doggers form the floor of the small bay between Rubha Garbhaig and Sgeir nam Faoileann. A second fault then throws down the sandstones again to the north after which they are not seen again on the east side of the peninsula.

The ground between Kilt Rock and the section just described, which displays interesting transgressions of two leaves of a sill, is most conveniently described from north to south. Southwards the section is obliterated by scree and rock falls from the overlying sill for about a quarter of a mile, but at the Kilt Rock a good, though less complete exposure of these beds is again visible. Where the sediments again appear to the south of the scree an upward transgression of the lower leaf of the sill has cut out about 10 ft of the limestones and shales at the base of the section and a downward transgression of the upper leaf has cut out the upper shales of the Lower '*Ostrea*' Beds (See (Figure 7). At the Kilt Rock the upper sill again has descended to rest on the lower shales of the Lower '*Ostrea*' Beds, but south of the Kilt Rock rises up again to the old position. About 70 yd south of Cadha an Tuill the upper sill transgresses downwards again and cuts out the whole of the Lower '*Ostrea*' Beds for a distance of 80 yd or so. Farther south it rises again to the middle of the Lower '*Ostrea*' Beds leaving a thin leaf between this group and the Concretionary Sandstones below, whilst the lower sill has dropped 16–17 ft leaving a thin leaf at the old level.

A deep cleft in the cliff one third of a mile south of the Kilt Rock marks the position of a considerable transgression. Here the upper sill moves downwards so as cut out all the sandstone with doggers and some of the shales and limestones below leaving only about 30 ft of sediment between the two main leaves of sill. At this point the succession in the Concretionary Sandstones varies slightly from that of the section to the north. The uppermost part of the sandstone with

doggers contains a 1-ft limestone overlain by a conspicupus coarse calcareous grit also 1 ft thick.

Immediately north of the Mealt waterfall the upper and lower leaves of the sill unite and with the exception of a few inches of limestone at sea-level the whole cliff 175 ft high is sill. This transgression at the Mealt fall as indicated by the distribution of the Jurassic rocks inland is actually parallel to the strike of the sediments, i.e. N.N.E., and not parallel to the dip as would appear to be the case from the cliff section. The elucidation of the transgressions of the sills at the Mealt fall is made more difficult by the sudden thickening of the lower leaf about 350 yd south of the fall, and by the fact that the cliff bulges seawards just at the plane of transgression (see (Figure 7) because of its resistance to marine erosion.

About 500 yd south of Mealt fall the section is obscure but the two leaves of the sill appear to separate and the upper leaf transgresses upwards whilst the lower leaf transgresses downwards, leaving at least two thin sills between, one lying near the base of the shales and limestones and the other between the shales and limestones and the overlying sandstone with doggers. Here lower beds appear at the base of the cliff than any seen north of the Mealt fall.

At Rubha Hunish, the extreme north-westerly point of Trotternish there are small exposures of the Concretionary Sandstones. The sediments are enclosed between the sill of Meal Tuath and that forming the promontory of Hunish, but are for the most part covered by scree. At the northern edge of the Meal Tuath scree however, fragments of baked shale and sandstone are to be seen resting on the sill dipping 10° to the south-east, and the following section is exposed on the eastern side of the headland in Lub a'Sgiathain: Thin bedded hard sandstone 1 ft; Soft sandstone with doggers 15 ft; on Thin argillaceous sandstones with *Viviparus scoticus* (Tate) 2 ft.

These beds are cut off on the seaward side by a N.W. fault which throws down to the cast and the cementstone exposed on the beach near low tide mark at about the same level as Bed 1 of the above section belongs to the Ostracod Limestones (seep. 46.)

The Concretionary Sandstones are again exposed in Lub Score south of Duntulm. Soft sandstones with doggers appear from below the Lower '*Ostrea*' Beds at a point [NG 402 727] on the coast. About 10 ft of sandstone are exposed in two small cliffs associated in the southerly one with ostracod marls, and small patches of sandstone with doggers, hard calcareous sandstones and sandy limestones are to be seen in the beach for the next 600 yd to the south after which they disappear below sea-level.

A small N.W. fault at Osmigarry throws down to the N.E. so that the calcareous sandstones are again seen in a small exposure [NG 392 720] on the beach before being finally covered by the Lower '*Ostrea*' Beds. This series is not again exposed on the west coast of North Trotternish.

In Vaternish and Duirinish there are no extensive sections in the Concretionary Sandstones. On the western shore of Loch Snizort is an area of landslip, Score Horan, which conceals an outcrop of Jurassic rocks which, from fragments seen in the landslip, must belong to this subdivision, and on the shore of Loch Losait, a bay cut in the northern side of the slipped mass, is a small exposure of brown sandstone, 200 yd west of which is a knob of dolerite sill. Eastwards, loose fragments of sandstone and *Neomiodon* limestone can be found on the beach and at the promontory of Oans is another outcrop of sill. Here sediments are brought above sea-level by a small anticline and along the axis at Biod a'Ghoill there is room for at least 300 ft of sediments below the lavas.

It is probable that the same subdivisions of the Great Estuarine Series are present here as in Loch Bay i.e. Ostracod Limestones, Lower '*Ostrea*' Beds and Concretionary Sandstones.

On the west coast of Vaternish the Concretionary Sandstones probably crop out in Ardmore Bay. At Trumpan the base of the lavas is seen resting on Palagonite Tuffs which are dipping to the north-east at 8° and are in turn underlain by a dolerite sill containing a lenticle of grey shale. Approaching Ard Beag the sill turns over to the west at an angle of 45° and appears to be faulted against the lava crags of Ard Beag. Though no sediments are exposed above sea-level in Ardmore Bay the beach is strewn with boulders of *Neomiodon* limestone, fragments of an '*Ostrea*' bed and large doggers.

Further south a sandy *Neomiodon* limestone is exposed at beach level on the western shore of Clett, dipping W.S.W. at 6° and probably belongs to the Concretionary Sandstones. The limestone is in two leaves separated by a one-inch layer

of 'beef', the lower is a *Neomiodon* shell-bed one-foot thick, the upper, two-feet thick, directly underlies dolerite sill. The lower portion of the sediments (see p. 42) exposed on Mingay, i.e. the white sandstone and *Neomiodon* limestone may also be part of the Concretionary Sandstones.

In Loch Bay the uppermost portion of the Concretionary Sandstones is exposed. The most complete section is that in a small cliff just north of Cnoc na Cairidh :

	Lower '*Ostrea*' Beds	feet	inches
14.	Grey shales	4	0
13.	Black shale		4
12.	Brown and purple sandstone with casts of *Neomiodon*, calcified in part	2	0
11.	Soft, white sandstone	2	9
10.	Grey, sandy shales	2	0
9	Soft, white sandstone	about 4	0
8.	Sandy *Neomiodon* limestone	1	6
7.	Soft, white sandstone	5	0
6.	Grey *Neomiodon* limestone	2	6
5.	Soft, grey, carbonaceous sandstone	1	6
4.	Calcareous and carbonaceous sandstone	1	3
3.	Sandy *Neomiodon* limestone	3	0+
2.	Black *Neomiodon* shale	3	0
	Dolerite sill, 12 ft, but thinning southwards		
1.	*Neomiodon* shales and limestones		

The most westerly occurrence of the Concretionary Sandstones is that concealed beneath the landslip between Waterstein Head and Loch Mor in Duirinish.

The occurrence of landslip at Geodh' an Tairbh, Dunvegan Head suggests that sediments crop out below the lavas but no trace of them has been detected.

Judd (1878, p. 724) stated that strata belonging to the Great Estuarine Series are to be seen beneath the lavas at "Copnahow Head" (Gob na Hoe) and showed the outcrop on his map (fig. 1). In this area, however, the base of the lavas is below sea-level and no other observer has recorded sediments in the neighbourhood of Hoe Point. As Judd's map does not show the sediments at Eist it is possible that he confused the two headlands. Bryce (1837) in his Map of the Islands of Skye and Raasay shows the outcrop correctly (fig. 1).

Lower '*Ostrea*' Beds

The Lower '*Ostrea*' Beds comprise a complete sedimentary cycle of the type seen in the Concretionary Sandstones, i.e. shales and limestone below, sandstones above, and the shale phase of a higher cycle, the sandstone portion of which is the lower half of the Ostracod Limestones.

The most complete sequence in this subdivision is seen in the section ¾ mile south of Rubha Garbhaig (p. 32), where the characteristic three subdivisions are well seen:

3.

	Soft shales and muddy limestones often crowded with *Liostrea hebridica*	about 35 ft

2.	Sandstone	about 17 ft
1.	Soft shales and thin limestones with *Liostrea hebridica*	about 10 ft

The upper shale-limestone group includes, about 15 ft from the top, an algal limestone which has been traced throughout Skye (Anderson 1948), and even further afield (Hudson 1963).

It consists of angular fragments of dark limestone originally a layer built up by the confluent growths of the alga Cayeuxia nodosa Anderson, but penecontemporaneously brecciated and re-cemented. The algal nodules are grey-blue in colour with a porcellaneous texture, and weather creamy white. Other fossils in the Lower '*Ostrea*' Beds consist mainly of *Liostrea* hebridica (Forbes) and *Neomiodon* spp. But Rhynchonellids, *Kallirhynchia concinna* (J. de C. Sowerby), are found in these beds at Duntulm, and Tate (in Bryce 1873) records a number of gastropod and lamellibranch species from Loch Bay, some of which are undoubtedly marine forms.

In addition to the common *L. hebridica*, Anderson and Cox (1948) recorded the following species from the Lower '*Ostrea*' Beds of Skye: *Pleuromya* robusta (Tate), *Corbula hebridica* Tate, *Neridomus arata* (Tate), Viviparus scoticus (Tate), Zebina caledonica (Tate), to which Hudson (1963) has added: Cuspidaria ibbetsoni, Placunopsis socialis, *Anisocardia* (*Antiquicyprina*) *cucullata* (Tate), *Quenstedtia forbesi* Anderson and Cox, *Myopholas acuticostata* (J. de C. Sowerby) and *Globularia formosa* ? (Morris and Lycett).

The shells of *Liostrea hebridica* are at times so plentiful that there are beds from 7 to 10 ft thick almost entirely composed of them.

The Lower '*Ostrea*' Beds represent a widespread brackish-marine phase and wherever the Concretionary Sandstones are exposed these '*Ostrea*' beds are seen to overlie them. They are present in Trottemish, Vatemish and Duirinish in North Skye, in Strathaird and Strollamus in South Skye, and in Eigg, Muck and Raasay. There is no palaeontological evidence that these '*Ostrea*' beds are contemporaneous for *Liostrea hebridica* occurs from top to bottom of the Great Estuarine Series. They do indicate however the occurrence of a tectonic disturbance which affected a wide area and resulted in a marine-estuarine phase lying between freshwater-estuarine beds. The absence of diagnostic zone fossils is a common feature of estuarine and freshwater deposits so that palaeontological zoning is rarely possible. Furthermore in shallow water deposits of this nature rapid lateral lithological changes are the rule. The only method of correlation left is the recognition of tectonic movements which have caused a widespread change in the sedimentation of the area. Shallow water deposits are particularly sensitive to small changes of level so that even minor movements may be often easily recognized. In the Hebridean area correlation by the comparison of sedimentary rhythms is especially valuable in the Great Estuarine Series, for as the name implies, the whole series was deposited in a large estuary in which facies changes were rapid and in which more or less the same fauna lived throughout the period.

In Trottemish the most southerly exposure of the Lower '*Ostrea*' Beds lies a few yards west of the road and 100 yd south of the southern end of Loch Fada, where 2 ft of calcareous sandstone and 2 ft of sandy *Neomiodon* limestone are exposed. The following section can be seen 120 yd north of this exposure:

	Dolerite sill	feet	inches
7.	Dark shale	1	0
6.	Limestone with scattered *Liostrea hebridica*	1	0
5.	Dark, brecciated algal limestone		4
4.	Shale with algal nodules	1	O¼
3.	Thin limestone		1
2.	Soft, brown shale	1	0
1.	Shale crowded with *Liostrea hebridica*	9	0

Further north, 3 ft of indurated limestone with *L. hebridica* are exposed 100 yd south of Lon Coire na h-Airidh, and in the next burn north, fragments of a white '*Ostrea*' limestone indicate the presence of an unexposed outcrop of the Lower '*Ostrea*' Beds. This white limestone is seen in situ 650 yd further north in a gully west of the .road. The section here is:

	Dolerite sill	feet	inches
11.	Sandy limestone	1	0
10.	White limestone crowded with L. *hebridica*	4	0
9.	Limestone with *Neomiodon*	2	0+
8.	Black shale		6+
7.	Hard, grey limestone		6
6.	Dark grey shale	4	0
5.	Light, grey marl	2	0
4.	Massive sandstone	3	0
3.	Platy sandstone	4	0
	Gap of 5 ft		
2.	Shaly, brown sandstone	1	0+
	Gap of 6 ft		
1.	Calcareous and carbonaceous sandstone	1	0+

North of this section '*Ostrea*' beds are exposed at intervals for the next 300 yd and again west of the middle of Loch Leathan just before the Lower '*Ostrea*' Beds disappear beneath the landslip to the north.

At Tottrome at the head of the most southerly of the two streams and 1100 yd 15° N. of E. of the Old Man of Storr the Lower '*Ostrea*' Beds are exposed as follows:

		feet	inches
7.	White limestone crowded with *L. hebridica*	3	0+
6.	Black, shaly limestone with *L. hebridica*	6	0
5.	White limestone with *L. hebridica*	3	0
4.	Soft, calcareous sandstone with *Neomiodon* and *L. hebridica*	6	0
	Gap of 6 ft		
3.	Yellow sandstone	7	0
	Gap of 14 ft		
2.	Sandy *Neomiodon* limestone	3	0
1.	White calcareous sandstone	3	0

The '*Ostrea*' Beds can be traced southwards for about 100 yd from the stream.

The difference in detail between this section and that west of Loch Fada emphasizes the rapid lateral change in lithology which is so characteristic of the sediments of the Great Estuarine Series.

North of the southern tributary of the most northerly stream at Tottrome 6 ft of '*Ostrea'* limestone are exposed, Northwards the Lower '*Ostrea*' Beds are covered by thick peat but the course of the overlying sill can be traced for the next three miles or so, until at Dun Connavem they are displaced by a downward transgression of the sill.

Section at Port Ciobhlaig, Kilmaluag

	Ostracod Limestones	feet	inches
20.	Sandy limestone	1	0
19.	Black shale		l½
18.	Pale grey cementstone		4
17.	Shelly and sandy limestone	1	0
16.	Soft sandstone	2	0
	Strata not exposed	8	0
15.	Black shale	3	0
14.	Pale grey marl with Ostracods and *Hydrobia praecursor* Sandberger	1	0
13.	Sandy shale	4	0
	Strata not exposed for a few feet		
	Lower '*Ostrea*' Beds		
12.	Algal Band	1	3
11.	Dark shales with *L. hebridica*; a thin '*Ostrea*' limestone near the middle	6	0
10.	Pale grey cementstone		3
9.	Marly shale with *Neomiodon*		0½
8.	Hard grey marl		1
7.	Sandy shale with *Neomiodon* ?		
	Strata not exposed for a few feet		
6.	Indurated limestone	1	0
5.	Indurated shale with L. *hebridica*	3	0
	Dolerite sill, 4 ft at the cliff and thinning to 1 ft seawards		
4.	Indurated shale with L. *hebridica*	3	0
	Thin dolerite sill	1 ft	
3.	Indurated shale	2	0
2.	Indurated shale with L. *hebridica*	2 ft to 3	0
1.	Indurated shale with *Neomiodon* spp. and Myopholas acuticostata	2	0
	Dolerite sill		

Two inclusions of baked limestone and shale in sill on the foreshore just west of Rubh' Bheanachain (Ru Vannarain) on the north side of Kilmaluag Bay may represent part of the Lower '*Ostrea*' Beds but are highly altered.

Numerous small exposures in the valley of Kilmaluag River south of the main road indicate a horizon very like that of the beds in Port Gobhlaig. In the bed of this stream 50 yd south of the road is a highly fossiliferous limestone, 2–3 ft thick, containing masses of *Neomiodon brycei* (Tate), and small patches of shale are exposed at the sides of the roads which run along the top of either bank. For some 400 yd south of the road the river runs in a narrow gorge and then for a third of a mile over a wide flat of Mottled Clays.

In a small cliff on the west bank of the stream opposite Connista the following section is seen in three successive exposures: Baked marls 3 ft; Gap of a few feet; Soft, white sandstone 6 ft, on Sandy shale 5 ft.

On the same side of the river, 200 yd south of this section, are a number of small exposures of irony, paper shales high up in the bank, whilst opposite a small cliff at a bend in the stream, shows about 5 ft of sandy shales and dark paper shales with abundant *Neomiodon* spp. A little to the south a small tributary enters the river with an exposure of rusty shales in the east bank near Point 197 [NG 433 727], and 800 yd further westwards grey shales and marls are exposed in the banks of the main stream.

There fragmentary exposures in the Kilmaluag River are clearly non-continuous masses of rock caught up in the sill and probably indicate that the river bed is not far above the base of the sill.

The Lower '*Ostrea*' Beds are well exposed south of Duntulm in Cairidh Ghlumaig. Here the general dip is easterly but the beds are disturbed by numerous dykes and irregular tongues of sill. The only continuous section of any great extent is in the northeast corner of the bay 500 yd S.S.E. of Duntulm Castle seen on the beach for about 200 yd and in a small cliff.

Section in the beach, Cairidh Ghlumaig, Duntulm

Lower '*Ostrea*' Beds		feet	inches
29.	Dark shales with *L. hebridica*	3	0
28.	Dark shales with fragments of *Liostrea* and *Myopholas*	1	0
27.	Hard limestone with *L. hebridica*	1	0
26.	Dark shales with *L. hebridica*	1	0
25.	Hard, fawn-coloured shelly limestone with *Neomiodon* spp.	1	4
24.	Grey, sandy shale with *Neomiodon*		5
23.	Brecciated, grey-brown algal limestone		6
22.	Dark grey, laminated shale		1½
21.	Irregular sheet of thin algal limestone		1
20.	Grey, sandy limestone		3
19.	Irregular beds of sandy, grey, calcareous shales with platy layers at the base	2	6
18.	Grey limestone with *L. hebridica*		9
17.	Sandy and argillaceous limestone with *L. hebridica*		5
16.	Sandy grey shale with *Kallirhynchia concinna*, *Myopholas acuticostata* *L. hebridica* and *Trapezium* sp.	2	0
15.	Sandy and argillaceous, grey limestone with *Neomiodon cunninghami*,		

	Corbula hebridica, *Myopholas acuticostata*, *Kallirhynchia concinna*, *L. hebridica* etc.		6
14.	Hard, grey limestone		6
13.	Dark grey, sandy shale		l½
12.	Dark brown, sandy and argillaceous limestone	1	7
11.	Black, sandy shale with thin sandstone ribs, *L. hebridica*		8
10.	Dark sandy and argillaceous limestone		11
9.	Hard, grey-brown, sandy limestone		2
8.	Dark sandy and argillaceous limestone		10
7.	Black, sandy shale		10
6.	Hard, grey limestone	1	0
5.	Slightly indurated, black shales	1	0
4.	White sandstone	1	0
3.	Indurated, pale grey, sandy shale	1	6
	Dolerite sill	17	0
2.	Hard, grey, sandy limestone		6
1.	Grey, sandy shale	2	0

A small cliff in the north-east angle of the bay is made up of beds 15–29 of the above section. Here the Rhynchonella beds (15–16) are more fossiliferous than in the beach, and the algal limestone (23) is more easily recognized. There is also an additional algal bed in the form of a thin layer 1 in thick on the top of bed 25.

The Lower '*Ostrea*' Beds exposed in Cairidh Ghlumaig represent only the lower part of this group (i.e. beds 24–30 of the Rubha Garbhaig section, p. 33) but show a much greater development than on the east coast. The abundance of such forms as *Kallirhynchia* and *Myopholas* show also that the beds were laid down under more marine condtitions.

From here southwards as far as Lon Onstatoin, the stream just S. of Bealach lochdarach, patches of the Lower '*Ostrea*' Beds are exposed between tide marks, and the main road cuts through a thick '*Ostrea*' bed 600 yd north-east of the bridge over this stream. The section seen in the banks of Lon Onstatoin continues the sequence upwards from the topmost bed of the Cairidh Ghlumaig section:

Section in Lon Onstatoin

		feet	inches
	Dolerite sill		
	Ostracod Limestones		
17.	Baked, cream-coloured mudstone	1	2
16.	White and glauconitic sandstones with casts of *Viviparus*	1	1
15.	Indurated, black shales	3	6
14.	Pale yellow, marly sandstone	1	4
13.	Iron-stained, blocky shales	5	0

	No exposure. Flat marshy ground	60 ft to 70	0
	No exposure. Probably sill. Gorge in stream	20	0
	Lower '*Ostrea*' Beds	ft	in
12.	Iron-stained, blocky shales	2	0
11.	Dark shales with L. *hebridica*		10
10.	Grey limestone with L. *hebridica*		9
9.	Thin, calcareous shales		5
8.	Pale grey cementstone with *Liostrea*		3
7.	Papery shales with *Neomiodon* spp.	3	10
6.	Blocky, grey shale with *Neomiodon* spp,	3	0
5.	Soft, yellow sandstone with shaly bands, abundant *Neomiodon* and Viviparus	2	3
	Strata not exposed	18	0
4.	Grey limestone with *Liostrea*	3	0
3.	Dark shale with *Liostrea*	3	0
2.	Grey limestone with *Liostrea*		4
1.	Dark shale with *Liostrea*	3	6

In a bluff on the east side of the road, 750 yd S.W. of Lon Onstatoin soft, pale brown sandstones are exposed to a depth of 50 ft. They are penetrated throughout by thin veins and irregular nodules of highly decomposed dolerite and rest on 6 ft of indurated shales and limestones with *Neomiodon*, which are underlain by dolerite sill. This sill and the overlying beds probably occupy the gap in the Lon Onstatoin section between the beds 12 and 13. At Peingown the sandstones are again seen in a cutting on the north-east side of the road, south-east from Flora Macdonald's Monument. At the east end of this section the 50-ft sandstone is exposed for about 300 yd; at the west end a series of small step faults drop down the beds to the west and marls and shales overlying the sandstones are exposed as far as the ruined chapel. The general dip here is easterly.

These sections again indicate a considerable increase in the thickness of the Lower '*Ostrea*' Beds as compared with the east coast. The lower series comprising *Liostrea* and *Neomiodon* shales is here about 45 ft thick as compared with a thickness of 10 ft for the corresponding beds in the Rubha Garbhaig section (p. 33), and the middle sandstone is here 50 ft thick as compared with a thickness of 17 ft in the east.

From Peingown the sandstone scarp swings round to the south-west and can be traced to Heribusta and for a short distance beyond until the beds are truncated by the north-west fault which runs out to sea at Osmigarry.

A few yards south-west of the mouth of Lon Onstatoin the lowest beds of the Lower '*Ostrea*' Beds are exposed on the beach overlying the Concretionary Sandstones. At Osmigarry the beds are thrown down to the south-west by a small fault and small outcrops of the Lower '*Ostrea*' Beds again appear at intervals on the beach between here and Lon Sgapail. On the north-east side of the mouth of Lon Sgapail a fault, at this point occupied by a large dyke, throws down the strata to the south-west and brings Lower '*Ostrea*' Beds against the Ostracod Limestones. This fault runs in a south-south-easterly direction through Hunglader and brings the Heribusta sill on its eastern side against Ostracod limestones and higher beds on the west.

The Lower '*Ostrea*' Beds are not seen again on the west coast of North Trotternish except for a lenticle caught up in sill 300 yd W. of Gairbh-sgeir and exposed in the sea-cliff near high-water mark showing a band a little over 6 ft thick

composed of black shale, marl and sandstone with *Neomiodon*, which extends for several hundred yards enclosed between two leaves of sill; and for a small exposure of about 6 ft of '*Ostrea*' and *Neomiodon* shales below the leaf of sill which forms Sgeir Lang and on the east side of the jetty. The dip here is south-west at about 5°.

In Vaternish, Lower '*Ostrea*' Beds probably crop out though not exposed in Score Horan and Ardmore Bay.

On the east coast of Mingay about 25 ft of sediments are visible below the sill which forms most of the island. They include 5 ft of '*Ostrea*' shales together with a white sandstone and a *Neomiodon* limestone dipping about 7°, a few degrees south of west. The limestone was once worked for lime and the old kiln still stands. On the beach at Stein boulders of '*Ostrea*' limestone are common and indicate an undisclosed, probably submarine, exposure of this bed. The strata at sea-level here appear to belong to the basal part of the Ostracod Limestones.

At the southern end of Loch Bay, Lower '*Ostrea*' Beds are to be seen resting on the Concretionary Sandstones in the lower reaches of the Bay River and at Slochd Mor. From the confluence to the first bend in Allt an t-Sluic Mhoir shaly '*Ostrea*' beds are exposed in the stream bed and in the west bank round the first bend as far as the second. Beyond the second bend a clear section in the east bank shows the upper calcareous-argillaceous phase of the Lower '*Ostrea*' Beds resting on part of the middle arenaceous beds. Just before reaching the third bend the beds are cut by a dyke, alongside the south side of which is a white sandstone overlain by a grey sandstone, both tufa-covered. A few feet of indurated '*Ostrea*' bed adhere to the north side of the dyke. Between this dyke and a waterfall high up on the south bank of the stream is an outcrop of '*Ostrea*' limestone overlain by the Cayeuxia nodosa algal band. Just west of the confluence at Slochd Mor in the north bank of the Bay River, '*Ostrea*' beds are exposed dipping S.S.W. and again, just west of the stepping stones in the north bank near the mouth of the Bay River, here dipping S.W. at 30°.

Tate (in Bryce 1873, pp. 346–7) recorded the following fossils from Loch Bay, almost certainly collected from the Lower '*Ostrea*' Beds. The names have been revised by Anderson and Cox (1948) and by Casey (1952, 1956): *Anisocardia* (*Antiquicyprina*) *cucullata* (Tate), *Corbula hebridica* Tate, *Liostrea hebridica* (Forbes), *Neomiodon brycei* (Tate), *Pleuromya robusta* (Tate), *Viviparus* (*Bathonella*) *scoticus* (Tate), *Globularia hebridica* Anderson and Cox, '*Leptoxis trochiformis*' Tate and *Neridomus arata* (Tate), *Zebina caledonica* (Tate).

In Lovaig Bay the shore is strewn with boulders of '*Ostrea*' limestone and though the bed was only found in situ in one small exposure near the centre of the bay there is little doubt that the Lower '*Ostrea*' Beds crop out beneath the landslip in the eastern part of the bay. Similarly, the fragments of '*Ostrea*' limestone in the landslip at Water-stein Head must indicate the presence of a hidden outcrop.

Ostracod Limestones

The Ostracod Limestones in North Trotternish consist chiefly of dark calcareous shales with thin impure limestones, light coloured cementstones and thin sandstones. The total thickness of these beds must be about 90 ft, but there is no complete section exposed and wherever seen the strata are invariably disturbed and often altered by intrusive dolerite sheets. Fossils are rare, the cementstones and marls contain ostracods, the limestones and calcareous shales in places contain *Euestheria murchisonae* and *Viviparus scoticus* is locally found in the sandstones. *Hydrobia praecursor* Sandberger was recorded by Cox (1950), *Assimea skyensis* Anderson and Cox by Anderson and Cox (1948) and *Quenstedtia staffinensis* Anderson and Cox by Hudson (1963), but these are uncommon.

A rough subdivision of this group can be made as the lower half contains most of the sandstones whereas mudstones and limestones are more common in the upper half. The succession of these beds indicates the gradual establishment of quiet lagoonal conditions following the marine-estuarine episode represented by the Lower '*Ostrea*' Beds.

In Strathaird the Ostracod Limestones are described as 'Group IV. Black and blue shales and mudstones with occasional thin limestones', and 'Group V. (Paludinas-scotica limestones) Blue, fine-grained smooth argillaceous limestones or cementstones, weathering cream-coloured, containing gasteropods and alternate with shales, fibrous carbonate of lime (' beef '), and thin beds of calcareous sandstone' (Peach and others 1910, p. 121). These two groups together comprise 77 ft of strata which do not differ essentially from the corresponding beds in the north of Skye.

The most extensive section in the Ostracod Limestones is to be seen in that stretch of the Kilmartin River which lies between the road bridge at Stenscholl and the sea. Here the highest leaf of the dolerite sill occupies its most usual position i.e. near the base of the Ostracod Limestones, so that the strata are broken, altered and injected by offshoots from the sill. As the bed of the Kilmartin River is only a little way above the top of the sill the section is much disturbed and difficult to interpret. So far as could be determined the succession is as follows:

Section in Kilmartin River from the Staffin-Portree Road bridge at Stenscholl to within 70 yd of the junction with Lon a'Mhuilinn

	Ostracod Limestones	feet	inches
24.	Thin, dark calcareous shales	3	0
23.	Dark grey, calcareous shale	1	0
22.	Grey cementstone with ostracods		10
21.	Thin, black shale		3
20.	Dark grey, argillaceous limestone	1	2
19.	Hard mudstone with shaly and sandy balls	1	10
18.	Black, calcareous shale	1	3
17.	Hard, grey limestone	1	0
16.	Calcareous shales with bands of impure limestone	4	0
15.	Indurated, black shale	3	0
	Dolerite sill	approx 10	0
14.	Indurated mudstone		11
13.	Indurated shale	5	6
12.	Very sandy limestone	1	0
11.	Indurated, dark calcareous shales	6	0
	Dolerite sill	approx 2	0
10.	Black shale	4	0
9.	Flaggy, white, calcareous sandstone	3	0
8.	Argillaceous mudstone	1	6
7.	Flaggy sandstone	2	0
6.	Flaggy, argillaceous sandstone		6
5.	Dark shale	1	0
	Dolerite sill	approx 10	0
4.	Indurated mudstone		6
3.	Black shale	2	6
2.	Flaggy, argillaceous sandstone	1	6
1.	Indurated, black shale	2	6

The beds apparently dip downstream at a low angle. Immediately downstream from the entrance of the tributary Lon a'Mhuilinn an exposure in the west bank of the river shows a mass of breccia composed of fragments of dark shale, limestone and cementstone, marking the place where a fault crosses the stream. At a bend of the river about 200 yd further north and opposite a small island the following section is exposed

in the west bank:

		feet	inches
6.	Shaly and pebbly limestone	2	6
5.	Dark, argillaceous limestone	1	3
4.	Pale brown, calcareous sandstone		10
3.	Black, calcareous shale	2	8
2.	Mudstone	3	0
1.	Grey sandy and calcareous shales	2	0

The beds apparently dip downstream at about 5°. Opposite the middle of the island the sediments stop abruptly at a deep cleft which marks the position of a fault, on the north side of which is a rubbly mass of dolerite cut by a dyke. For the next 300 yd the river apparently runs in sill but near the mouth, low down in the western bank opposite Staffin Lodge is a small exposure of thin limestones, dark shales and a cement-stone with ostracods resting on sill.

It is difficult to estimate the total thickness of the Ostracod Limestones exposed in this stream but there cannot be less than 70 ft of strata.

Lower beds than these exposed in Kilmartin River overlie the Lower '*Ostrea*' Beds in the cliff section south-east of Rubha Garbhaig (Beds 43–46, of the Rubha Garbhaig section p. 32). They consist of sandy marls and sandstone with *Viviparus* and a very dark brown, waxy clay with ostracods. Southwards these beds are cut out from the cliff section by a downward transgression of the upper leaf of sill, but northwards the dark brown clay is exposed low down on the western side of the cart-road 100 yd south of An Corran. Sediments caught up in the sill at An Corran belong to the Ostracod Limestones. They consist of calcareous shales, shaly limestones and mudstones, disturbed by small faults and a dyke.

A further small exposure of these beds lies 250 yd S.W. of An Corran and about 70 yd south-east of the road. It shows grey shale with loose blocks of ripple-marked sandstone. Though somewhat disturbed these beds are probably not far out of place.

The Ostracod Limestones must pass below sea-level some little distance west of Kilmartin River and are not seen again until the axis of the Jurassic syncline is crossed when they reappear on the coast north of Kildorais, in a small cliff just above high water mark 550 yd N.E. of Flodigarry Hotel as indurated white marl. On the north side of Eilean Altavaig (Flodigarry Island) about 6 ft of badly baked sediments are exposed, comprising calcareous shales with abundant *Euestheria* and a 1-ft bed of white limestone. A small quarry on the east side of the Flodigarry-Kilmaluag road and slightly north of west from Druim na Slochd exposed baked marls and cement-stones with ostracods resting on sill and northwards another small quarry 300 yd W. N. W. of Tom na h-Uraich shows a few feet of indurated dark calcareous shale resting on sill. Baked shales and marls are again seen 350 yd further to the northwest in a small quarry above the sill.

In the small bay between Sgeir nan Eathar Bana and Stac Buidhe, Ostracod Limestones are exposed in the cliff. There are sediments below the sub-soil resting on a 15-ft leaf of sill and again between this and the lower leaf which forms the base of the cliff. Between Sgeir nan Eathar Bana and Balmacquien are several small patches of baked sandy shale and on the foreshore east of Bogha Ruadh is a small lenticle of black shale, calcareous shale and sandy beds enclosed in sill.

Ostracod Limestones are exposed in the bed of Kilmaluag River near its mouth and immediately north of the ford. They are indurated calcareous shales and mud-stones resting on sill and dipping W.S.W. at about 15°. From these beds Malcolm MacGregor (1934, p. 395) has recorded *Viviparus* sp., '*Unio*' *staffinensis* (Forbes), ostracods and *Euestheria murchisoni* (Jones). The low ground between this point and Kilmaluag is occupied by the Ostracod Limestones in the form of a shallow syncline the axis of which runs approximately east and west. The centre of the syncline must however be occupied by the overlying Mottled Clays which account for the marshy nature of the ground.

On the shore of Port Gobhaig, Kilmaluag Bay, the Ostracod Limestones are seen overlying the Lower '*Ostrea*' Beds (see Section, beds 12–19, p. 39). They represent about 23 ft of sandy and shaly beds with cementstones and marls and

contain ostracods, *Euestheria murchisoniae*, *Viviparus* sp. and *Hydrobia praecursor* Sandberger. The general dip is southerly at about 20° but the lower beds rest on sill and are much disturbed and injected by it. Small exposures of indurated black shale between Shulista and the main road probably belong to the same series.

At the base of the cliff by the small promontory of Bun-idein in the middle of Lub a'Sgiathain a lenticle of baked shales and limestones may belong to the Ostracod Limestones but the beds have yielded no fossils. At the western extremity of this bay in Port Lag a'Bhleodhainn on the east side of Meall Tuath is a small cliff immediately above high water mark in the Concretionary Sandstones. A N.W. fault in the beach below the cliff throwing down to the north-east brings the Ostracod Limestones, here represented by a hard cementstone with ostracods, *Euestheria* and *Viviparus*, against the lower beds.

In Port Duntulm east of the castle three small lenticles of the Ostracod Limestones are exposed on the foreshore in sill. The most westerly of these lies under the castle and shows calcareous dark shales, a sandy bed and ?mottled clay all highly indurated and altered. The central lenticle is bisected by a north-south fault, to the west of which sandstones and shales are exposed and to the east, black shales and marls all badly baked by the sill. The eastern lenticle consists of altered cementstone.

Indurated and shattered calcareous shales are seen in the gravel pit on the north side of the main road south-east of Duntulm Castle, and again 150 yd to the south-east, west of Cnoc Roll. A small roadside cutting and quarry north-east of the cart-road at the south-western side of Cnoc Roll, shows at the eastern end sandy shales, in the middle part pale marls, and at the western end a small quarry in indurated calcareous shale.

The uppermost beds exposed in the Lon Onstatoin section belong to the Ostracod Limestones (see Section, beds 13–17, p. 41). Here shales, sandstones with *Viviparus*, and a cream-coloured mudstone lie immediately below the sill. At Peingown along the north-east side of the road leading from Flora Macdonald's Monument to Heribusta is a steep bank in which strata belonging to the Ostracod Limestones are exposed at the western end opposite a ruined chapel. They are indurated white and grey marls and fragmental shale dipping eastwards at about 10° and are brought against Lower '*Ostrea*' Beds sandstones to the east by an east-west fault (see p. 42). On the west the marls are dropped down to the west by several small step faults.

At the mouth of Lon Sgapail and extending eastwards along the foreshore to the second dyke (a multiple dyke) are about 25 ft of shales, limestones and sandstones resting on sill and dipping E.N.E. at 15–20° except between the two dykes where the beds are disturbed and dip south-east and south-west. The sequence in these beds is as follows:

Section at the mouth of Lon Sgapail

	Ostracod Limestones	feet	inches
16.	Calcareous sandstone	1	6
15.	Hard, black calcareous shale	2	9
14.	Sandstone		11
13.	Hard, grey calcareous shale	1	3
12.	Soft sandstone		3
11.	Hard, grey calcareous shale	1	0
10.	Hard, grey marly shale	7	0
9.	Soft, shaly sandstone	1	0
8.	Hard, grey calcareous shale	2	3
7.	Hard, grey, sandy limestone	1	5
6.	Soft, greenish sandstone		4
5.	Hard, grey, sandy limestone		2
4.	Hard, black shale	1	4
3.	Dark green, sandy shale	1	0
2.	Dark grey, shaly limestone		9

1.	Grey shale with hard sandy bands Dolerite sill	2	6

These beds probably represent the lower sandy portion of the Ostracod Limestones exposed in Kilmartin River (see Section p. 44).

Along the beach 20 yd N.W. of Lon Sgapail a lenticle in the sill is composed of indurated sandstone, sandy shale, sandy limestone and shales. Other small lenticles of baked shale are exposed on the north side of Gairbh-sgeir, and at the southern side of Camas Mor.

Beds probably belonging to the Ostracod Limestones are to be seen in a small quarry 500 yd N. of the Highland Home Industries Factory north of Kilvaxter, and in a stream bed 100 yd further to the north-east. The sediments are indurated sandy shales and limestone dipping W.S.W. at about 5°. The horizon of other small exposures of indurated shales in Kilvaxter Burn 300 yd west of the road and in the burn half a mile south of Balgown, also west of the road, cannot be determined with any certainty; it is even doubtful that these beds are in situ.

South of Prince Charles's Point the Ostracod Limestones are again exposed on the beach. They consist of a hard, grey, sandy limestone 3 in, resting on an irregular carbonaceous, sandy limestone 5 in, on dark, carbonaceous shale with ostracods 2 ft. The beds are high up in the series and to the south pass below the Mottled Clays.

In the east of North Trotternish, south of Staffin there are a few isolated exposures of the Ostracod Limestones. At Clachan, a short distance east of the Dun, is a small quarry in indurated shale and there are several fragmentary exposures nearby in the same material. North-east from here, across the main road a little way south-east of the Free Church, baked marls, shales and sandstones are exposed in a small pit to the south of a cart-road and in a gravel pit near by. The beds are much altered especially in the gravel pit which shows at its southern end a leaf of sill transgressing the sediments of which about 16 ft are here exposed. At Elishader two small quarries on the northeast side of the main road give sections in the Ostracod Limestones. The northerly one shows soft sandstones and marly, shaly and sandy beds in all about 5 ft thick as a lenticle in sill. The southerly exposures show sandy grey marl 4 ft, on soft yellow marl 10 in, on black shales with ostracods and Euestheria murchisoniae 3 ft, again enclosed between two leaves of sill. The relationship of these beds to the cliff section a short distance away is difficult to interpret. At the Loch Mealt fall the base of the sill rests on beds low down in the Concretionary Sandstones and in these road-side pits Ostracod Limestones are enclosed in the same sill, i.e. the sill has apparently displaced 120 ft of strata. It is clear, therefore, that between the pits and the cliff top the sill has transgressed downwards through the Lower '*Ostrea*' Beds and part of the Concretionary Sandstones on a line parallel to the coast. In the most southerly of these two quarries the upper leaf of sill rests on the shales below without disturbing them, but within the body of the shale are planes of crush and the surface of the lower sill is covered with brecciated material suggesting that the upper sill was already in place when the lower was intruded.

At Raisaburg there is a small exposure of baked marl with ostracods in the bank of Lon Buideil about 150 yd before the stream enters the south-west corner of Loch Mealt.

The Ostracod Limestones have not been seen in situ south of Tottrome but fragments of shale with ostracods and 'beef' and thin argillaceous limestones are abundant in the landslip north-west of Loch Leathan.

Near the source of the most northerly stream at Tottrome is a section showing about 5 ft of indurated sediments—limestone and '*Estheria*' shale dipping at 10° a few degrees south of west. A large slipped mass 50 yd south-west of the stream was composed of ostracod shales 3–4 ft, grey cementstones with *Euestheria* 2 ft, black shales lft. Below the sill and 100 yd downstream from the first exposure the following strata overlie the Lower '*Ostrea*' Beds:

		feet	inches
6.	Impure, Shelly limestone with 'beef'	1	2
5.	Calcareous grit	1	6
4.	Sandy marl		2

3.	White cementstone with Viviparus	1	8
2.	Black shale		7
1.	Massive sandstone with doggers	10	0

There appear to be about 15 ft of shale between the top of this section and the base of the overlying sill.

A few feet of dark indurated shale can be seen below a transgressing sill S.S.W. of Dun Connavern and west of Culnaknock; and there is a small patch of baked, spotted shale at Marishader.

In Vaternish, Ostracod Limestones are exposed at Port na Cagain. Lenticles of sediment enclosed and altered by the sill include a white and grey, marly limestone with tufaceous bands and abundant ostracods, dark ostracod shales and a white sandstone.

On the beach west of Stein sediments belonging to the Ostracod Limestones are exposed as follows: west of a 13-ft multiple dyke, black shales and a white sandstone; east of the dyke and north of the piers, black shale in very thin beds 2 ft 6 in, above grey shale with marly bands and thin algal limestones 3 ft, above 10 ft of soft greenish-white sandstone. East of this are thin black shales with 'beef' and ostracods followed by the greenish-white sandstone.

At this locality the author found a fossil coniferous tree trunk 8 inches in diameter and over 5 ft long lying prostrate on top of the sandstone, covered and surrounded by grey shale. This appears to have been the remains of a large tree as the beach in the vicinity was strewn with fragments of fossil wood. The dip of the strata here is about 2° to the north-east.

The algal band in this section is an earthy limestone 1½ in thick, with dark purplish, spheroidal nodules of about ¼ inch diameter in the upper half. In thin section the rock is seen to consist of a dense mass of broken ostracod carapaces set in a dark, granular calcite. The nodules are composed of a dense, very finely granular calcite with traces of algal filaments. These algal remains are very fragmentary but appear to consist of fairly straight tubules of about 0.01 mm diameter. Though not specifically identifiable it is clear that these are not the species of algae found in the Lower 'Dstrea' Beds but are much more like those described from the '*Estheria*' shales in the Lealt River (Anderson 1948, p. 126).

At the southern end of Loch Bay an outcrop of the Ostracod Limestones is hidden beneath the landslip at Slochd Mor. Angular fragments of cementstone, grey marl and ostracod shales are common. The marls contain Viviparus, *Neomiodon*, fish scales, plant fragments, ostracods and *Euestheria*.

Mottled clays

Immediately succeeding the Ostracod Limestones are about 40 ft of marly clays with beds of calcareous sandstone. The clay is grey, red, green and blue mottled, and black, and contains sporadic algal (?) nodules from ½ in to 2 inches in diameter and small septaria. The sandstones are hard, fine-grained calcareous beds with a slightly greenish tinge. Though this group has not hitherto been recognized in North Skye, it has been recorded in Straithaird as 'Blue shaly marl with blue or white calcareous nodules up to 30 or 40 feet' (Wedd in Peach and others 1910, p. 121). The calcareous grits, which in Raasay yielded fossils of Combrash age, are most likely part of the Mottled Clays (Lee, 1920, p. 58). The Mottled Clays are as a rule unfossilifer ous, but a black clay near the top of these beds in Staffin Bay is full of obscure plant remains and the majority of the concretionary nodules are probably of algal origin. A fish tooth was found by Malcolm MacGregor (1934, p. 401) in a Mottled Clay sandstone at Poll an Staimh, north of Uig.

The characteristic red and green mottling of the clays and the presence of fresh feldspars in the sandstones probably indicate that these beds represent a period of arid climate between the deposition of the Ostracod Limestones and the gradual establishment of marine conditions in the succeeding strata.

The most complete section of the Mottled Clays is that exposed on the beach at the south-western corner of Staffin Bay, between Point 1 (Figure 8) and the River Brogaig. Reference points in Staffin Bay are illustrated in (Figure 9). (Figure 10). (Figure 11). (Figure 12).

Section 400 yd south of Point 1 [NG 474 694], Staffin Bay

		ft	in
	Upper '*Ostrea*' Beds		
21.	Black, calcareous shale	1	0
20.	Thin, sandy *Ostrea* limestone with a layer of cone-in-cone near the middle	1	0
19.	Black shale with well-preserved *Neomiodon*		6
18.	Rusty, black shales with *Liostrea hebridica*	8	0
17.	Black, calcareous shale	4	0
16.	Indurated shale with *Liostrea hebridica*	2	6
15.	Indurated shale		2 in to 3
	Dolerite sill, thickness variable but up to	15	0
14.	Black shale	1	6
13.	Dark limestone with *Liostrea hebridica*		6
12.	Dark shales with *Liostrea hebridica*	3	0
11.	Black shale	1	9
10.	Dark limestone with *Liostrea hebridica*		4
9.	Grey shales with abundant *Neomiodon*	?6	0
	Mottled Clays		
8.	Red and green, mottled clay with an irregular bed of black clay full of plant fragments near the top; irregular calcareous concretions, septaria and algal nodules scattered throughout	20	0
7.	Current-bedded, greenish-white, calcareous sandstone	1	0
6.	Green, sandy clay	1	4
5.	Current-bedded, greenish-white calcareous sandstone	1	7
4.	Red and green, mottled clay	8	0
3.	Current-bedded, greenish-white, calcareous sandstone	1	0
2.	Red and green mottled clay	?6	0
	Strike fault		
	Upper '*Ostrea*' Beds		
1.	Grey shale with *Neomiodon*	2	0

This section is in a wedge of sediments let down by faults to the north and south. The Mottled Clays must underlie the greater part of the beach at the southern end of Staffin Bay and the presence of this soft, easily eroded material probably accounts for the smooth contour of this part of the bay.

Northwards at the seaward extremity of the boat-slip a N.E. fault throwing down the beds to the north brings Lower Corallian shales (*Cardioceras cawtonense* Zone) against the Mottled Clay.

At the northern end of the Point 5 [NG 472 708] (Figure 10) section the base of the Upper '*Ostrea*' Beds is again seen resting on a black clay with plant fragments, below which is typical red and green mottled clay. The full thickness of this group is not here exposed as a strike fault on the seaward side cuts across the beds just below the uppermost calcareous sandstone and repeats the Belemnite Sands and Upper '*Ostrea*' Beds (see Section of beach at Point 5, p. 52).

From here northwards to within a short distance of Point 6 [NG 470 712] the Mottled Clays are well seen in the beach near low-water mark underlying Upper '*Ostrea*' Beds.

The Mottled Clays probably occupy the centre of a shallow syncline north of Kilmaluag but are not exposed.

Half-way between Prince Charles's Point and Kilbride Point the Mottled Clays crop out on the beach, evidently overlying the Ostracod Limestones a short distance to the north, and here contain thin sandstones as in Staffin Bay. At Port Kilbride the clays are baked by the intrusive dolerite which forms Kilbride Point and Geodha Dubh. On the south side of Geodha Dubh mottled clay is exposed below the sill but is very much altered, the clay being converted into a hard, dark, shaly material whereas the concretionary nodules have been changed into a white chalky substance, and stand out very conspicuously. The section here shows: Indurated, black shales with white nodules (mottled clay) 12 ft, on Sandstone 1 to 2 ft; on Indurated, marly shale 4 ft. The lower beds, being less affected by the intrusion, approach more closely to the normal lithology of this series.

In Poll an Staimh, a small bay on the north side of the Stack of Skudibrugh, is a section of the Mottled Clays showing an unusual development of one of the sandstones. The section shows 5–6 ft of calcareous sandstones and "pebble " beds resting on grey shale 1 ft, on grey, green, red and blue mottled clays. The "pebble" beds are actually calcareous sandstones with numerous algal(?) nodules and septaria, and an occasional pebble of quartz. The matrix has a dark green colour and the nodules weather out white, though they have the characteristic bluish-purple colour of algal concretions when freshly broken. In thin section the algal nodules occasionally show tubules but they are never sufficiently well-preserved to be identified even generically.

Malcolm MacGregor (1934, p. 401) referred these beds tentatively to the Cretaceous but their characteristic lithology and the presence of the underlying typical mottled clays, which are well exposed at low tide, indicate clearly that these "pebble" beds are simply a sandy portion of the Mottled Clays of Staffin Bay which have been slightly baked by the overlying sill.

The Mottled Clays are not exposed south of Uig but E.N.E. of the Old Man of Storr the landslip contains a mass of grey and red mottled clay resting on a large fragment of dolerite sill. Thus it is certain that these clays crop out below the lava scarp at least as far south as this.

Upper '*Ostrea*' Beds

The Upper '*Ostrea*' Beds are only to be seen in North Trotternish where the Mottled Clays are overlain by 35 ft of rusty black shales and grey calcareous shales with two thin limestones, which represent the re-establishment of marine-estuarine conditions similar to those which obtained during the deposition of the Lower '*Ostrea*' Beds. The subdivision is extremely fossiliferous, some strata being chiefly composed of shells, but relatively few species are represented and the great majority belong to the genera *Liostrea* and *Neomiodon*.

During the survey of this area the following species were collected at Point 5 in Staffin Bay: *Neomiodon* brycei (Tate), N. *cunninghami* (Forbes), N. *staffinensis*? Anderson and Cox, *Staffinella* cf. *macullochi* (Forbes), *Anisocardia*

(*Antiquicyprina*) *cucullata* (Tate), *Liostrea* hebridica (Forbes), *Isognomon murchisoni* (Forbes), *Neridomus* (*Staffinia*) *staffinensis* (Forbes), *Quenstedtia ? forbesi* Anderson and Cox and *Zebina caledonica* (Tate).

Forbes and Tate recorded several other species but as these authors did not distinguish any of the subdivisions of the Great Estuarine Series the exact horizon of these forms can only be determined by future collecting.

The most southerly exposure of the Upper '*Ostrea*' Beds is in the south-west corner of Staffin Bay south of Point 1 [NG 474 694] (see p. 50). Here exposed in a low cliff are contorted, rusty, black shales passing upwards at the northern end of the section into shales with *Liostrea hebridica*. The sediments are intruded by an irregular mass of dolerite. This locality is undoubtedly that visited by Murchison—' in the low and ruinous cliffs of blue shale associated with zeolitic and amygdaloidal trap on the north-eastern (= south-western) shores of Loch Staffin, were found during my late excursion with Professor Sedgwick flattened masses of shelly limestone containing five species of cyclas, one *paludina*, one *neritina* ? one *Ostrea*, one *mytilus*, and some undescribed bivalves ' (Murchison, 1829, p. 358). 'North-eastern' is clearly a misprint for 'south-western' as Staffin Bay has no northern or eastern shore. Murchison's list is almost identical with that given above, his *Cyclas* is '*Cyrena*' (*Neomiodon*), the *Paludina* was probably *Viviparus scoticus*, the Neritina7 is *Neridomus staffinensis*, the *Ostrea* is *Liostrea hebridica*, the *Mytilus* is *Isognomon murchisoni*. The undescribed bivalves were apparently collected from loose blocks of the Belemnite Sands (see Tate in Bryce 1873, p. 346 and Forbes 1851, p. 110).

In the beach below this section, about 20 ft of black shales with abundant *Liostrea* hebridica are exposed dipping westwards at angles varying from 30–90° into which an irregular tongue of sill is intruded. The lowest beds of the Upper '*Ostrea*' Beds, i.e. shales with *Neomiodon* are here seen resting on the Mottled Clays. A north-south strike fault near low water mark repeats the Upper '*Ostrea*' Beds on the seaward side and at very low tide *Neomiodon* shales can be seen brought against the Mottled Clays by this fault.

The Upper '*Ostrea*' Beds and the Mottled Clays here comprise a wedge-shaped mass thrown down by faults to the north and south. The southern fault is small and displaces the Upper '*Ostrea*' Beds only a few feet, but the northern fault with a bigger throw brings Upper '*Ostrea*' Beds against Mottled Clays. Within a very few yards however a second, almost parallel fault throws down the beds to the north and brings Mottled Clays against Lower Corallian shales. At Point 3 [NG 473 698] the Upper '*Ostrea*' Beds are cut out by a strike fault but to the north at Point 4 [NG 473 701] there appear to be a few feet of shales belonging to this group below the Belemnite Sands but the beds are covered even at low tide.

At Point 5 [NG 473 708], Staffin Bay there is a complete section of the Upper '*Ostrea*' Beds repeated to seaward by a strike fault. They here consist of 30 ft of dark shales with *Neomiodon* and *Liostrea*, in places in the form of shell beds, and with two thin limestones near the middle (see p. 51).

Section in the beach at Point 5 [NG 473 078], Staffin Bay

		feet	inches
	Oxford Clay		
26.	Grey shale with *Cardioceras* spp., *Parallelodon* semulus (Phillips) and Pinna sp.; and thin calcareous ribs	60	0
25.	Dark grey cementstone weathering red		4 in to 5
24.	Grey shale with *Cardioceras* spp. and thin calcareous ribs	14	0
23.	Dark grey cementstone weathering red		4 in to 5
22.	Dark grey shale with *Quenstedtoceras* spp.	15	0

21.	Dark grey cementstone weathering yellow	1	0
20.	Dark grey shale	1	9
19.	Dark grey cementstone weathering yellow 6 in	to 1	0
18.	Dark grey shale with *Kosmoceras* spp. and belemnites, concretionary at the base	30	0
	Belemnite Sands		
17.	Hard calcareous concretionary bed with belemnites, weathering red		9
16.	Dark green shale with belemnites 1 ft 6 in	to 2	0
15.	Hard, calcareous, concretionary and pebbly bed with belemnites		6
14.	Hard calcareous concretionary bed weathering yellow		4 in to 6
13.	Grey-green, streaky, shaly sands with *Pleuromya* spp. etc.	8	6
12.	Hard, calcareous sandstone with Modiola, *Pleuromya* and *Trigonia*	2	0
11.	Grey-green, streaky, shaly with *Liostrea* and *Pleuromya*	10	0
	Upper'*Ostrea*' Beds		
10.	Shell bed composed of *Neomiodon* spp.		4 in to 6
9.	Dark grey shale with abundant *Neomiodon* 1 ft	to 2	6
8.	Grey-green shale with a band rich in *Liostrea* at the base	10	0
7.	Dark grey shale	3	6
6.	Hard, grey limestone with L. *hebridica*	2	0
5.	Dark grey shale with L. *hebridica*	1	11
4.	Grey shale	2	6
3.	Hard, grey, shelly limestone with ½ in of cone-in-cone at the top	1	0
2.	Grey shale	10	0
	Mottled Clays		
1.	Red and green, mottled clay	20	0
	Dolerite sill and strike fault		

To the seaward of the sill beds 2–17 are repeated by the strike fault.

At the northern end of the Point 5 section a strike fault cuts out the Upper '*Ostrea*' Beds and Belemnite Sands and throws Mottled Clays against Lower Oxford Clay.

A few yards south of Point 6 (Figure 10) the whole of the Upper '*Ostrea*' Beds is exposed resting on Mottled Clays and thrown against Upper Corallian on the landward side by a strike fault. The dip is westwards at 45°. An east-west fault separates these beds from a small wedge of sediments to the north in which fragmentary exposures indicate that the succession is complete from the Mottled Clays to the Lower Oxford Clay without the intervention of strike faults.

In the west, Upper '*Ostrea*' Beds with the overlying Belemnite Sands and Oxford Clay must floor the valley once occupied by Loch Chaluim Chille. Murchison (1829, p. 311) examined beds in the canal cut to drain the loch and recorded blue shales with '*Ammonites Konigi*, *Ostreae* in masses, many belemnites, flattened tellinae, etc.' Clearly the canal must have cut through Ostracod Limestones ('flattened *tellinae*?' = *Euestheria murchisonae* (Jones)), Mottled Clays, Upper '*Ostrea*' Beds (' *Ostreae* in masses'), and Belemnite Sands ('many belemnites' and '*Ammonites Konigi*') to the Oxford Clay.

Belemnite Sands

Overlying the Upper '*Ostrea*' Beds are about 20 ft of grey-green, argillaceous sands with a 2-ft hard, calcareous sandstone near the middle and thin, concretionary and pebbly beds at the top. The sands are soft and fine grained with much carbonaceous material and a characteristic streaky appearance. The constituent quartz grains are angular and there is a little feldspar. The middle sandstone is simply a portion of the sands cemented with calcium carbonate, resulting in a grey-green, hard, muddy, calcareous sandstone. The pebbly and concretionary beds represent a somewhat coarser phase of the sands irregularly cemented by calcium carbonate. They contain small quartz pebbles and, especially the upper band, numerous belemnite guards (see Section, Beds, 11–17, pp. 52, 53).

The lower sands (below the middle sandstone) contain *Liostrea hebridica* Forbes, *Oxytoma inequivalve* (J. Sowerby) and *Pleuromya* cf. *alduini* (Brongniart.)

The central sandstone is very fossiliferous, most likely because the calcareous cement has preserved the fossils which in the softer beds have probably been leached out by percolating water. This bed contains: *Astarte staffinensis* Anderson and Cox, *A. extensa* Phillips, *Camptonectes lens* (J. Sowerby), *Neomiodon brycei* (Tate), *Liostrea hebridica* (Forbes), *Pleuromya alduini* (Brongniart), *P. securiformis* (Phillips), *P. uniformis* (J. Sowerby).

The upper sands contain : *Isognomon promytiloides* Arkell [= cf. *isognomoides* (Stahl)], *Modiola bipartita* J. Sowerby, *Pleuromya alduini* (Brongniart), *P. securiformis* (Phillips), *Trigonia* (*Vaugonia*) *tripartita* Forbes, *Hydrobia praecursor* Sandberger, *Littorina* cf. *muricata* J. Sowerby, *Belemnites* sp. (*oweni* type).

This fauna clearly indicates that truly marine conditions followed the marine-estuarine episode of the Upper '*Ostrea*' Beds. The lithology, however, shows that these beds were laid down in shallow water, indeed, as will be shown later, even the succeeding Oxford Clay shales cannot have been laid down far from land.

The presence of such forms as *Pleuromya alduini*, *P. securiformis*, *P. umformis*, *Isognomon* cf. *isognomoides* (Stahl) suggests that these beds are the equivalents of the Kellaways Beds of England. A single ammonite fragment was found in the middle sandstone by the author which Dr. J. H. Callomon has identified as a *Kepplerites*, which again suggests a Kellaways age. No exact zonal correlation can therefore be made but in general terms there can be little doubt that the Belemnite Sands are to be regarded as approximately contemporaneous with the Brora Roof Bed, as was suggested by Malcolm MacGregor (1934, p. 400). In Strathaird a black sandstone at the foot of the sea-cliff near Carn More has yielded a Kellaways fauna including *Ornithella kellowaysensis* (Davidson), and *Kepplerites gowerianus* J. de C. Sowerby sp. (Wedd in Peach and others 1910, p. 128).

Thus the Great Estuarine Series can be said with reasonable certainty to extend from the *Parkinsonia parkinsoni* Zone of the Bajocian to and including the *Proplanulites koenigi* of the Lower Callovian and Murchison's record of this zone fossil from Loch Chaluim Chille is probably correct.

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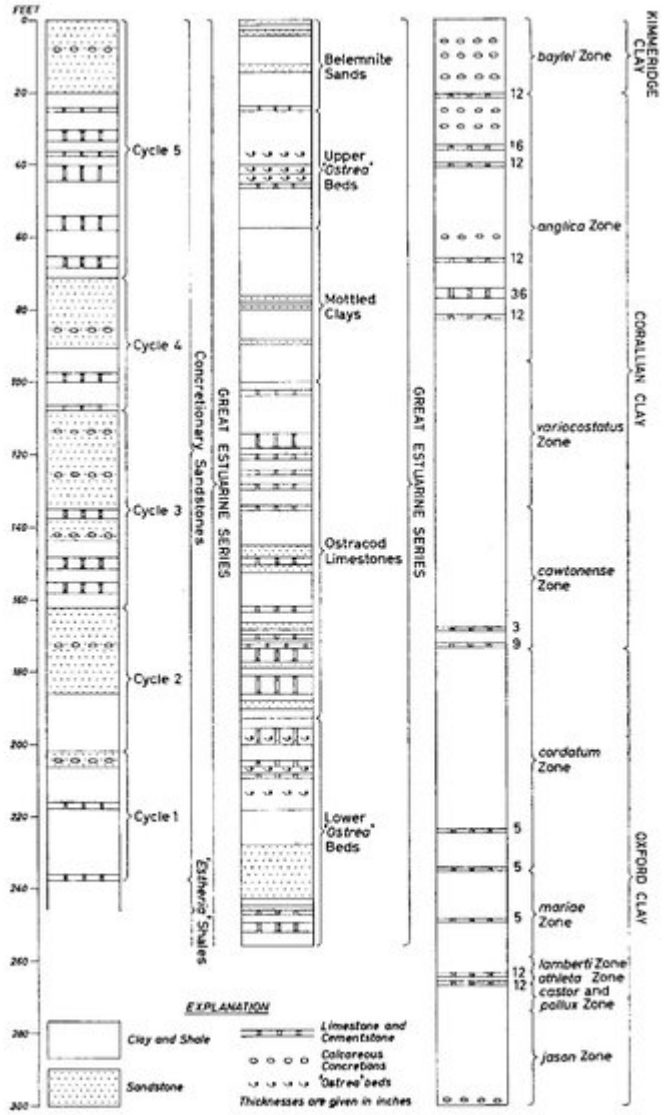

FIG. 4. *Sections showing the sequence of strata in the Concretionary Sandstones, Lower 'Ostrea' Beds, Ostracod Limestones, Mottled Clays, Upper 'Ostrea' Beds, Oxford Clay, Corallian and Kimmeridge Clay*

(Figure 4) Sections showing the sequence of strata in the Concretionary Sandstones, Lower 'Ostrea' Beds, Ostracod Limestones, Mottled Clays, Upper 'Ostrea' Beds, Oxford Clay, Corallian and Kimmeridge Clay.

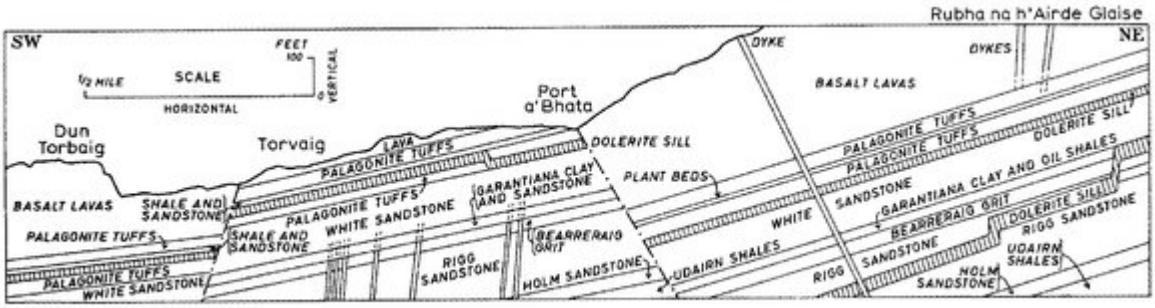

FIG. 5. *Section in sea-cliff on north side of Portree Bay*

None

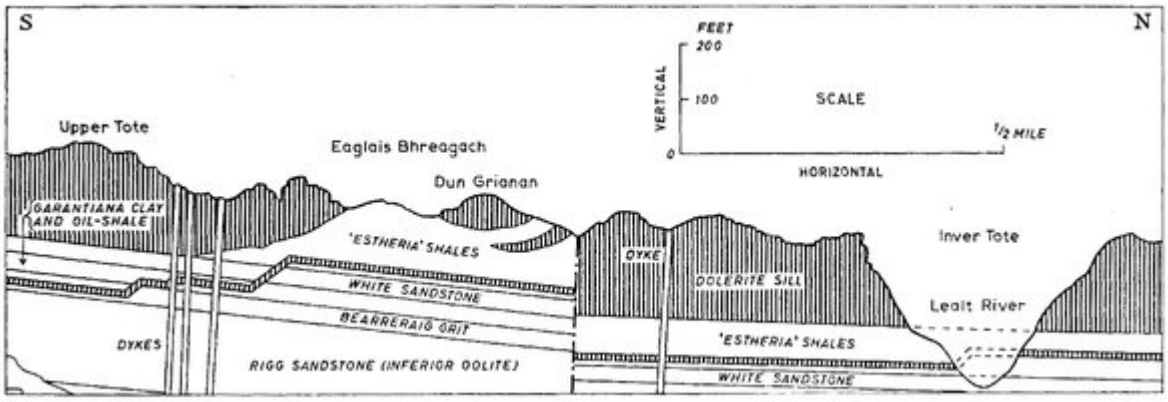

FIG. 6. *Section in sea-cliff between Upper Tote and Inver Tote*

(Figure 6) Section in sea-cliff between Upper Tote and Inver Tote.

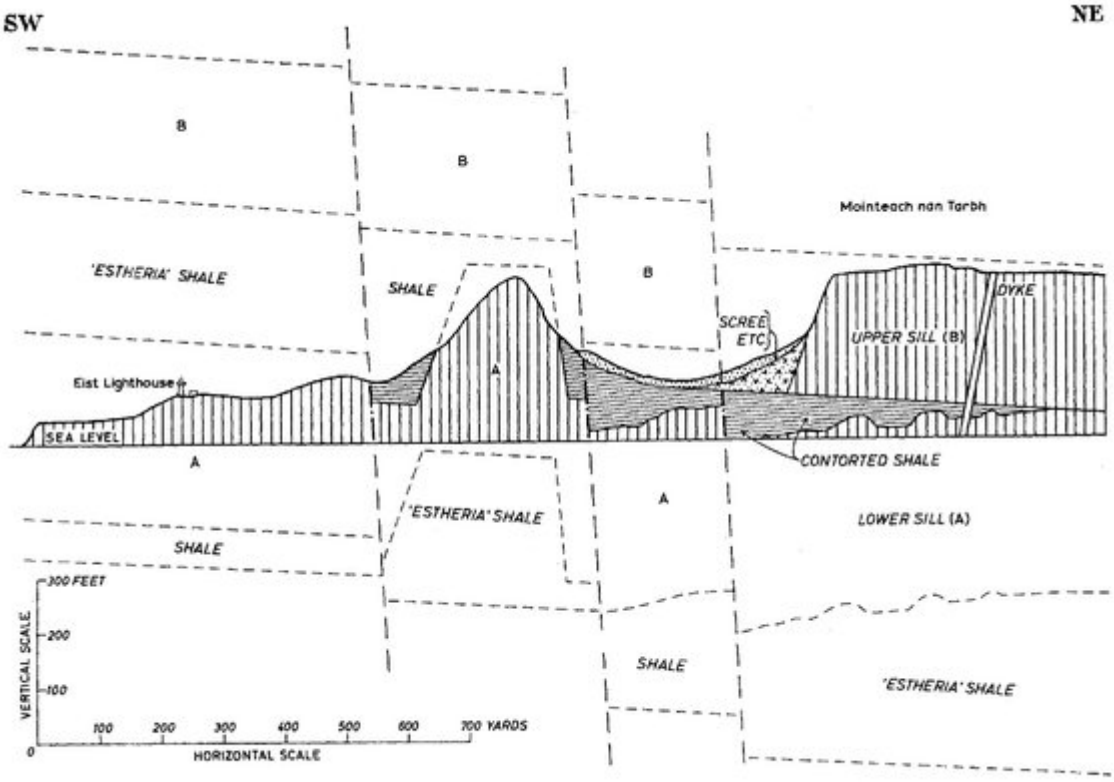

FIG. 14. *Section showing the behaviour of part of the Tertiary sill-complex at Eist*

(Figure 14) Section showing the behaviour of part of the Tertiary sill-complex at Eist.

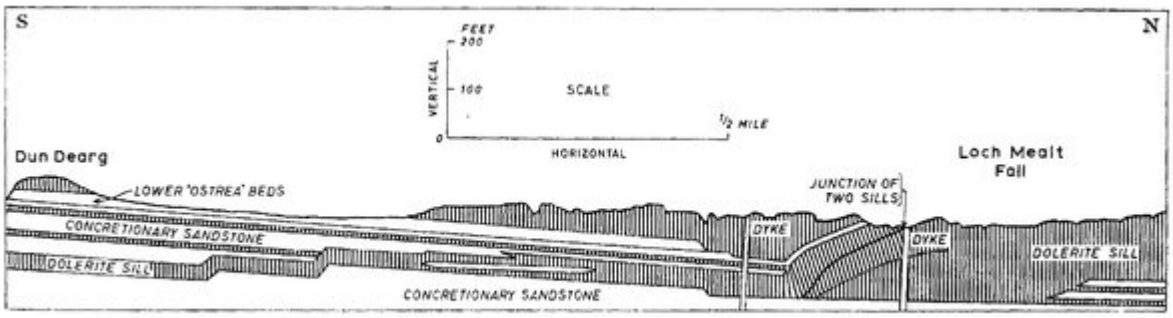

FIG. 7. *Section in sea-cliff between Drum Dearg and Loch Mealt fall*

(Figure 7) Section in sea-cliff between Drum Dearg and Loch Mealt fall.

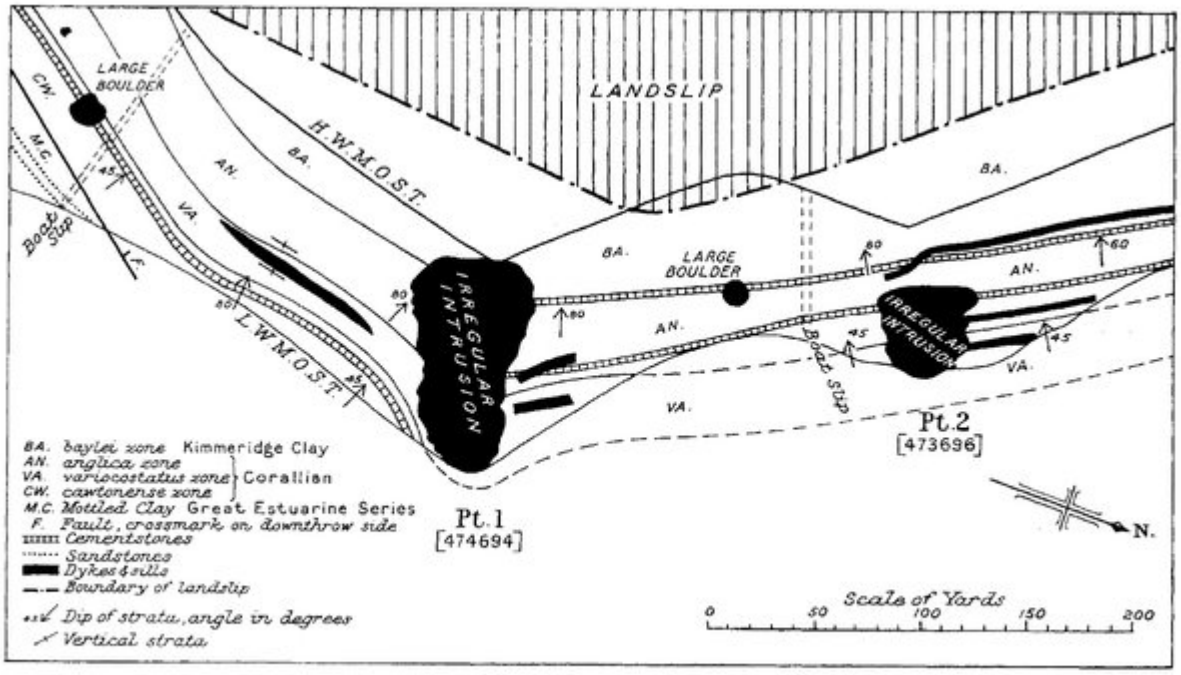

FIG. 8. *Map of Jurassic strata in Staffin Bay, coast east of Digg. Grid references in square brackets*

(Figure 8) Map of Jurassic strata in Staffin Bay, coast east of Bligg. Grid references in square brackets.

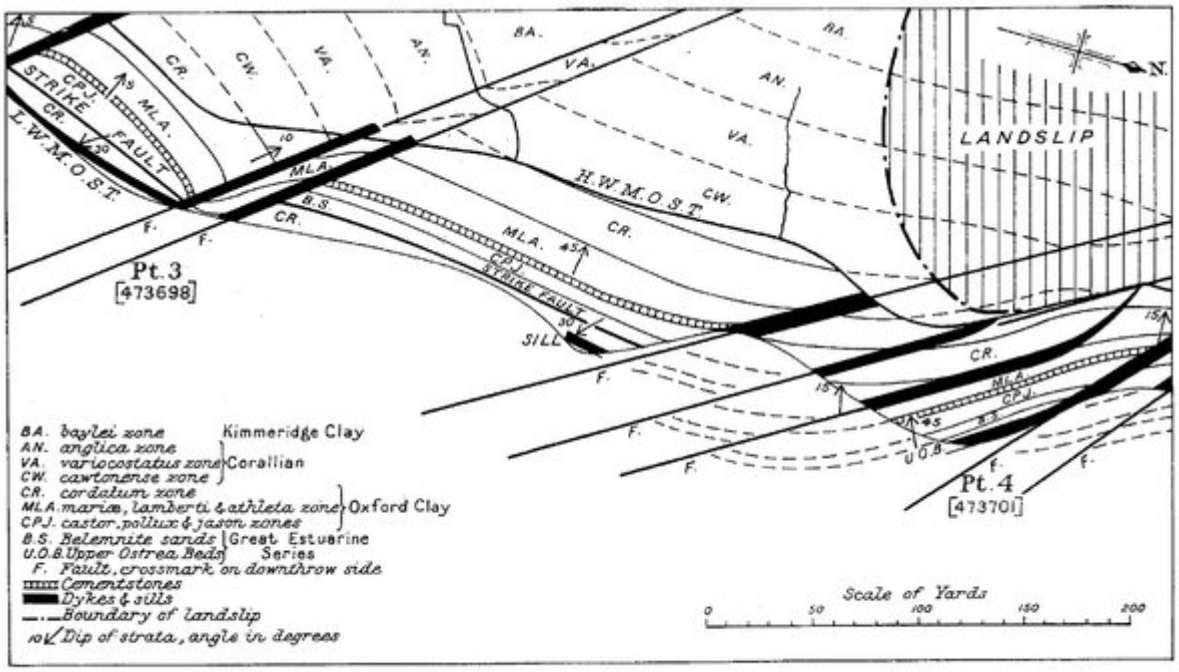

FIG. 9. *Map of Jurassic strata in Staffin Bay, coast east of Loch Leum nam Bradh. Grid references in square brackets*

(Figure 9) Map of Jurassic strata in Staffin Bay, coast east of Loch Learn nam Bradh. Grid references in square brackets.

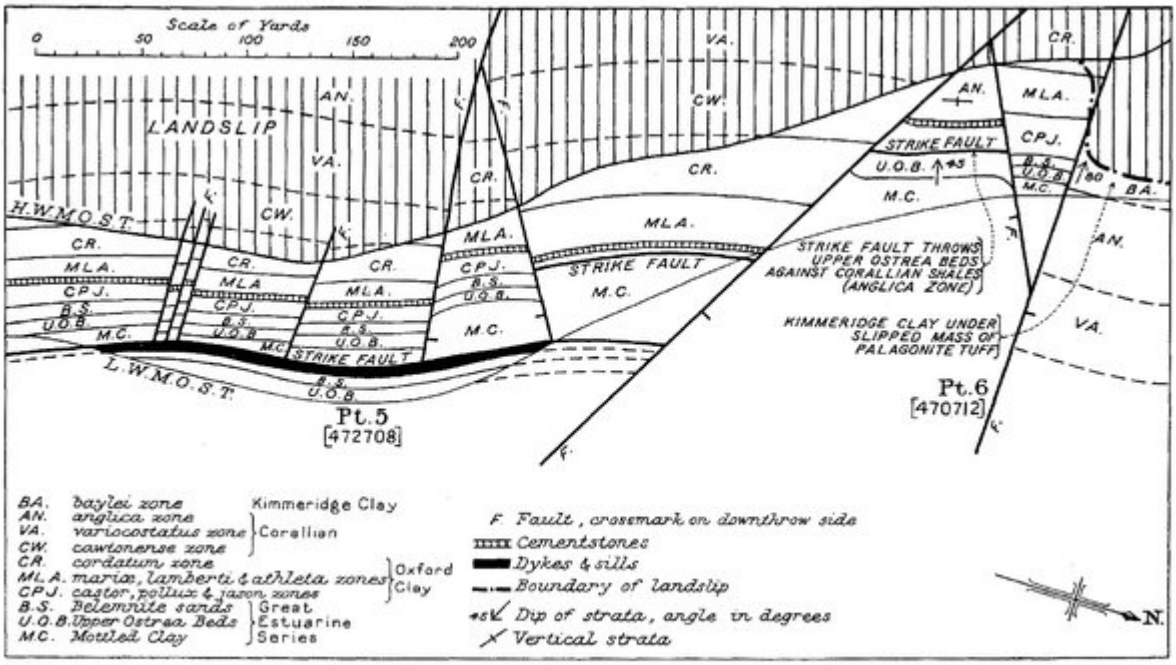

FIG. 10. *Map of Jurassic strata in Staffin Bay, coast east of Loch Langaig. Grid references in square brackets*

(Figure 10) Map of Jurassic strata in Staffin Bay, coast east of Loch Langaig. Grid references in square brackets.

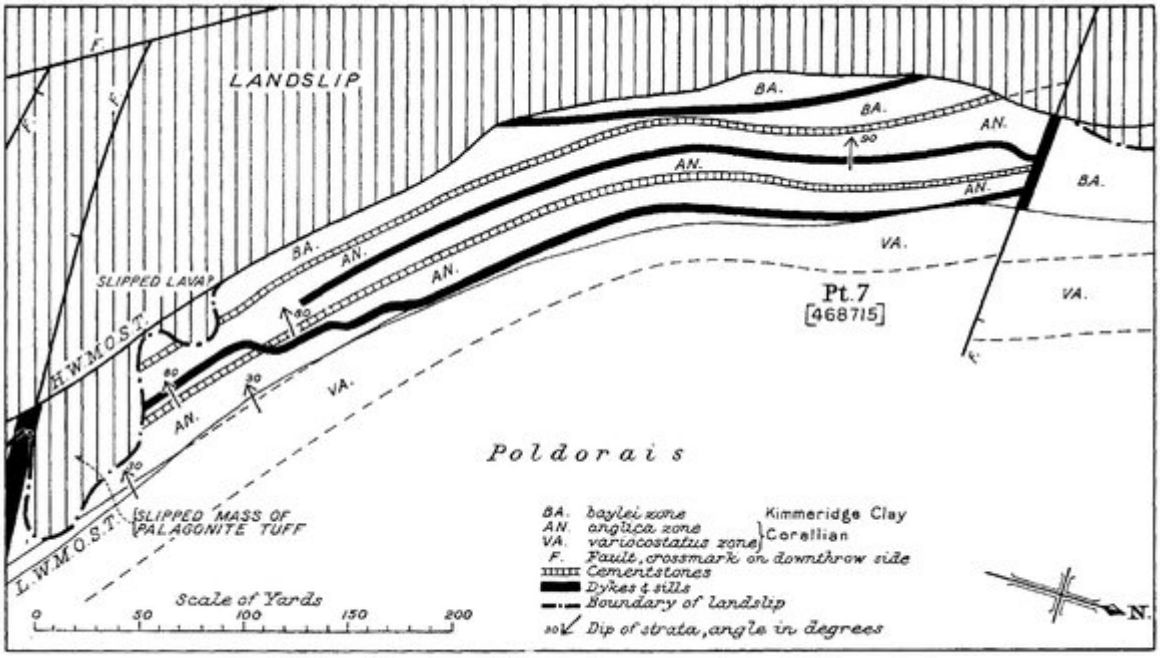

FIG. 11. *Map of Jurassic strata in Staffin Bay, coast south-east of Flodigarry Hotel. Grid references in square brackets*

(Figure 11) Map of Jurassic strata in Staffin Bay, coast south-east of Flodigarry Hotel. Grid references in square brackets.

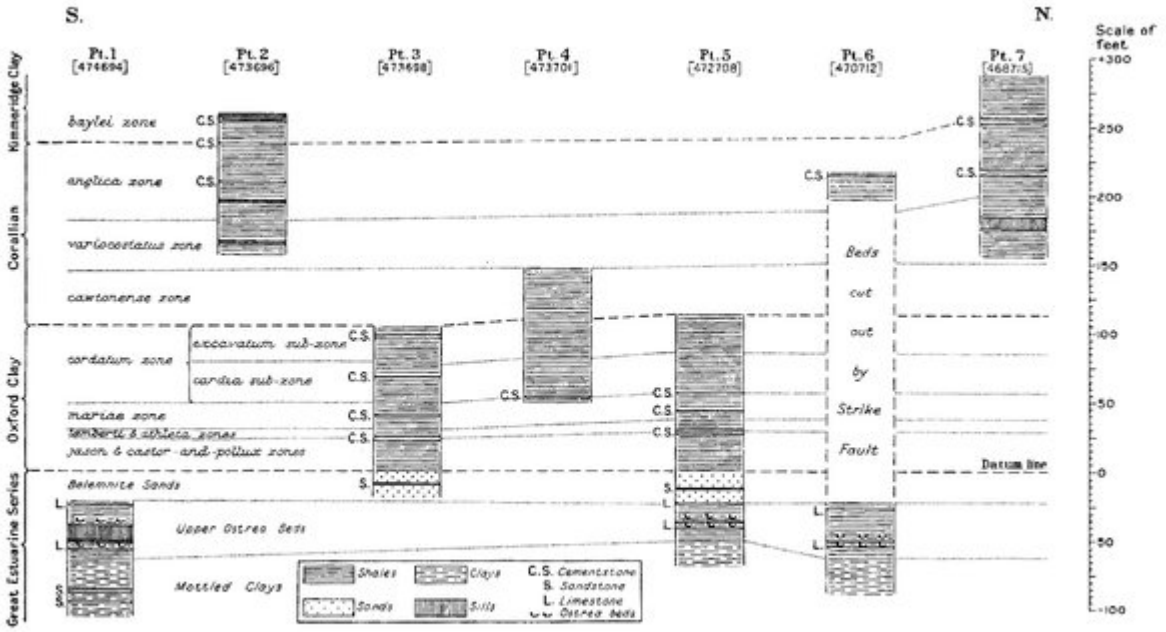

FIG. 12. *Correlation of the Jurassic strata exposed in Staffin Bay. Grid references in square brackets*

(Figure 12) Correlation of the Jurassic strata exposed in Stain Bay. Grid references in square brackets.