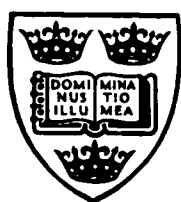


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Thesis presented to the
University of Oxford
for the degree of
Doctor of Philosophy

Sedimentological and Palaeoenvironmental Studies in
the Broadford Beds (Hettangian - Sinemurian) of
North West Scotland

Volume 2

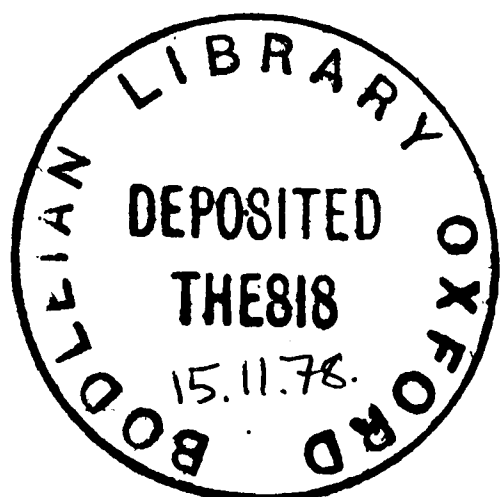
KOUROSH AMIRI-GARROUSSI, B.Sc.

St. Peter's College

and

Department of Geology and Mineralogy

June 1978



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CHAPTER 1

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Fig. 1.1

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Table 1.1

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Plate -

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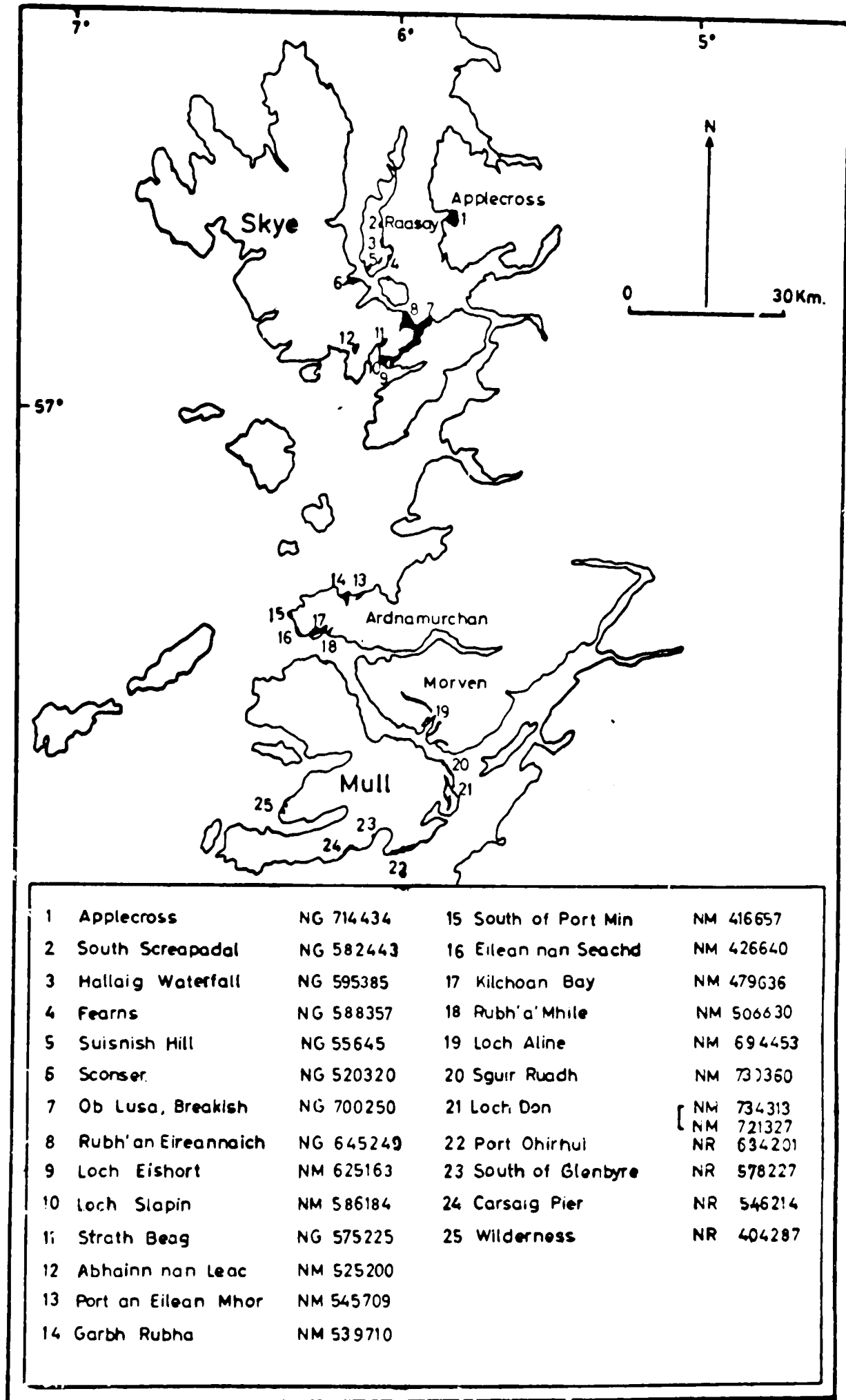


Figure 1.1. Map showing outcrops of the Broadford Beds of NW Scotland.

LOWER LIAS											M. LIAS		Age		
Nettangian			Sinemurian						Pliensbachian					Stage	
			L.		M.		U.		L.(Carixian)		U.(Domer.)				
Planorbis	Liasicus	Angulata	Bucklandi	Semicost.	Turneri	Obtusum	Oxynotum	Raricost.	Jamsoni	Ibex	Davoei	Margarit.	Spinatum	Zone	
Gryphite Limestone													Sandst. of Scalpa		Macculloch(1819)
Oolitic Series															Murchison (1819)
Lias Limestone															Murchison (1819)
Oolitic Serie															Murchison(1889)
Lower Lias											M. Lias				Geikie (1858)
Broadford Lst. Breakish Shales											Pabba Shales		Scalpa		
Lower Lias Shales & Lsts. of English geologists													Marlstone	Wright (1858)	
Lussay											Pabba Shales		Scalpa		
Lower Lias Beds											M. Lias Strata				Bryce and Tait (1873)
Broadford Strata											Pabba Shales				
Infra Lias Beds			Lower Lias Beds				M. Lias Beds						Judd(1878)		
			(Lima or Bucklandi Beds of England)				Pabba Series				Scalpa Se.				
Broadford Beds				Pabba Shales						Scalpa Sst.		Woodward(1896)			
Broadford Beds						Pabba Shales				Scalpa Sst.		Peach et al.(1910)			
Broadford Beds						Pabba Shales				Scalpa Sst.		Lee et al.(1920)			
Hallaig Sst.															
Broadford Beds				Pabba Shales						Scalpa Series		Lee & Bailey (1925)			
Broadford Beds						Pabba Beds				Scalpa Series		Richey (1930)			
Broadford Beds						Pabba Shales				Scalpa Sst.		Arkell (1933)			
Broadford Beds					Pabba Beds		——						MacLennan(1953)		
					L. A. Sst.										
Broadford Beds						Pabba Shales				——		Hallam(1959)			
Lower				Upper											
Broadford Beds						Pabay Beds				Scalpa Sst.		Oates (1976)			
Blue Lias				Pabay Beds						Scalpa Sst.					
Broadford Beds Arenaceous Group						——						This study			
Broadford Beds Argillaceous Group															

Table 1.1

Nomenclature history of the Lower Liassic beds of northwest Scotland.

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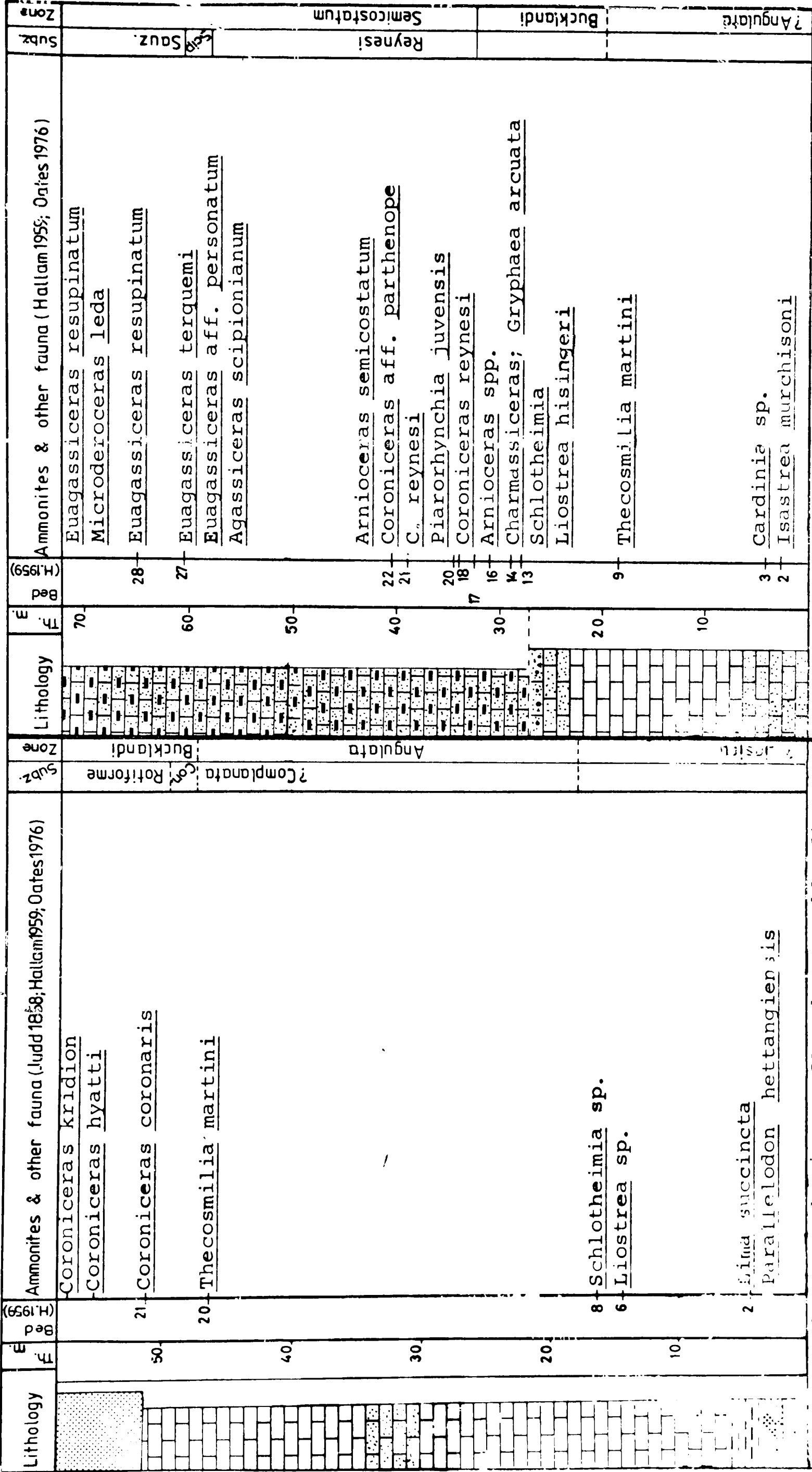


Fig. 2.1 Ammonite horizons: ?Angulata-Bucklandi
Zones at Allt nan Breugh, Applecross

Fig. 2.2 Ammonite horizons: Angulata-Semicostatum
Zones at Ob Lusa and Ob Breackish Skye.

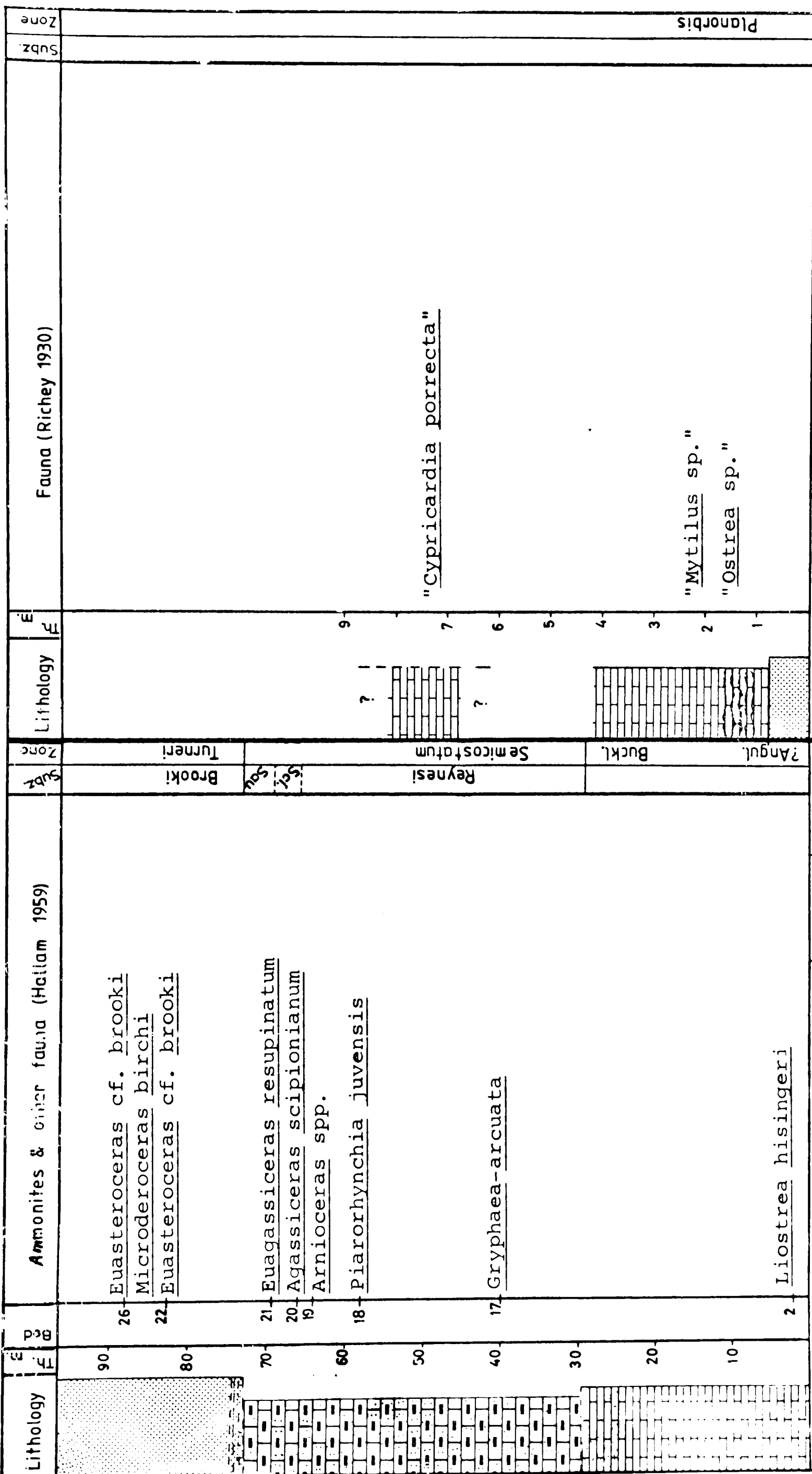


Fig. 2.5 Ammonite horizons: Bucklandi-Turneri Zones at Rubha na Leac, Raasay.

Fig.2.6 Fauna: Planorbis Zone at Mingary Pier, Ardnamurchan.

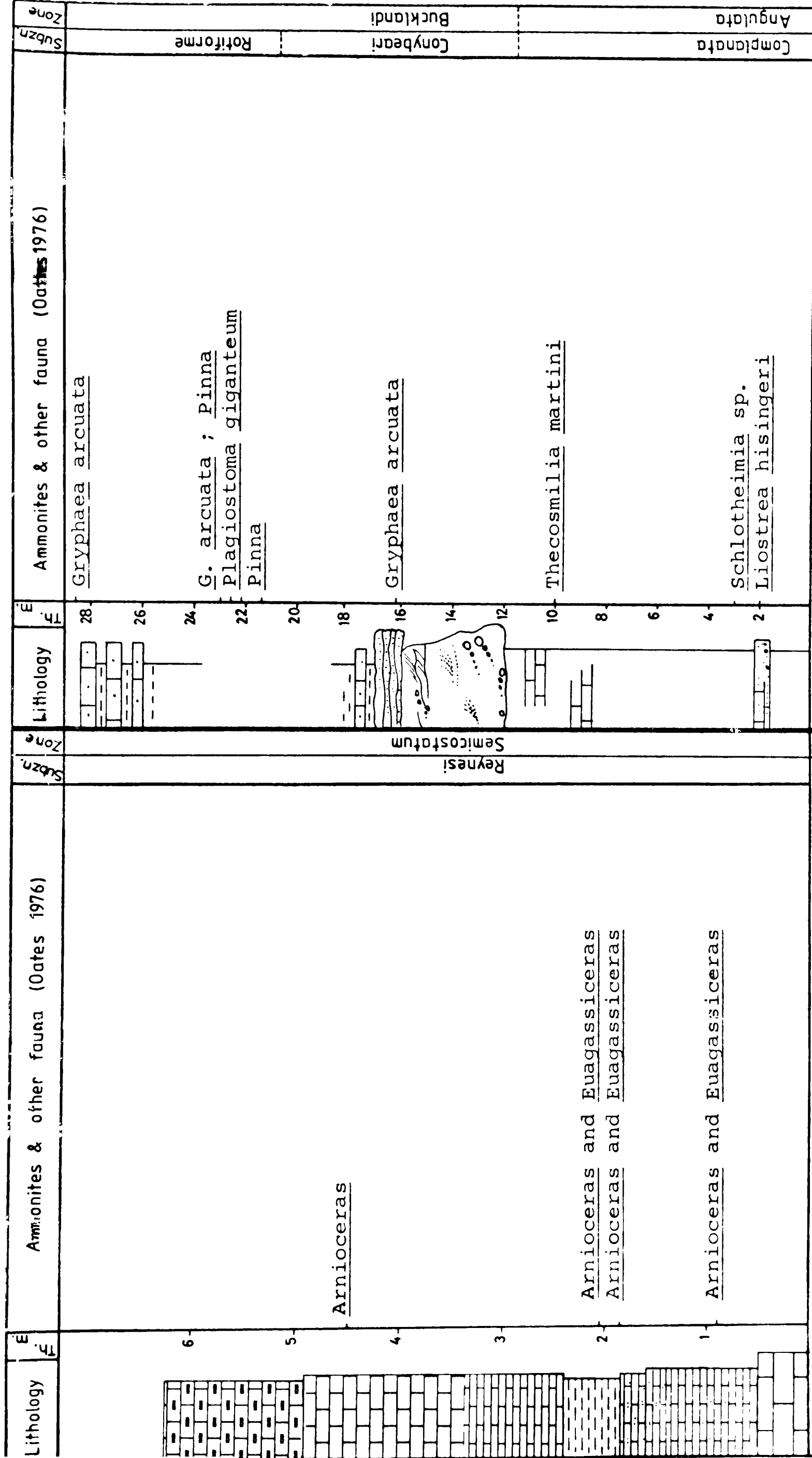
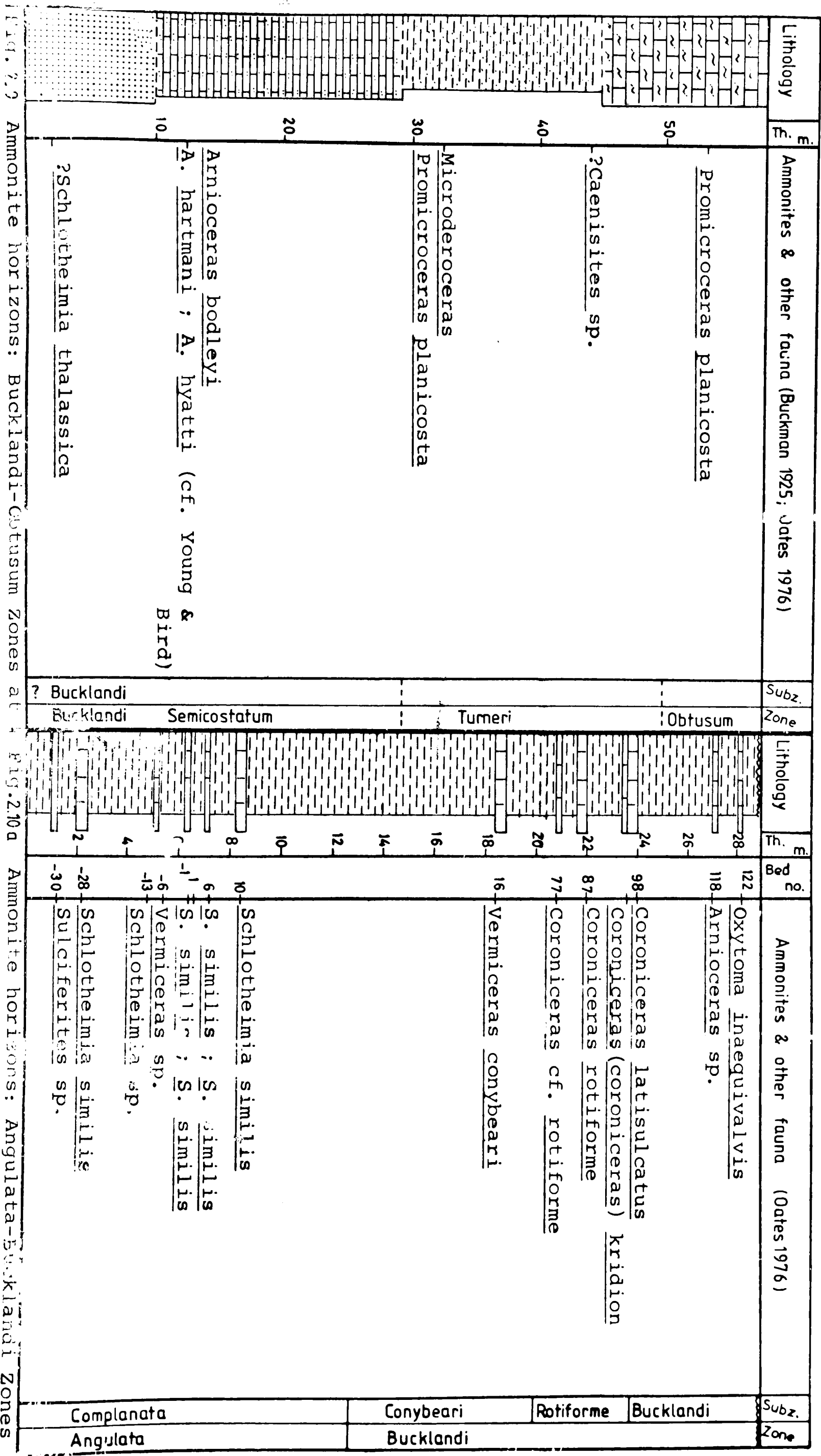


Fig.2.7 Ammonite horizons: Semicostatum Zone at Mingary Castle, Ardnamurchan.

Fig.2.8 Ammonite horizons: Bucklandi Zone at Garbh Rubha, Ardnamurchan.



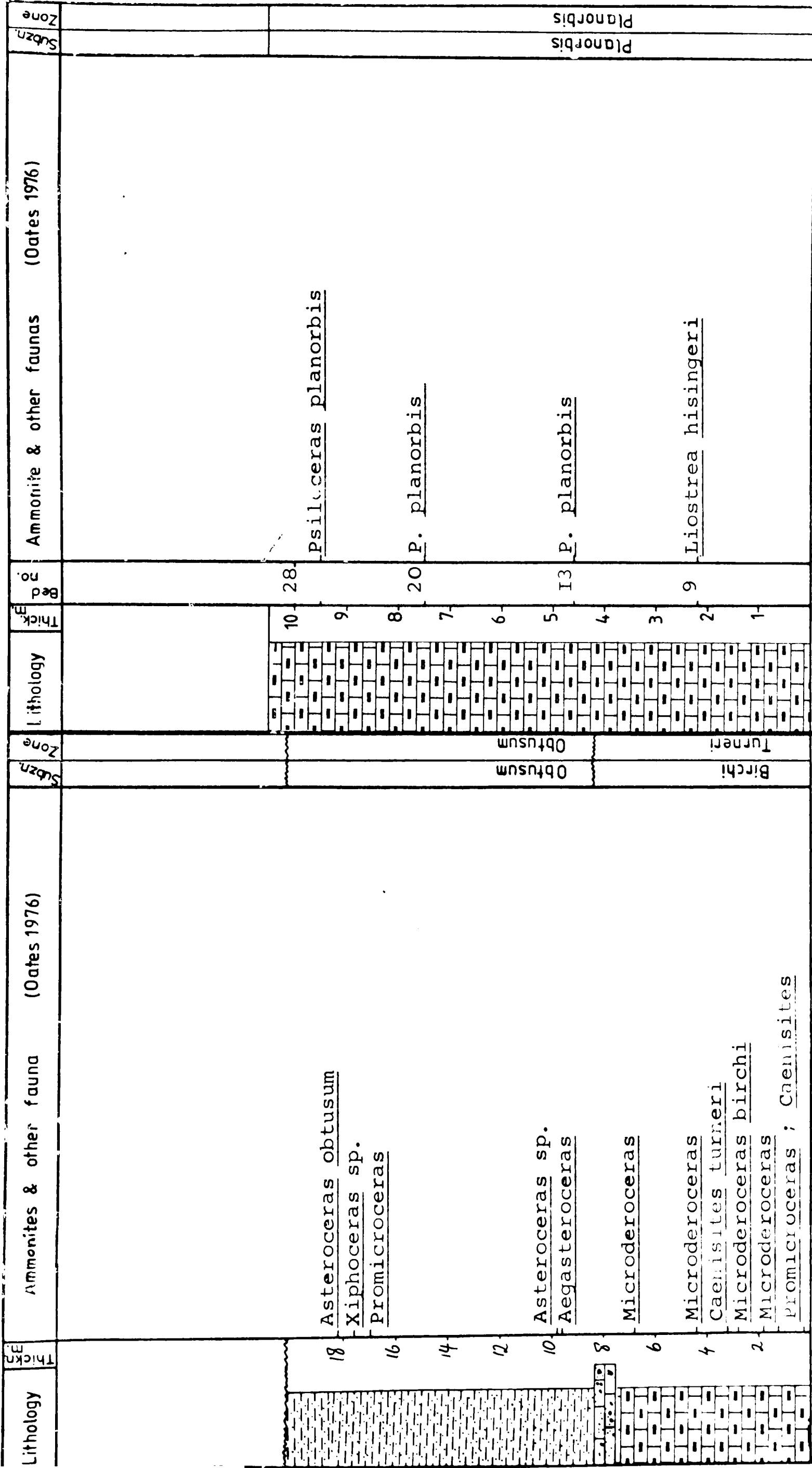


Fig.2.10b Ammonite horizons: Turneri-Obtusum Zones
at Allt Leacach, Loch Aline.

Fig.2.11 Ammonite horizons: Planorbis Zone at
Wilderness, Mull.

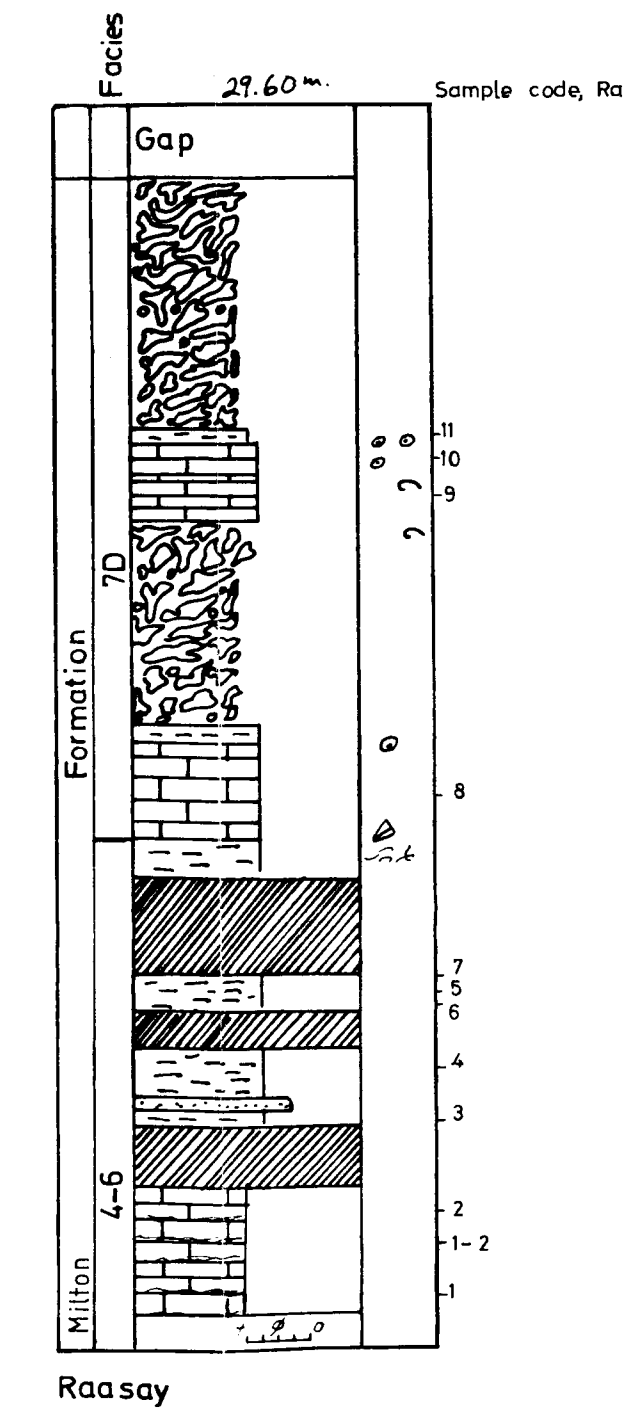
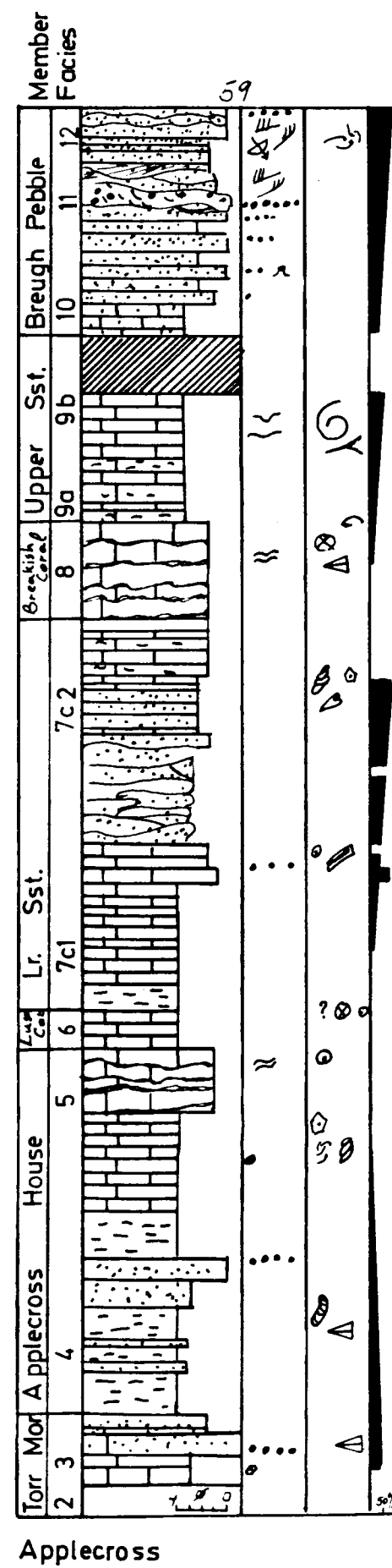
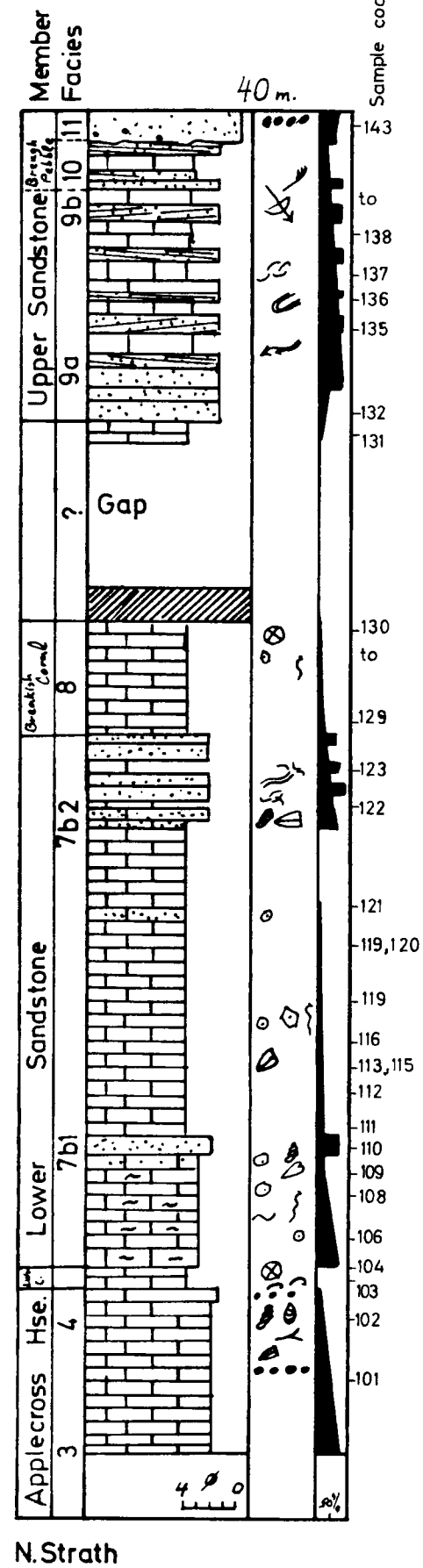
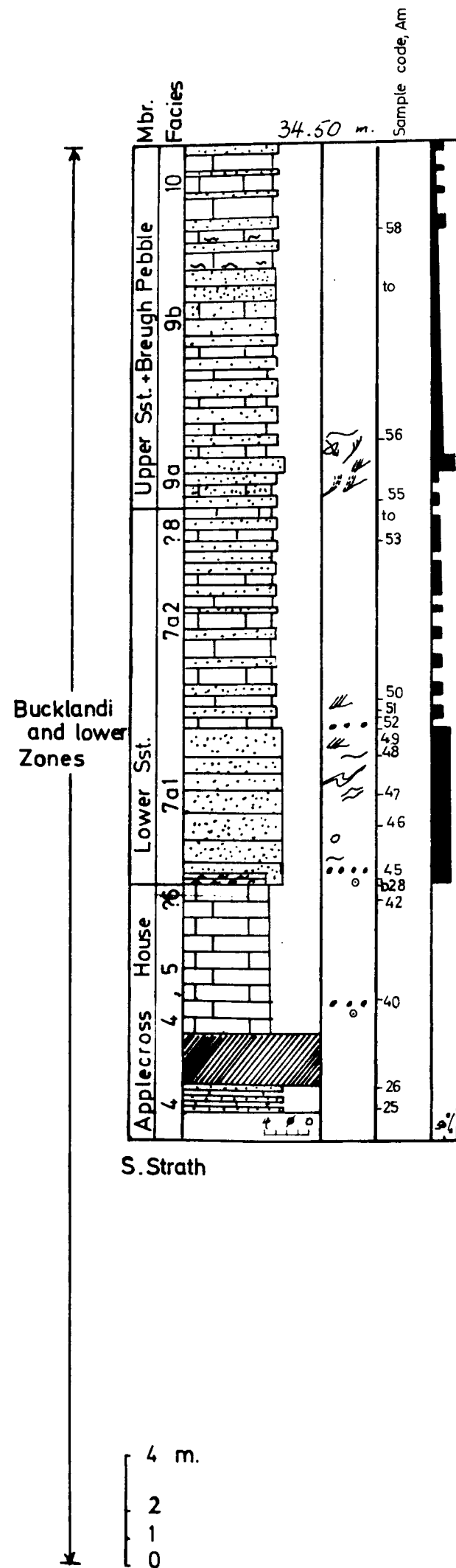


Fig. 2.13
Lithostratigraphy and facies
in the northern area of study.

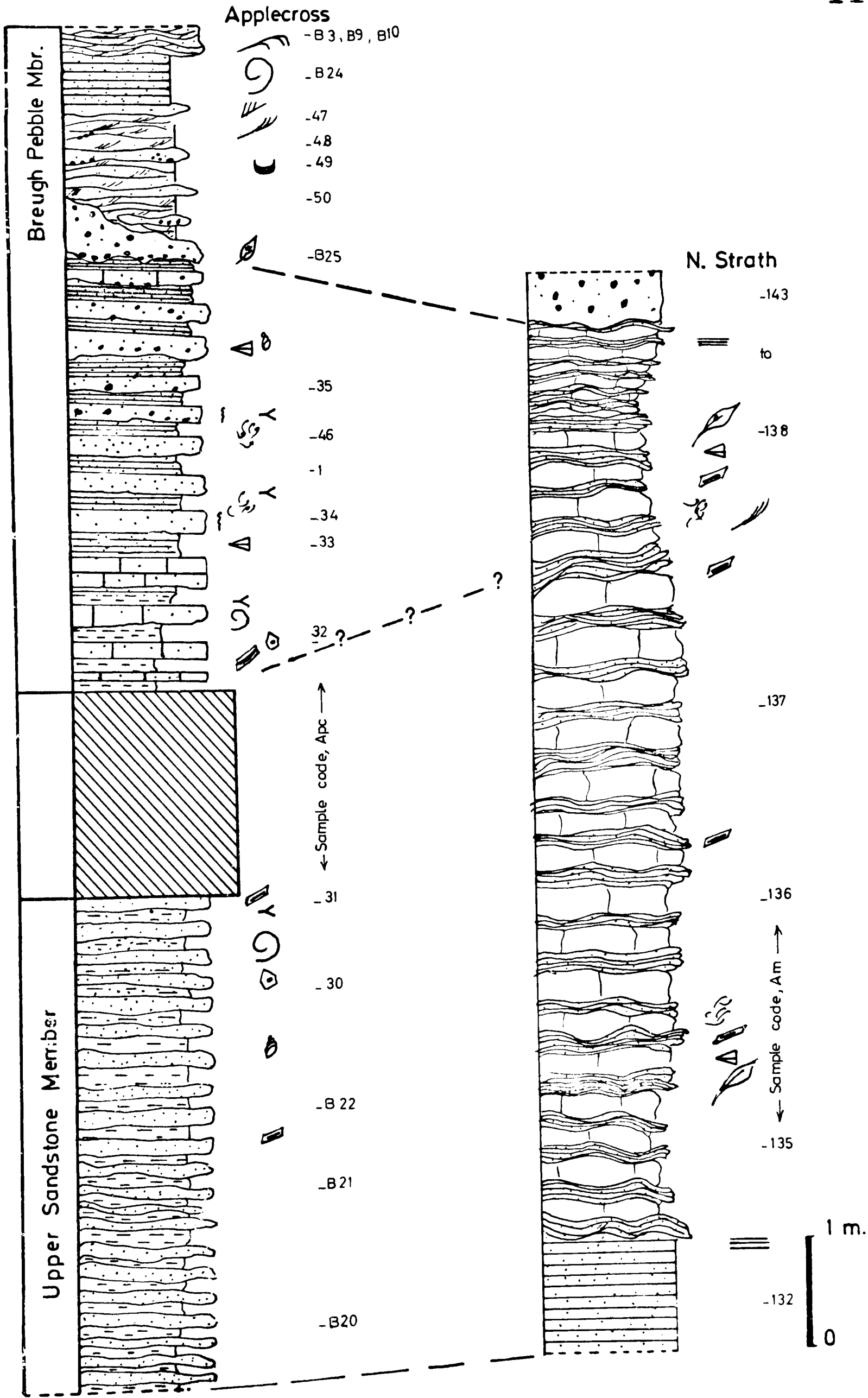


Fig. 2.14 The Upper Sandstone and Breugh Pebble Members in Applecross and northern Strath.

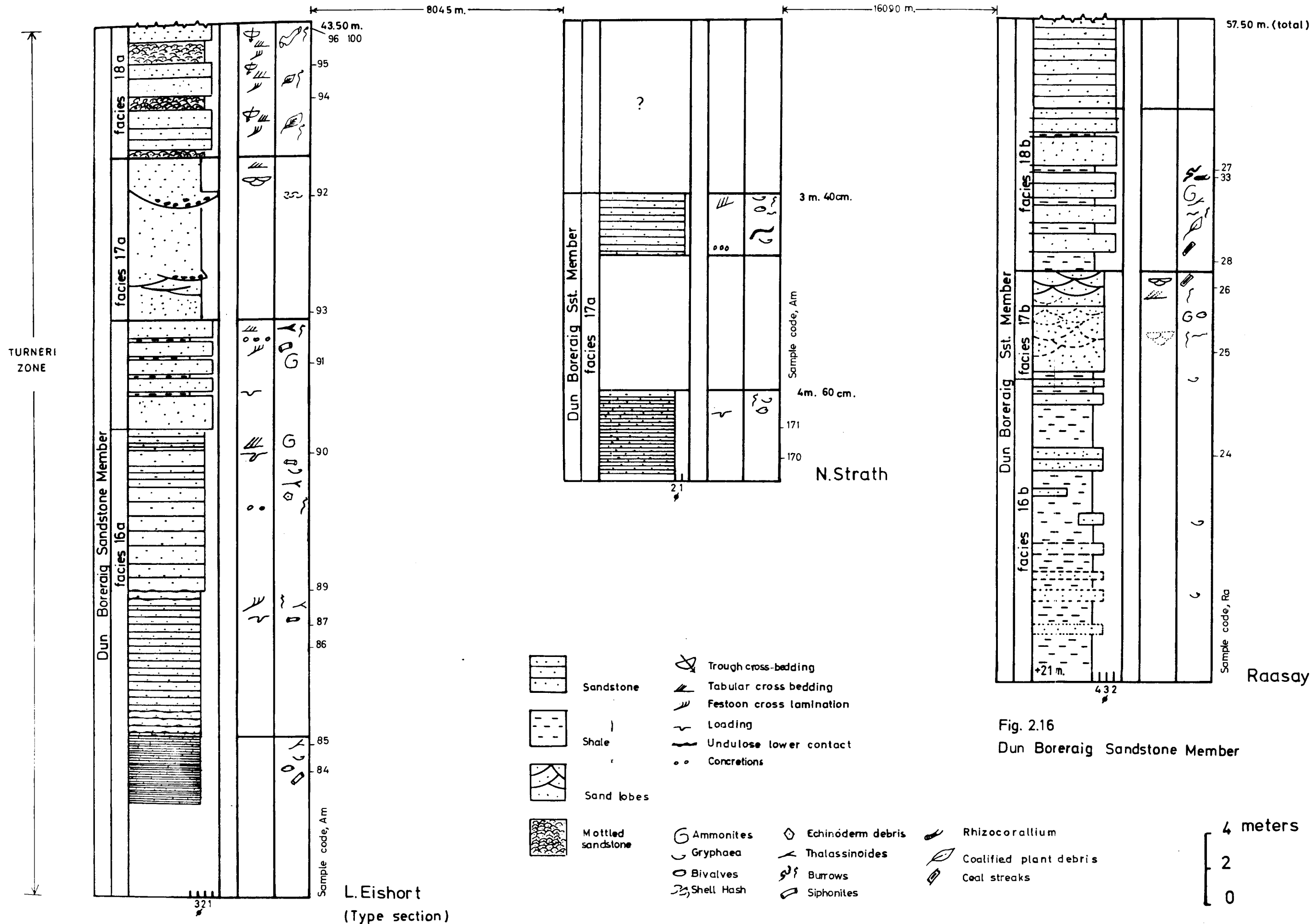


Fig. 2.16
Dun Boreraig Sandstone Member

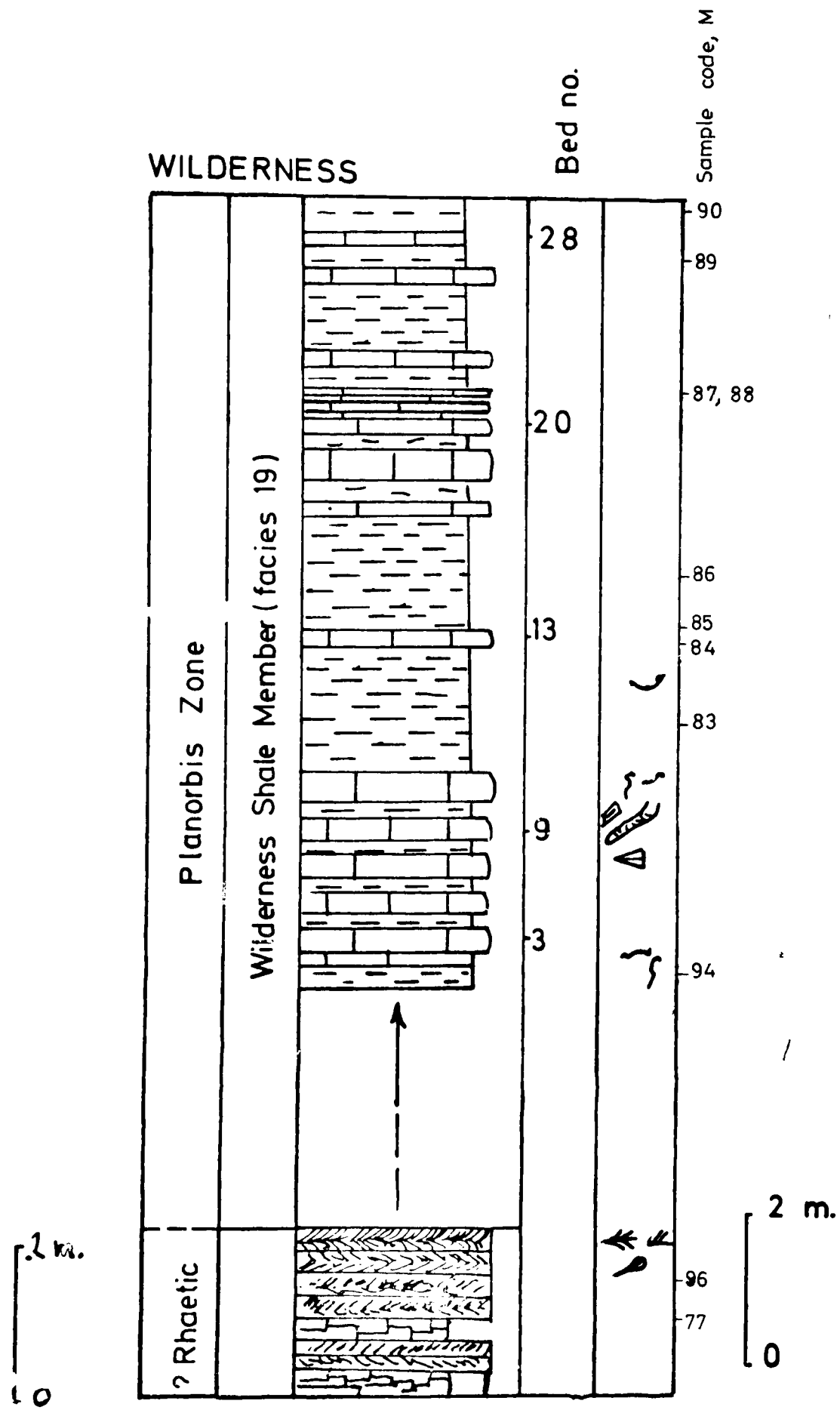


Fig. 2.17

Wilderness Shale Member (Type section).

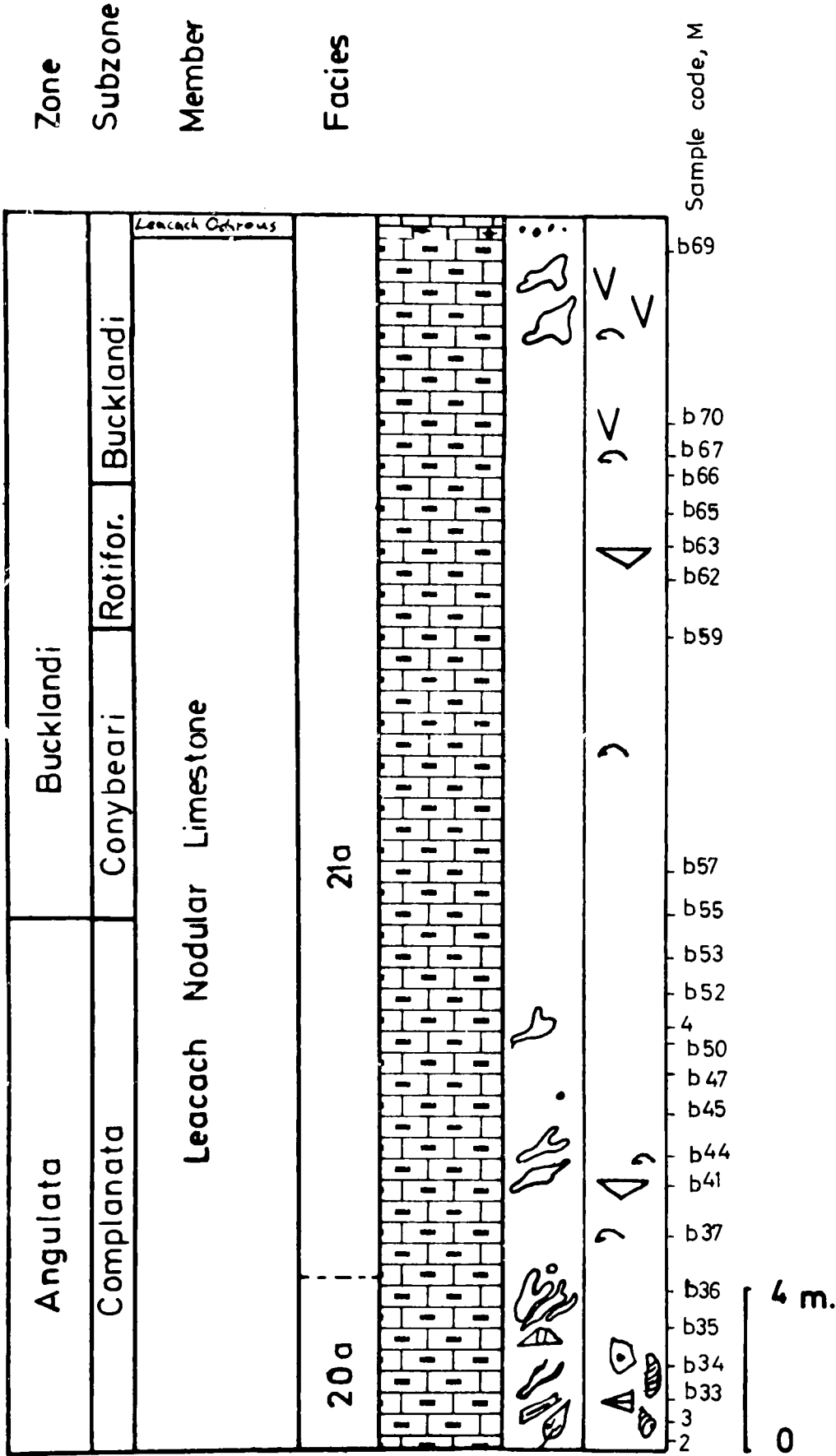


Fig. 2.18
Leacach Nodular Limestone Member, Allt Leacach Loch Aline.

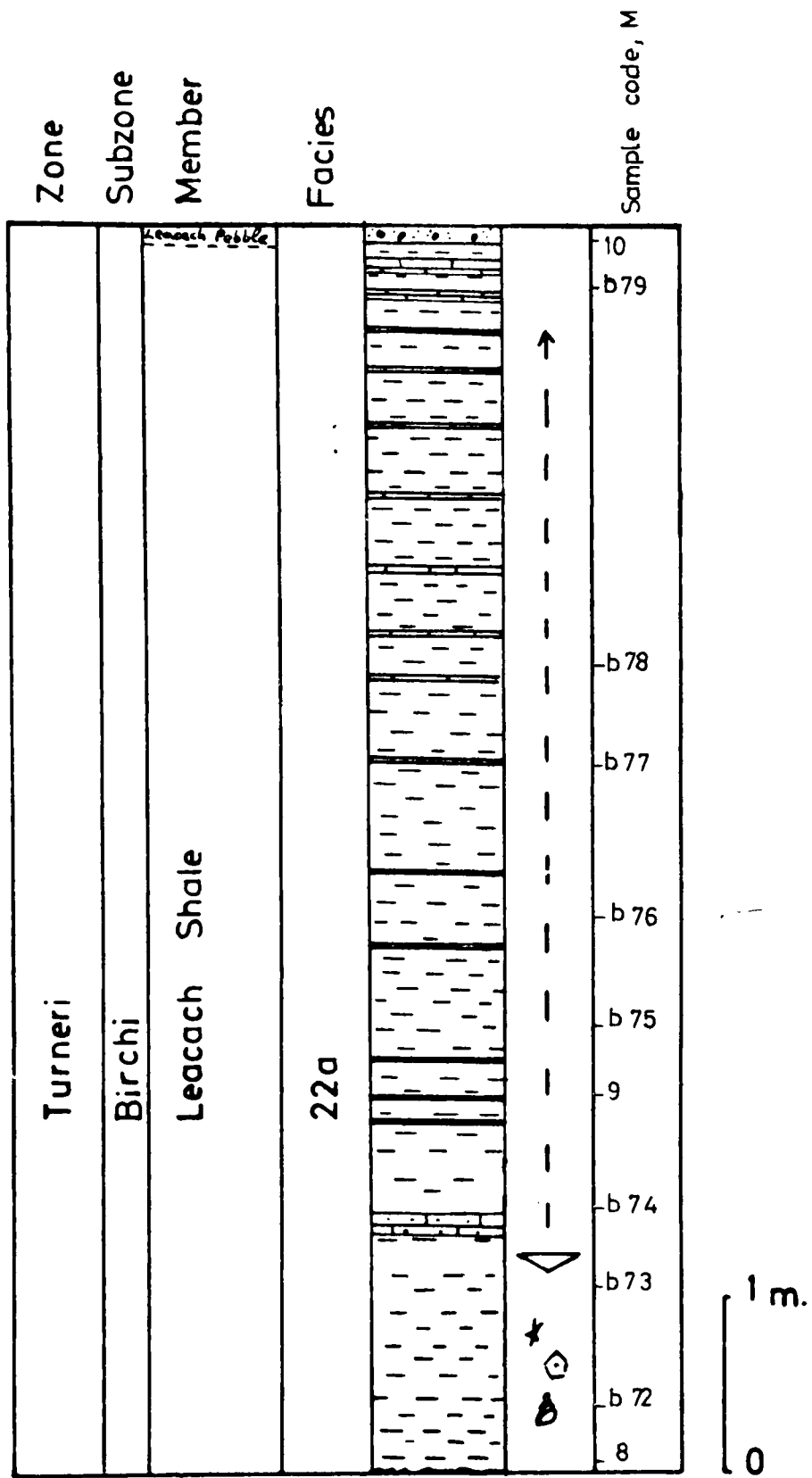


Fig. 2.19

Leacach Shale Member, Allt Leacach Loch Aline.

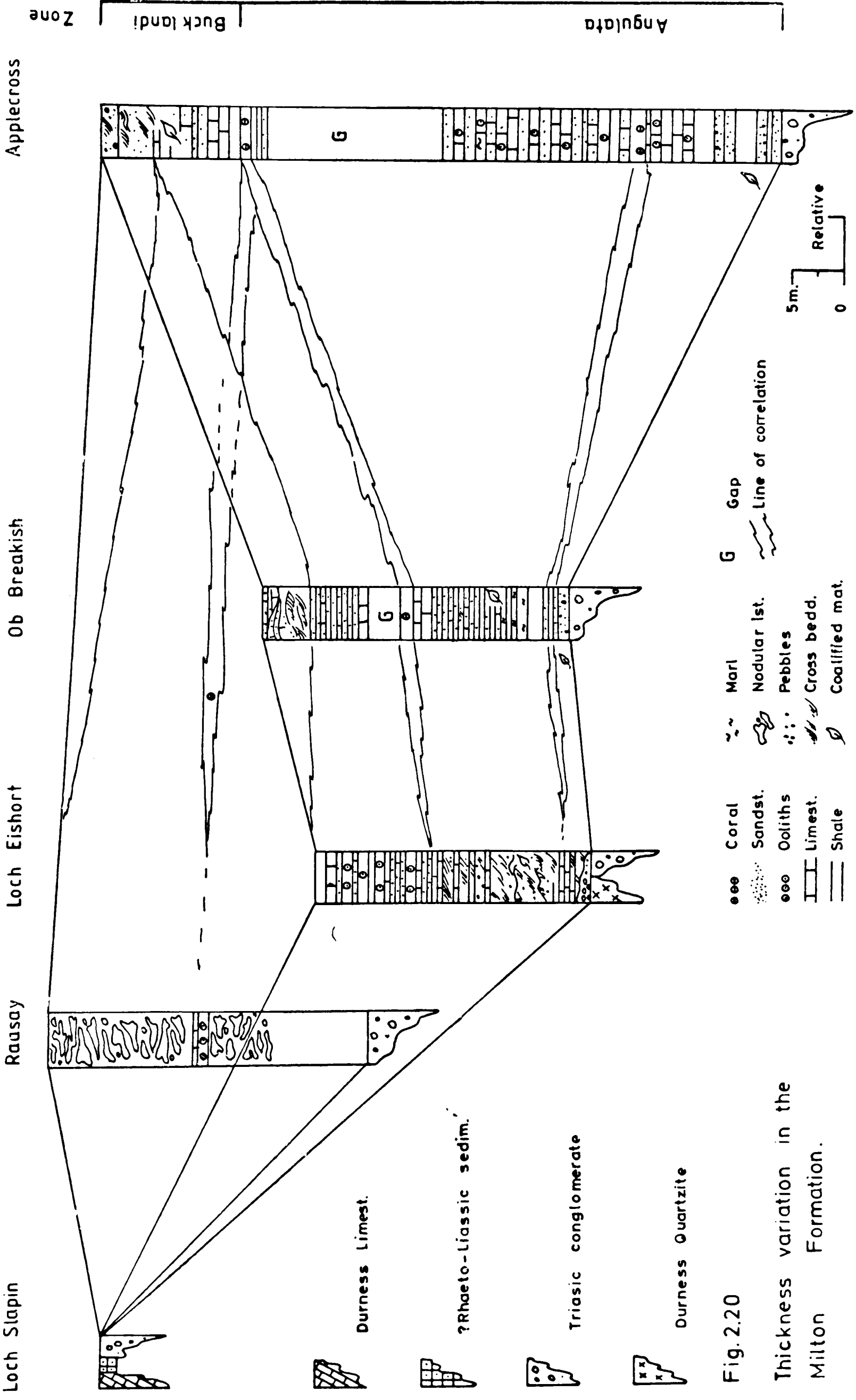


Fig. 2.20

Thickness variation in the Milton Formation.

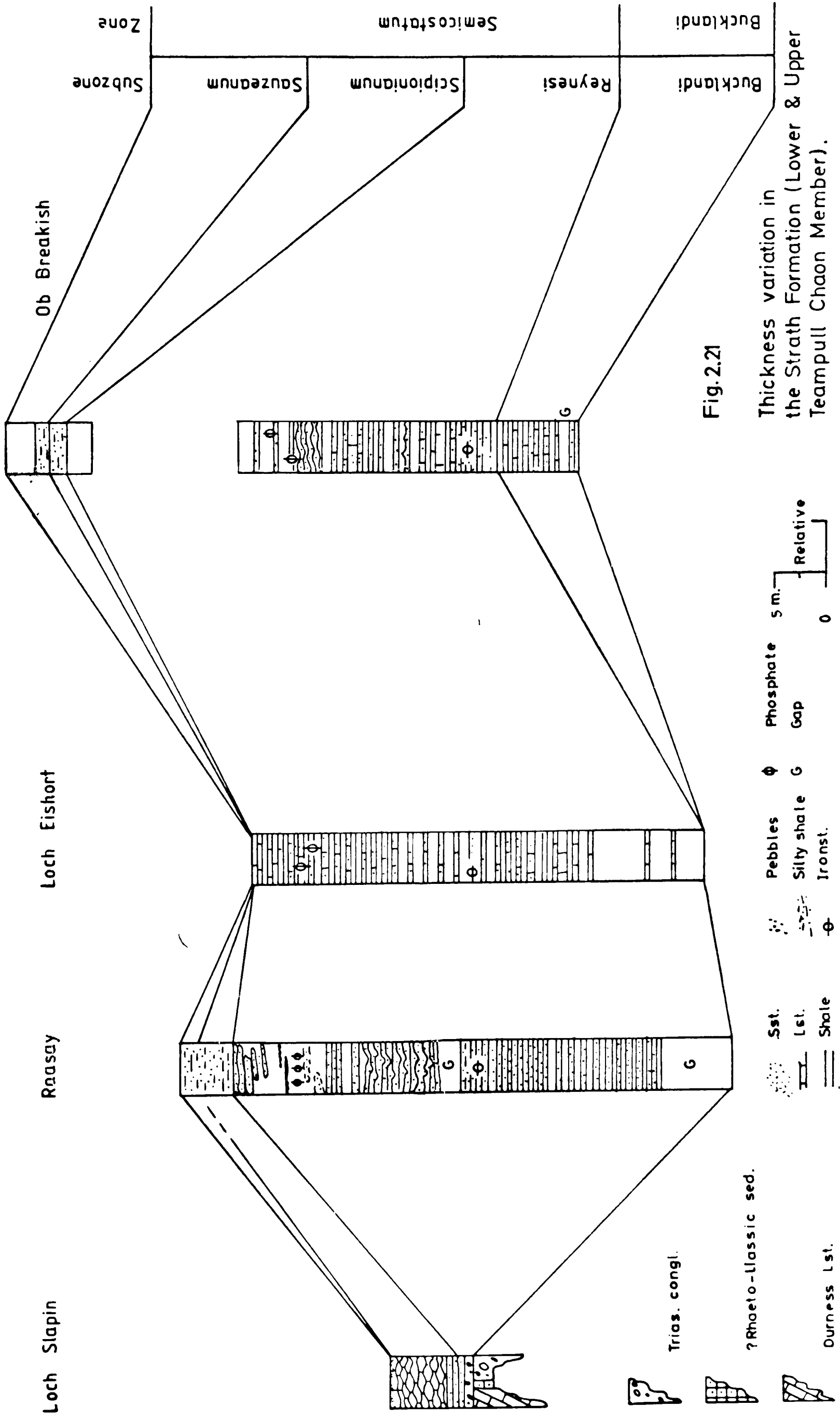


Fig. 2.21

Thickness variation in the Strath Formation (Lower & Upper Teampull Chaon Member).

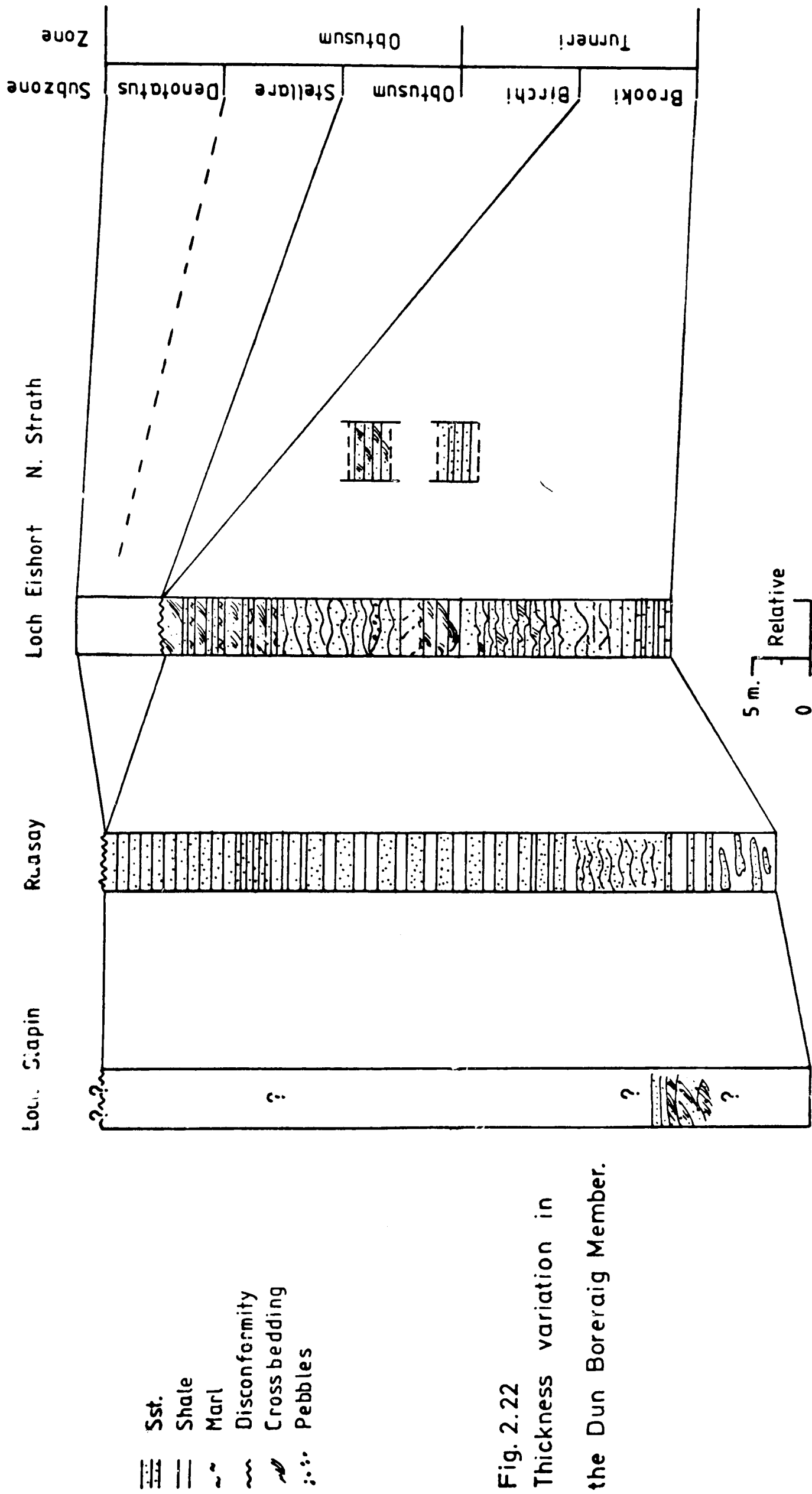
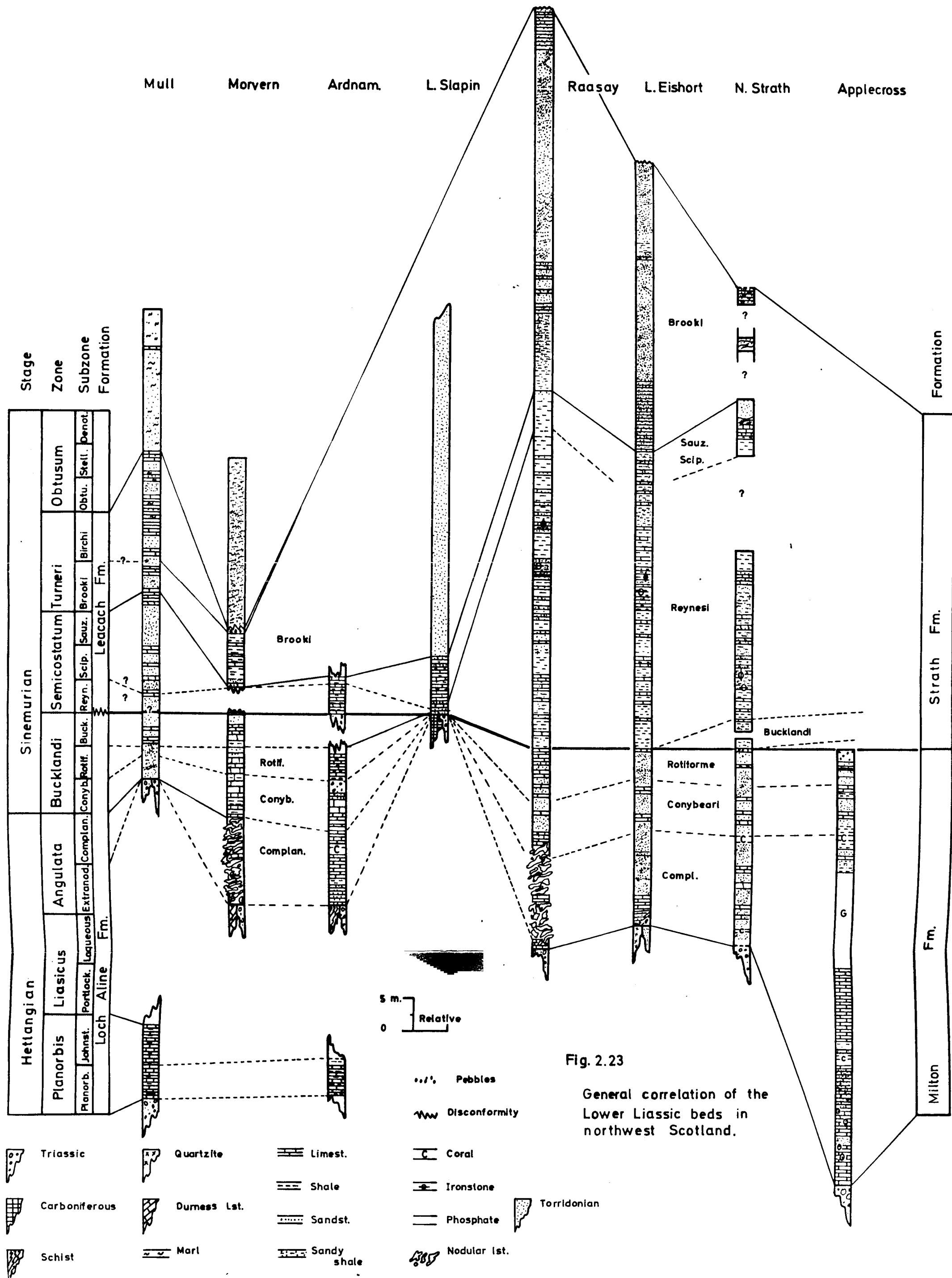


Fig. 2.22
Thickness variation in
the Dun Boreraig Member.



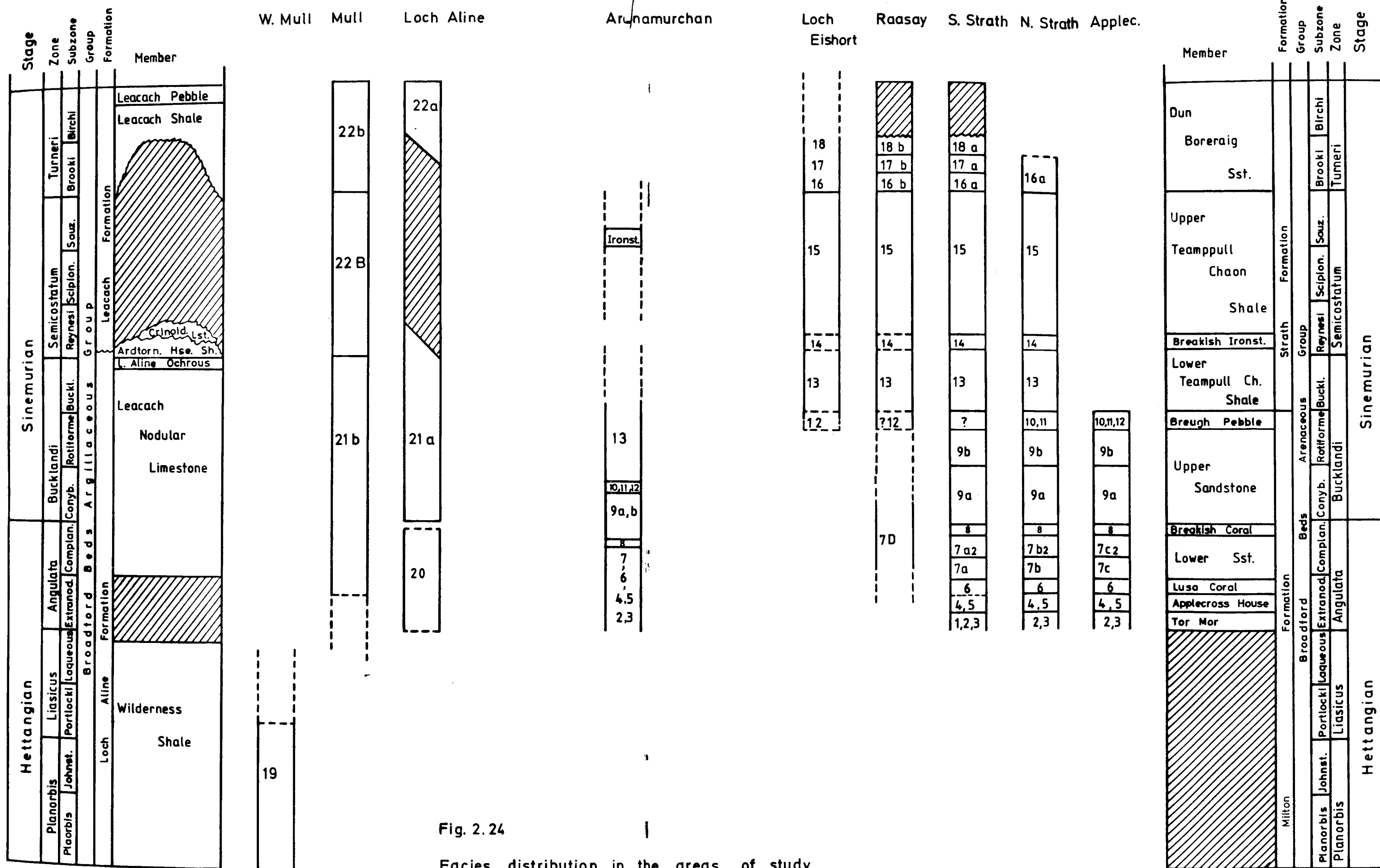


Fig. 2. 24

Facies distribution in the areas of study.

Table 2.2
Explanation of lithostratigraphy
in the southern area.

Group	Form.	Member	Th m.	Hallam (1959)	Oates (1976) Bed no.	Subzone	Zone	Stage
BROADFORD BEDS ARGILLACEOUS	LEACACH	Leacach Pebble	0.8	UPPER BROADFORD BEDS	PABAY BEDS	Obtusum	Obtusum	SINEMURIAN
		Leacach Shale				Birchi	Turneri	
						Brooki		
						Sauzeanum	Semicostratum	
	LOCH ALINE			Scipionianum				
				Reynesi				
				Bucklandi	Bucklandi			
				Rotiforme				
				Conybeari				
					Complanata	Angulata	HETTANGIAN	
	Not exposed	12.28	Extranodosa	Liasicus				
			Laqueous	Planorbis				
			Portlocki	Johnstoni				
				Wilderness Shale	10.50			

	Sandstone		Ostracods
	Limestone		Echinoderms
	Lst./Sh.		Bioturbation
	Congl.		Plant Fragments
	Shale		Coalif. wood & rootlets
	Pebbly sst.		<u>Thalassinoides</u>
	Silty sh.		<u>Diplocraterion</u>
	Silty calc. sh. & calc. sst.		<u>Rhizocorallium</u>
	Nodular Lst.		<u>Chondrites</u>
	Silty calc. sh.		Escape features & worm tubes
	Marlst./Lst.		Ferruginous beds
	Oolites		Phosphatic beds
	Bioclastic rocks		Festoon cross lam.
	<u>Pinna</u>		Tabular cross lam.
	<u>Gryphaea</u>		Trough cross lam.
	Brachiopods		Ripples
	Bivalves		Parallel lam.
	Corals		Ripple cross lam.

Table 2.3 Explanation of the different symbols used.

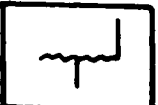
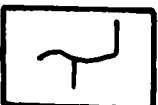
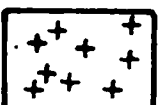
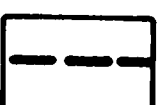
	Scour marks		Escape features
	Channel		<u>Kulindrichnus</u> <u>langi</u>
	Sharp contact		Mounds
	Burrowed contact		Gastropods
	Wavy contact		Liostrea
	Graded contact		
	Schists (Precambrian)		
	Quartzite (Cambrian)		
	Durness limestone		
	Torridonian sandstone		
	Permo/ Triassic congl.		
	Gap		
	Dykes (Tertiary)		

Table 2.3 (continued) Explanation of the different symbols used .

Plate 2.1a. Extremely metamorphosed (? Hettangian), limestone/shale beds found near Glenbyre Farm, Loch Buie, Mull. Beds contain crinoidal debris and Gryphaea. Dip 80-90° to the northwest.

Plate 2.1.b. Alternating limestone/shale beds (?Hettangian) seen at the same locality as that of Plate 2.1.a. Note Gryphaea shells at the base of limestone bed which is fractured and has a variable thickness.



Plate 2.1.c. Massive ?Hettangian limestone with abundant
cylindrical (horizontal and vertical burrows). Dip un-
determinable; locality as plate 2.1a.



Plate 2.2.a. Basal beds of the ?Hettangian succession at Rubha na Fear (southern Mull NR634201). Beds shown at the lower part of the photograph are near the base of the succession, overlying Triassic conglomerates. Note thinning upward character of the calcareous sandstone/silty shale beds (dip 25⁰ to the north).

Plate 2.2.b. ?Hettangian succession at Rubha na Fear, Thin bedded alternating limestones and calcareous sandstones comprising the middle part of the succession; dip 25⁰ to the north. (cf. Plate 2.2a.).

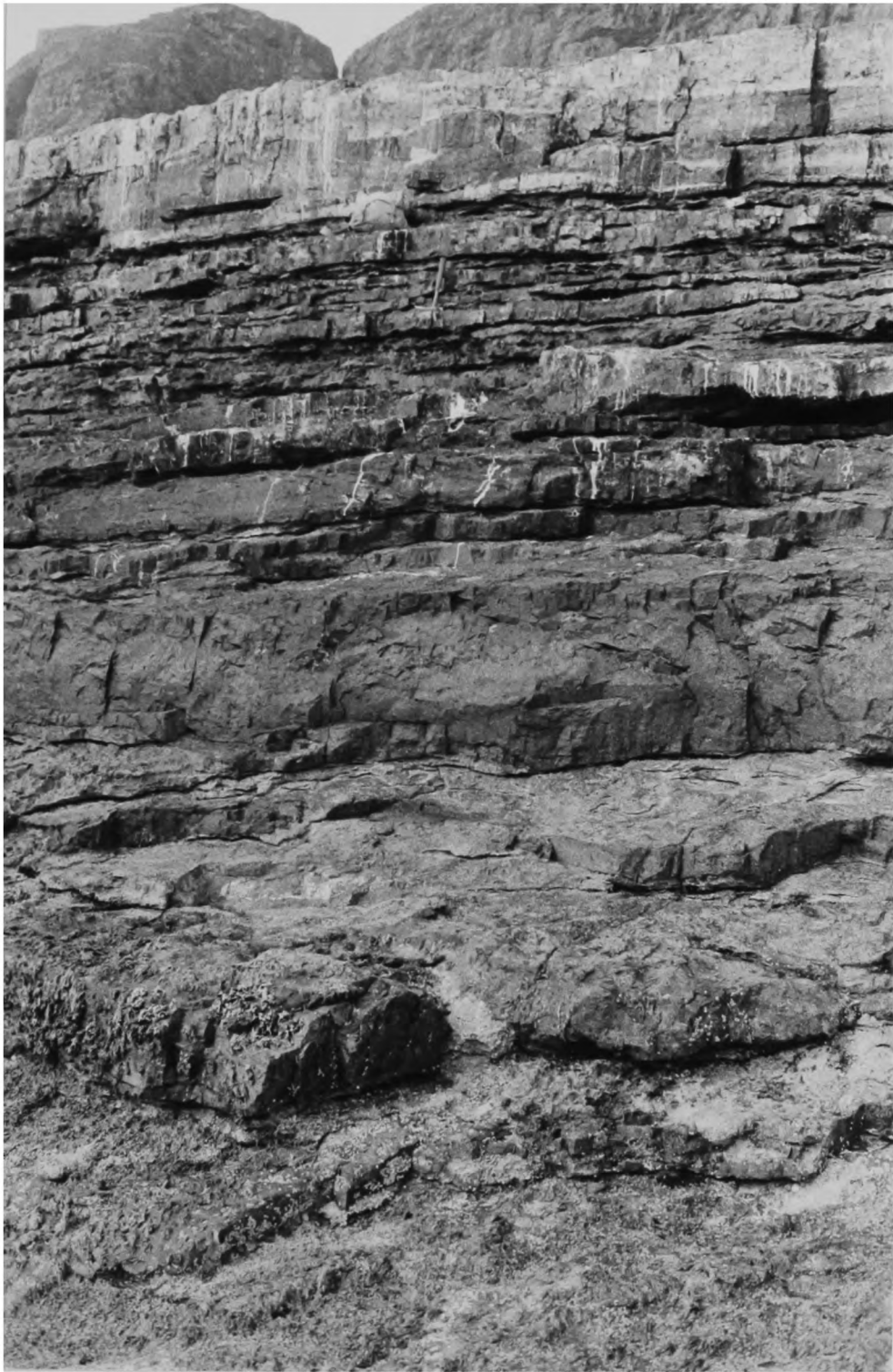


Plate 2.2.c. ?Sinemurian beds immediately underlying Pabba Shales at Rubha na Fear (Mull). Note the development of silty shales at the expense of limestone beds; dip 25° to the north (cf. Plate 2.2b).

Plate 2.3. Faintly cross-laminated beds with symmetrical and interference ripples on top surface. Note gyrocorde-like markings. ?Obtusum Zone of ~~Carsaig~~ Bay.

Craignure
(see text p. 48)



Plate 2.4. Cross bedded calcareous sandstones with calcareous

doggers found in the beds of ?Obtusum Zone age of ~~Carsalg~~,

Bay, (Mull).

Craigmuir
(see text pg 48)



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Plate 3.1. Fractured quartz grain with corroded margin, often found in the calcareous beds of the Milton Formation. x 16. Thin section.

Plate 3.2. Possible mould of feldspar crystal, note faint indication of cross hatching. Photograph taken from the surface of a quartz grain (Milton Formation). x 25K.

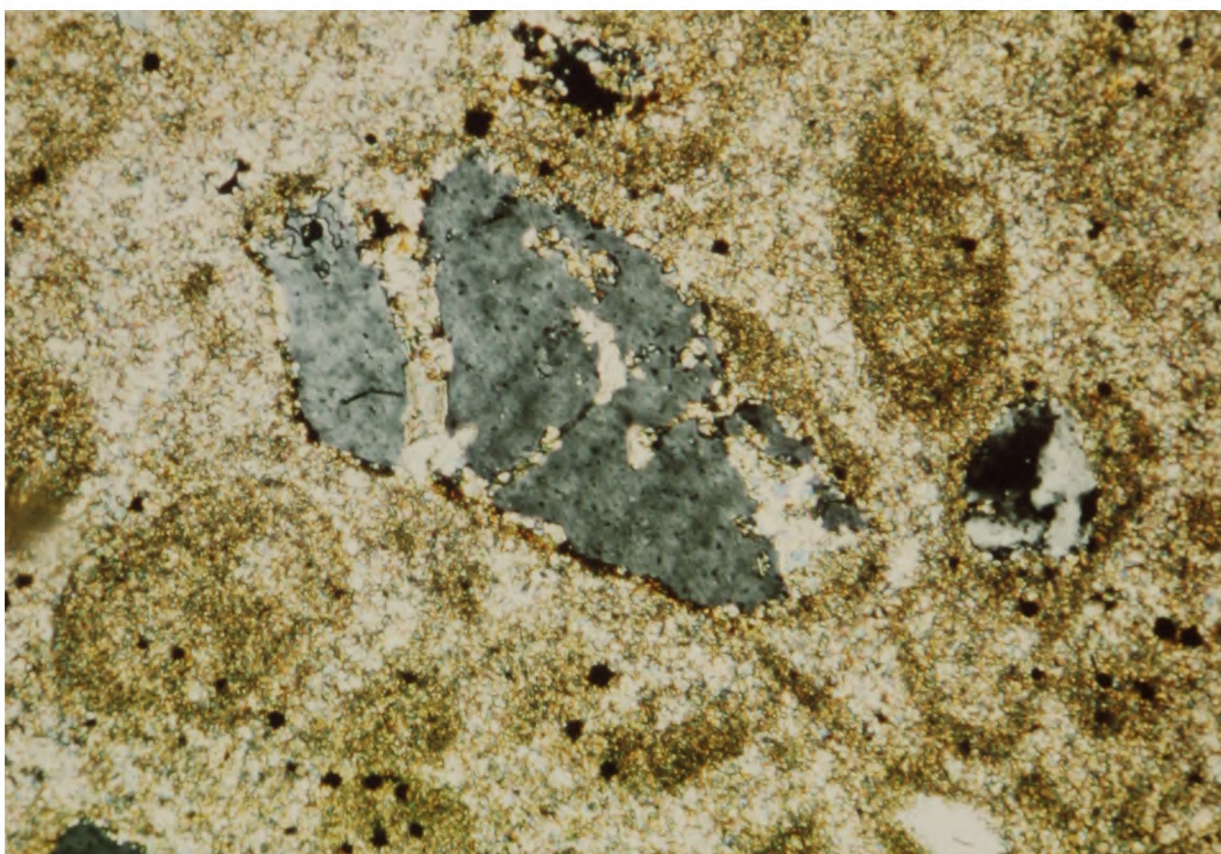


Plate 3.3. Surface pitting and etching on quartz grain found in
the calcareous siltstones of the Strath Formation.
xlK.

Plate 3.4. Upturned quartz plates on the surface of a grain
from the *Milton* Formation, Skye.
x36K.

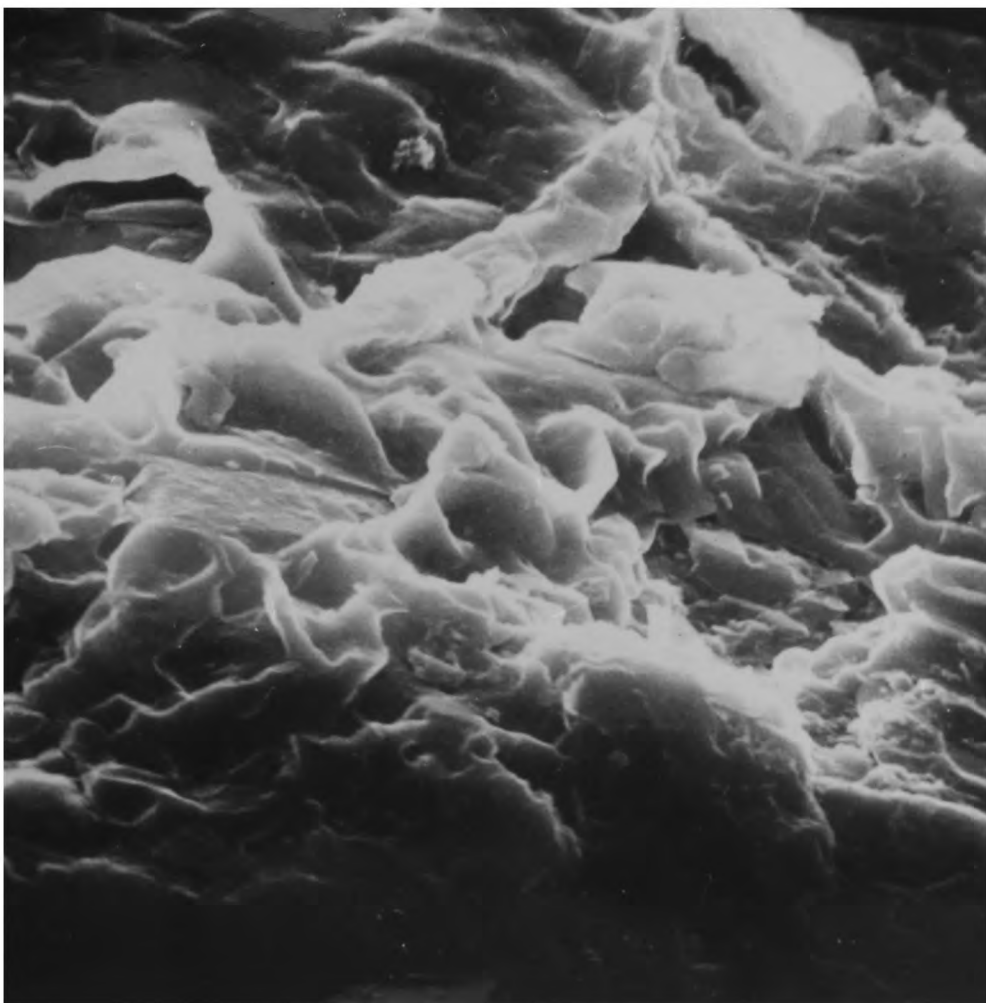
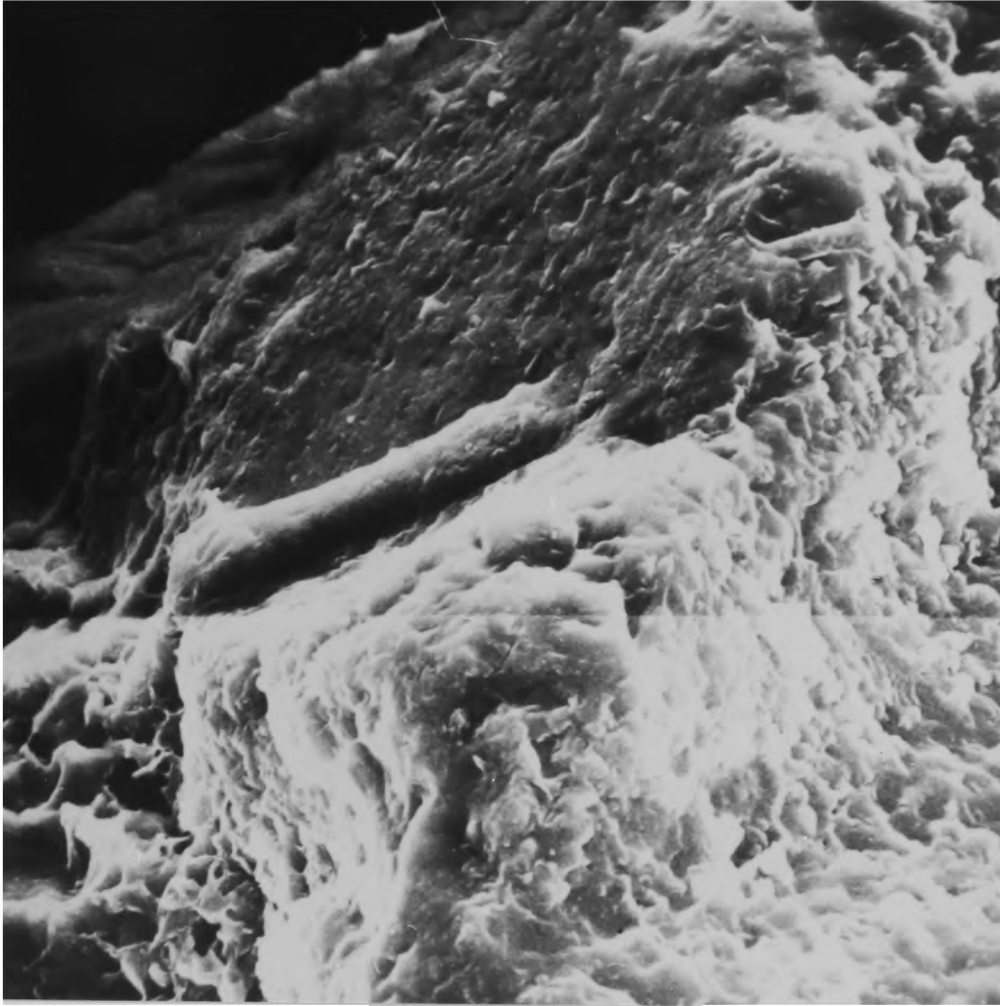
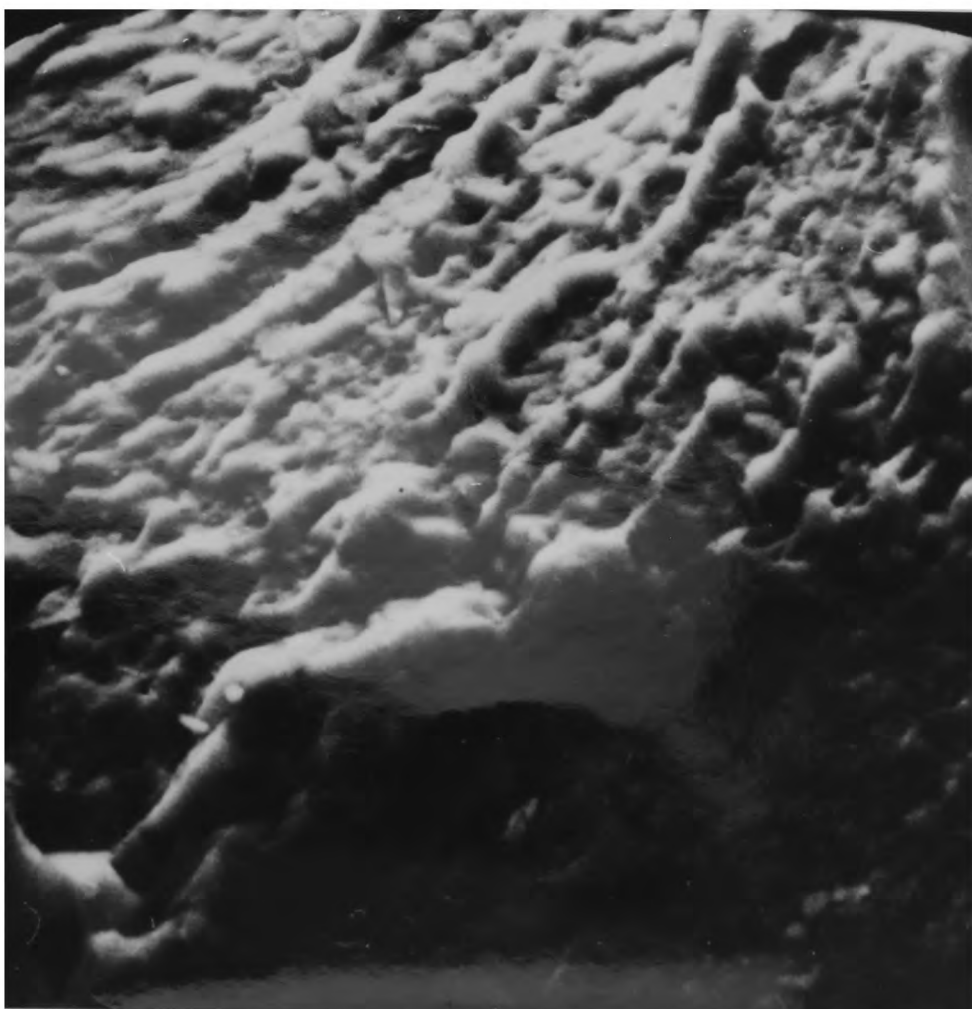


Plate 3.5. Silica precipitation on grain surface. Note possible original grain ornamentation on the surface to the left of the photograph; the fresh surface to the right shows no sign of solution-precipitation. Sample taken from the calcareous sandstones of the Strath Formation.
x 12K.

Plate 3.6. Surface of quartz grain of Plate 3.5 at 24K.



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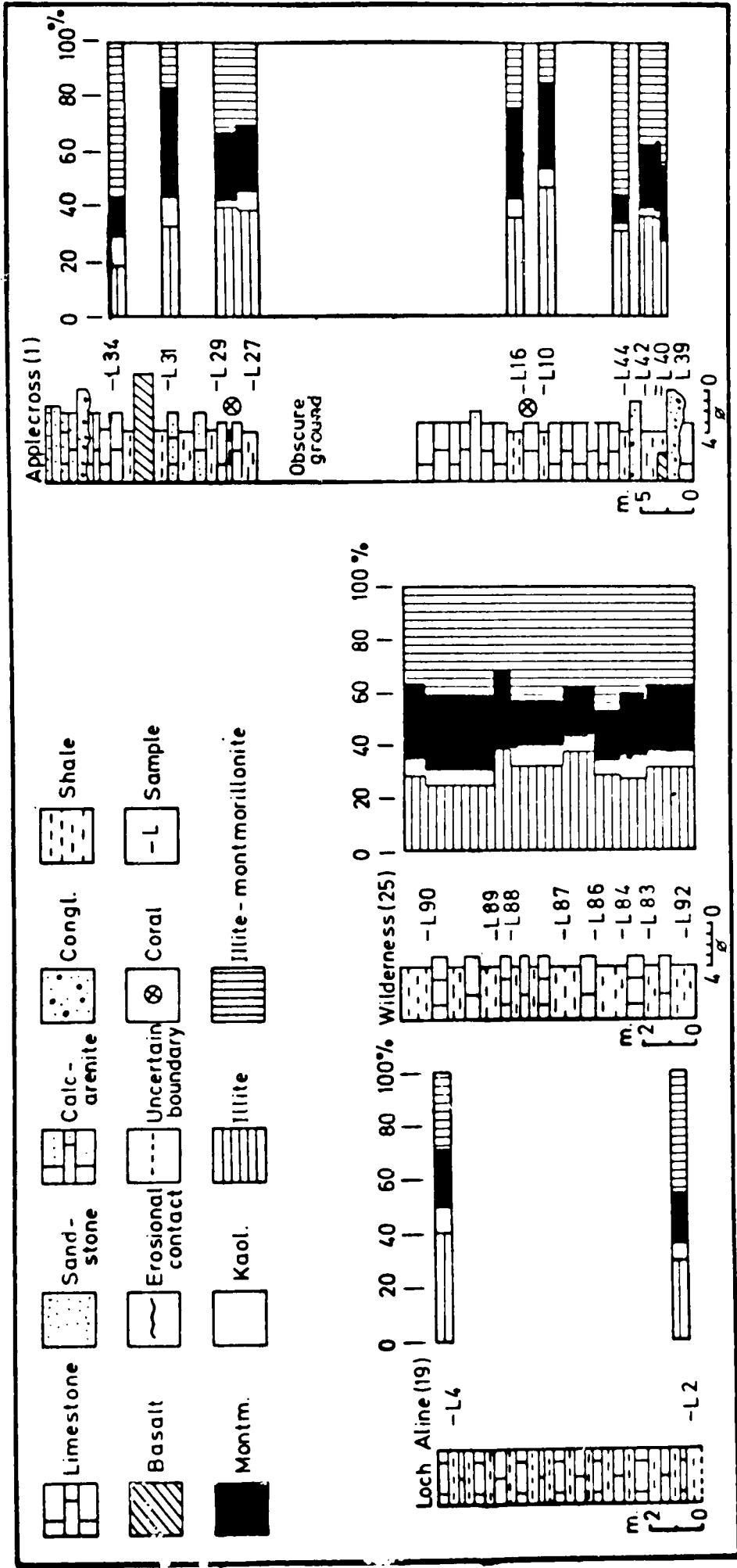


Figure 4.1 Clay mineral content of the Lower Broadford Beds (Upper Planorbis - Lower Bucklandi zones). Location of sections given in parentheses.

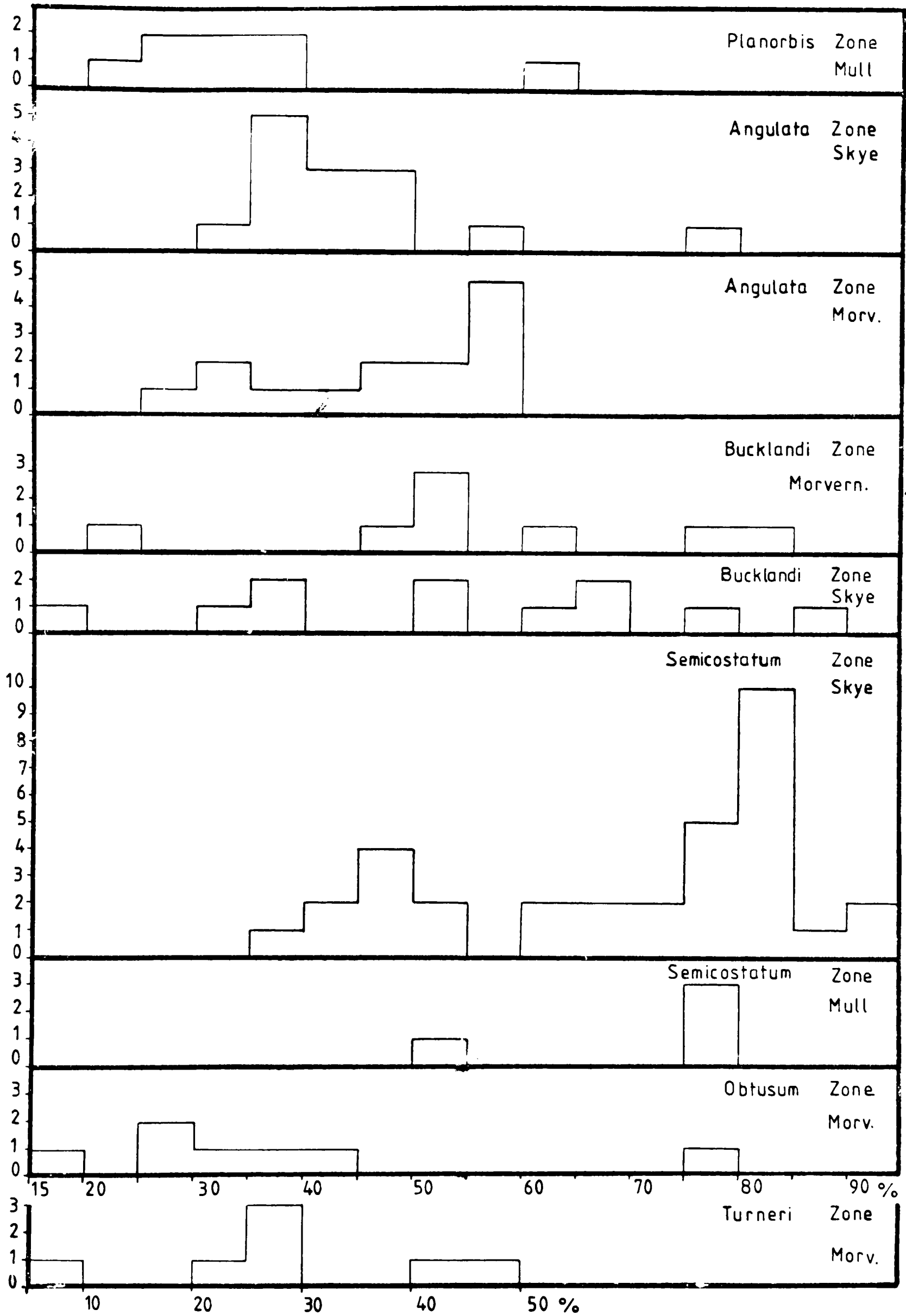


Fig.4.2
Relative abundance of illite clay minerals in the Lower Liassic beds of northwest Scotland.

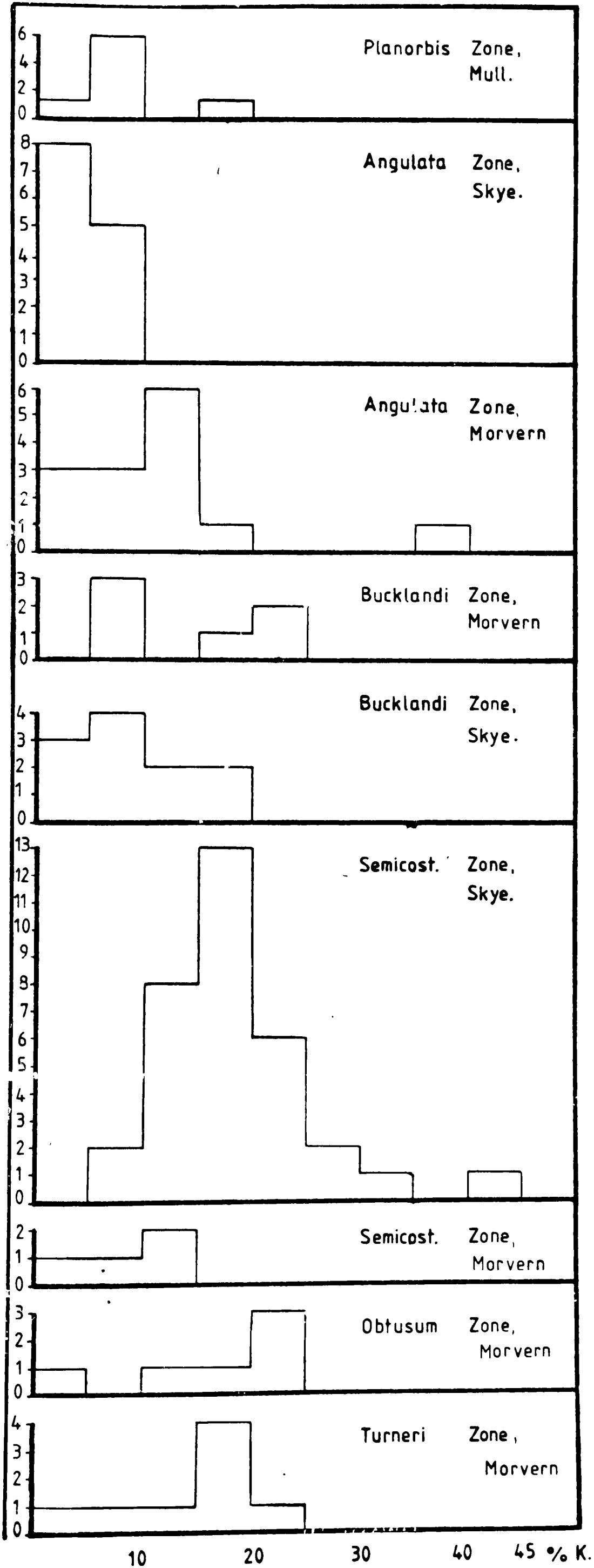


Fig.4.3
Relative abundance of kaolinite clay minerals in the Lower Liassic beds of northwest Scotland.

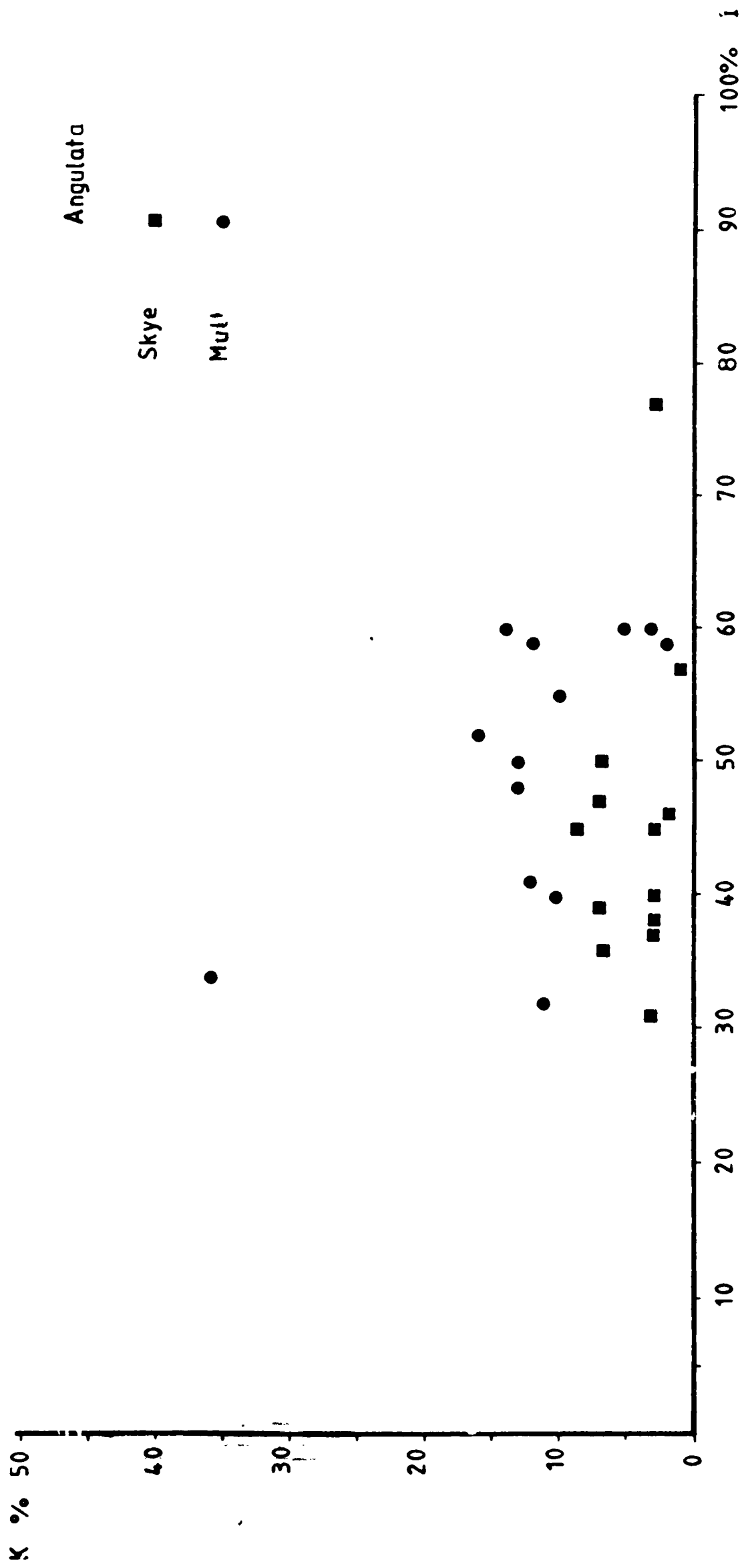


Fig. 4.4

Kaolinite vs. Illite in the Lower Liassic shales of northwest Scotland.

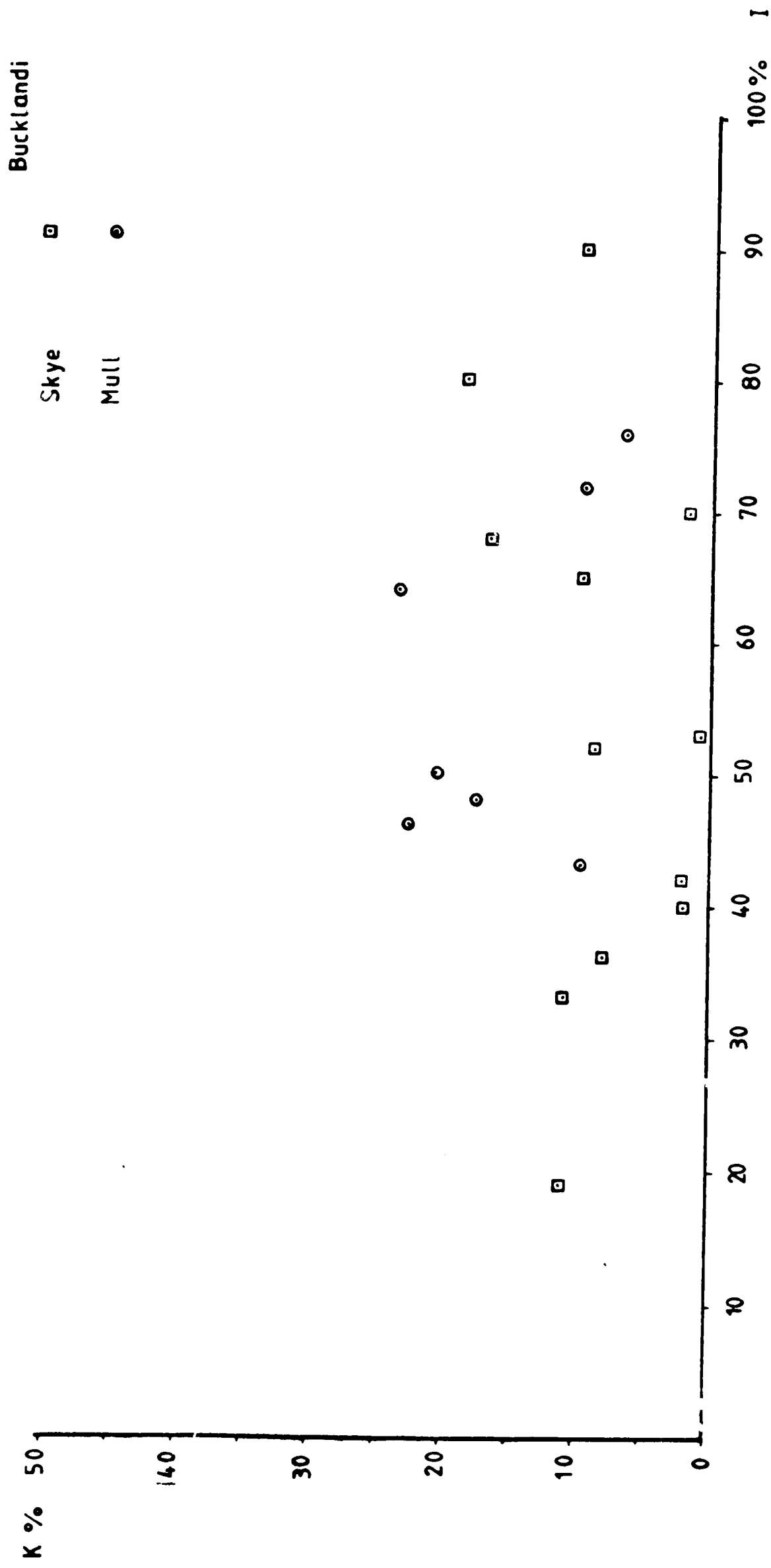


Fig. 4.5

Kaolinite vs. illite in the Lower Liassic shales of northwest Scotland.

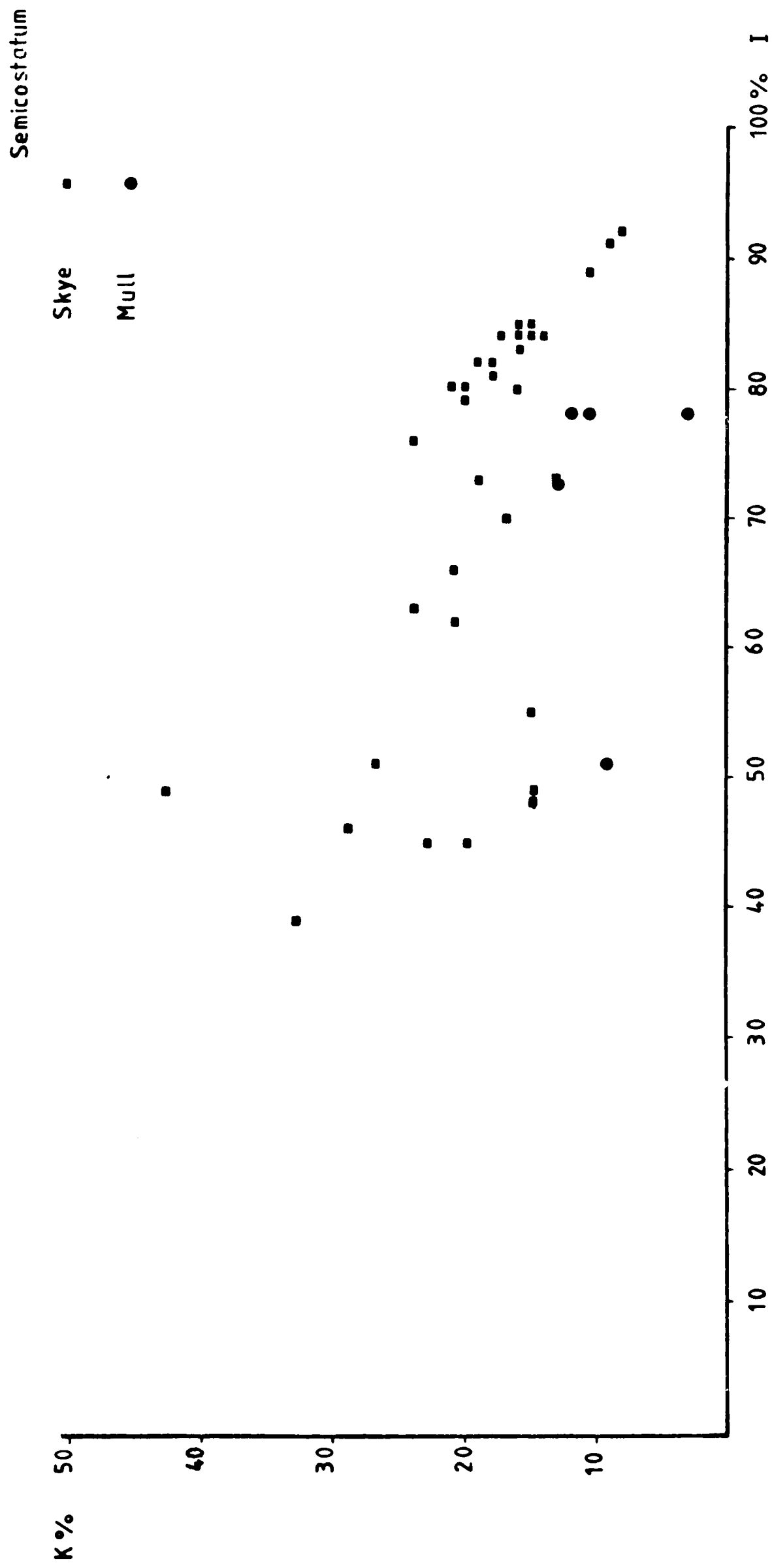


Fig. 4. 6

Kaolinite vs. Illite in the Lower Liassic shales of northwest Scotland.

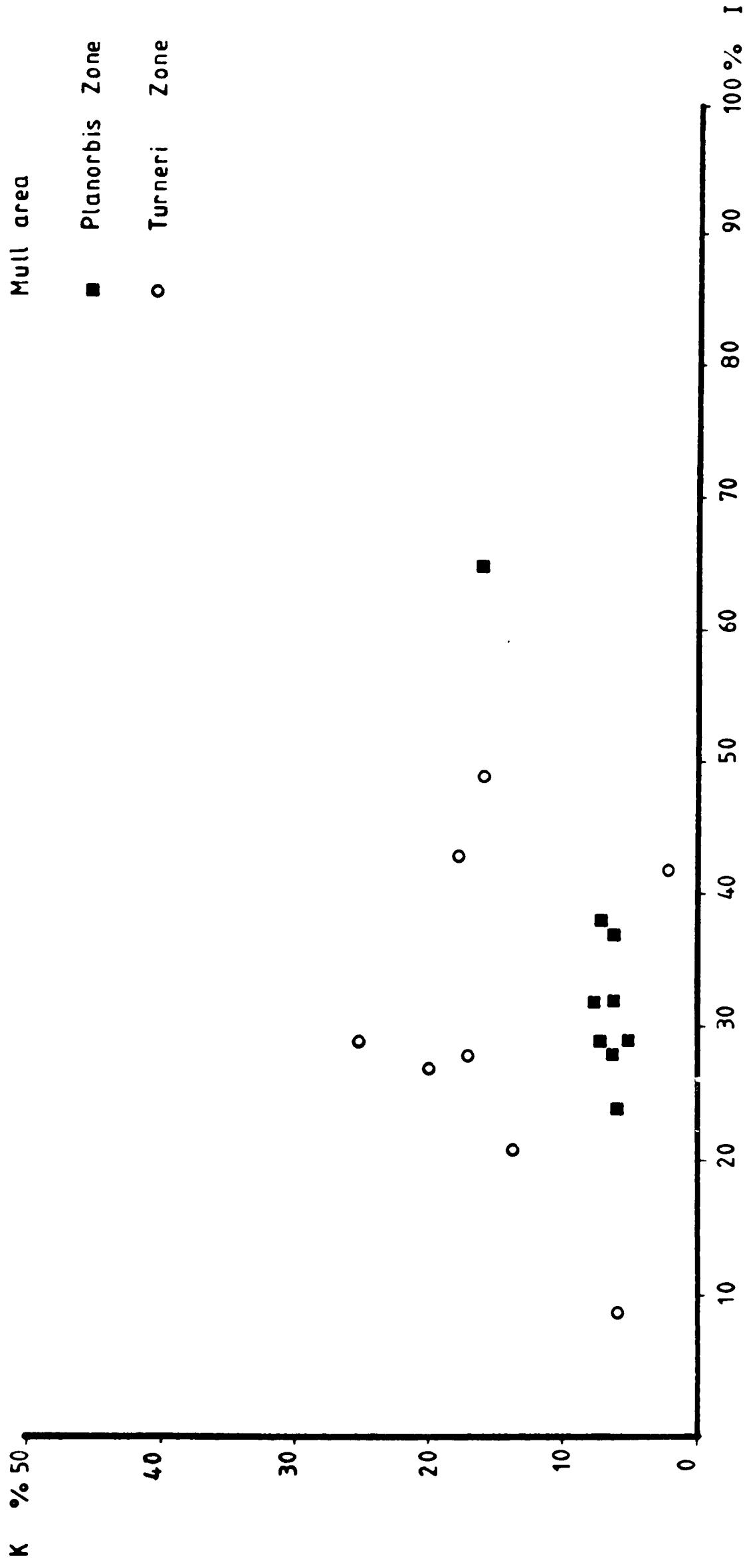


Fig. 4.7
Kaolinite vs. Illite in the Lower Liassic shales of northwest Scotland.

Zone	Subzone	Format.	Out-crop	Sample	Smec. %	Chlor. %	Ill. %	Ill.- smec. %	Kaol.	I/K
Bucklandi	Bucklandi	Loch Aline	19	Mb69	12	-	64	-	24	2.67
			19	Mb70	15	-	50	14	21	2.38
			19	Mb67	12	-	48	22	18	2.67
			19	Mb66	3	-	21	-	76	0.28
			19	Mb65	13	-	43	34	10	4.3
			19	Mb63	10	-	76	7	7	10.86
			19	Mb62	15	-	46	16	23	2
			19	Mb59	18	-	72	-	10	7.2
			19	Mb57	29	-	59	-	12	4.92
			19	Mb55	26	-	60	-	14	4.29
Angulata	Complanata	Loch Aline	19	Mb53	32	-	48	7	13	3.69
			19	Mb52	29	-	41	18	12	3.42
			19	M4	21	-	40	29	10	4
			19	Mb50	35	-	55	-	10	5.5
			19	Mb47	24	-	32	33	11	2.91
			19	Mb45	22	-	34	8	36	0.94
			19	Mb44	22	-	50	15	13	3.85
			19	Mb41	32	-	52	-	16	3.25
			19	Mb37	37	-	60	-	3	20
			19	Mb36	39	-	59	-	2	29.50
			19	Mb35	35	-	60	-	5	12
			19	M2	18	-	29	46	7	4.14

Table 4.1. Relative amounts of clay minerals in the Lower Liassic shales of northwest Scotland.

Table 4.1 contiued

Zone	Subzone	Format.	Out-crop	Sample	Smec. %	Chlor. %	Ill. %	Ill.- smec. %	Kaol. %	I/K
Bucklandi	?	Milton	3	Rab8	-	5	39	23	33	1.18
			3	Rab10	-	-	60	40	-	-
			3	Ra11	26	-	53	20	1	53
			3	Ra7	2	-	40	56	2	20
			3	Ra6	-	-	70	28	2	35
Semicostatium	?	Leacach	Mu11							
			20	M76	-	-	100	-	-	
			20	M63	-	11	78	-	11	7.09
			21	M19	-	10	78	-	12	6.50
			21	M16	-	18	78	1	3	26
Planorbis	?	Loch Aline	21	M14	-	24	51	6	9	5.67
			25	M94	19	-	65	-	16	4.06
			25	M90	29	-	28	37	6	4.67
			25	M89	28	-	24	42	6	4
			25	M88	23	-	38	32	7	5.43
Obtusum		Leacach	25	M87	17	-	32	43	8	4
			25	M86	20	-	37	37	6	6.17
			25	M84	19	-	29	47	5	5.80
			25	M83	25	-	32	37	6	5.33
			Loch Aline							
Turneri	Birchi	Leacach	19	Mb89	-	4	76	-	20	-
			19	Mb88	2	-	33	40	25	1.32
			19	Mb87	-	3	30	43	24	1.25
			19	Mb85	4	-	39	32	25	1.56
			19	Mb84	17	-	44	34	5	8.80
			19	Mb83	-	-	-	-	-	-
			19	Mb82	1	-	27	52	20	1.35
			19	Mb81	1	-	30	55	14	2.14
			19	Mb79	2	-	9	83	6	1.50
			19	Mb78	-	-	48	52	-	-
			19	Mb77	2	-	29	39	25	1.16
			19	Mb76	1	-	43	38	18	2.39
			19	Mb75	3	-	49	32	16	3.06
			19	Mb74	4	-	42	52	2	21
			19	Mb73	1	-	28	54	17	1.65
			19	Mb72	4	-	21	61	14	1.50

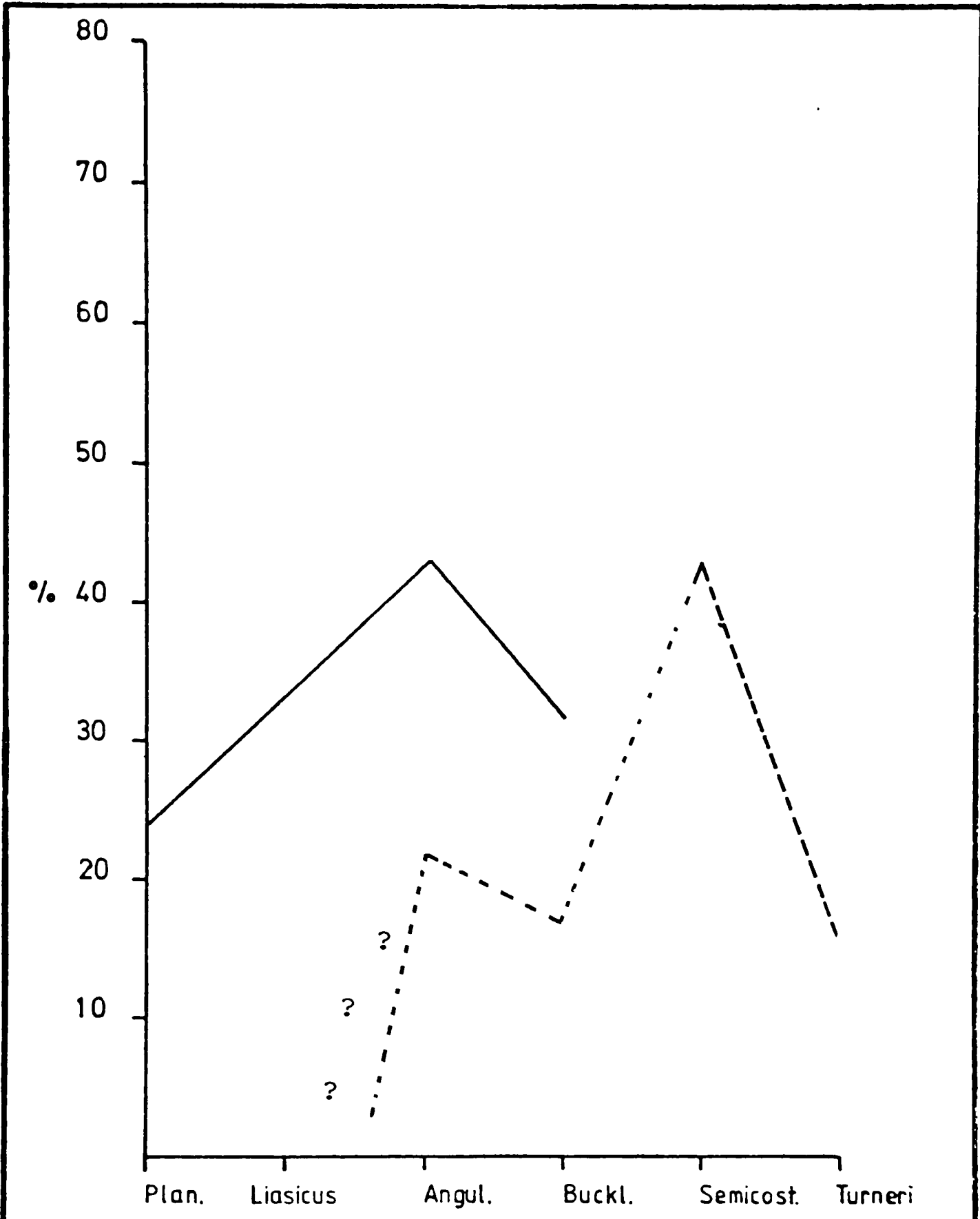
Table 4.1 continued

Zone	Subzone	Format.	Out-crop	Sample	Smec. %	Chlor. %	Ill. %	Ill. smect. %	Kaol. %	I/K	
Bucklandi	Semi-costatum	Reynesi	9	Am61	-	-	85	-	15	5.67	
			9	Am60	-	-	45	35	20	2.25	
			9	Am59	-	-	90	-	10	9	
			9	Amb37	-	-	68	15	17	4	
			9	Amb28	-	-	83	17	-	-	
Bucklandi	?Conybeari		Apple-cross	1	Apc34	14	-	19	56	11	1.73
				1	Apc31	40	-	33	16	11	3
				1	Apcb22	17	-	65	8	10	6.5
				1	Apcb21	25	-	36	32	7	5.14
				1	Apcb20	32	-	52	7	9	5.78
	Complanata			1	Apc29	24	-	40	33	3	13.3
				1	Apcb23	20	-	77	-	3	25.67
				1	Apc27	24	-	39	30	7	5.57
				1	Apcb9	19	-	50	24	7	7.14
				1	Apcb16	19	-	45	27	9	5
				1	Apc16	33	1	36	24	7	5.14
				1	Apcb14	36	-	45	16	3	15
				1	Apcb13	23	-	38	36	3	12.67
				1	Apcb15	-	-	-	-	-	-
				1	Apc10	32	-	47	14	7	6.71
				1	Apc44	11	-	31	50	3	10.33
				1	Apcb6	10	-	57	32	1	57
				1	Apc42	22	-	37	38	3	12.33
				1	Apcb7	2	-	47	51	-	-
				1	Apcb5	11	-	46	40	2	23
				1	Apcb3	-	-	58	42	-	-
	1	Apcb4	-	-	100	-	-	-			
	1	Apcb2	18	-	42	28	2	21			
	1	Apc40	-	-	-	-	-	-			
	1	Apc39	27	-	28	45	-	-			
	Semicostatum	Scip.- Sauz.	Strath	Raasay							
3				Ra28	-	4	51	18	27	1.89	
3				Rab5	-	8	49	-	43	1.14	
3				Ra31	-	10	45	22	23	1.96	
			3	Ra21	-	18	48	19	15	3.20	

Table 4.1 continued

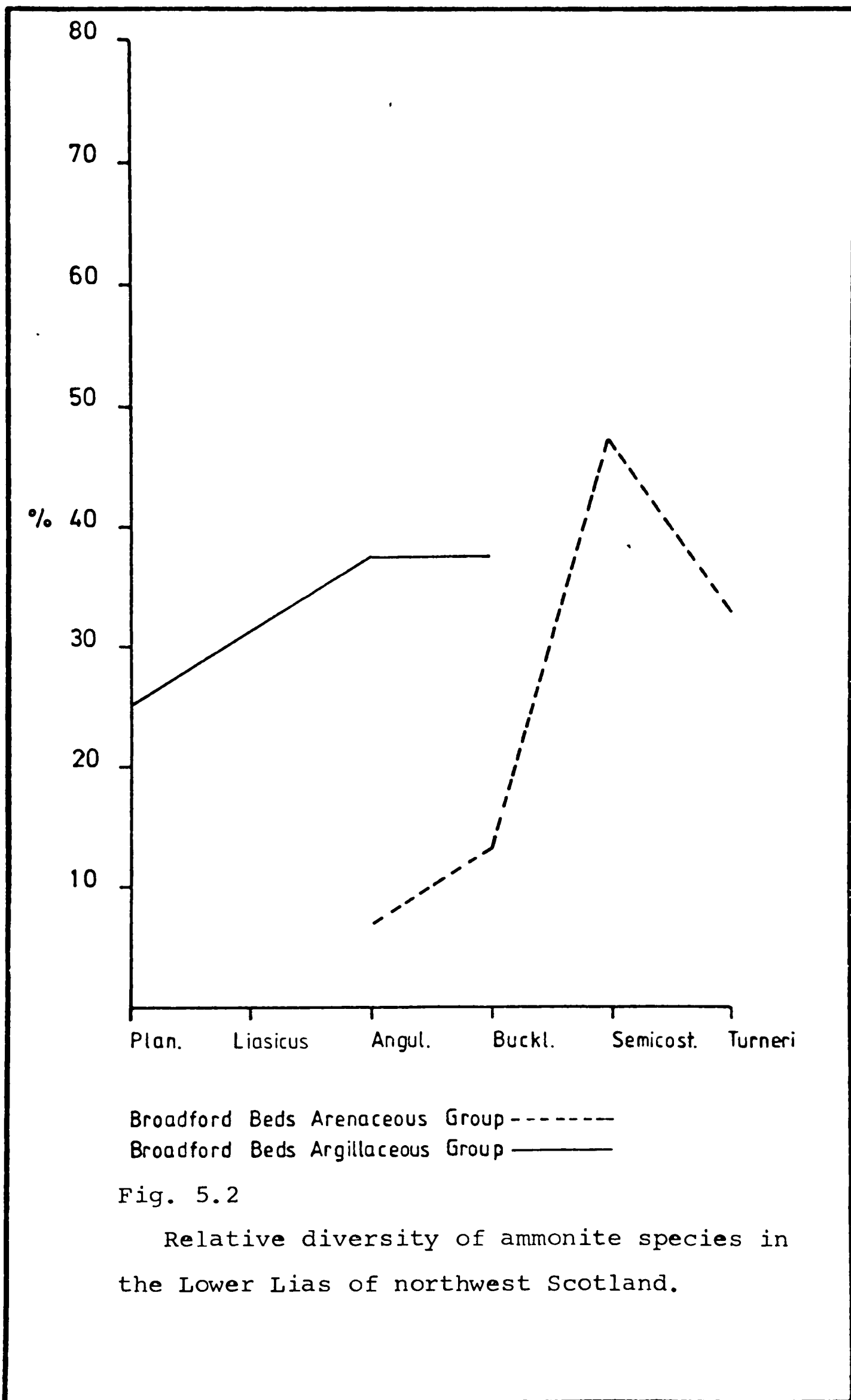
Zone	Subzone	Format.	Out-crop	Sample	Smec. %	Chlor. %	Ill. %	Ill. smect. %	Kaol. %	I/K
Semicostatum	Scip.- Sauz.	Strath	Skye							
			7	Am177	-	-	100	-	-	-
			7	Am168	-	-	84	-	16	5.25
			7	Am167	-	-	82	-	18	4.56
			7	Am166	-	7	62	10	21	2.95
			7	Am162	-	-	80	4	16	5.00
			7	Am161	-	-	66	13	21	3.14
			7	Am159	-	-	82	-	18	4.56
			7	Amb72	-	-	80	-	20	
			7	Am155	-	-	92	-	8	11.50
			7	Am154	-	-	73	14	13	5.62
			7	Am153	-	-	84	-	16	5.25
			7	Am152	-	-	84	2	14	6
			7	Am146	-	-	100	-	-	-
			7	Am144	-	-	97	3	-	-
			7	Am125	-	-	80	-	20	4
			7	Am114	-	-	100	-	-	-
			7	Am107	-	-	100	-	-	-
			7	Am104	-	-	100	-	-	-
Semicostatum	Scip. - Sauz.	Strath								
			9	Am188	-	-	48	37	15	3.20
			9	Amb79	-	-	76	-	24	3.17
			9	Amb42	-	-				
			9	Am77	-	-	82	-	18	4.56
			9	Am76	-	-	80	-	20	4
			9	Am75	-	29	55	1	15	3.67
			9	Am74	-	-	85	-	15	5.67
			9	Am71	-	9	46	16	29	1.59
			9	Am70	-	8	73	-	19	3.84
			9	Am68	-	-	91	-	9	10.11
			9	Am67	-	-	84	-	16	5.25
			9	Am65	-	-	63	-	24	2.63
			9	Am64	-	-	89	-	11	8.09
			9	Am63	-	-	85	-	15	5.67
			9	Amb40	-	-	80	-	20	4
			9	Amb39	-	-	70	13	17	4.12

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Plate -	-



Broadford Beds Arenaceous Group -----
Broadford Beds Argillaceous Group —————

Fig.5.1
Relative diversity of species in the
Lower Lias of northwest Scotland.



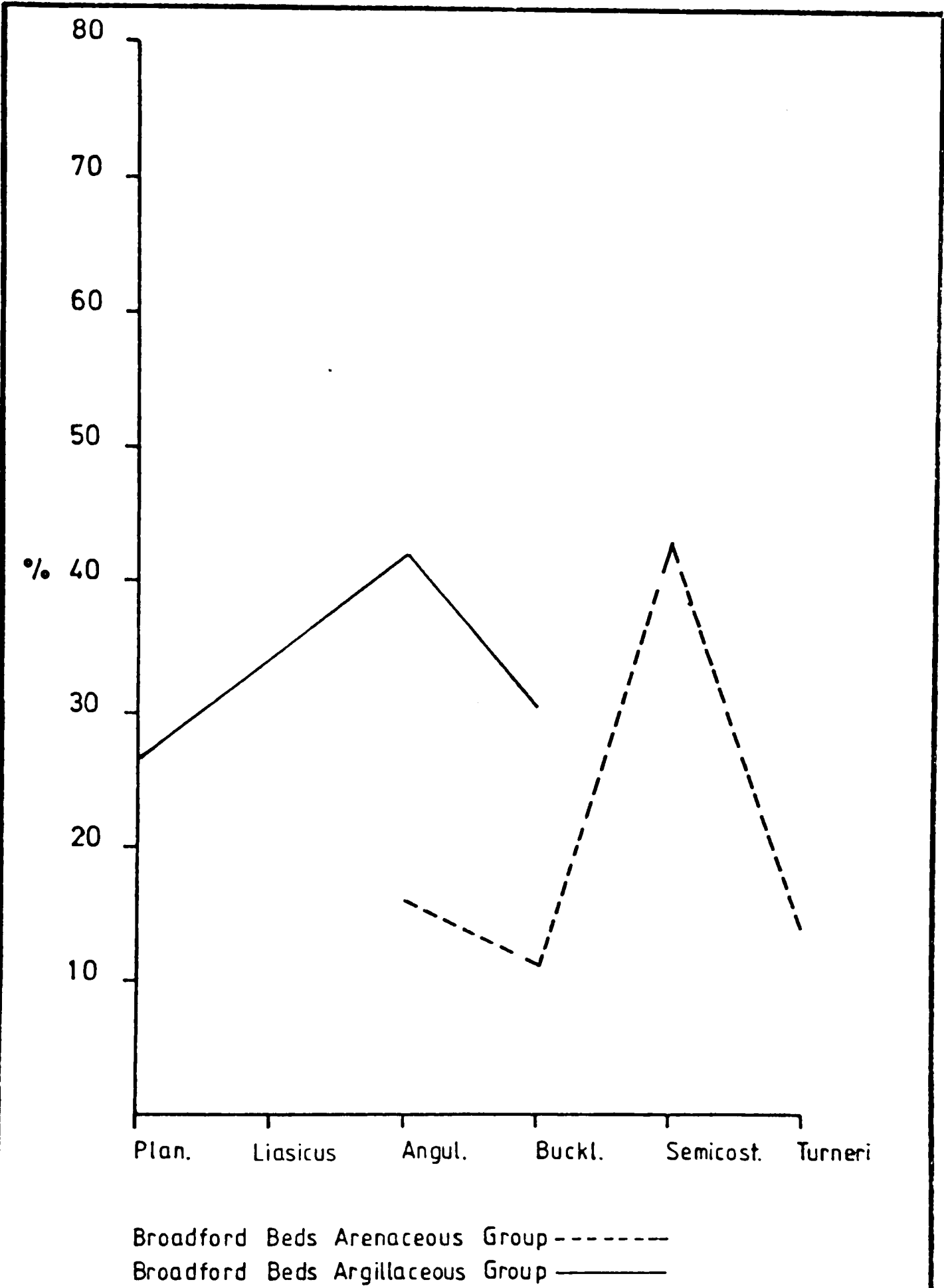
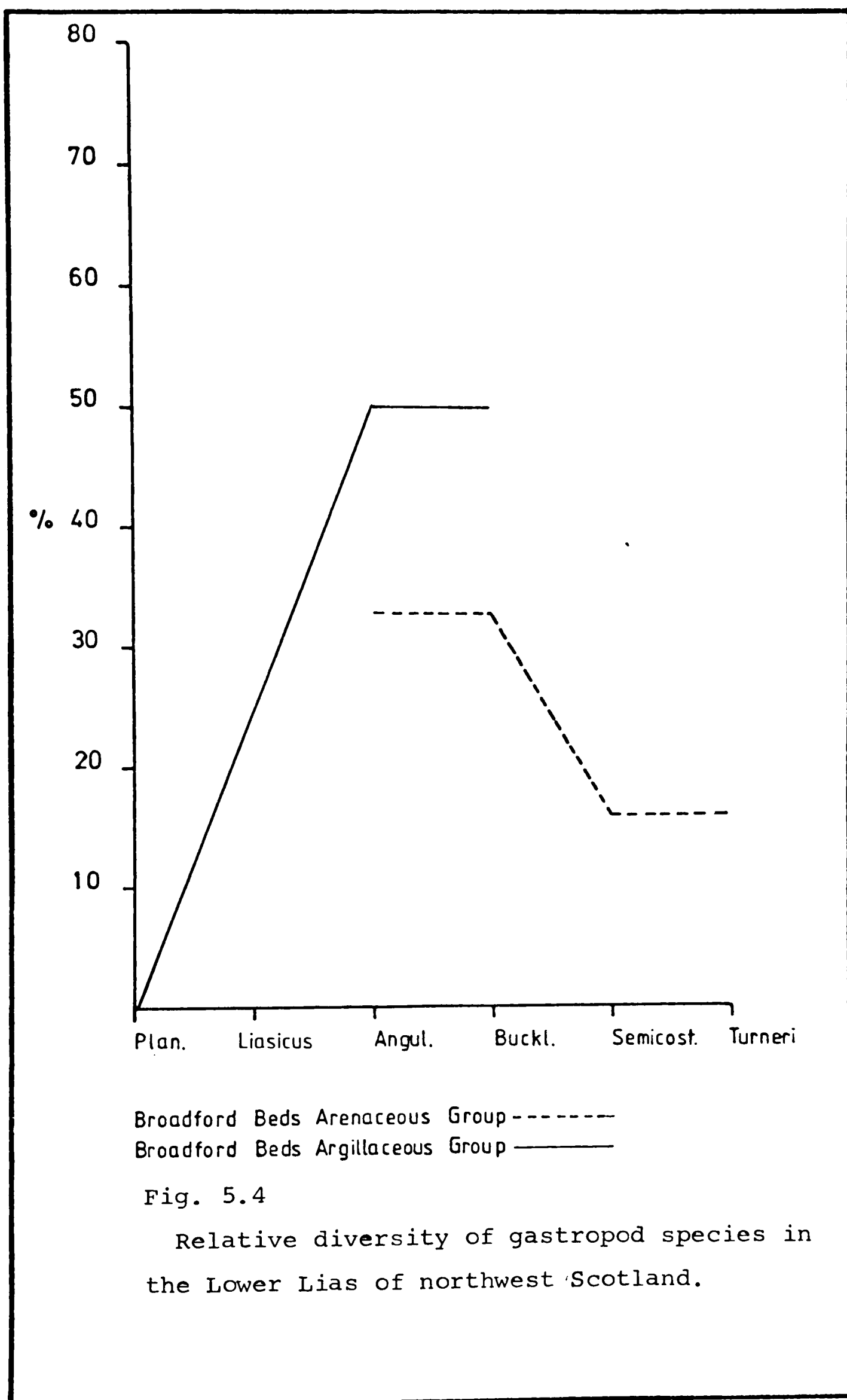


Fig. 5. 3

Relative diversity of bivalve species in the Lower Lias of northwest Scotland.



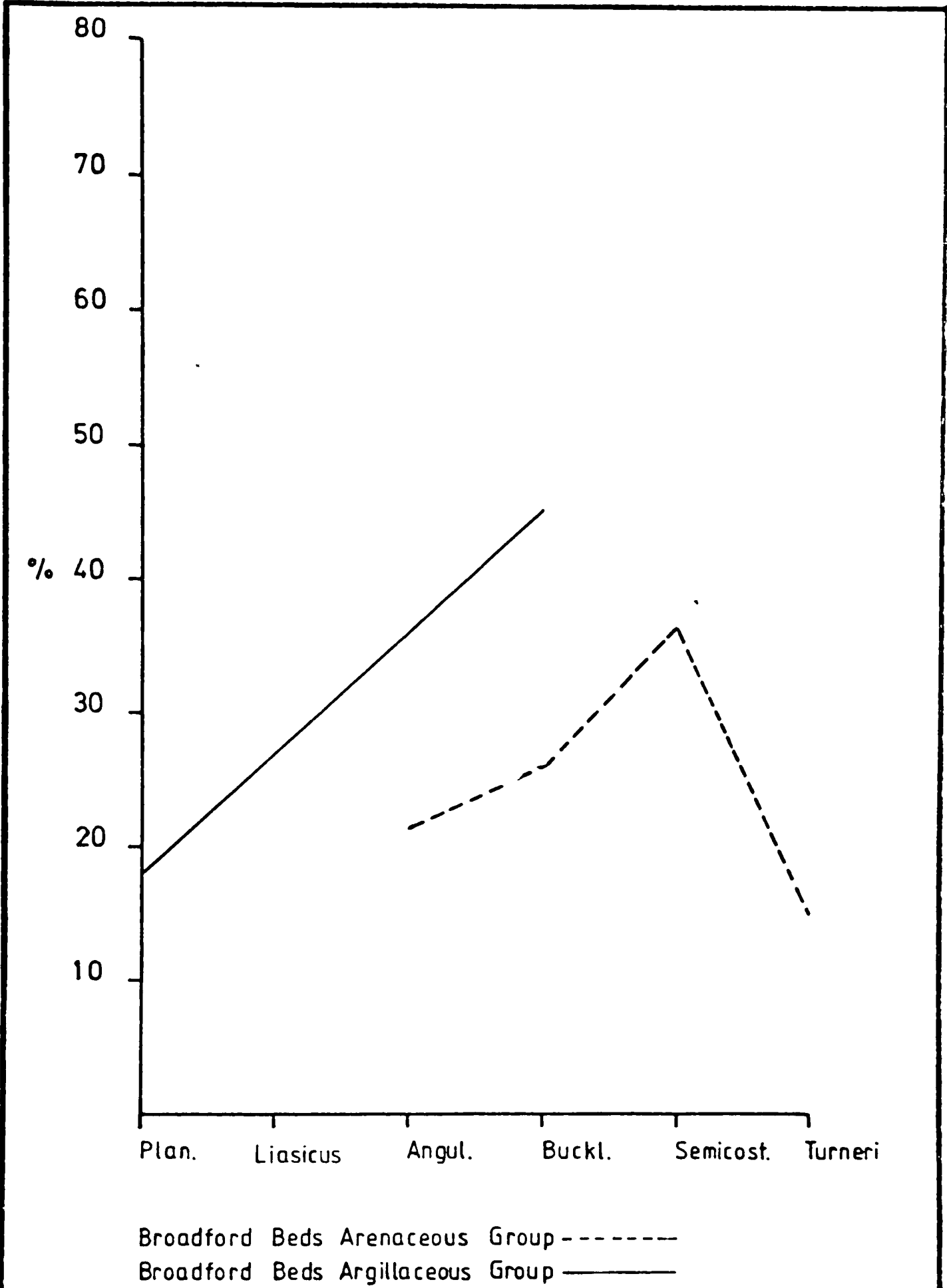
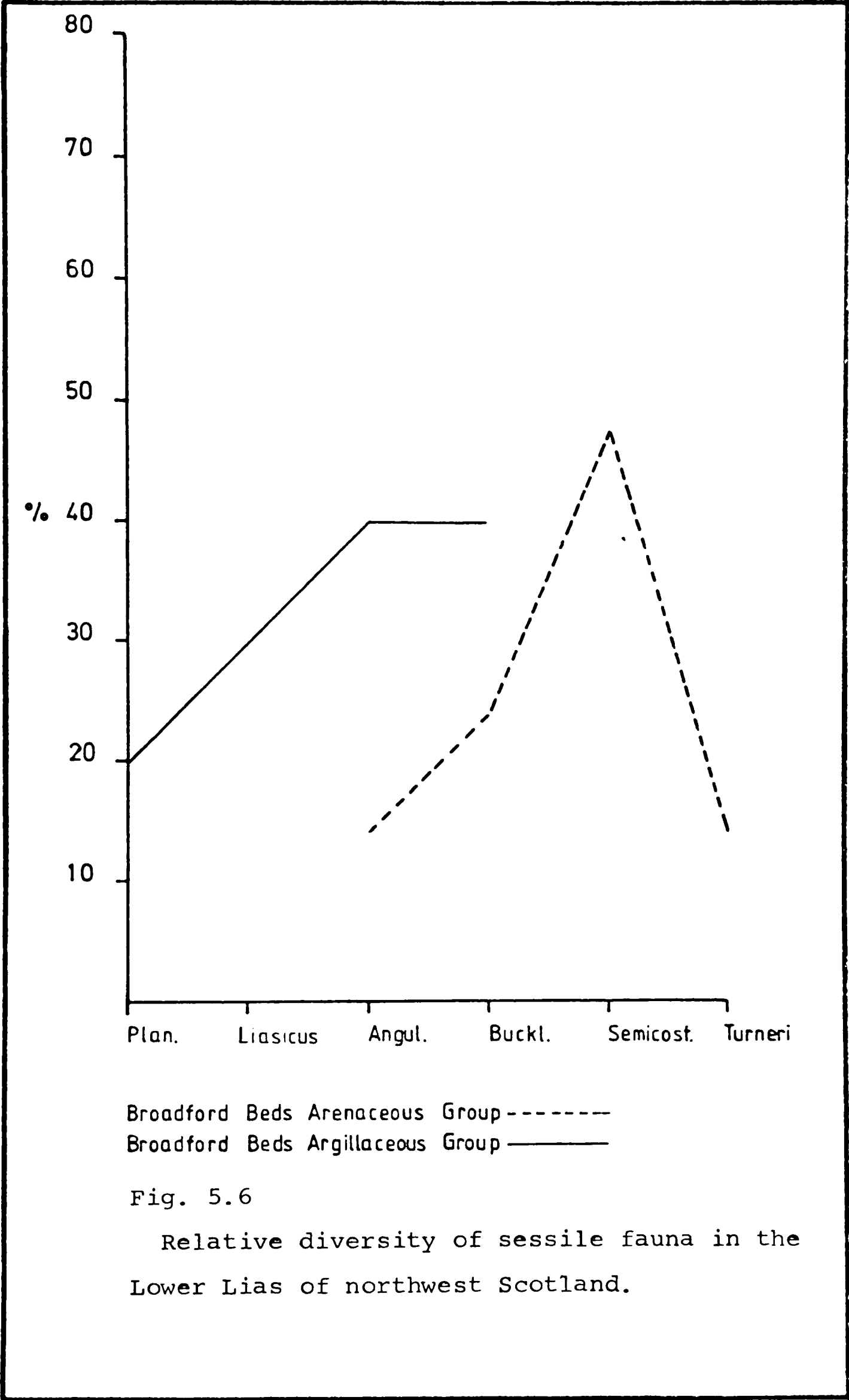
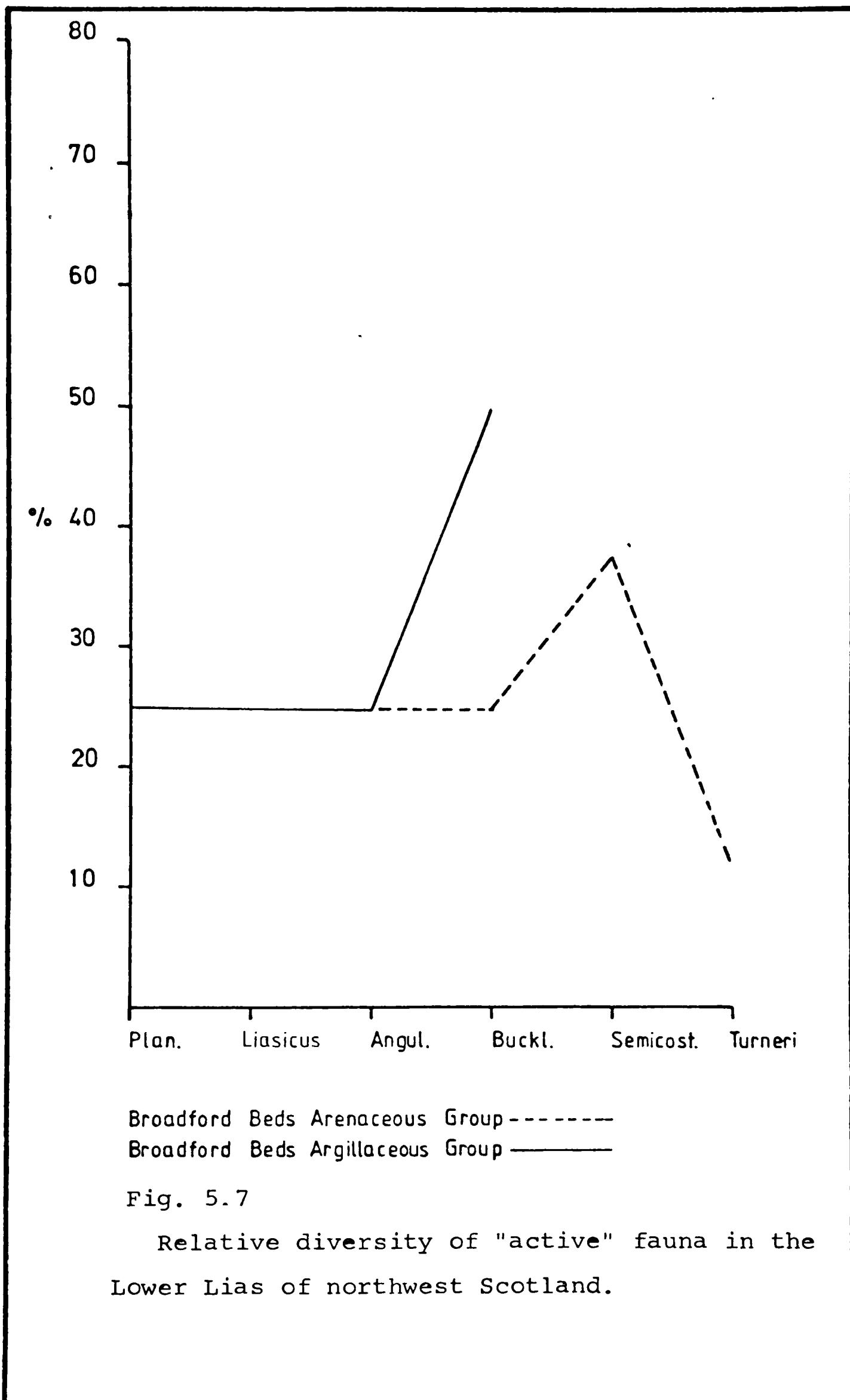
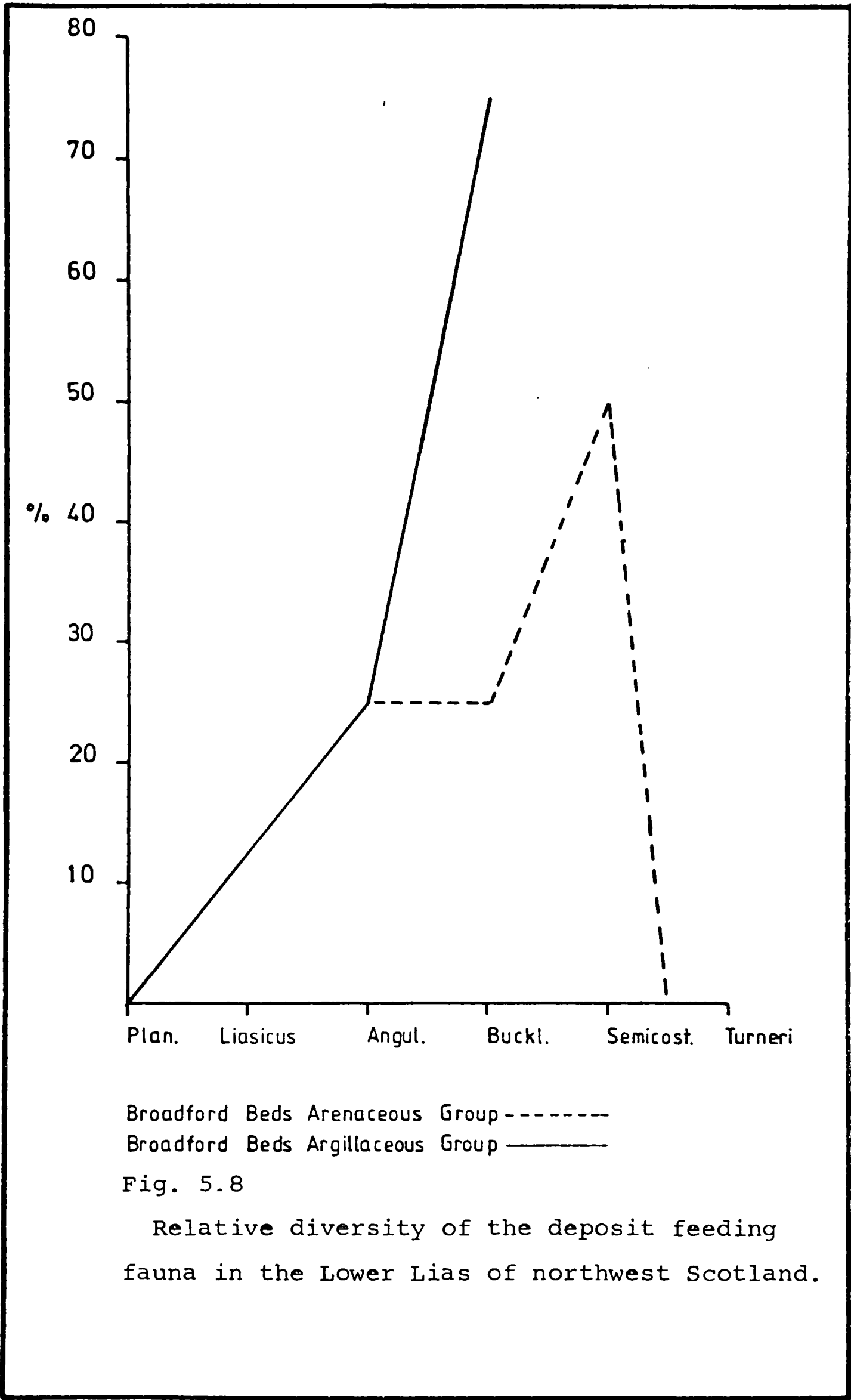


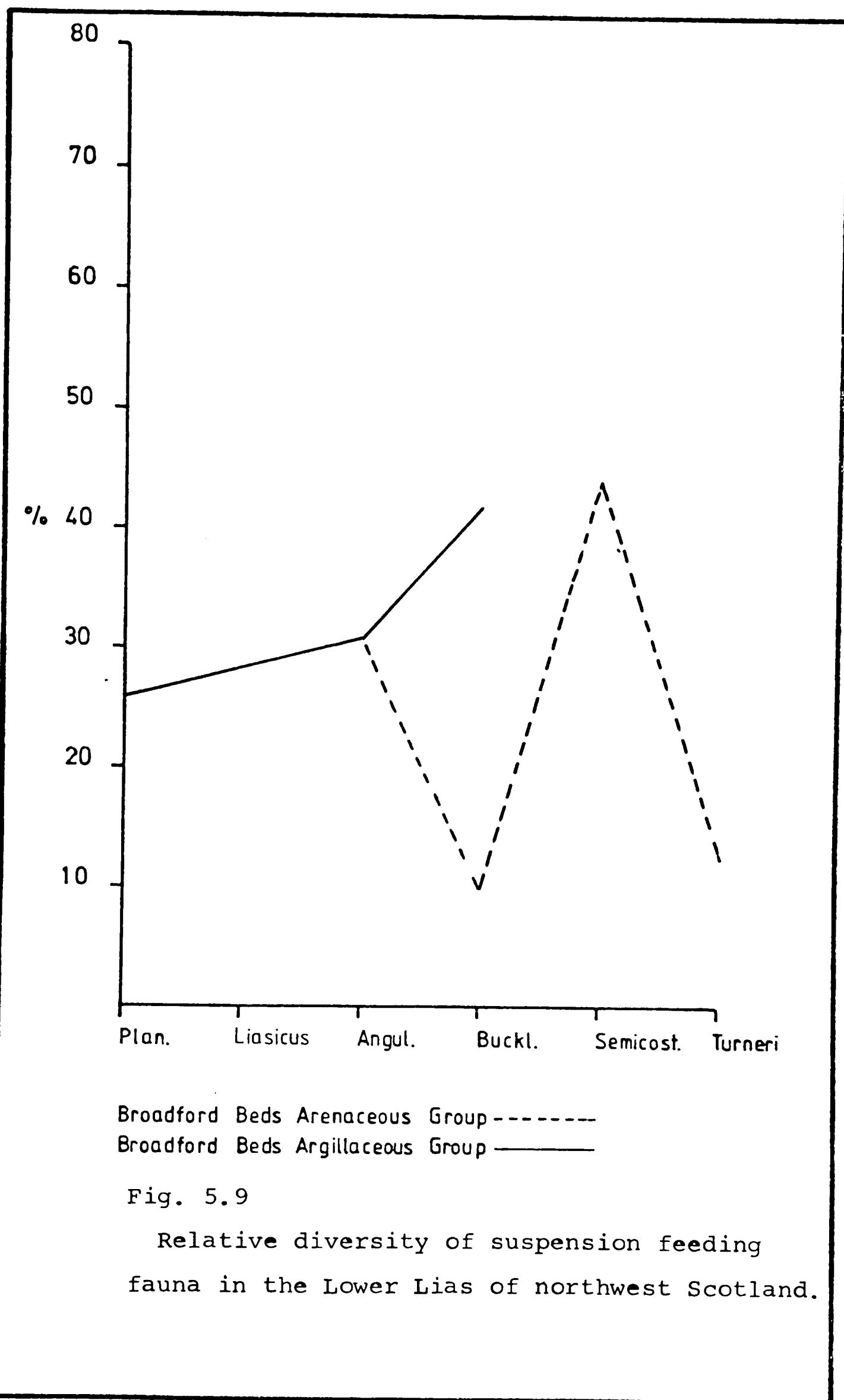
Fig. 5.5

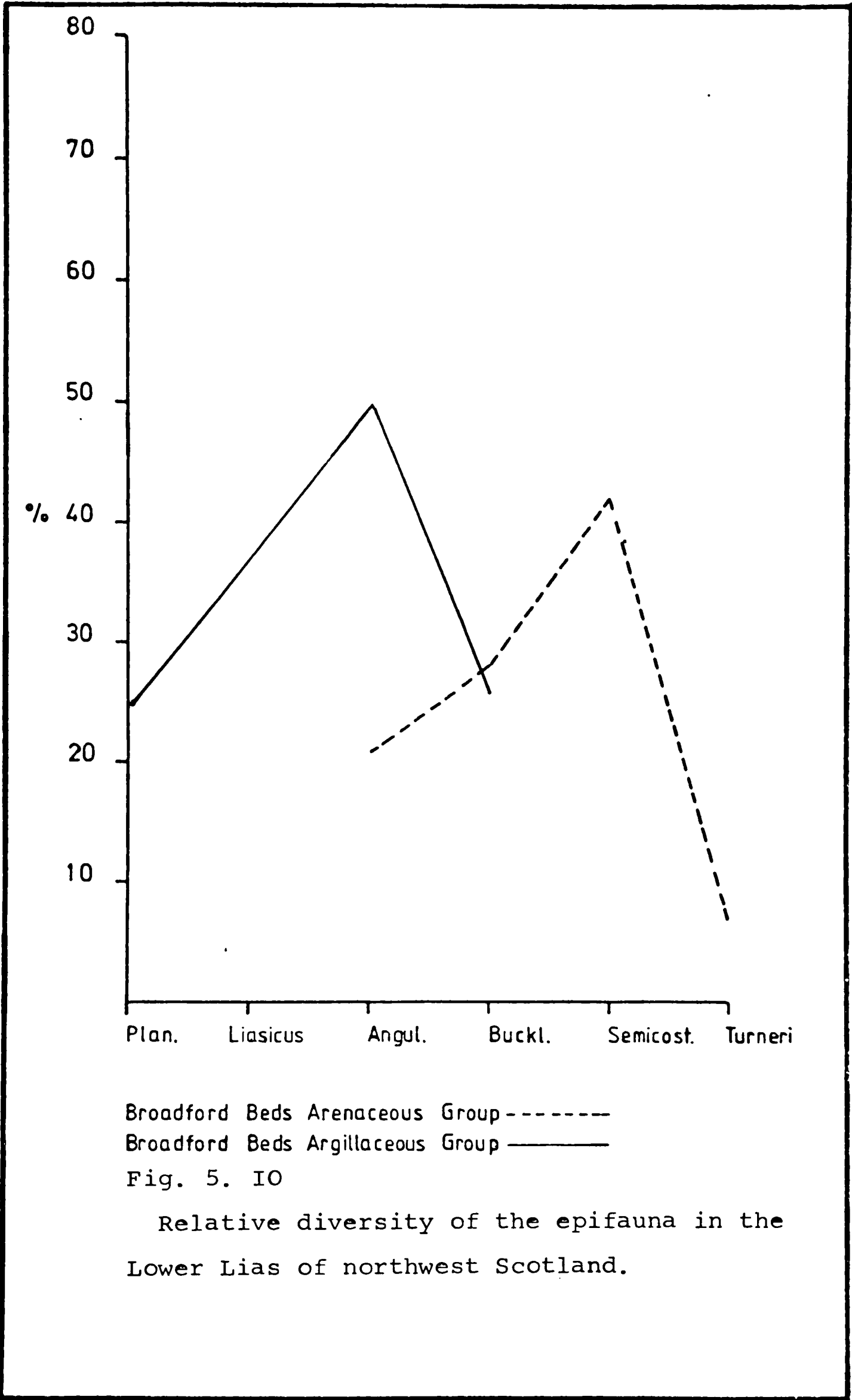
Relative diversity of attached fauna in the Lower Lias of northwest Scotland.

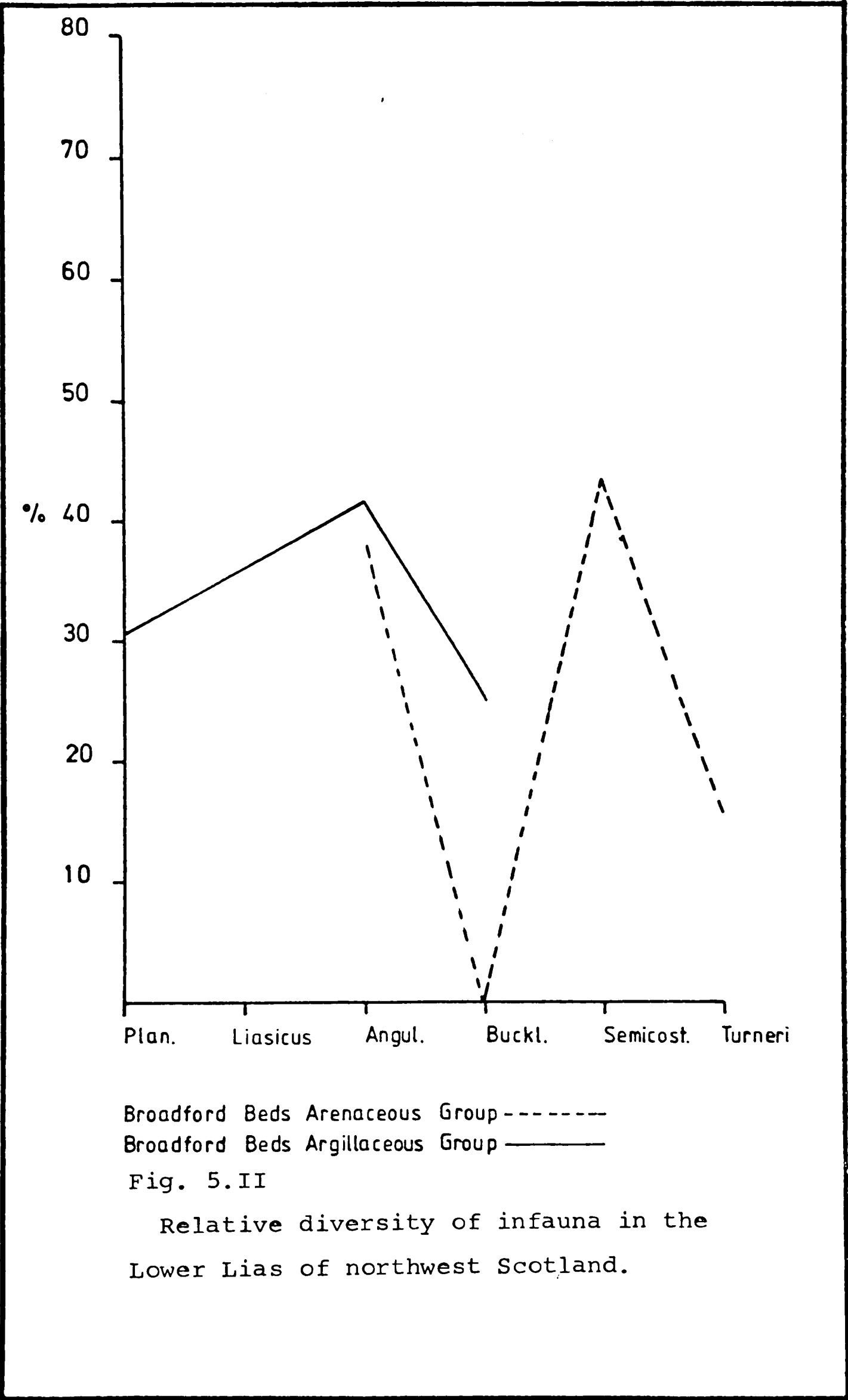


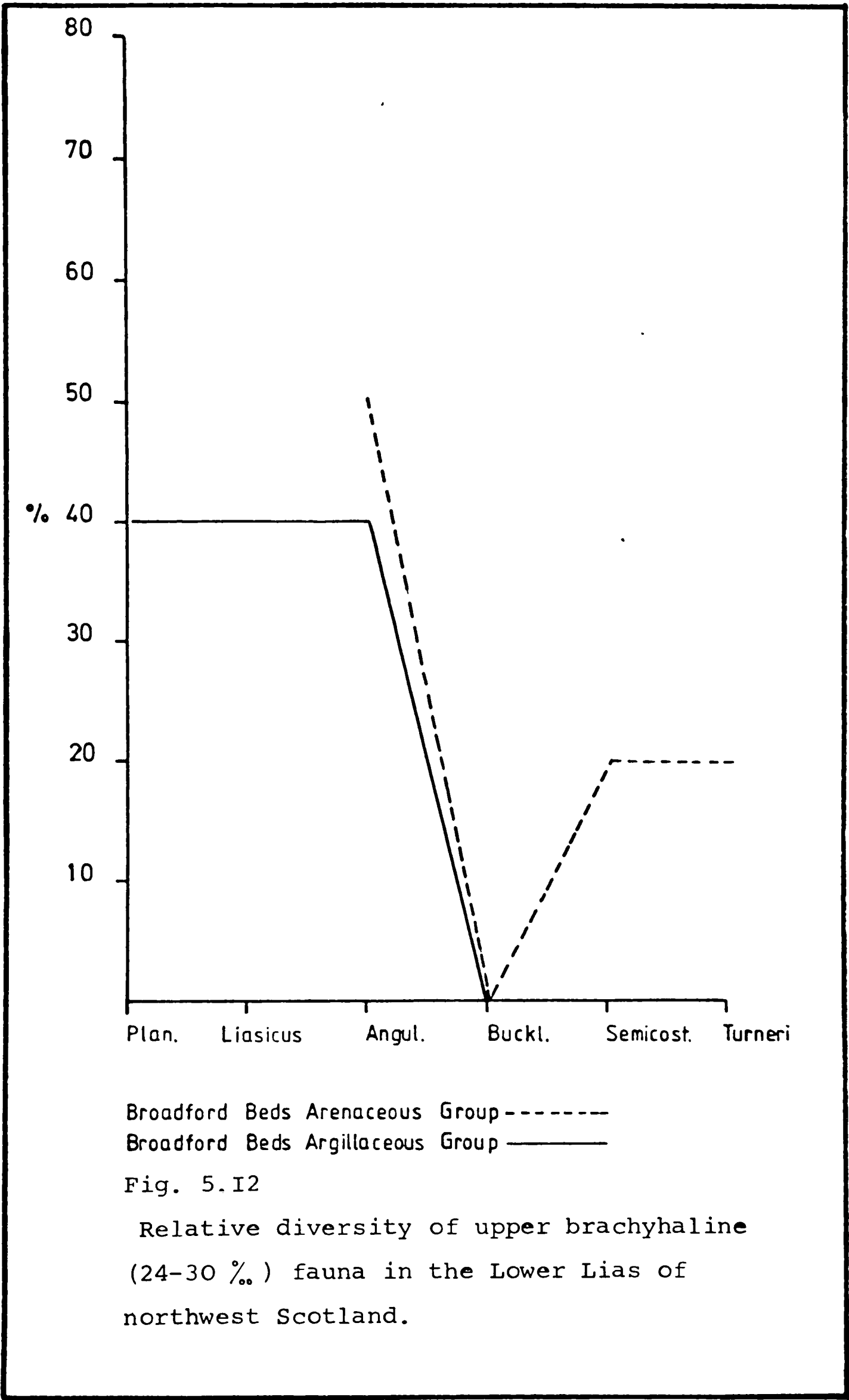


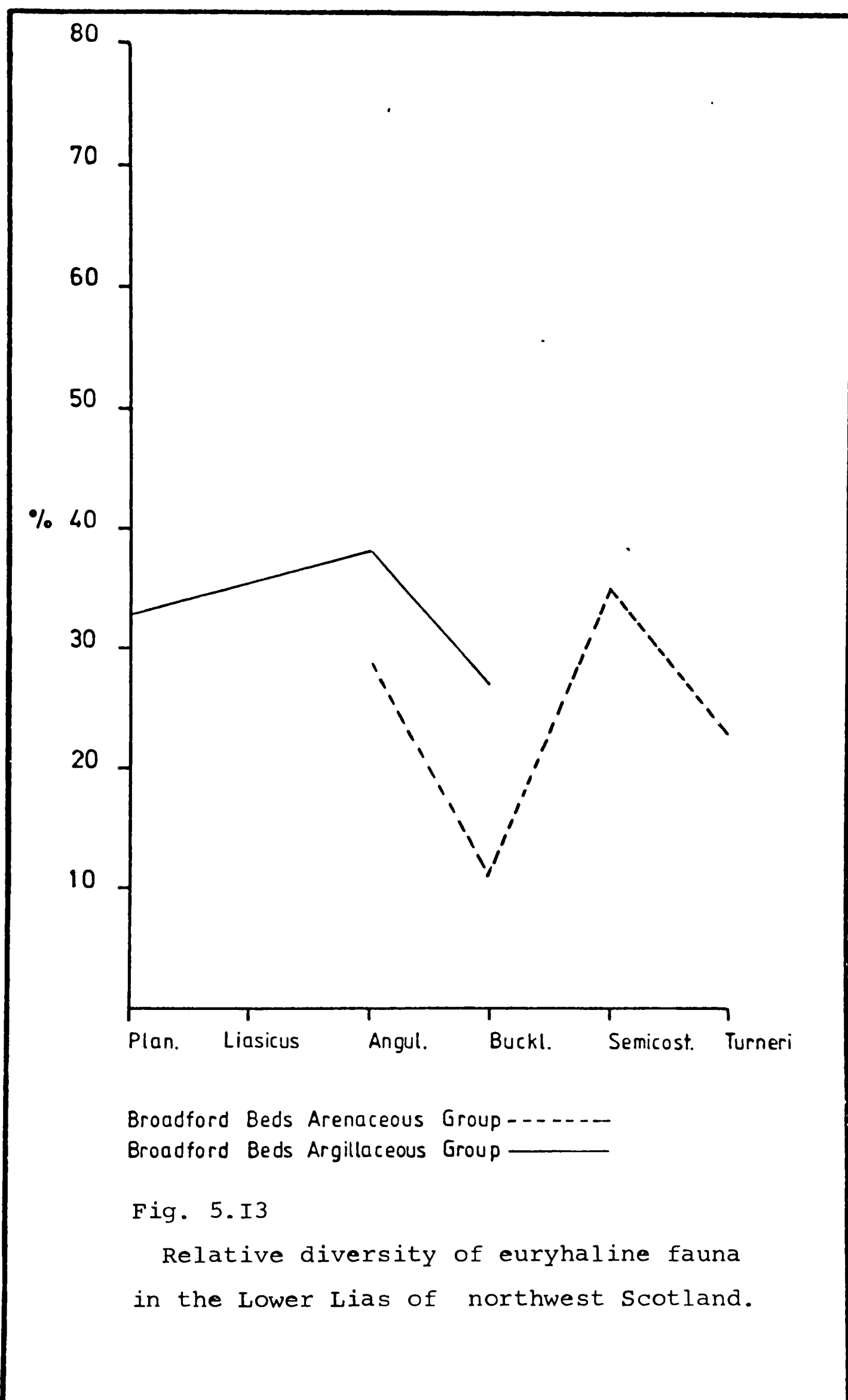


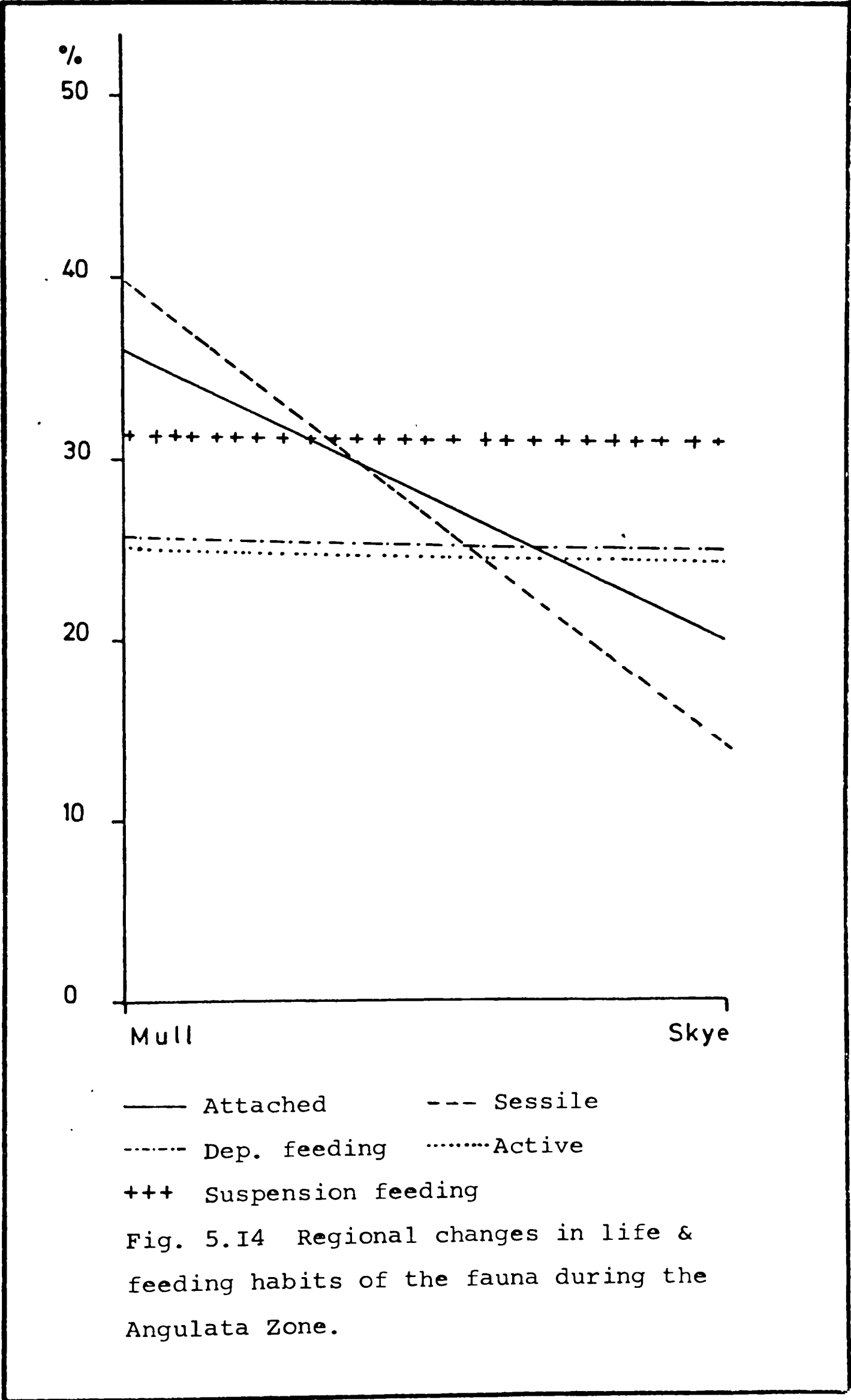












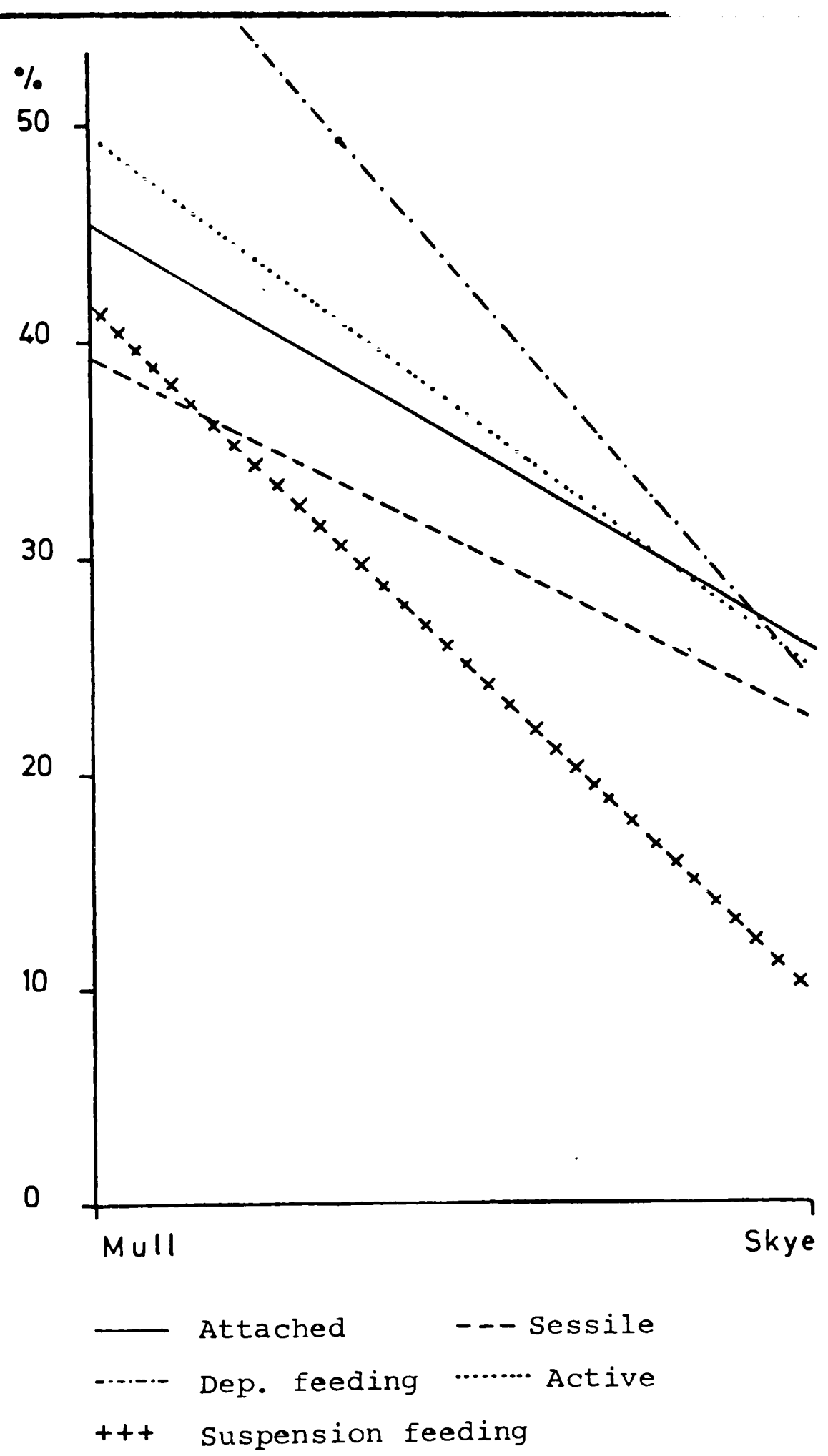
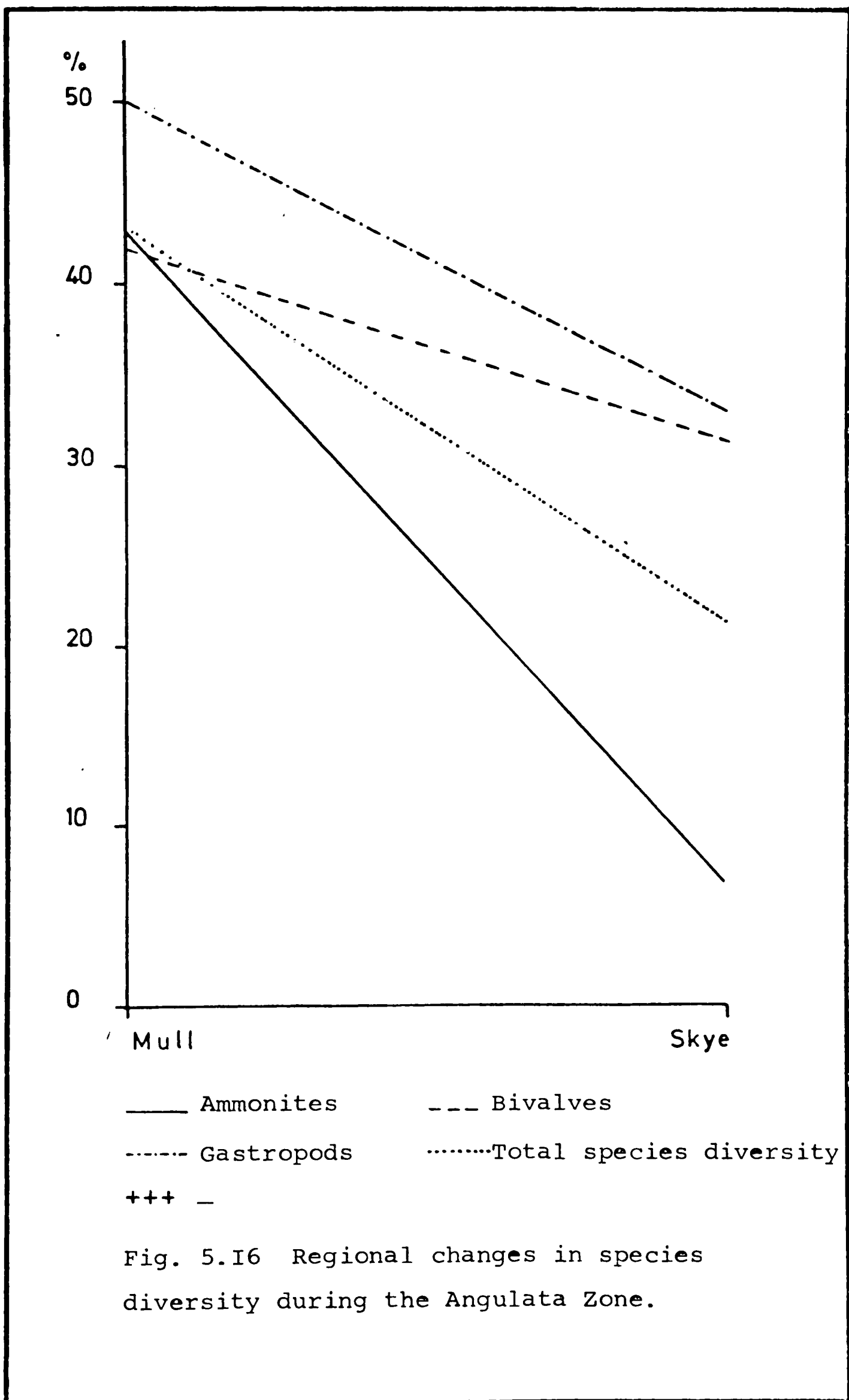
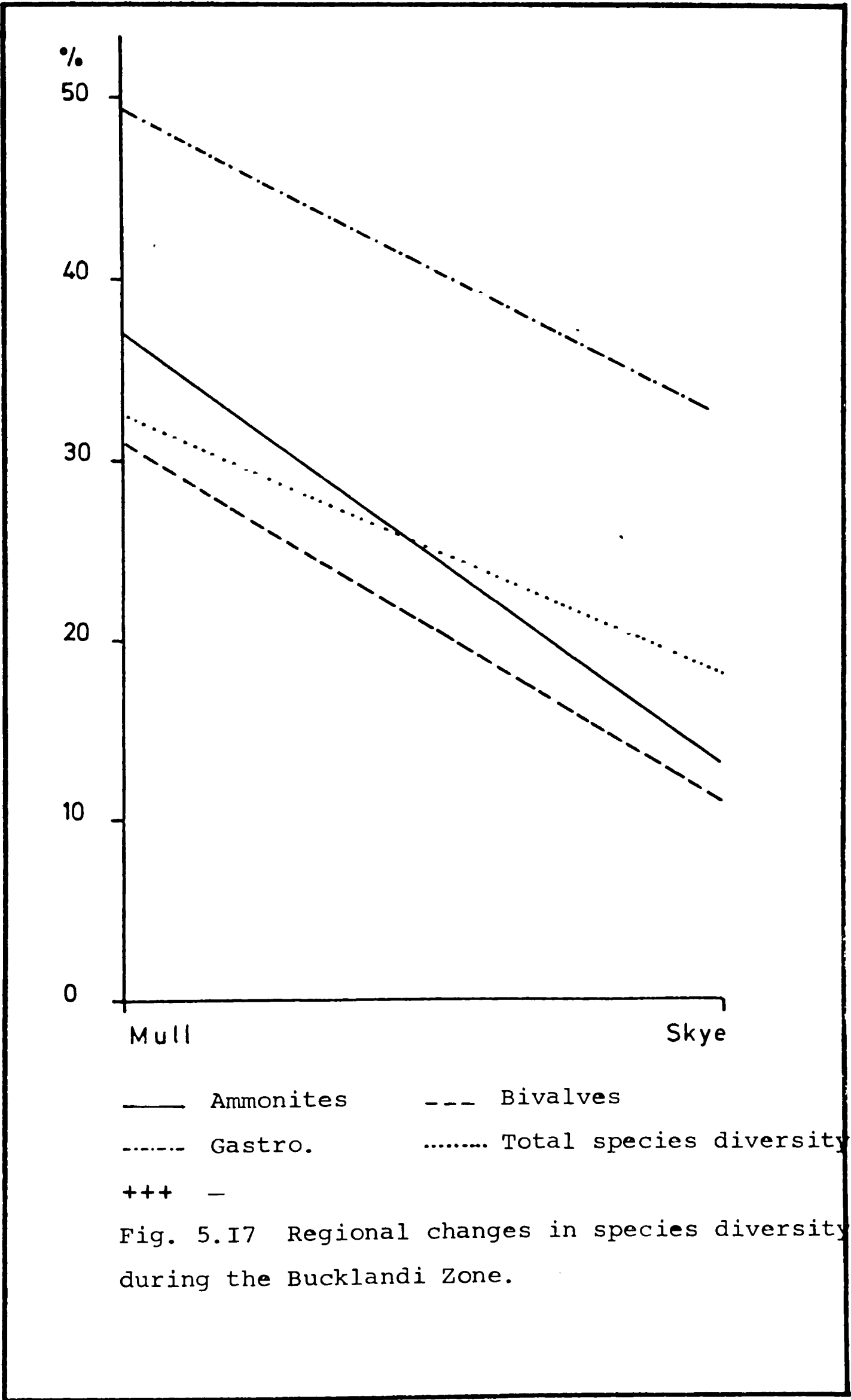
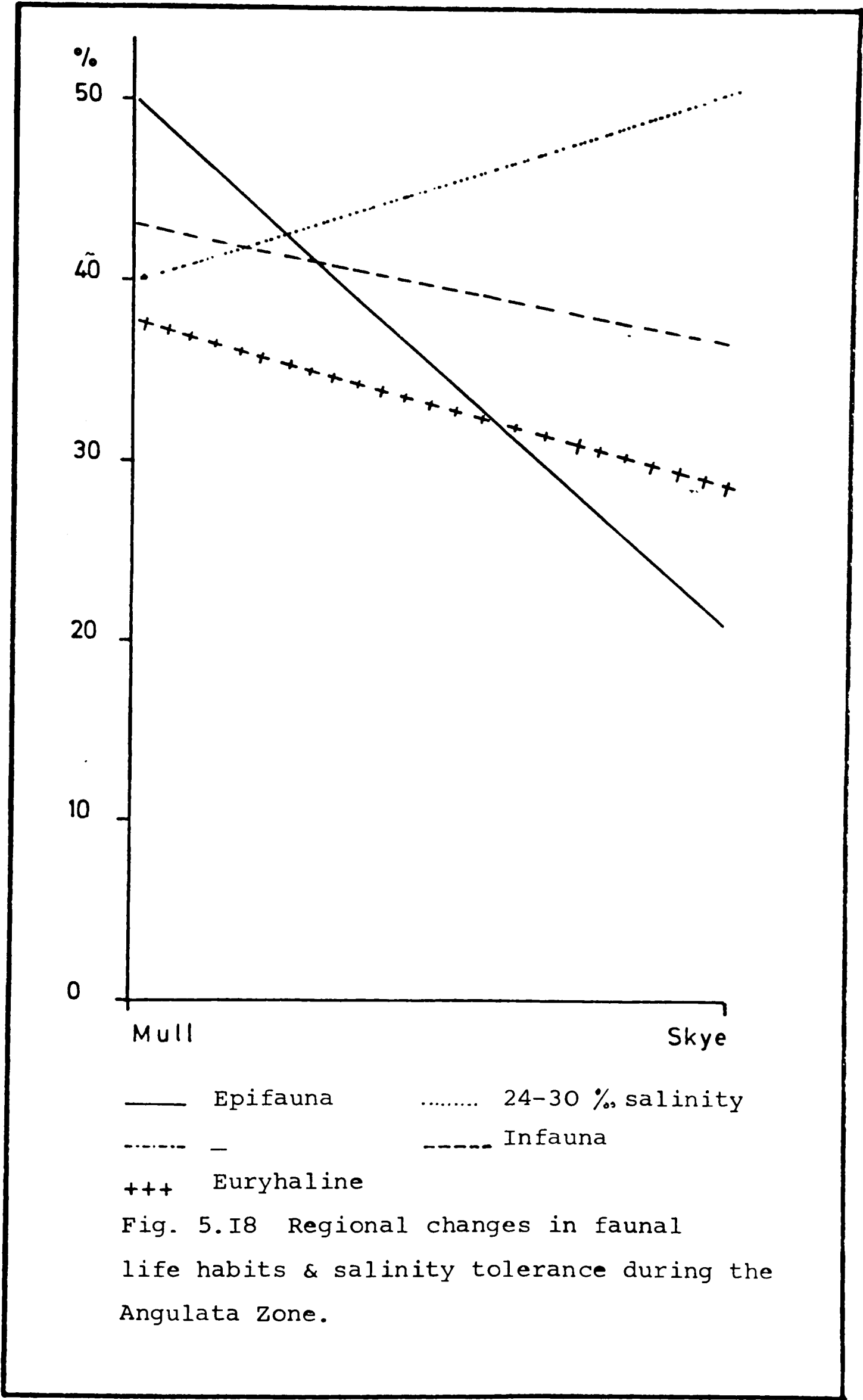


Fig. 5.15 Regional changes in faunal life & feeding habits for the Bucklandi Zone.







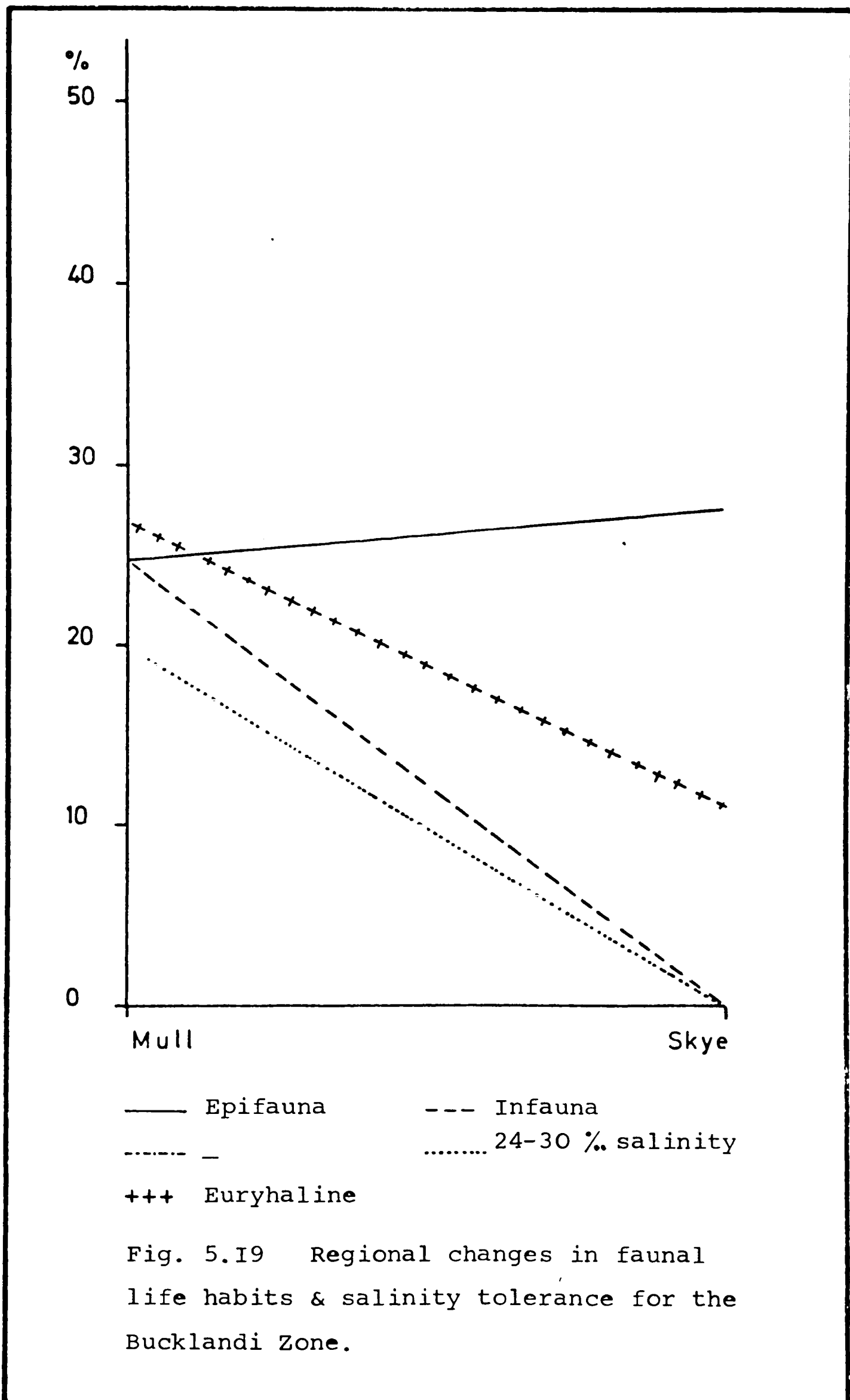


Table 5.1a. Faunal list for the Broadford Beds Arenaceous Group (see next page).
(after Hallam, 1959).

- = common
- + = occurs
- A = Angulata Zone
- B = Bucklandi "
- S = Semicostatum "
- T = Turneri "

Table 5.1a.

Fauna	A.	B.	S.	T.
<u>Agassicer</u> <u>scipionanum</u> (d'Orbigny)			●	
<u>Arnioceras</u> aff. <u>semicostatum</u> (Young and Bird)			●	+
<u>Charmassiceras</u> sp.			+	
<u>Coroniceras</u> (<u>Metophioceras</u>) aff. <u>conybeari</u> (J. Sowerby)		+		
<u>C.</u> (<u>Primarietites</u>) <u>reynesi</u> (Spath)			●	
<u>C.</u> (<u>P.</u>) aff. <u>rotiforme</u> (J. de C. Sowerby)		+		
<u>Euagassicer</u> <u>resupinatum</u> (Simpson)			●	
<u>Euasteroceras</u> cf. <u>brooki</u> (J. Sowerby)				+
<u>E.</u> aff. <u>Turneri</u> (J. de C. Sowerby)				+
<u>Microderoceras</u> <u>birchi</u> (J. Sowerby)				+
<u>Pararnioceras</u> cf. <u>alcinoe</u> (Reynes)				+
<u>P.</u> aff. <u>parthenope</u> (Reynes)			●	
<u>Schlotheimia</u> sp.		+		
<u>Nautilus</u> <u>striatus</u> J. Sowerby			●	
<u>Nannobelus</u> <u>brevi</u> (Blainville)			●	●
<u>Cardinia</u> cf. <u>concinna</u> (J. Sowerby)	+			
<u>C.</u> <u>listeri</u> (J. Sowerby)	+		●	
<u>Chlamys</u> ? <u>calva</u> (Goldfuss)			+	
<u>C.</u> <u>textoria</u> (Schlotheim)		+	●	+
<u>Gryphaea</u> <u>arcuata</u> Lamark		+	●	+
<u>Hippopodium</u> <u>ponderosum</u> J. Sowerby			+	
<u>Lima</u> (<u>Plagiostoma</u>) <u>gigantea</u> (J. Sowerby)	+	+	●	
<u>L.</u> <u>Antiquilima</u> <u>succincta</u> Schlotheim	+			
<u>Liostrea</u> <u>irregularis</u> (Munster)	●			
<u>L.</u> sp.			+	
<u>Mactromya</u> <u>unionides</u> (Goldfuss)			+	
<u>Modiolus</u> sp.	+			+
<u>Nuculana</u> sp.	+		+	
<u>Oxytoma</u> <u>inaequivalve</u> (J. Sowerby)			●	
<u>Parallelodon</u> cf. <u>hettangiensis</u> (Terquem)	+			
<u>Pholadomya</u> sp.			+	+
<u>Pinna</u> <u>hartmanni</u> Zieten	+		●	
<u>Pleuromya</u> <u>galathea</u> Agassiz			●	+
<u>P.</u> sp.	+			
<u>Pseudolimea</u> <u>pectinoides</u> (J. Sowerby)	+		+	
<u>Terquemia</u> <u>arietis</u> (Quenstedt)			+	
<u>Bourguetia</u> sp.	+			
<u>Pleurotomaria</u> <u>anglica</u> (J. Sowerby)		+		
<u>Porcerithium</u> sp.	+			
<u>Ptychomphalus</u> <u>expansus</u> (J. Sowerby)		+		
Indet trochoids			+	+
<u>Calcirhynchia</u> <u>calcaria</u> S. Buckman		+		
<u>Piarhynchia</u> <u>juvensis</u> (Quenstedt)			+	
<u>Spiriferina</u> <u>pinquis</u> (Zieten)			+	
<u>S.</u> <u>walcotti</u> (J. Sowerby)			.	
<u>Zeilleria</u> <u>perforata</u> (Piette)		+	+	
<u>Isocrinus</u> sp.		+	+	
Echinoid spines			●	
<u>Isastrea</u> <u>murchisoni</u> Wright	+			
<u>Thecosmilia</u> <u>martini</u> de Fromental		+		
<u>Chondrites</u> Sternberg			+	
<u>Rhizocorallium</u> Zenker			●	●
<u>Thalassinoides</u> Fiege	+		●	●

Table 5.1b. Palaeoecological summary of benthonic macrofauna
in the Broadford Beds Arenaceous Group

Table 5.1b. Palaeoecological summary of benthonic macrofauna in the Broadford Beds Arenaceous Group			GENERAL ACTIVITY		FEEDING HABIT			SALINITY TOLERANCE						
			Attached	Usually sessile	Generally active	Carnivorous scavengers	Herbivorous	Suspension feeders	Deposit feeders	5-10°/oo	16-23°/oo	24-30°/oo	Euryhaline	
EPIFAUNA	BIVALVES	Arcoida <u>Parallelodon</u> cf. <u>hettangiensis</u> (Terquem) Pterioida <u>Chlamys</u> ? <u>calva</u> (Goldfuss) <u>Chlamys</u> <u>textoria</u> (Schlotheim) <u>Gryphaea</u> <u>arcuata</u> Lamark <u>Oxytoma</u> <u>inaequivalvis</u> (J. Sowerby) <u>Lima</u> (<u>Plagiostoma</u>) <u>gigantea</u> (J. Sowerby) <u>L.</u> (<u>Antiquilina</u>) <u>succincta</u> Schlotheim <u>Liostrea</u> sp. <u>Pseudolimea</u> <u>Terquemia</u> <u>arietis</u> (Quenstedt)	• • (o) • • • (•) • •	• o	•			• • • • • • • •	o				•	•
	GASTRO- PODS	Pleurotomaridae <u>Pleurotomaria</u> <u>anglica</u> (J. Sow.) Cerithiacea <u>Porcerithium</u> <u>Ptychomphalus</u> <u>expansus</u> (J. Sow.)			• •	• •							•	
		Crinoidea <u>Isocrinus</u>		•				•						
	BRACHIO- PODS	Spiriferida <u>Spiriferina</u> <u>walcotti</u> (J. Sow.) <u>S. pinquis</u> Zieten Rhynchonellida <u>Calcirhynchia</u> <u>calcaria</u> (S. Buckman) <u>Piarorhynchia</u> <u>juvensis</u> (Quenst.)		o o o o				o o o o						
SEMI-INFAUNAL	BI- VALVES	Mytiloida <u>Modiolus</u> sp. <u>Pinna</u> <u>hartmanni</u> Zieten	• •					• •				•	• •	
	BRACHIOPODS	Zeilleracea <u>Zeilleria</u> <u>perforata</u> (Piette)												
	GASTROPODS	-												
	ECHINODERMS	-												
	BIVALVES	Nuculoida <u>Nuculana</u> sp. <u>Cardinia</u> sp. <u>C. concinna</u> Veneroida <u>Hippopodium</u> <u>ponderosum</u> (J. Sow.) <u>Mactromya</u>		• • • •	•			o • •						
	GASTROPODS	<u>Bourguettia</u>												
	BRACHIOPODS	-												
	TRACE FOSSIL	Rhizocorallium animal Chondrites animal			• •			•	•					
DEEP INFAUNAL	BI- VALVES	Pholadomyoida <u>Pholadomya</u> sp. <u>Pleuromya</u> <u>galata</u> <u>P.</u> sp.			• • •			• • •				• • •		
	TRACE FOSSIL	Thalassinoides animal				•								

o = uncertain

(.) = when young

• = ?capable of swimming

For references see text (p.89).

<u>Fauna</u>	<u>Zone</u>		
	P.	A.	B.
<u>Arnioceras</u> sp.			+
<u>Coroniceras</u> sp.	+		+
<u>Psiloceras planorbis</u> J. de C. Sowerby	+		
<u>Schlotheimia similis</u>		+	
<u>Sulciferites</u> sp.		+	
<u>Vermiceras</u> sp.		+	+
<u>Astarte</u> sp.		+	
<u>Camptonectes punctatissimus</u>		+	
<u>Cardinia ovalis</u>		+	
<u>Cardinia</u> sp.	+		
<u>Chlamys sublata</u>		+	
<u>Chlamys</u> sp.	+		
<u>Gryphaea</u> sp.			+
<u>?Isocardia arenacea</u>		+	
<u>Lima</u> sp.		+	
<u>Liostrea hisingeri</u>		+	
<u>Modiolus</u>			+
<u>Modiolus</u> sp.	+		
<u>M. laevis</u>		+	
<u>Nuculana</u> sp.			+
<u>Oxytoma</u> sp.			+
<u>Pholadomya</u> sp.	+		+
<u>Pinna</u> sp.	+		
<u>Pinna</u>			+
<u>Plagiostoma</u>			+
<u>P. gigantea</u>		+	
<u>P.</u> sp.	+		
<u>Plicatula spinosa</u>		+	
<u>Pleuromya</u> sp.		+	
<u>Pleuromya</u>			+
<u>?Pteromya</u>	+		
<u>Pleurotomaria</u>			+
Indet gastropods		+	
<u>Squamirhynchia</u> sp.			+
<u>Lingula</u> sp.			+
<u>Rhynconelloida</u> sp.			+
<u>Cidarids</u>	+	+	
<u>Rhizocorallium</u>			
<u>Thalassinoides</u>			
<u>Teichichnus</u>			

Table 5.2a. Faunal list for the Broadford Beds Argillaceous Group
(after Oates, 1976).

P = Planorbis Zone
A = Angulata "
B = Bucklandi "

Table 5.2b. Palaeoecological summary of benthonic macrofauna in the Broadford Beds Argillaceous Group

			General Activity			Feeding Habit			Salinity Tolerance				
Table 5.2b. Palaeoecological summary of benthonic macrofauna in the Broadford Beds Argillaceous Group			Attached	Usually sessile	Generally active	Carnivorous scavenger	Herbivore	Suspension feeder	Deposit feeder	5-10°/oo	16-23°/oo	24-30°/oo	Euryhaline
EPIFAUNAL	BIVALVES	Pteroida <u>Plagiostoma</u> <u>Oxytoma</u> <u>Liostrongia</u> <u>Crostrongia</u> <u>Gryphaea</u> <u>Camptonectes</u> <u>Chlamys</u>	(●) (●) (●) (●) (○) (○) (○) ●	● ● ● ● ○ ○ ○ ●	●			● ● ● ● ● ● ●	○ ○ ○ ○ ○ ○ ○		●		● ● ● ● ○ ○ ○
	GASTROPODS	Pleurotomaridae <u>Pleurotomaria</u>			●	●							
	SERPULIDS	Serpulids						●					
	ECHINODERMS	Echinoids Cidarids											
	BRACHIOPODS	Rhynchonellida <u>Rhynchonellidea</u> <u>Squamirhynchia</u>		○ ○				○ ○					
SEMI-IFAUNAL	BI-VALVES	Mytiloida <u>Modiolus</u> sp. <u>Pinna</u> sp. Veneroidea <u>Astarte</u>	● ●	●				● ● ●				●	● ○ ●
	GASTROPODS	-											
	ECHINODERMS	-											
SHALLOW	BIVALVES	Nuculoida <u>Nuculana</u> Veneroidea <u>Cardinia</u> <u>?Isocardia</u> <u>?Lima</u> Pteroida <u>Platystrophia</u>		●	●			●	○			●	●
	GASTROPODS	-											
	BRACHIOPODS	Lingulida <u>Lingula</u>	●					●					●
	TRACE FOSSILS	Rhynchonellid animal Teichichnus animal			● ●				● ●				
DEEP IFAUNAL	BI-VALVES	Pholadomyoida <u>Pholadomya</u> <u>Pleuromya</u> <u>Pteromya</u>		● ● ○				● ● ○					● ● ○
	TRACE FOSSILS	Thalassinoides animal Zoophycos animal Skolithos animal		●	● ●		?	●	●				?

○ = uncertain

(●) = when young

●' = ?capable of swimming

For references see text (p.89).

Zone	Species No. %	Necton No. %	Bivalv. No. %	Gastrs. No. %	Brachs. No. %	Echin. No. %	Attach. No. %	Active No. %	Sess. No. %	Dep. feeder No. %	Susp. feeder No. %	Epif. No. %	Infau. No. %
Planorbis & Johnstoni	9 24.32	2 25	7 26.92	0 0	0 0	1 50	2 18.18	1 25	3 20	0 0	5 26.32	2 25	5 31.25
Angulata	16 43.24	3 37.50	11 42.31	1 50	0 0	1 50	4 36.36	1 25	6 40	1 25	6 31.58	4 50	7 43.75
Bucklandi	12 32.93	3 37.50	8 30.77	1 50	3 100	0 0	5 45.95	2 50	6 40	2 75	8 42.10	2 25	4 25
Semicostatum	-												
Turneri	-												
Total	37 100	8 100	26 100	2 100	3 100	2 100	11 100	4 100	15 100	3 100	19 100	8 100	16 100

Zone	Salin. 5-10 ⁰ /oo No. %	16-23 ⁰ /oo No. %	24-30 ⁰ /oo No. %	Euryh. No. %
Planorbis & Johnstoni	-		2 40	6 33.33
Angulata	-	1 100	2 40	7 38.89
Bucklandi	-		1 20	5 27.78
Semicostatum				
Turneri				
Total	-	1 100	5 100	18 100

Table 5.2c. Broadford Beds Argillaceous Group - Faunal Data.
Number of species (+ ammonites) = 36.

CHAPTER 6

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Figs. 6.1 - 6.41

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Tables 6.1 - 6.2

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Plates 6.1 - 6.130

120- 177

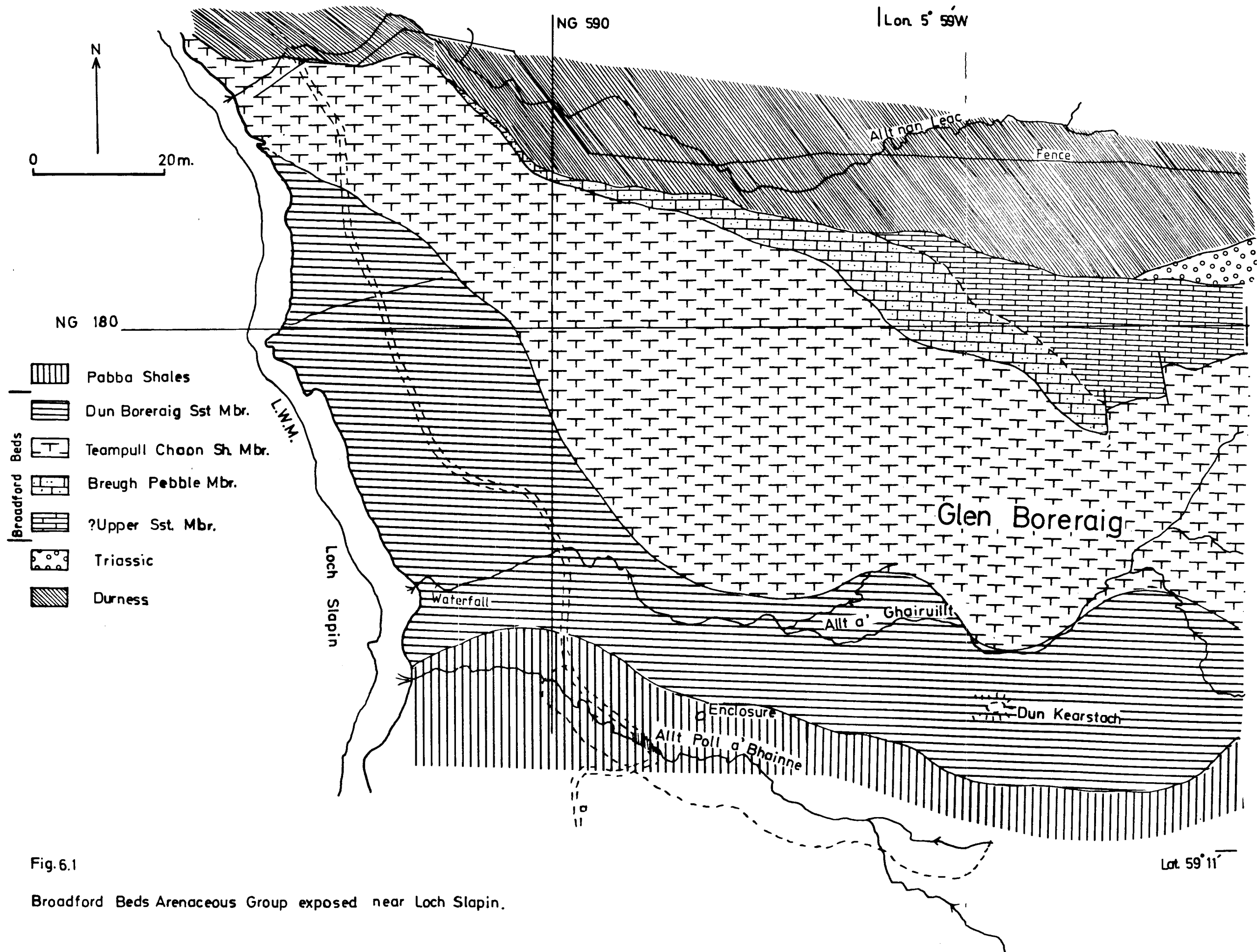


Fig.6.1

Bradford Beds Arenaceous Group exposed near Loch Slapin.

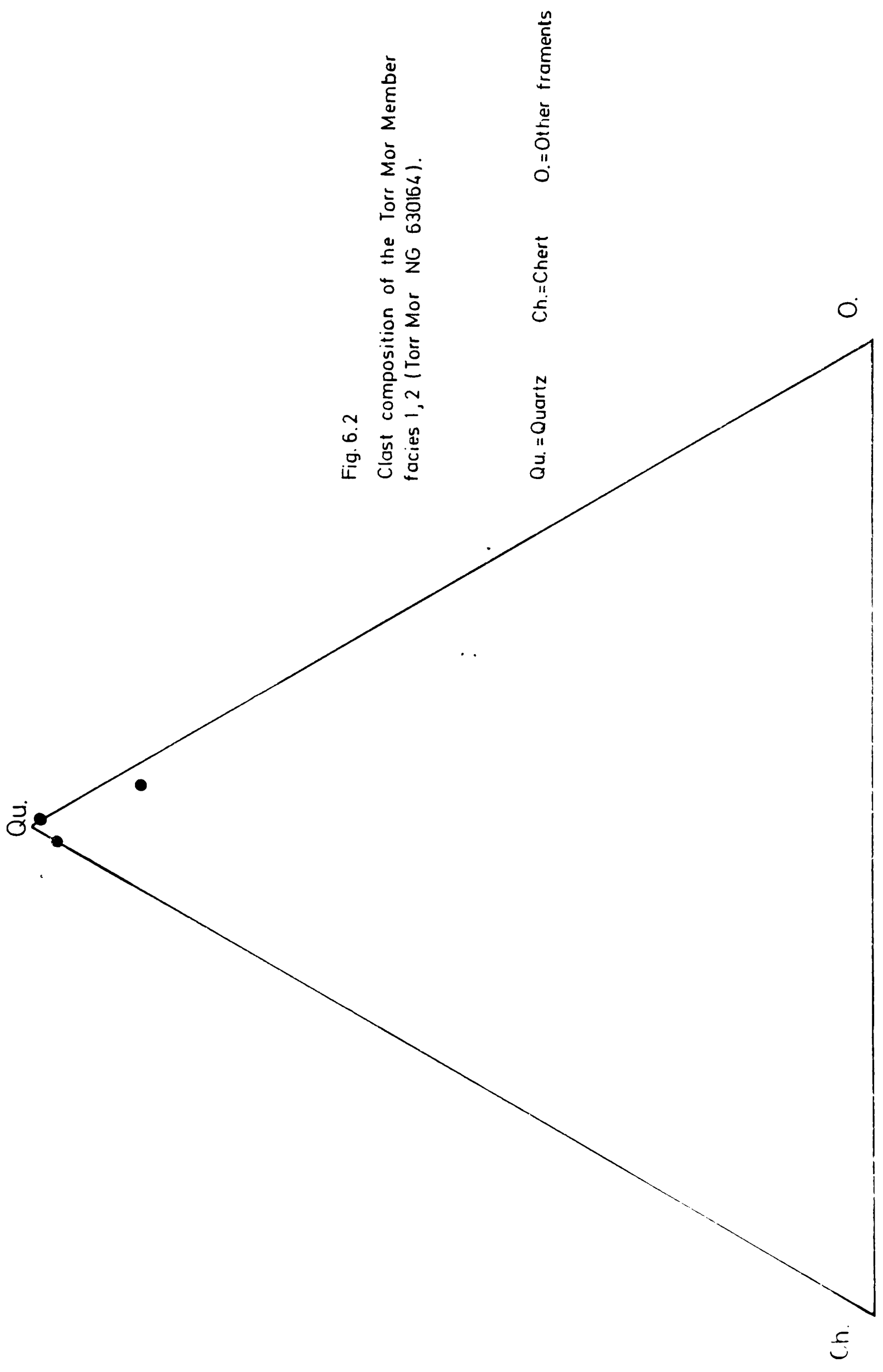
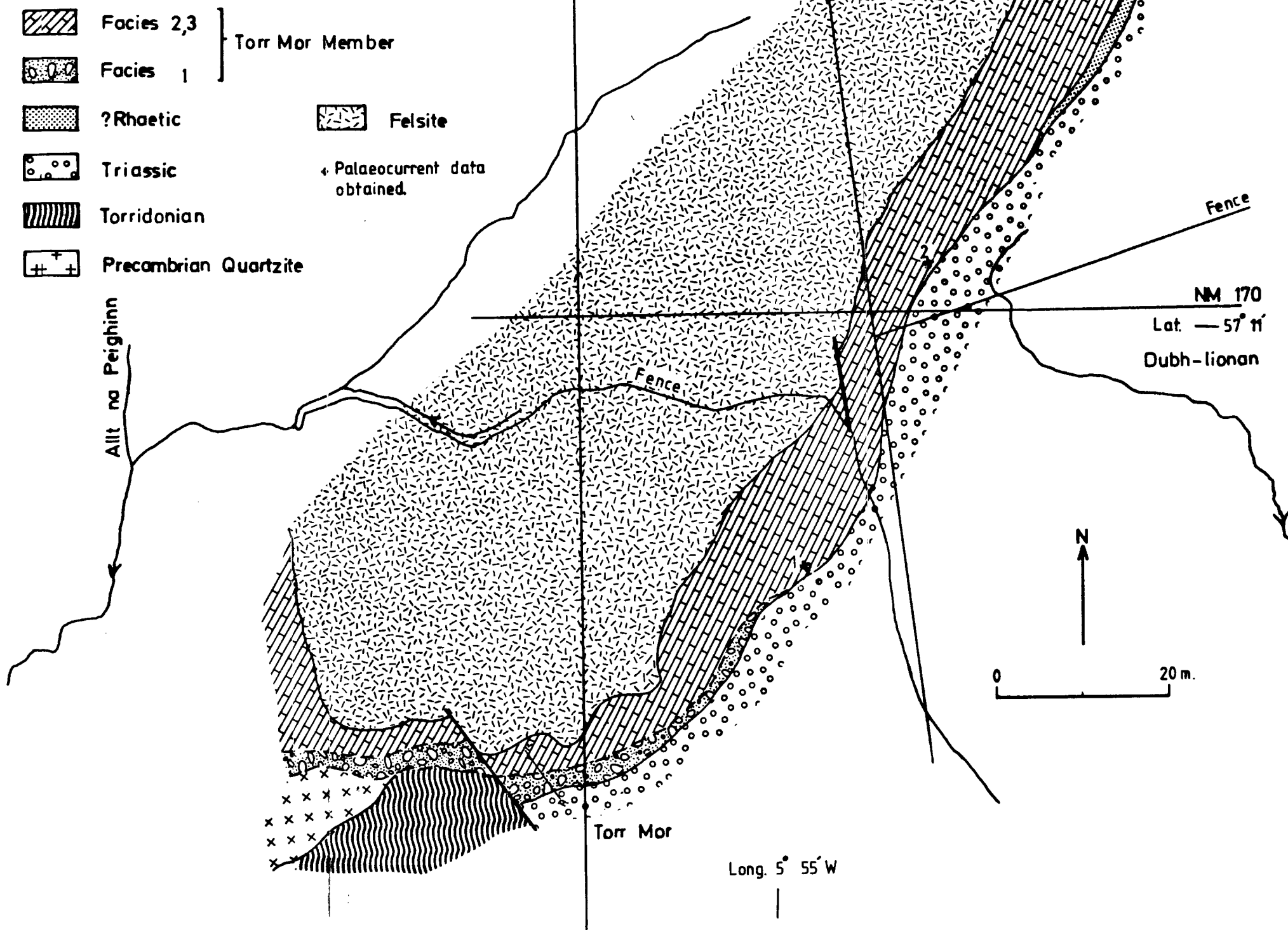


Fig. 6.2
Clast composition of the Torr Mor Member
facies 1, 2 (Torr Mor NG 630164).

Fig. 6.3

Field relationship between the Torr Mor Member and the surrounding strata.



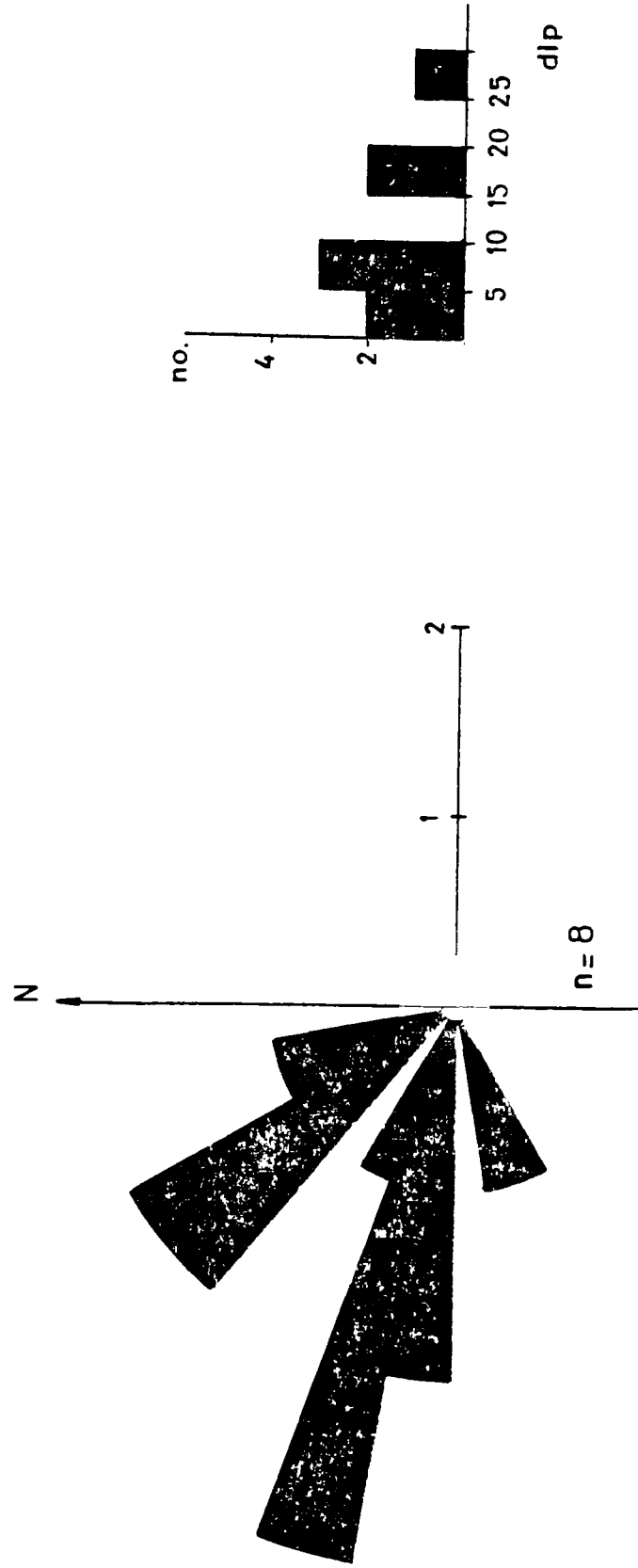


Fig. 6.4

Palaecurrent data obtained from the Torr Mor Member, Facies 2 in Loch Eishort(NG 630164), location 1.

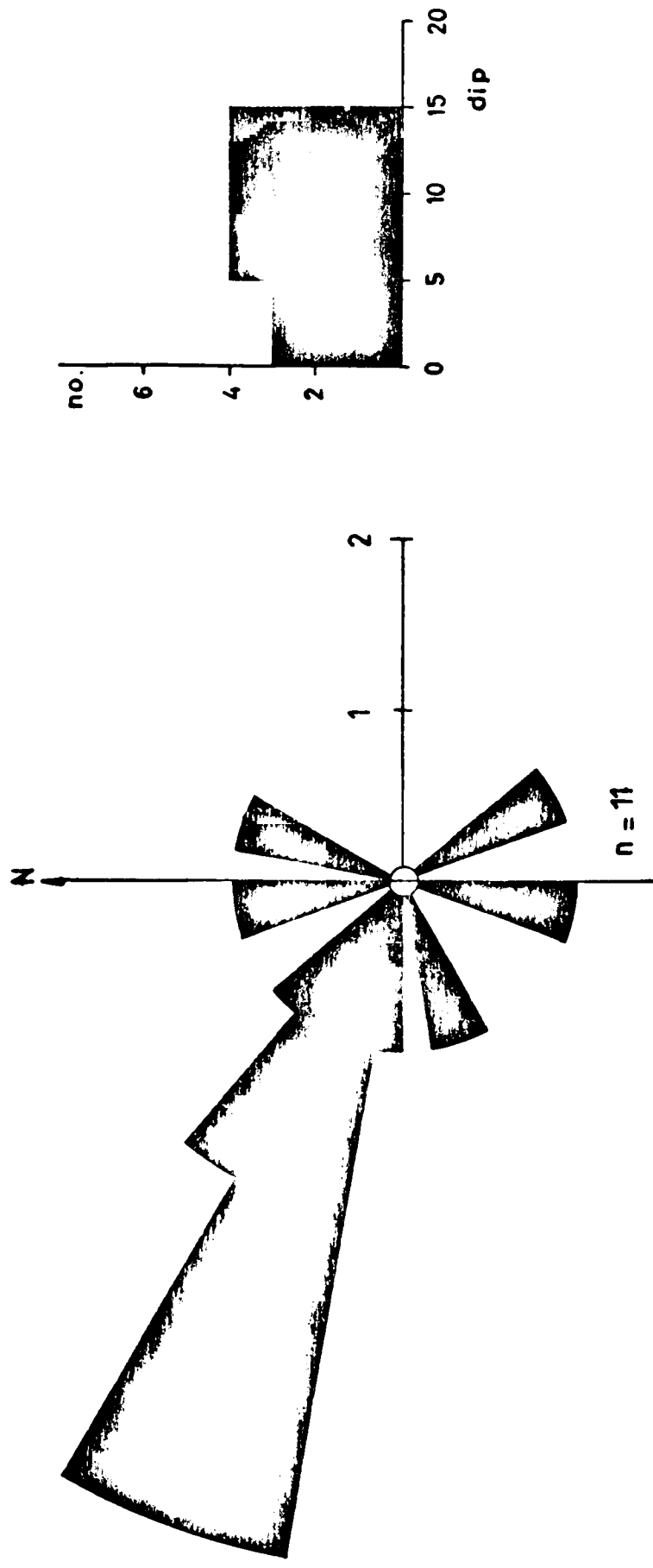


Fig. 6.5
Palaeocurrent data obtained from the Tor Mor Member, Facies 2 in Loch Eishort(NG 63251675), location 2.

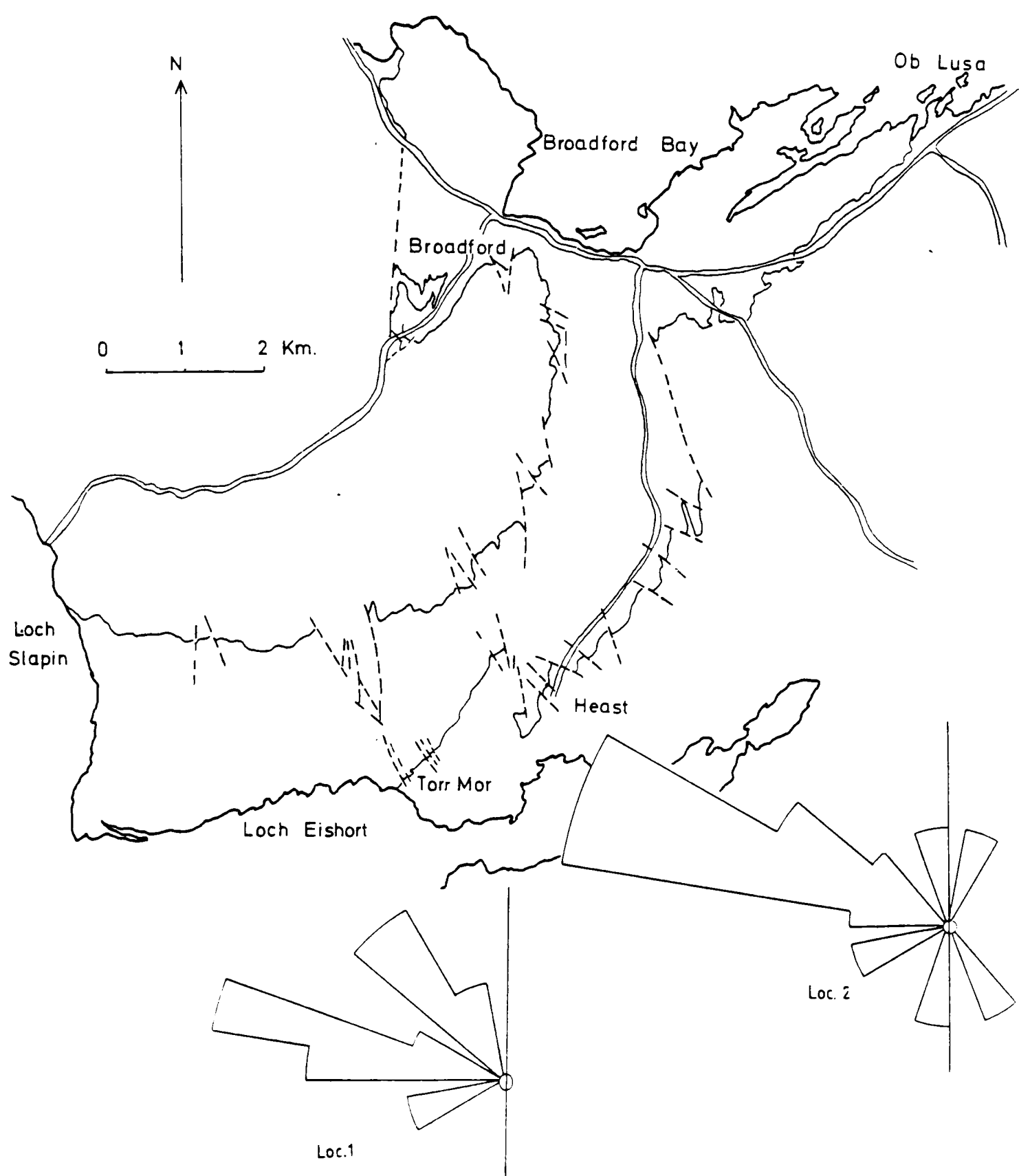
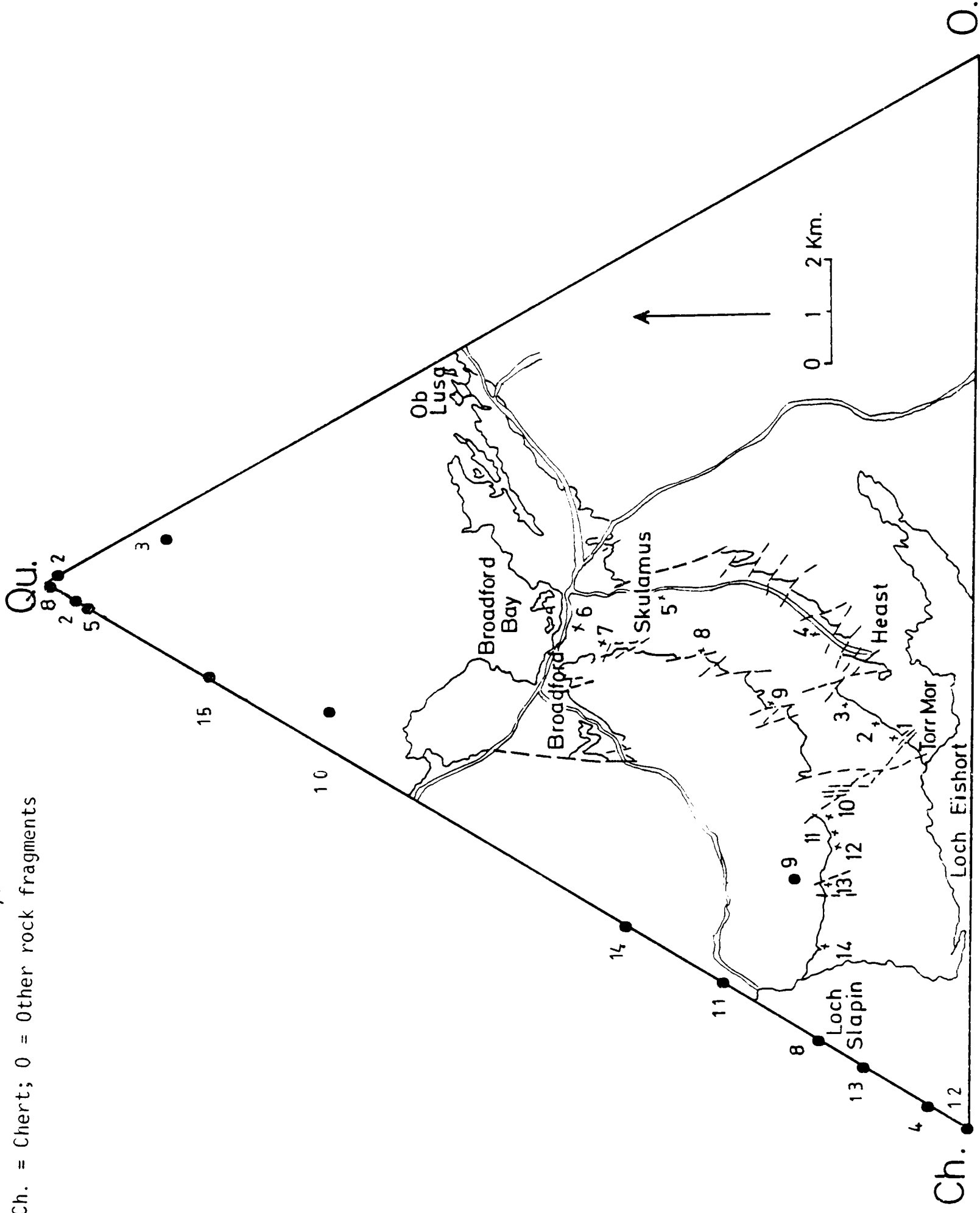


Fig. 6.5a
Palaeocurrent data obtained from the Torr Mor Member, facies 2 in Loch Eishort(NG 630164).

Fig.6.6. Clast composition of the Milton Formation in the Skye area, (Angulata-Bucklandi Zones).

Qu. =Quartz; Ch. = Chert; 0 = Other rock fragments

- 1 -NG630164
- 2 -NG63251675
- 3 -NG63251705
- 4 -NG185657
- 5 -NG660217
- 6 -NG64752305
- 7 -NG64902125
- 8 -NG643196
- 9 -NG63751905
- 10 -NG179612
- 11 -NG616181
- 12 -NG181598
- 13 -NG178601
- 14 -NG585181



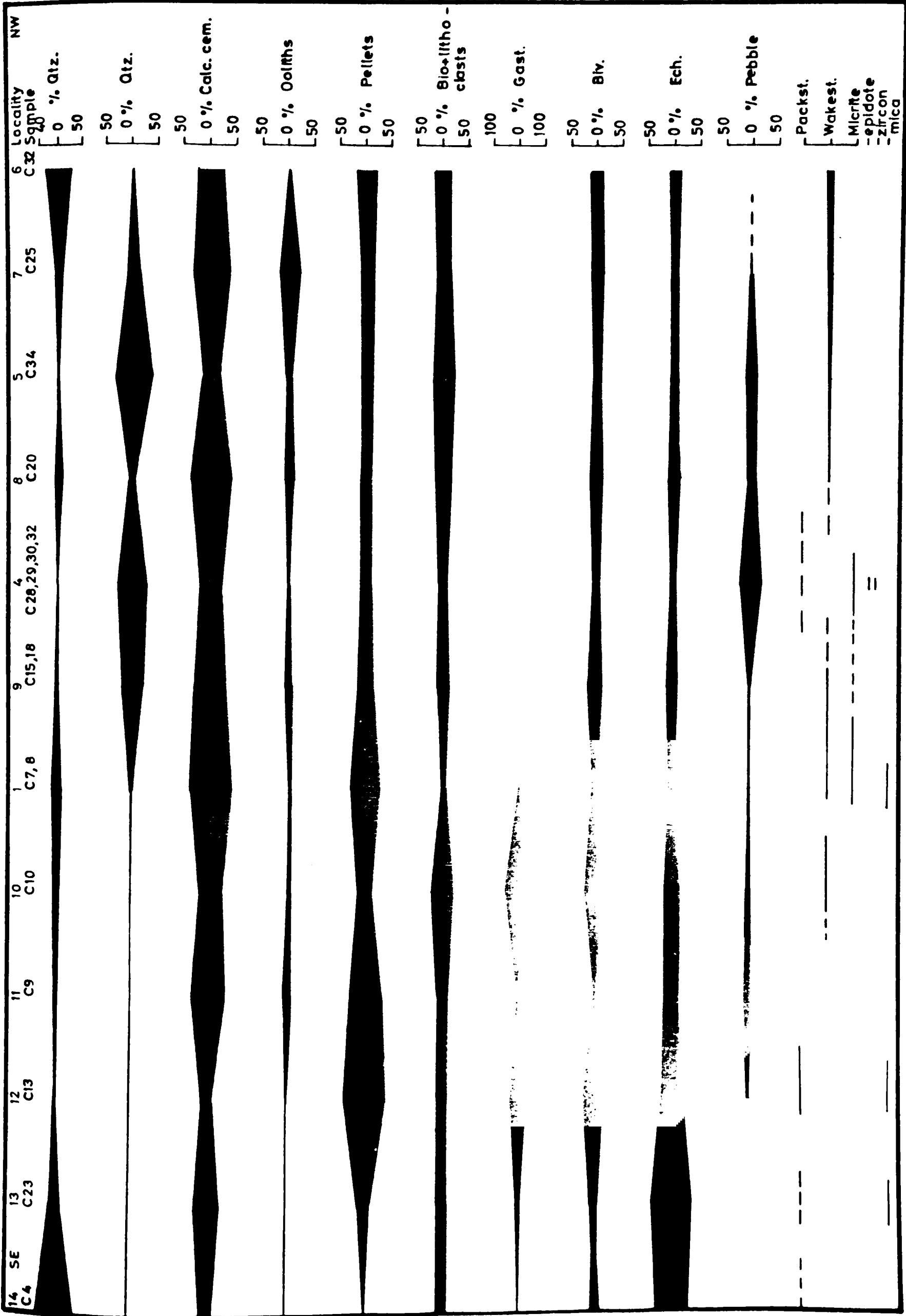


Fig. 6.7

Lateral composi-
change in the
lowermost beds of
the Milton Fm.
in the Strath area
(see Fig.6.6 for locs.)

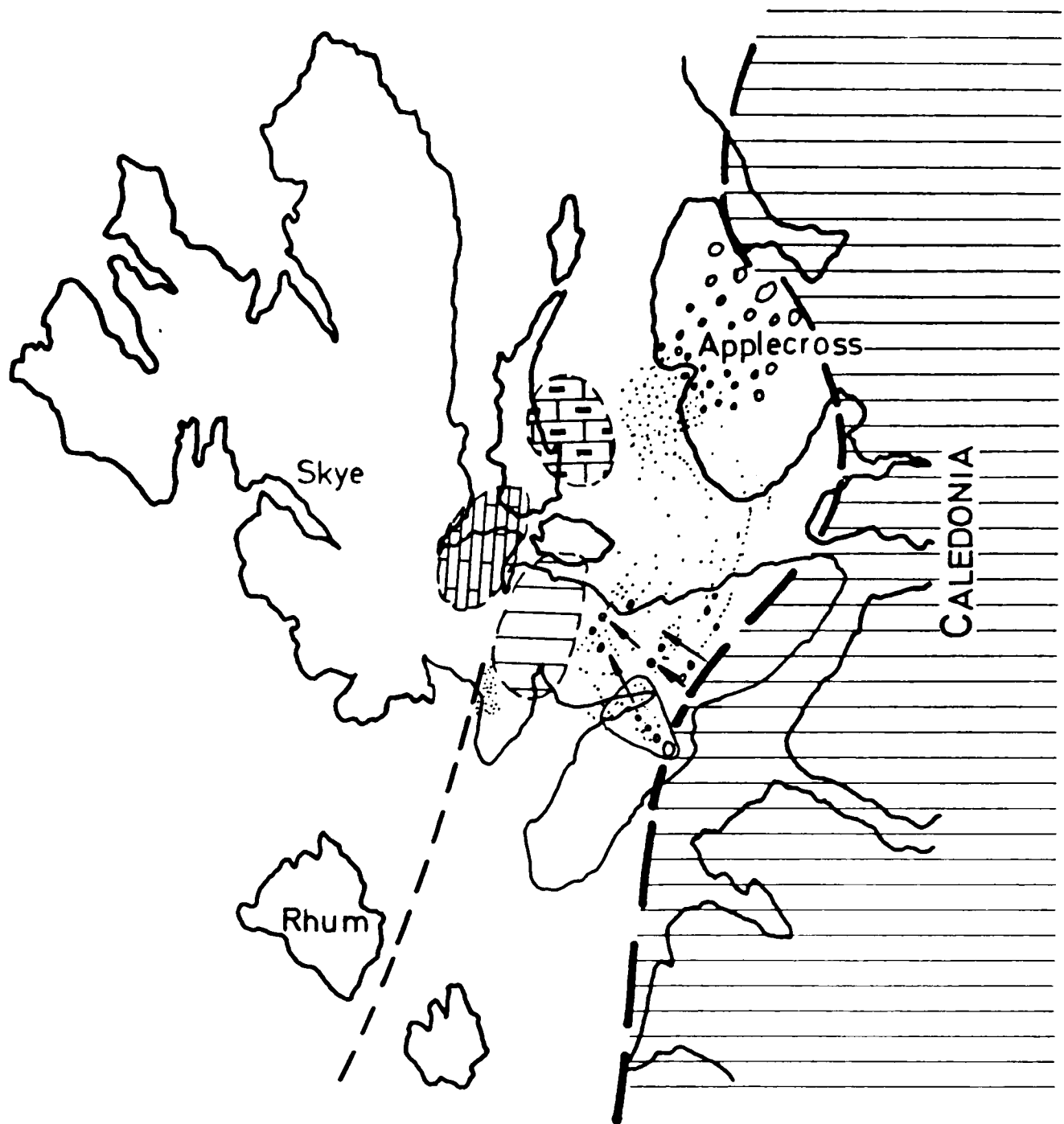
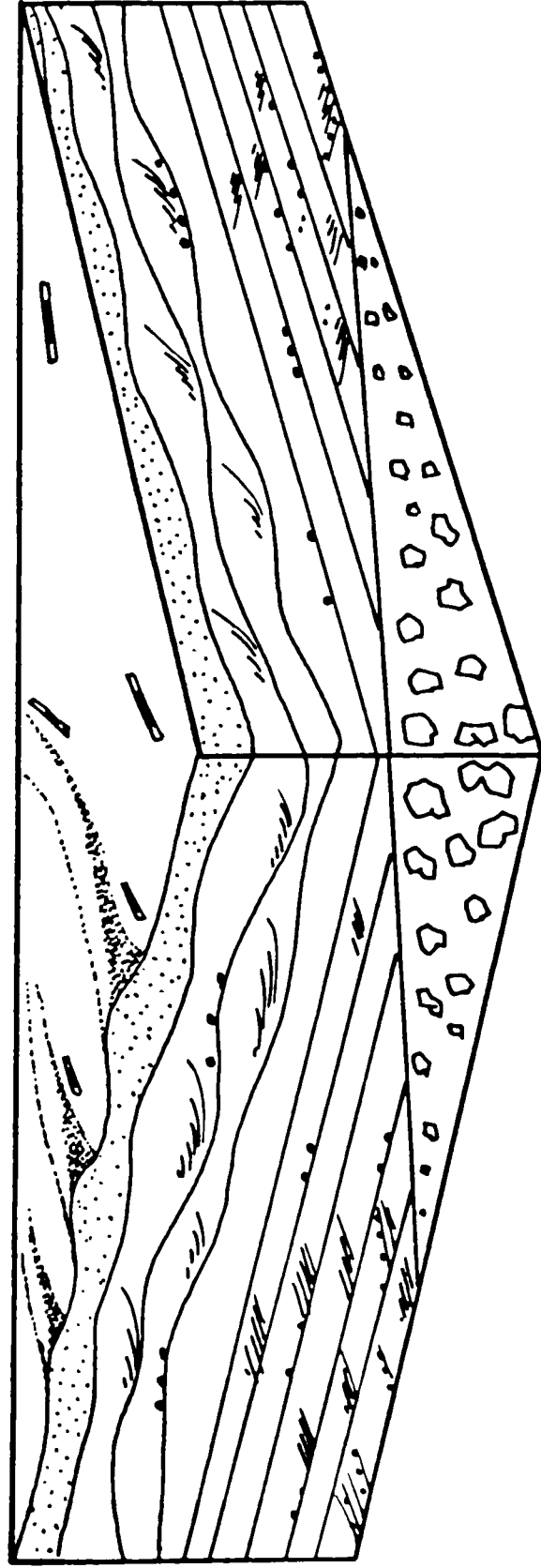


Fig. 6.8

Facies distribution during the Angulata-Bucklandi Zones (Facies 1,2,3), in the northern area of study. The symbols are explained in Table 12.1



0
2
3

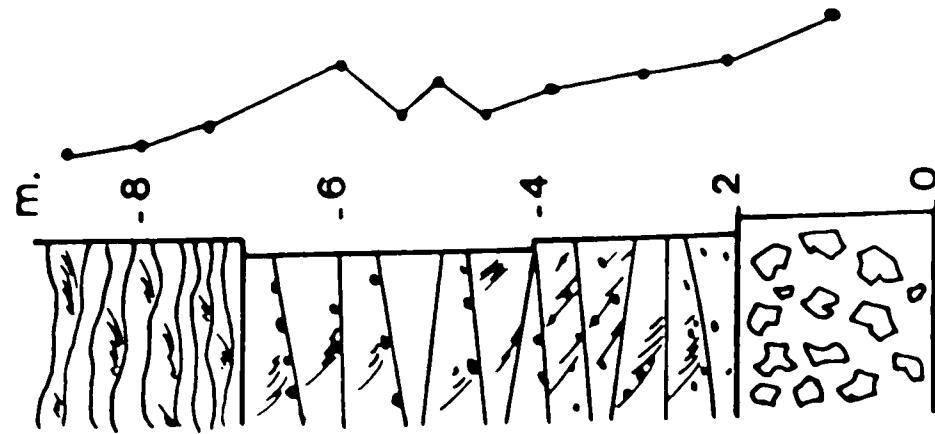


Fig. 6.9
Idealized section of
Torr Mor Member and
tentative environments
of deposition.

Feldspathic calcareous sandst., tabular + tangen. tosets; some horizontal laminated sheets.	Combined-flow ripples, migrating sand-waves.	Lower-shoreface
Faintly cross-laminated calcareous siltst. + sandst. with rounded pebbles at base; lensoid.	Wave currents	Upper shoreface
Poorly sorted, crossbedd. pebbly sand lenses.	Turbulent	Transition zone
Polymict, matrix supported unsorted conglomerate.	Debris-flow, building into ? foreshore channels	Foreshore

Offshore

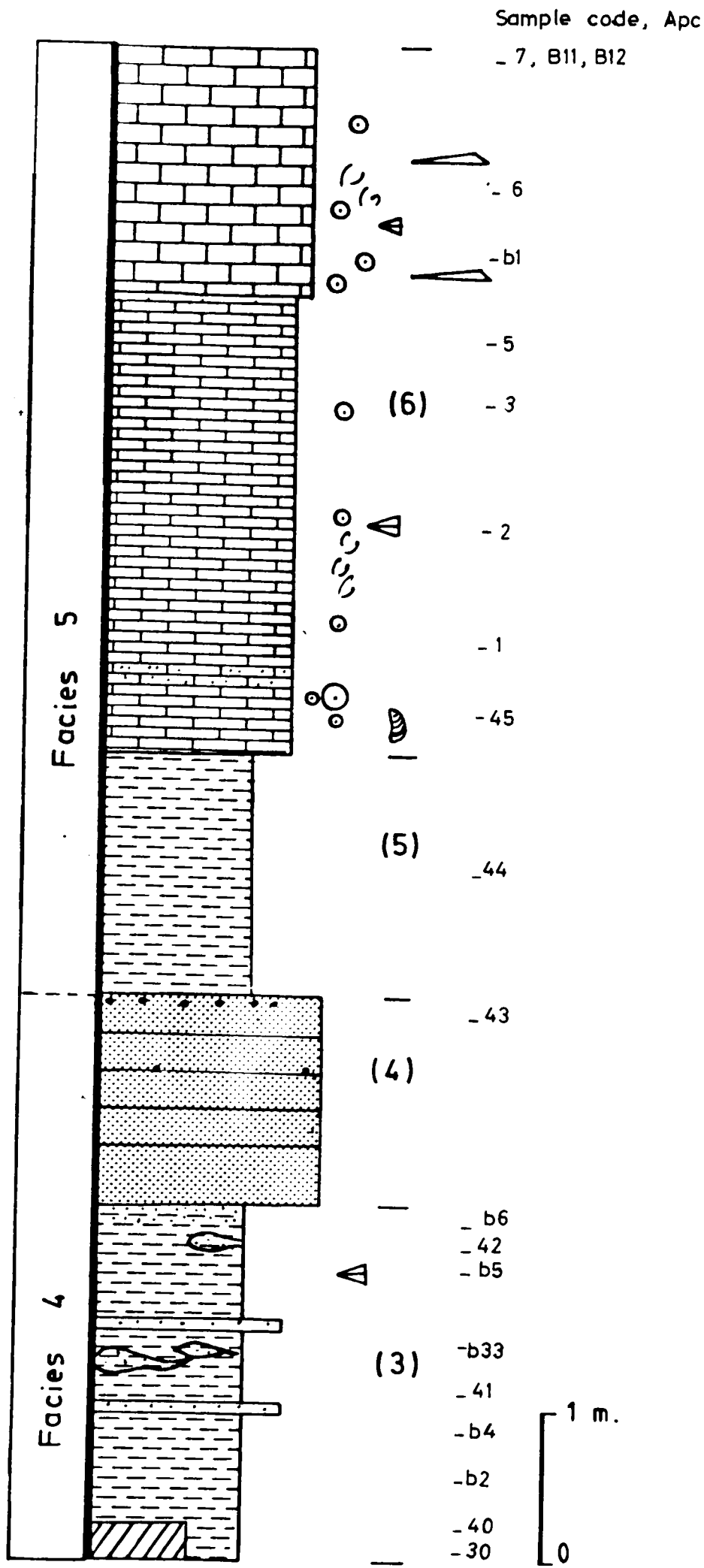


Fig. 6.11
Facies in the Applecross House Member, Applecross (bed numbers of Hallam, 1959).

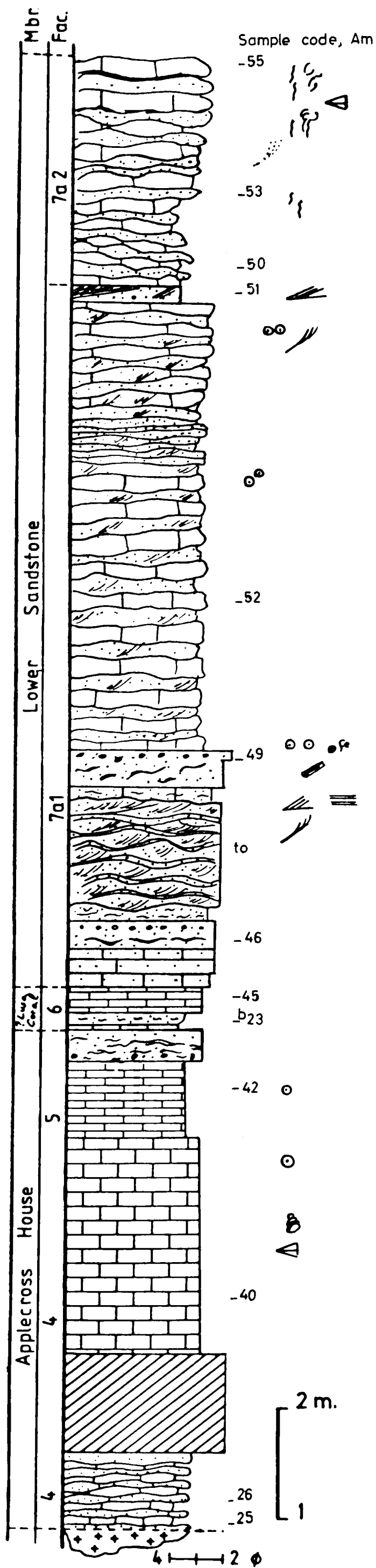


Fig. 6.12
Lower beds of the Milton
Formation, Loch Eishort (625162).

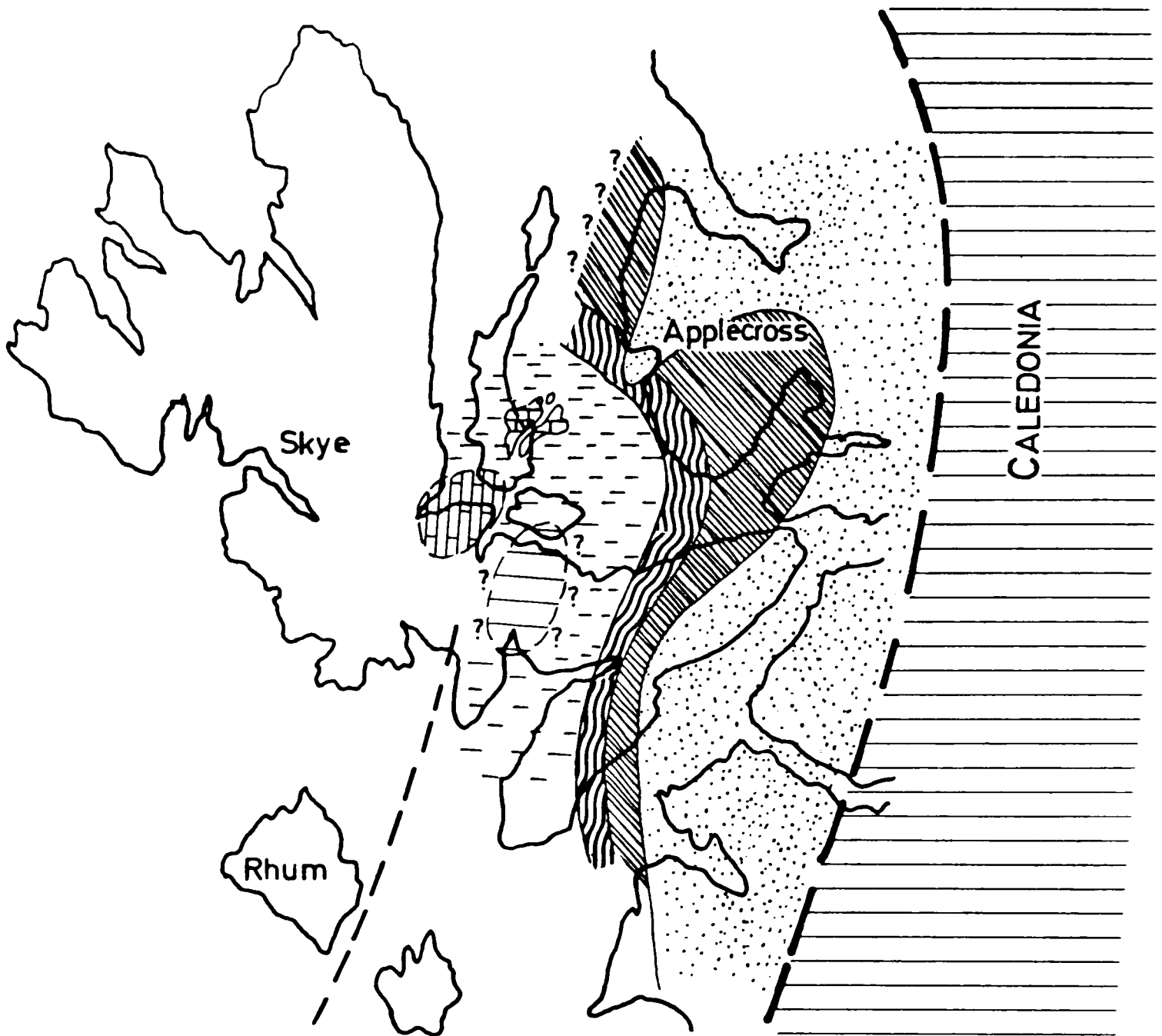


Fig. 6.13

Facies distribution in the northern area of study during the Angulata-Bucklandi Zones (facies 4-I). The symbols are explained in Table 12.1

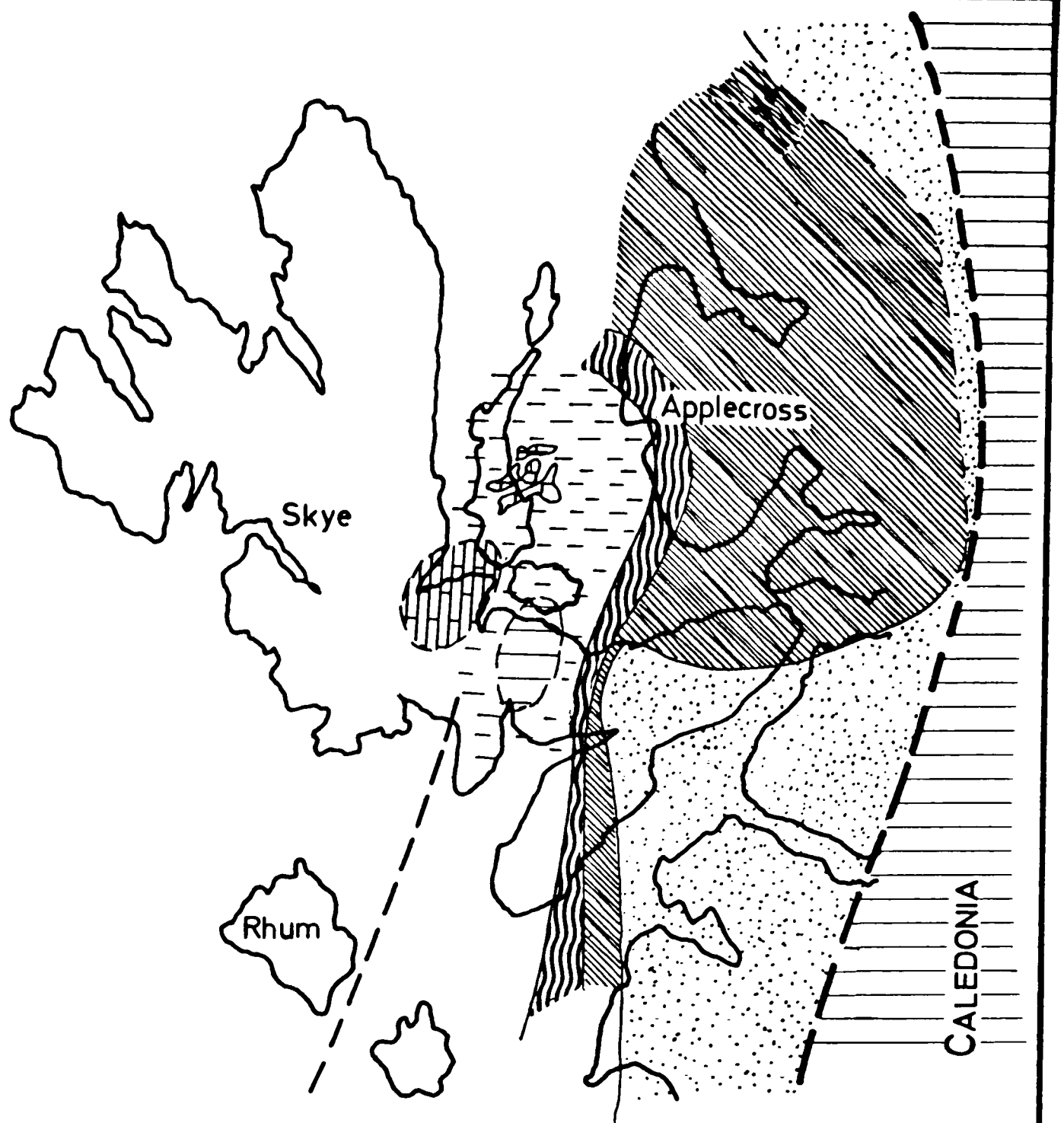


Fig.6.14

Facies distribution in the northern area of study during the Angulata-Bucklandi Zones (facies 4-2). The symbols are explained in Table 12.1

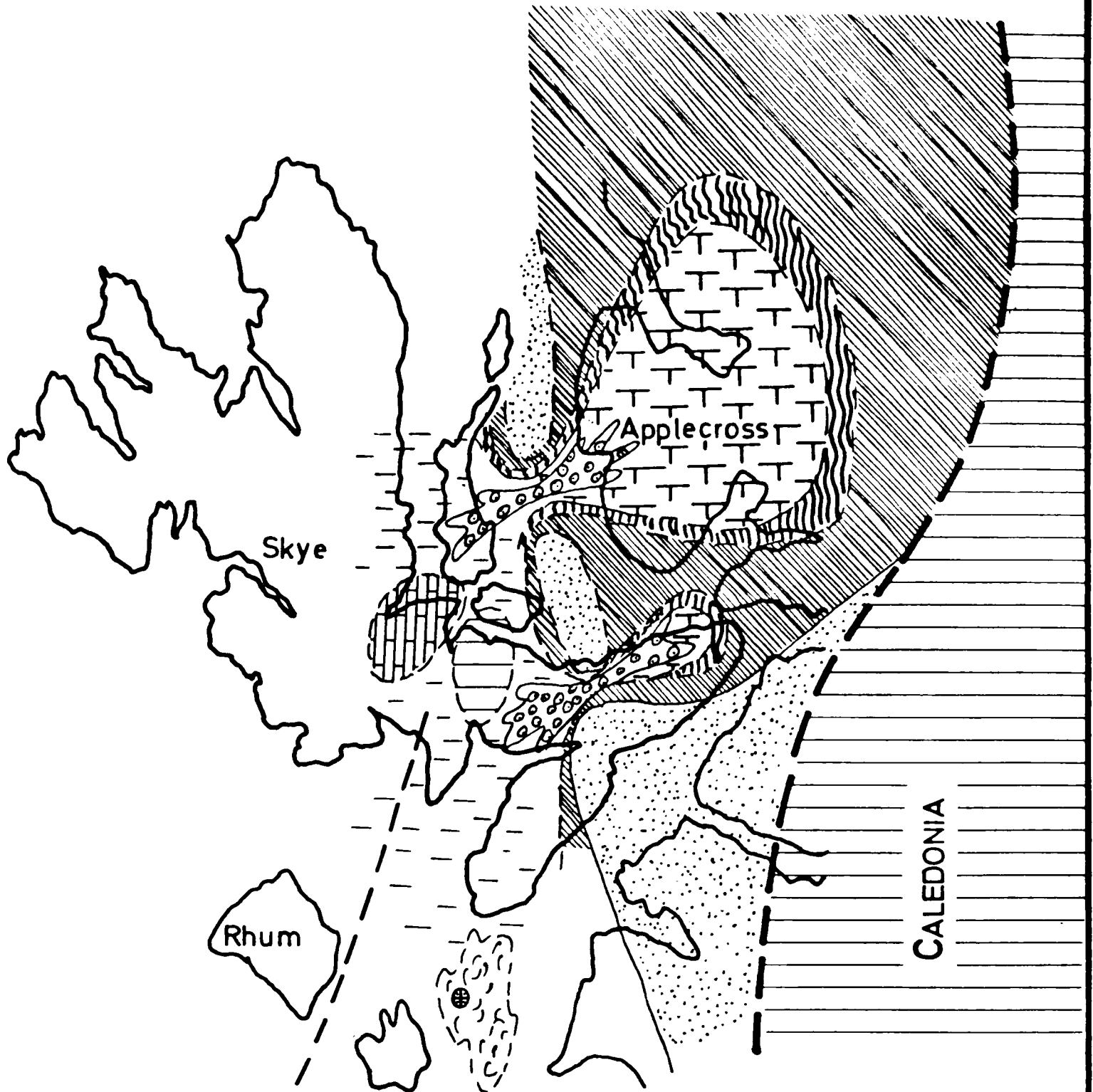


Fig.6.15

Facies distribution in the northern area of study during the Angulata-Bucklandi Zone (facies5). The symbols are given in Table 12.1

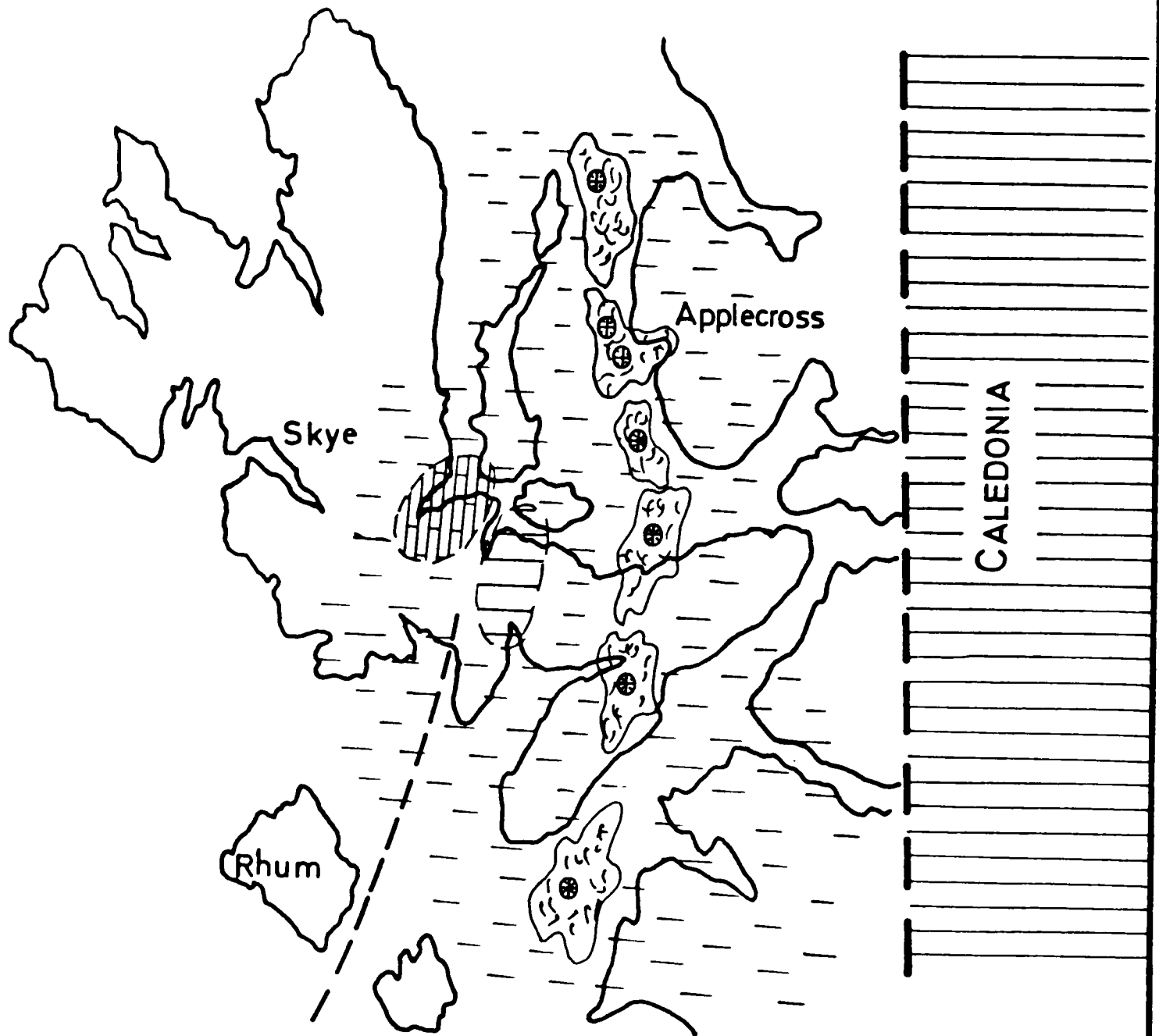


Fig. 6.16

Facies distribution in the northern area of study during the Angulata-Bucklandi Zones (Facies 6). The symbols are explained in Table 12.1

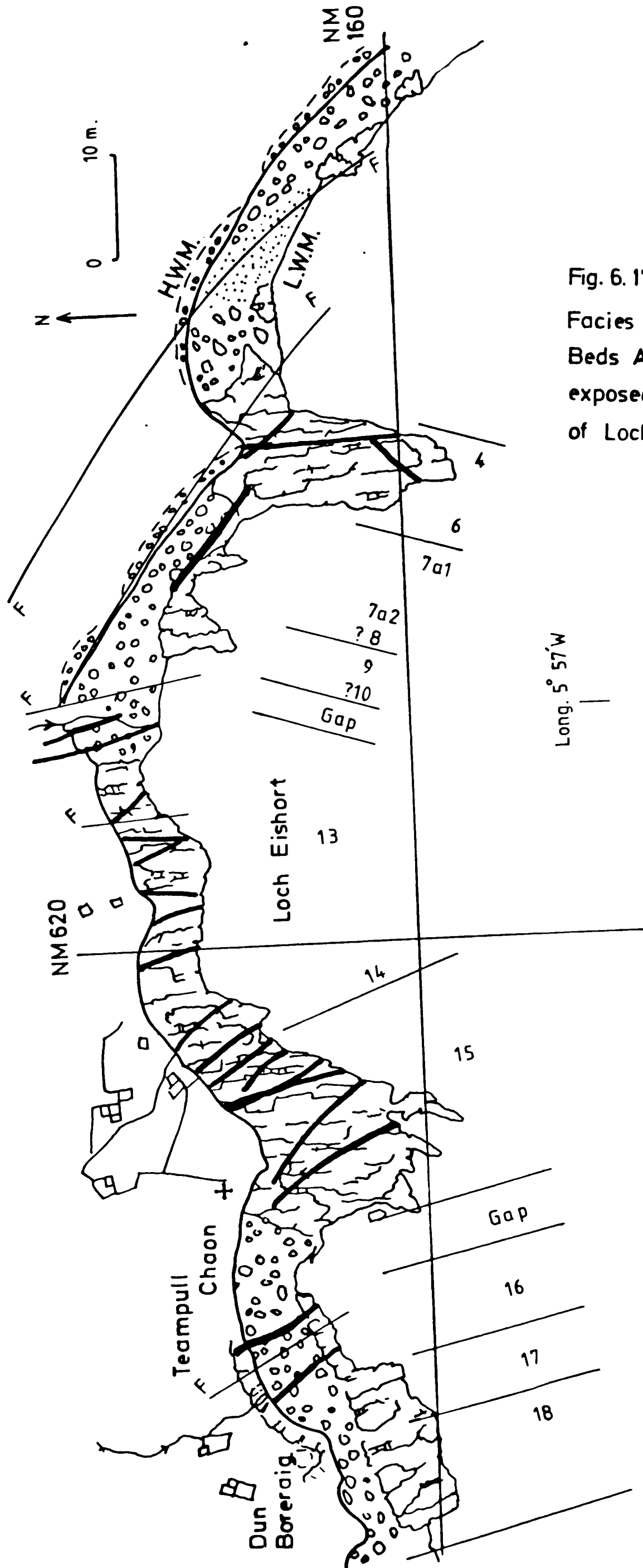


Fig. 6.17
Facies in the Broadford
Beds Arenaceous Group
exposed along the coast
of Loch Eishort.

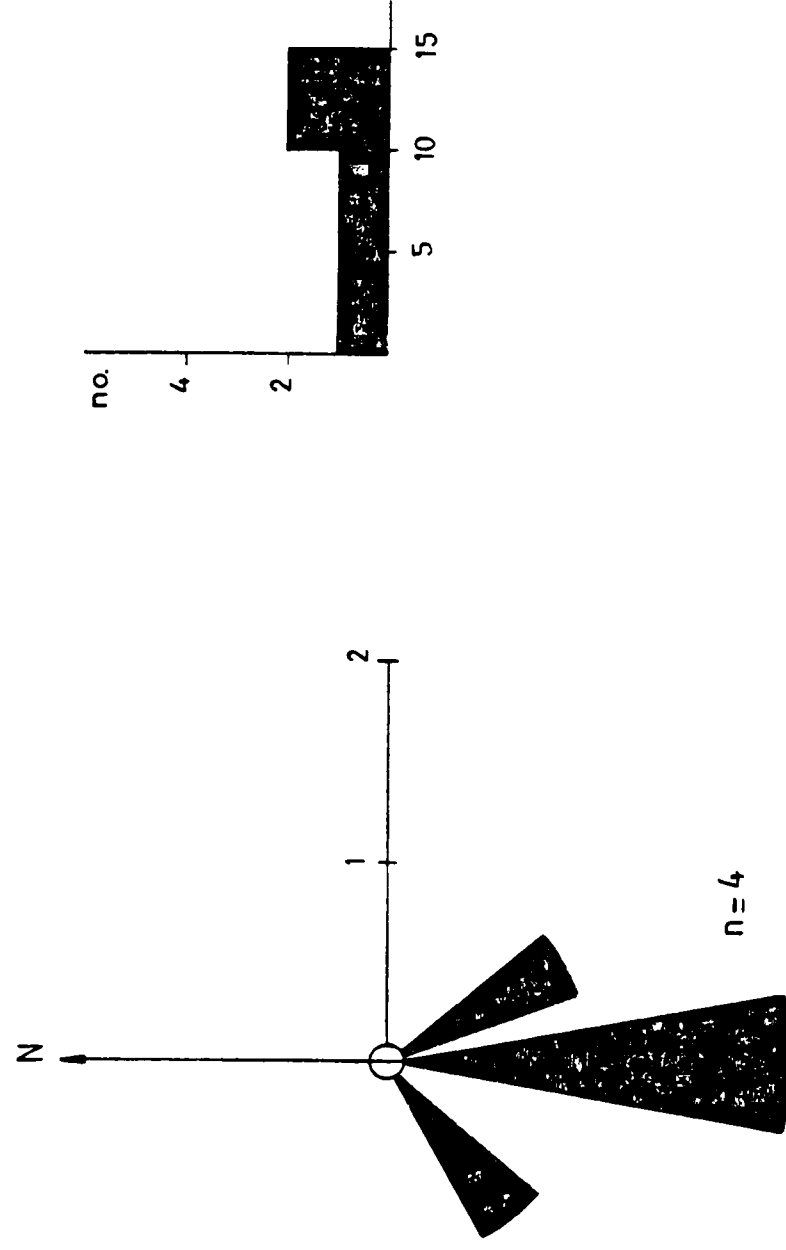


Fig. 6.18

Palaeocurrent data obtained from the Lower Sandst. Member, Facies 7a1 in Loch Eishort (NM 625163).

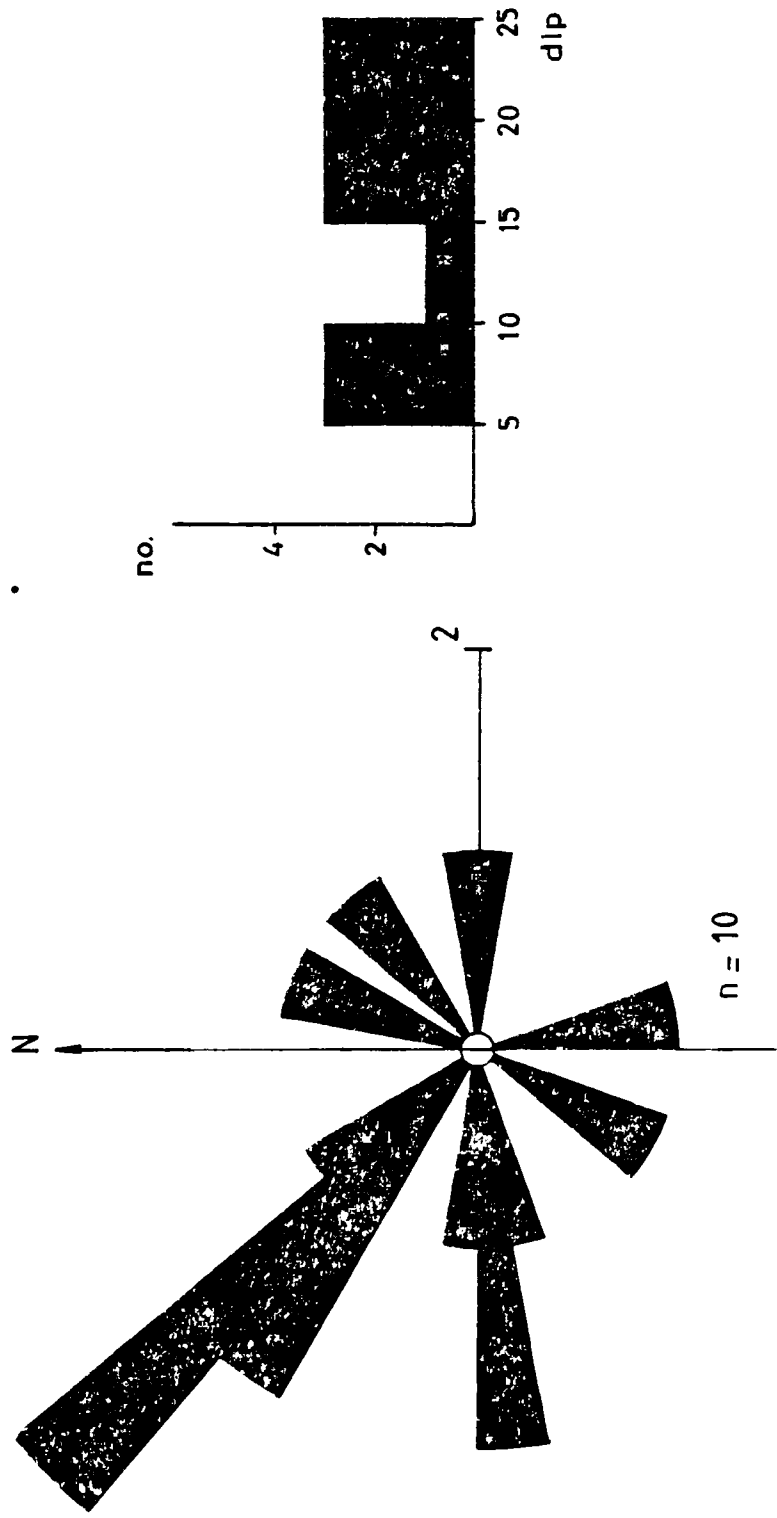


Fig. 6.18 a
Palaeocurrent data obtained from the Lower Sand Member, Facies 7a1 in Loch Eishort
(NM 625163).

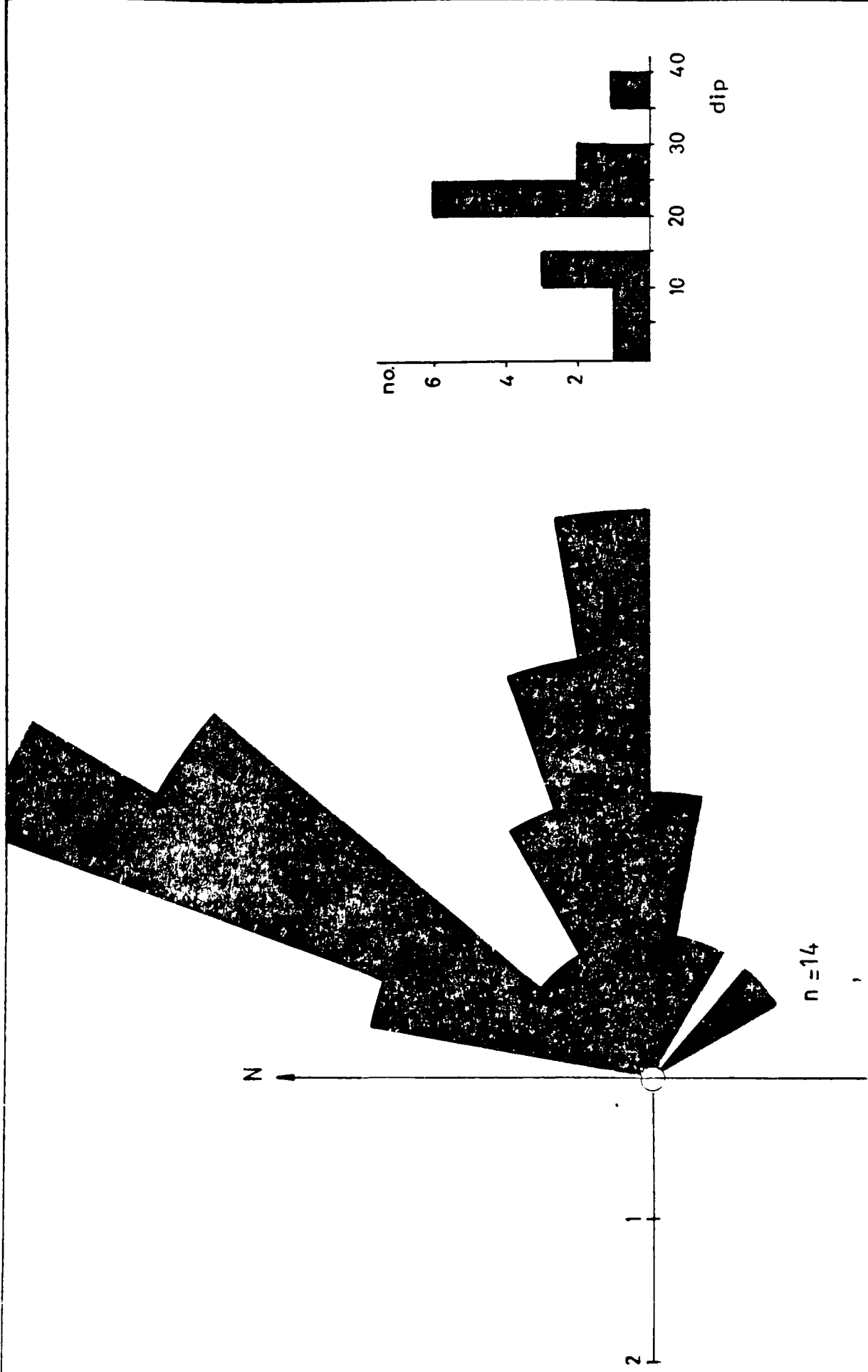


Fig. 6. 19

Palaeocurrent data obtained from the Lower Sst. Member, Facies 7a1 in Loch Eishort(NG 624162),
(see Fig. 6.19a also).

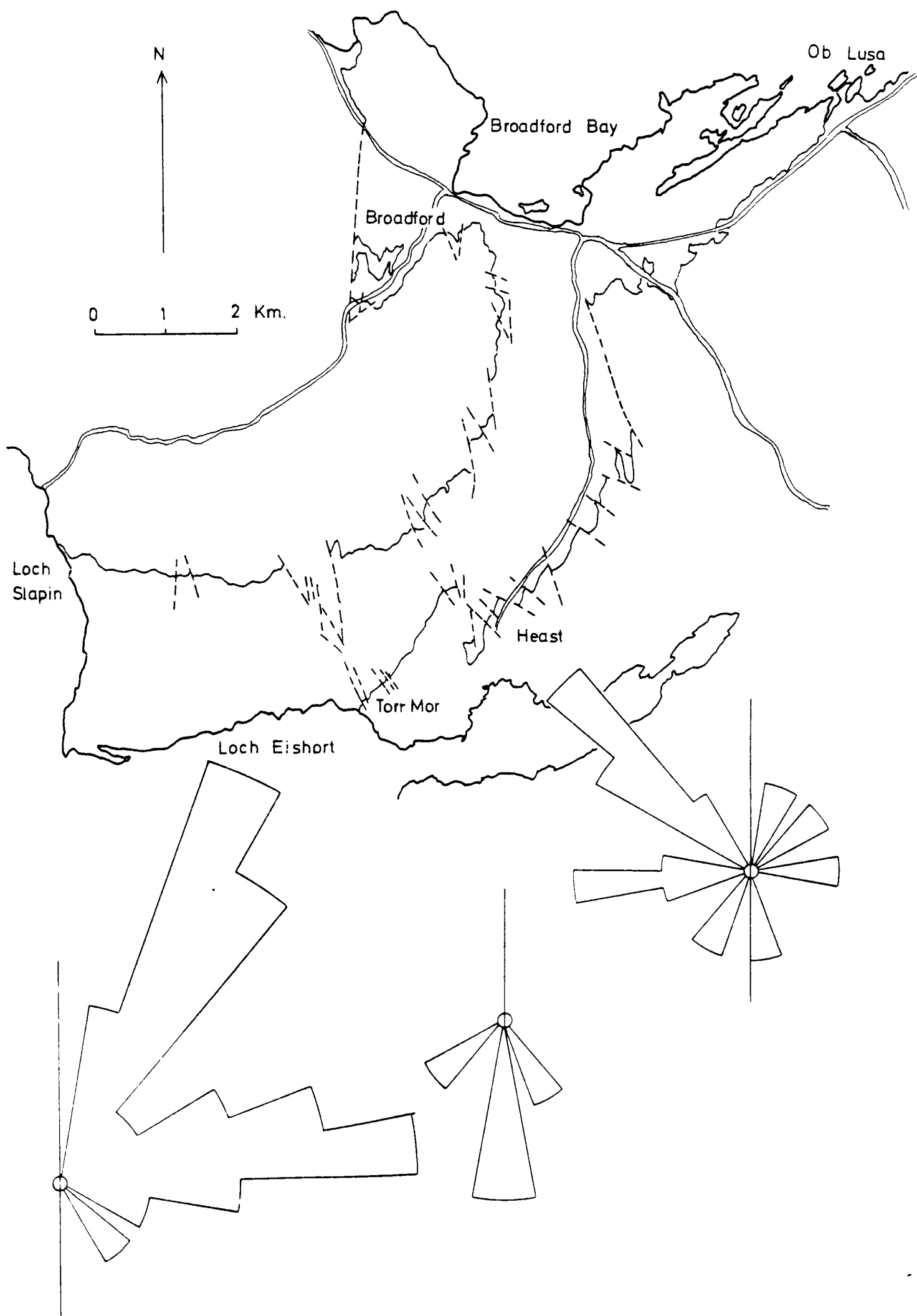


Fig. 6.19a Palaeocurrent data obtained from the Lower Sst. Member, Facies in Loch Eishort (NG 624162)

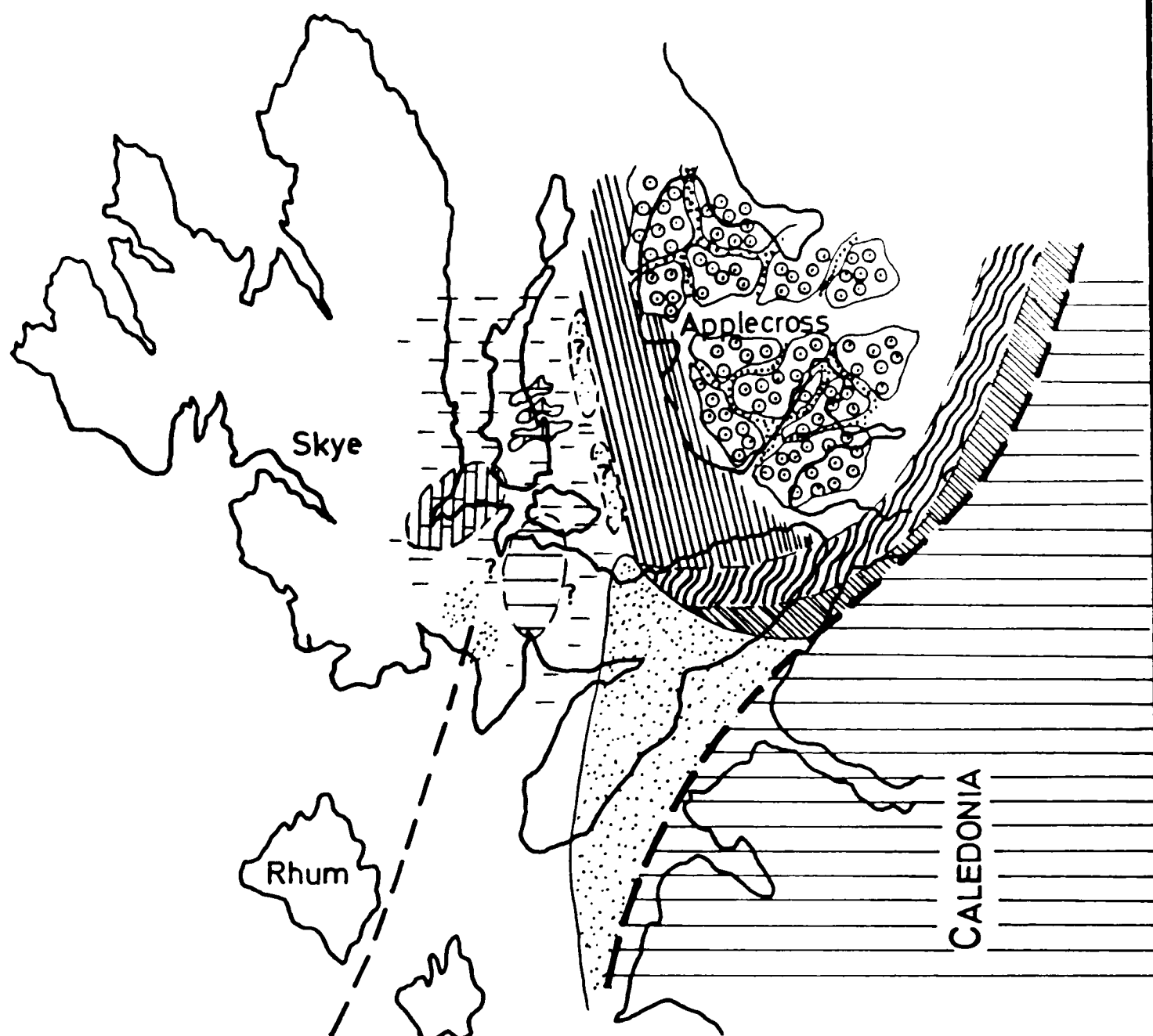


Fig. 6.20

Facies distribution in the northern area of study during the Angulata-Bucklandi Zones (Facies 7-1). The symbols are explained in Table 12.1

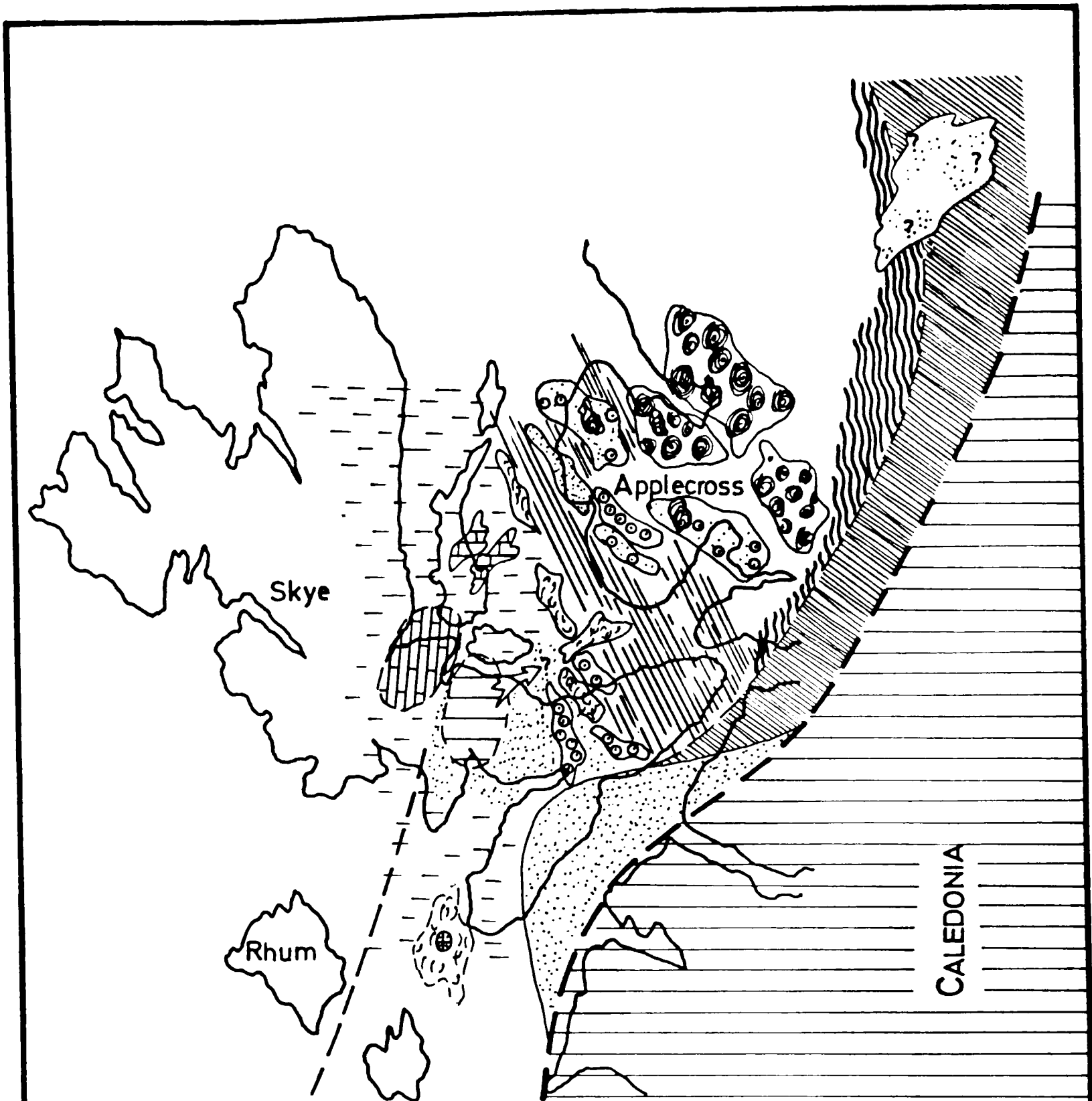


Fig. 6.21

Facies distribution in the northern area of study during the Angulata-Bucklandi Zones (Facies 7-2). The symbols are explained in Table 12.1



Fig.6.22

Facies distribution in the northern area of study during the Angulata-Bucklandi Zones (Facies 7-3). The symbols are given in Table 12.1

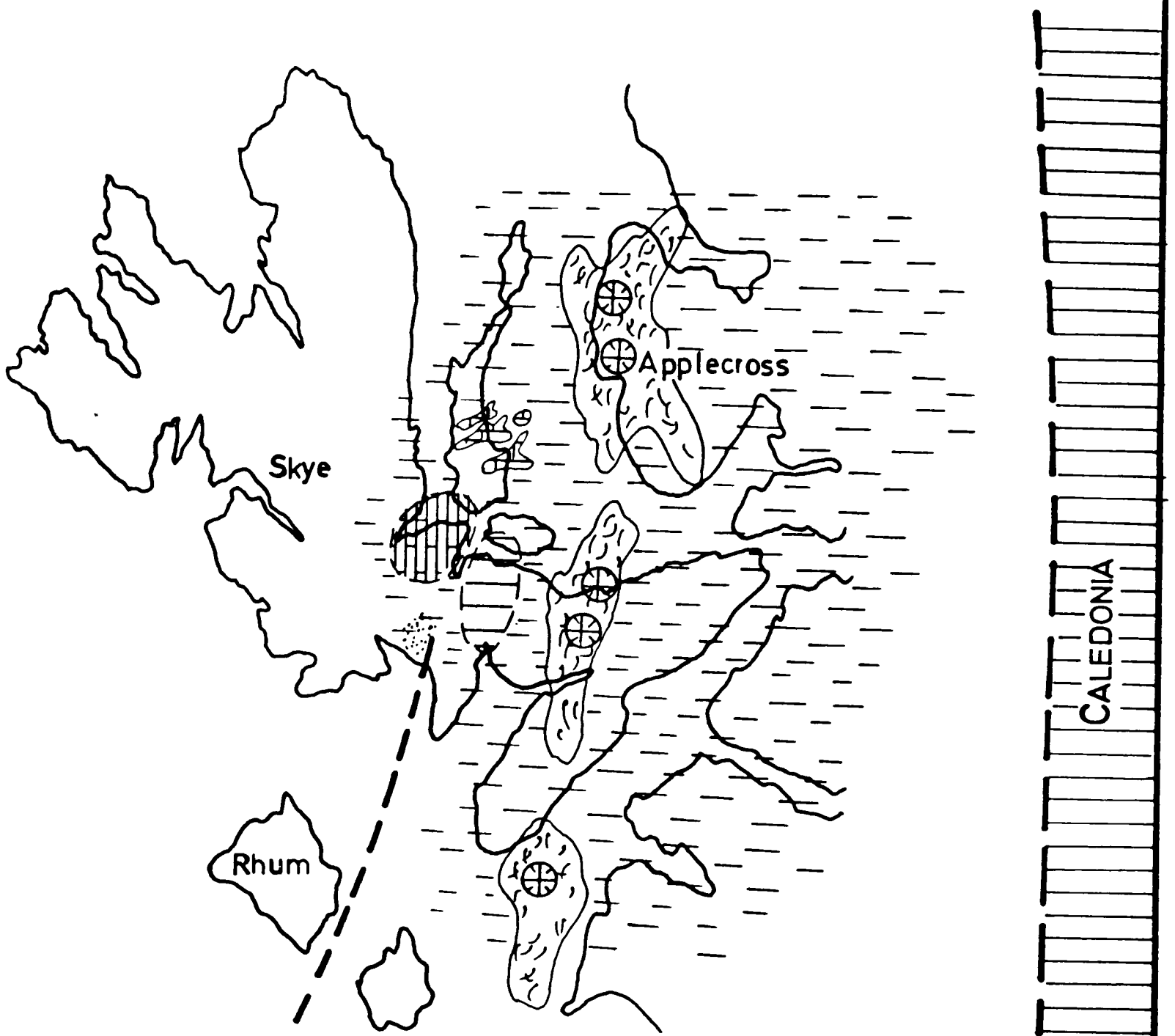


Fig.6.23

Facies distribution in the northern area of study during the Bucklandi Zone (Facies 8). The symbols are explained in Table 12.1

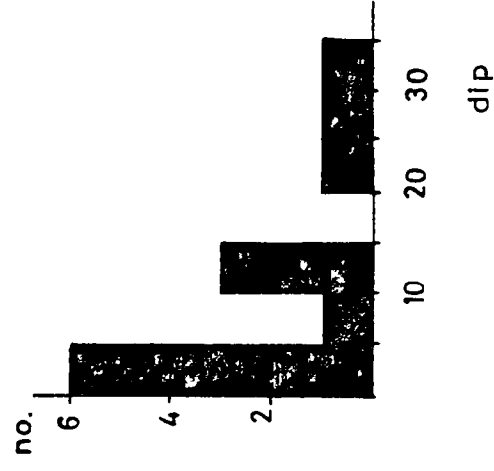
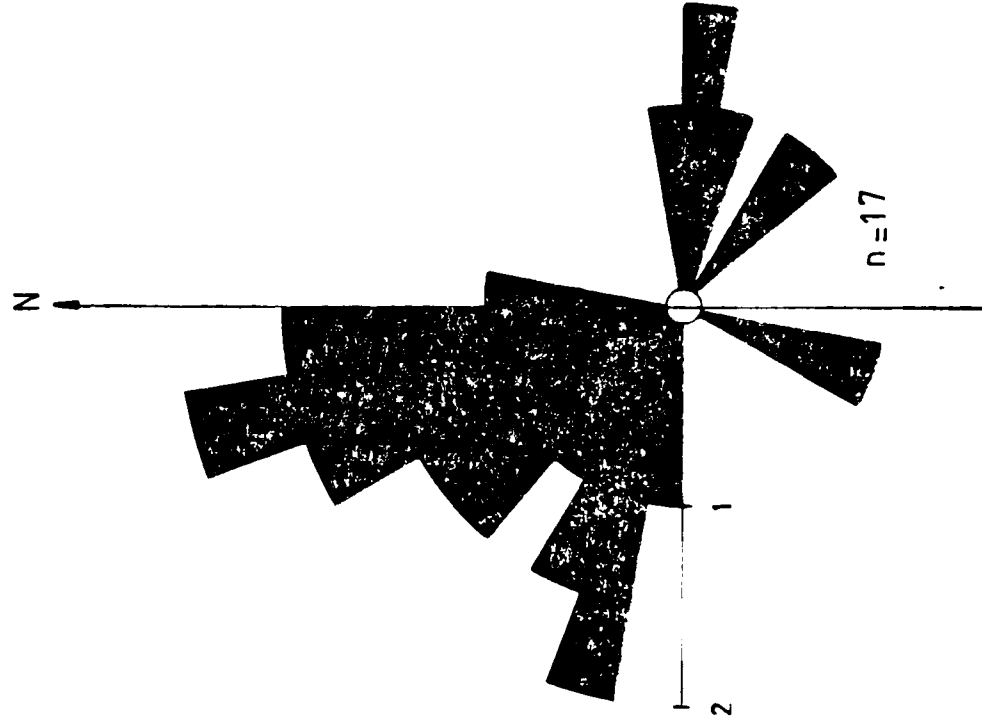


Fig. 6. 24
Palaeocurrent data obtained from the Upper Sst. Member, Facies 9b in Ob Lusa(NG 698251).

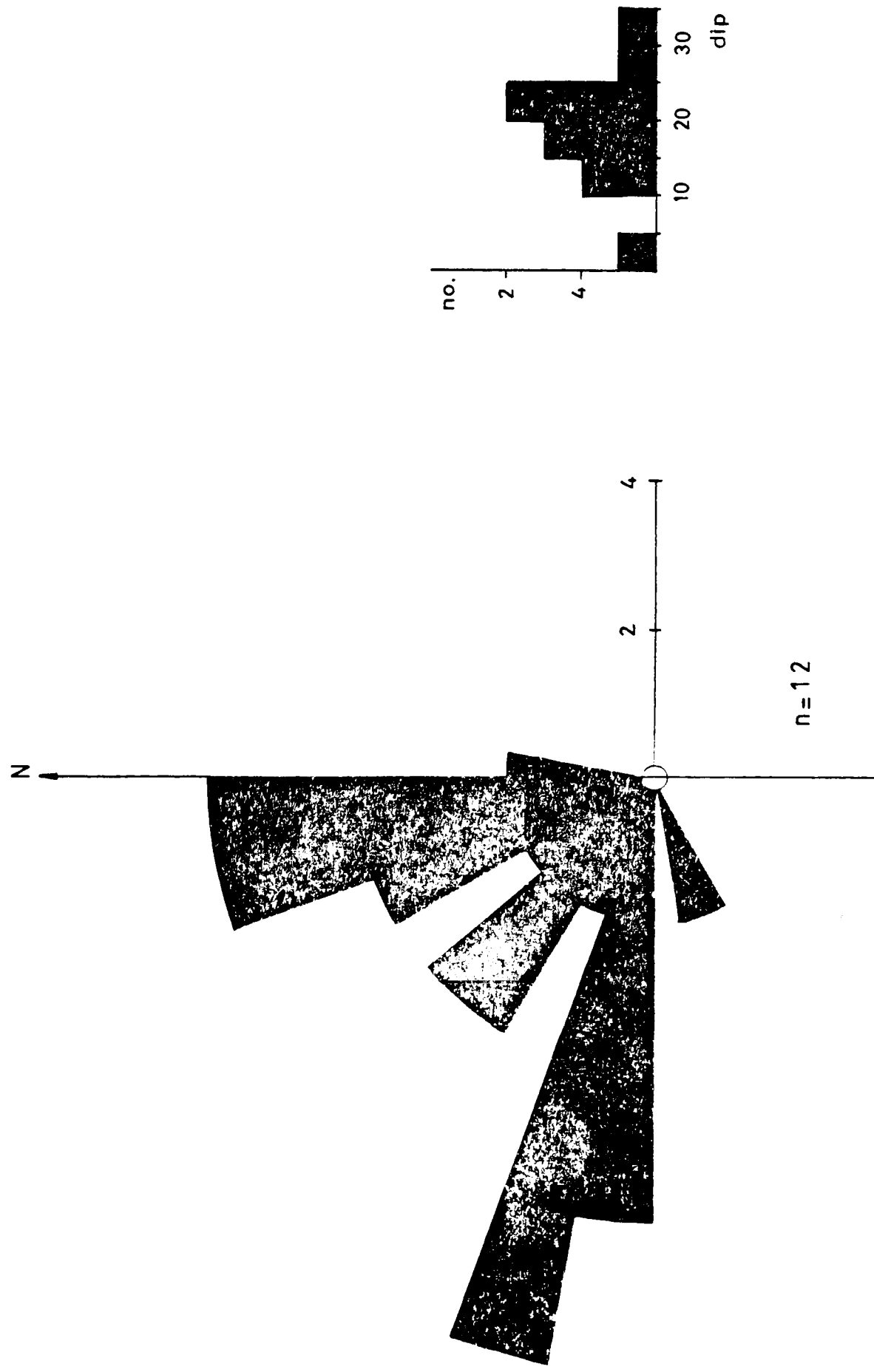


Fig. 6.25

Palaeocurrent data obtained from the Upper Sst. Member, Facies9b near Loch Lonachan(NG 635187).
(see also Fig. 6.25a).

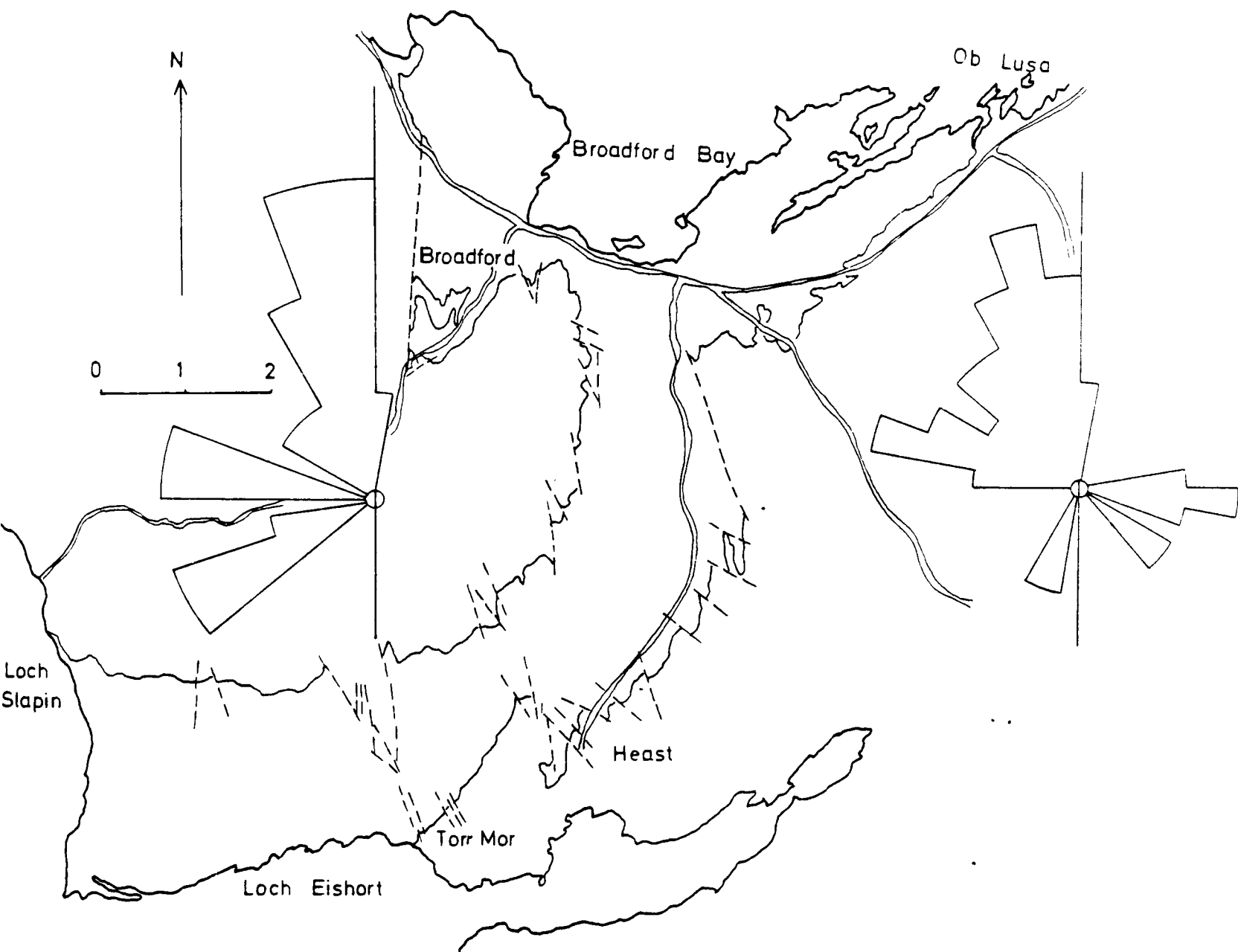
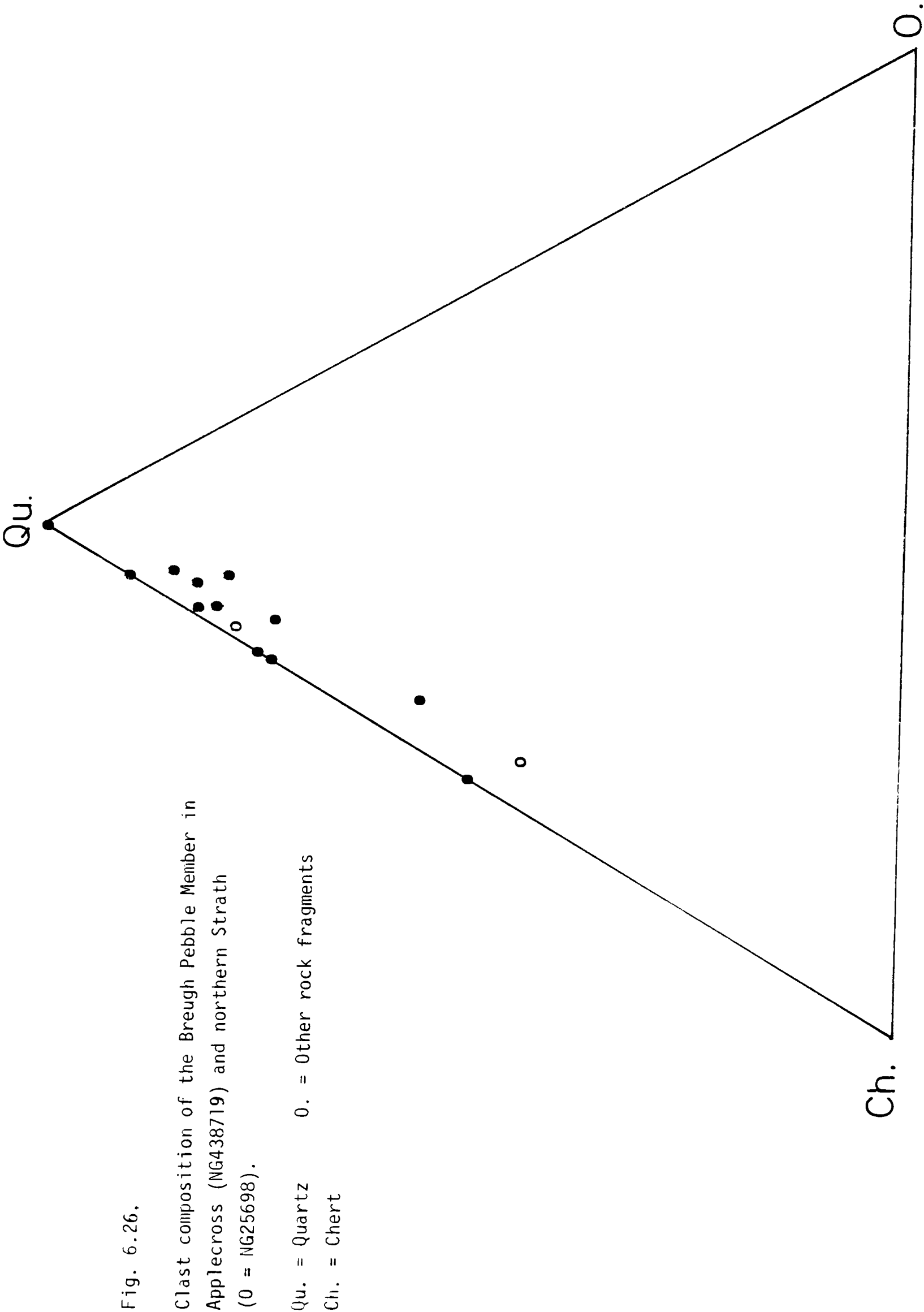


Fig.6.25a Palaeocurrent data obtained from the Upper Sst. Member, Facies 9b in north Strath.



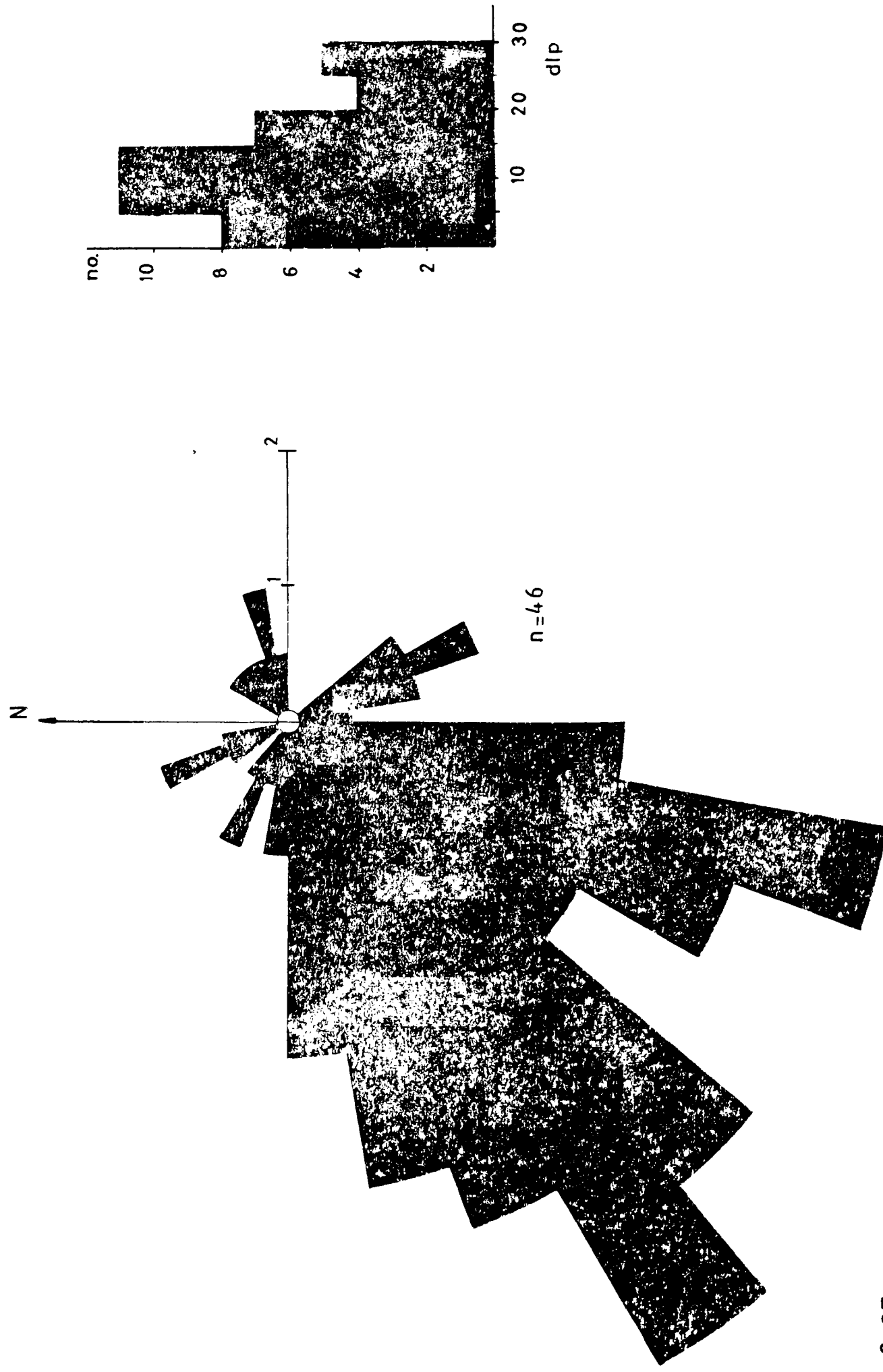


Fig. 6. 27

Palaeocurrent data obtained from the Breugh Pebble Member, Facies 10 & 11 in Applecross(NG 719438).

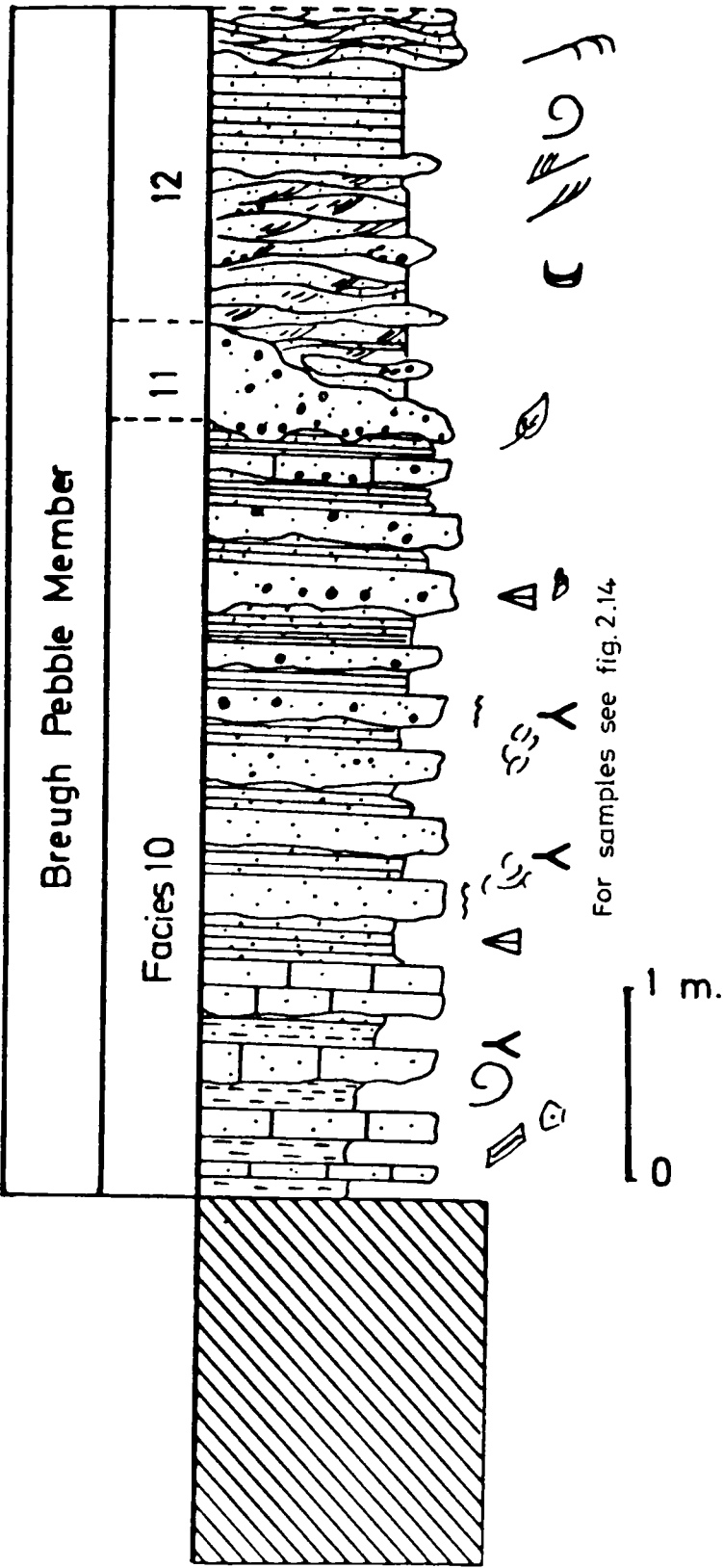


Fig. 6. 28

Facies in the Breugh Pebble Member, Applecross.

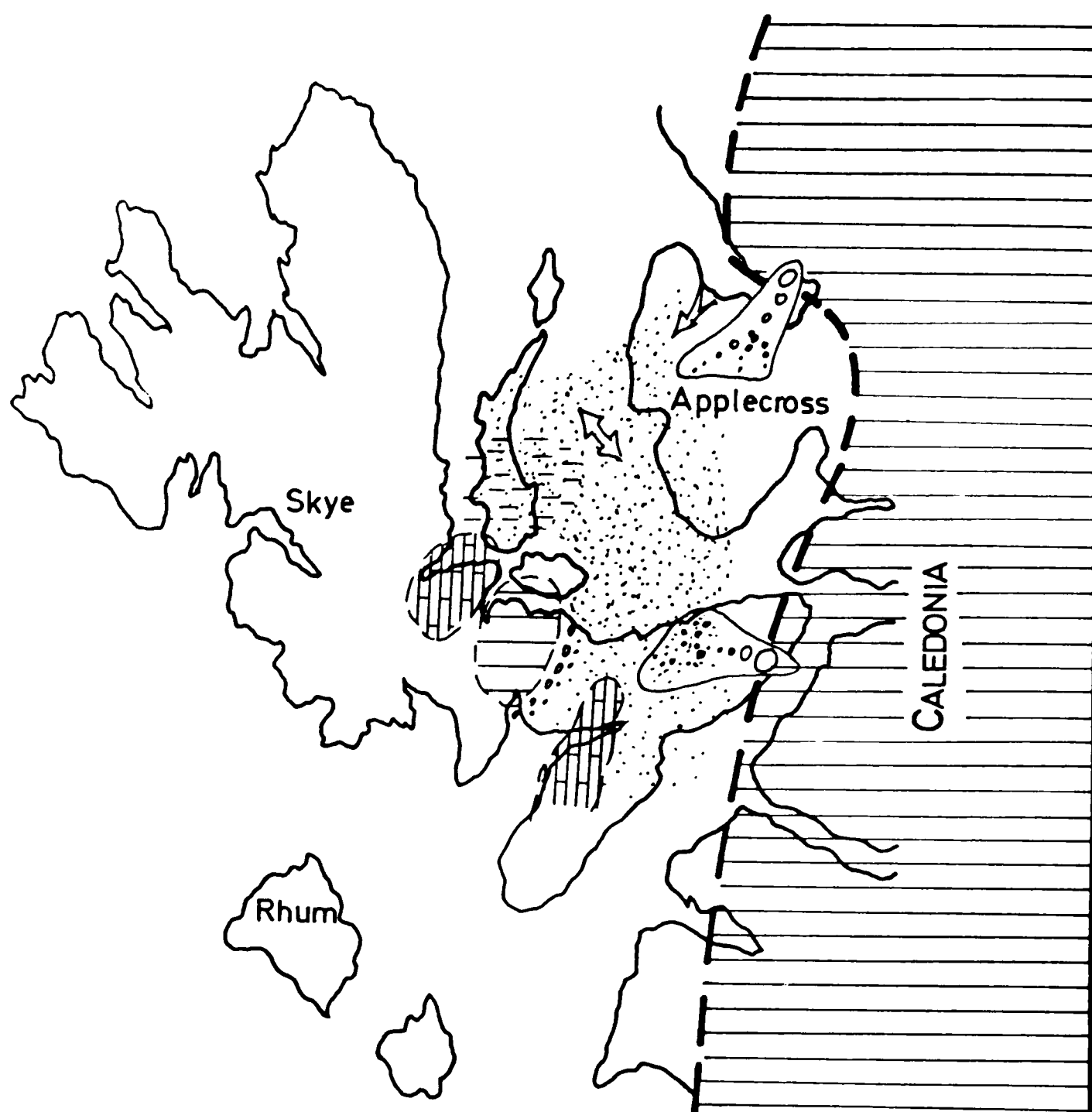
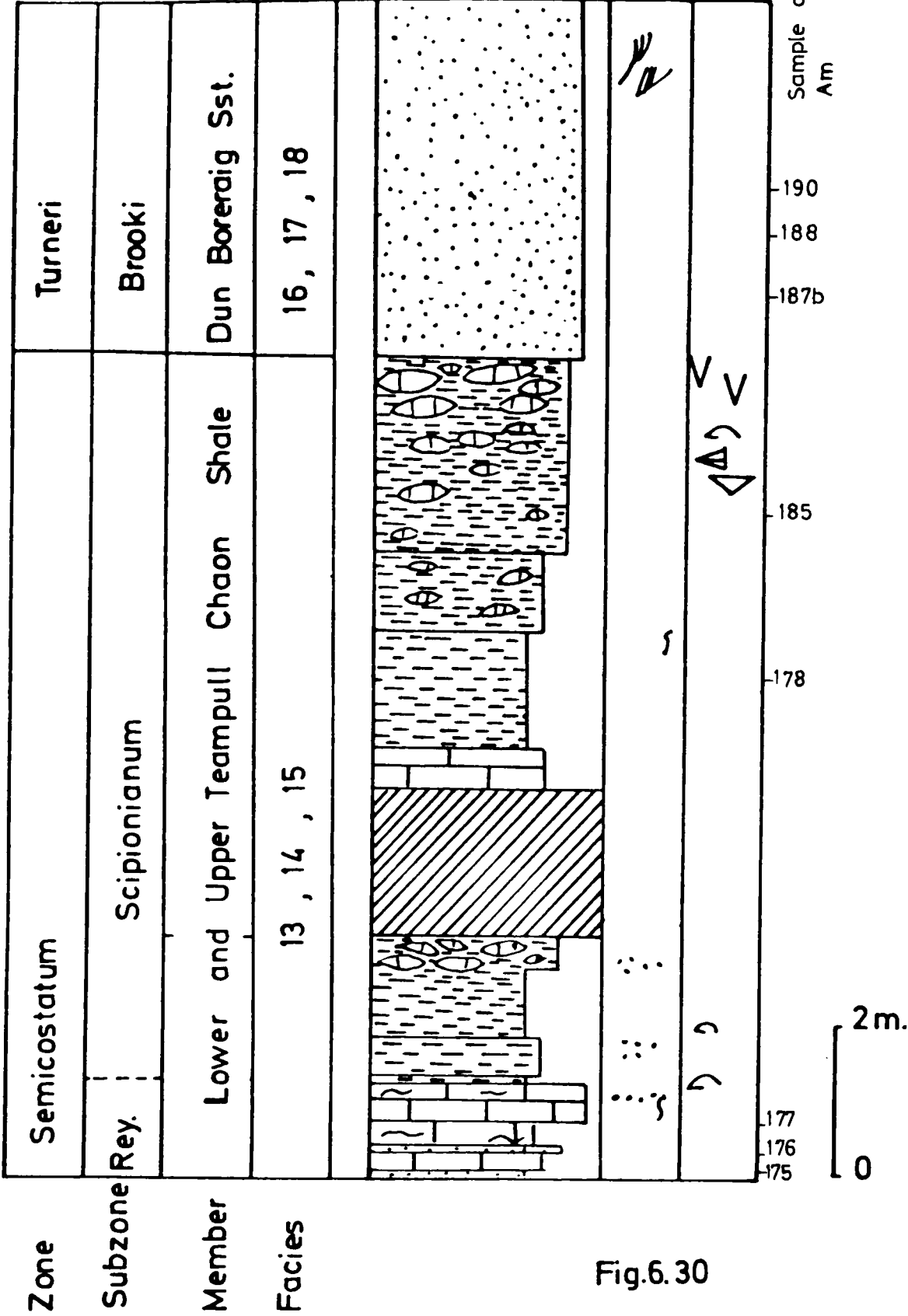


Fig. 6.29

Facies distribution in the northern area of study during the Bucklandi Zone (Facies 9, 10, 11, 12). The symbols are explained in Table 12.1



Liassic succession at Loch Slapin, Skye.

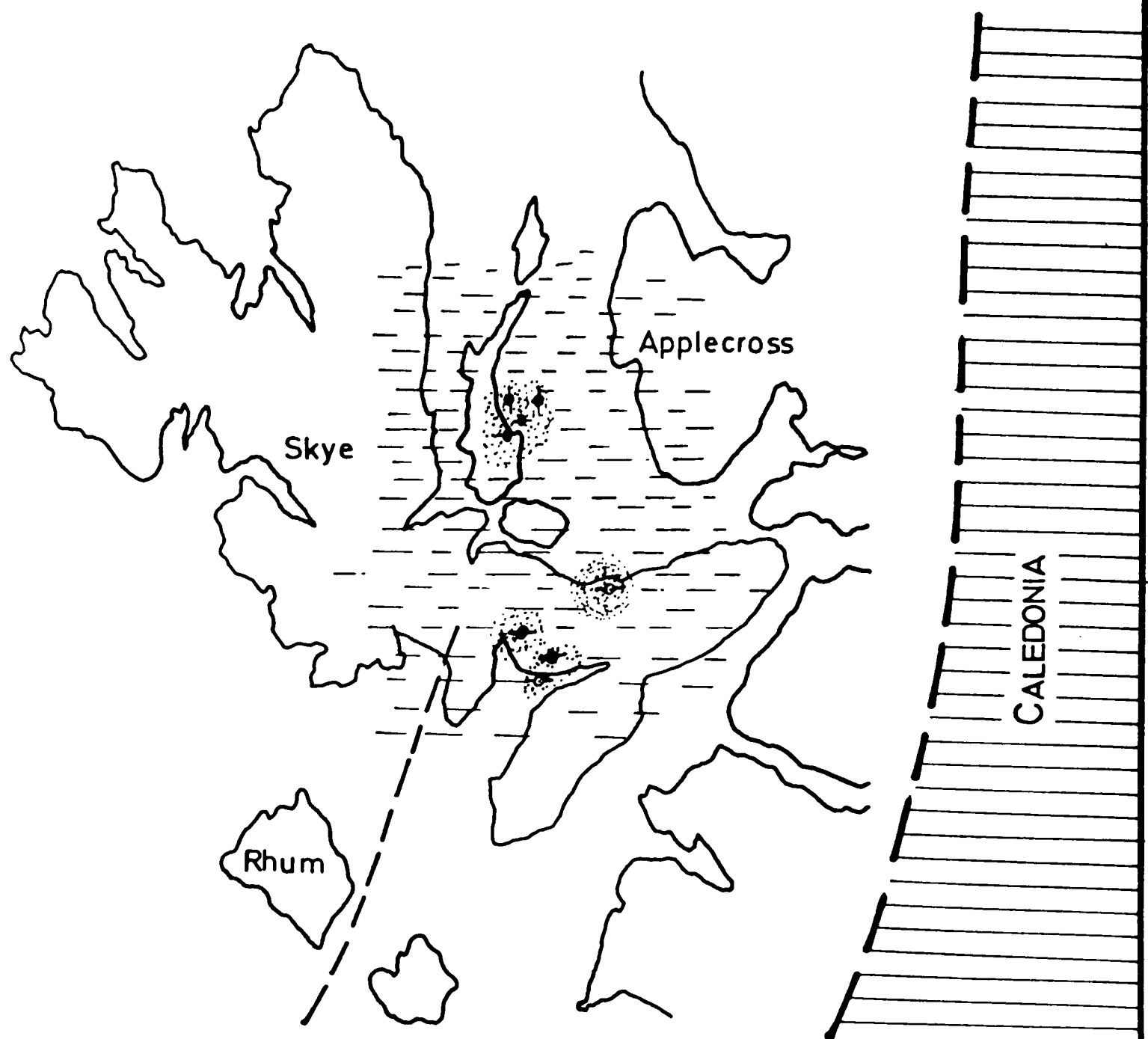


Fig.6.31

Facies distribution in the northern area of study during the Semicostatum Zone (Facies I3,I4). The symbols are explained in Table 12.1

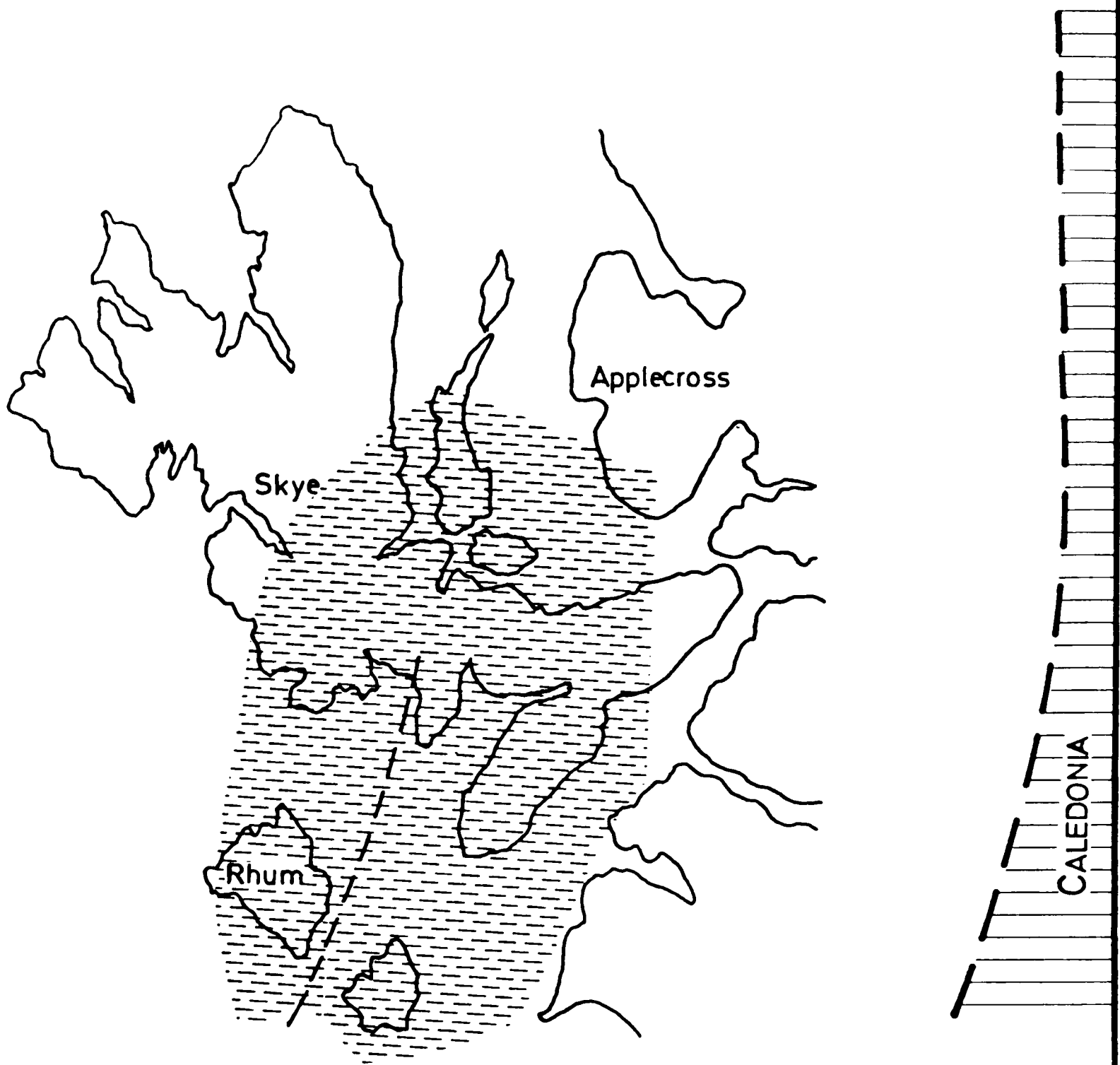


Fig. 6.32
Facies distribution in the northern area of study during the Semicostutum Zone (Facies I5). The symbols are explained in Table 12.1

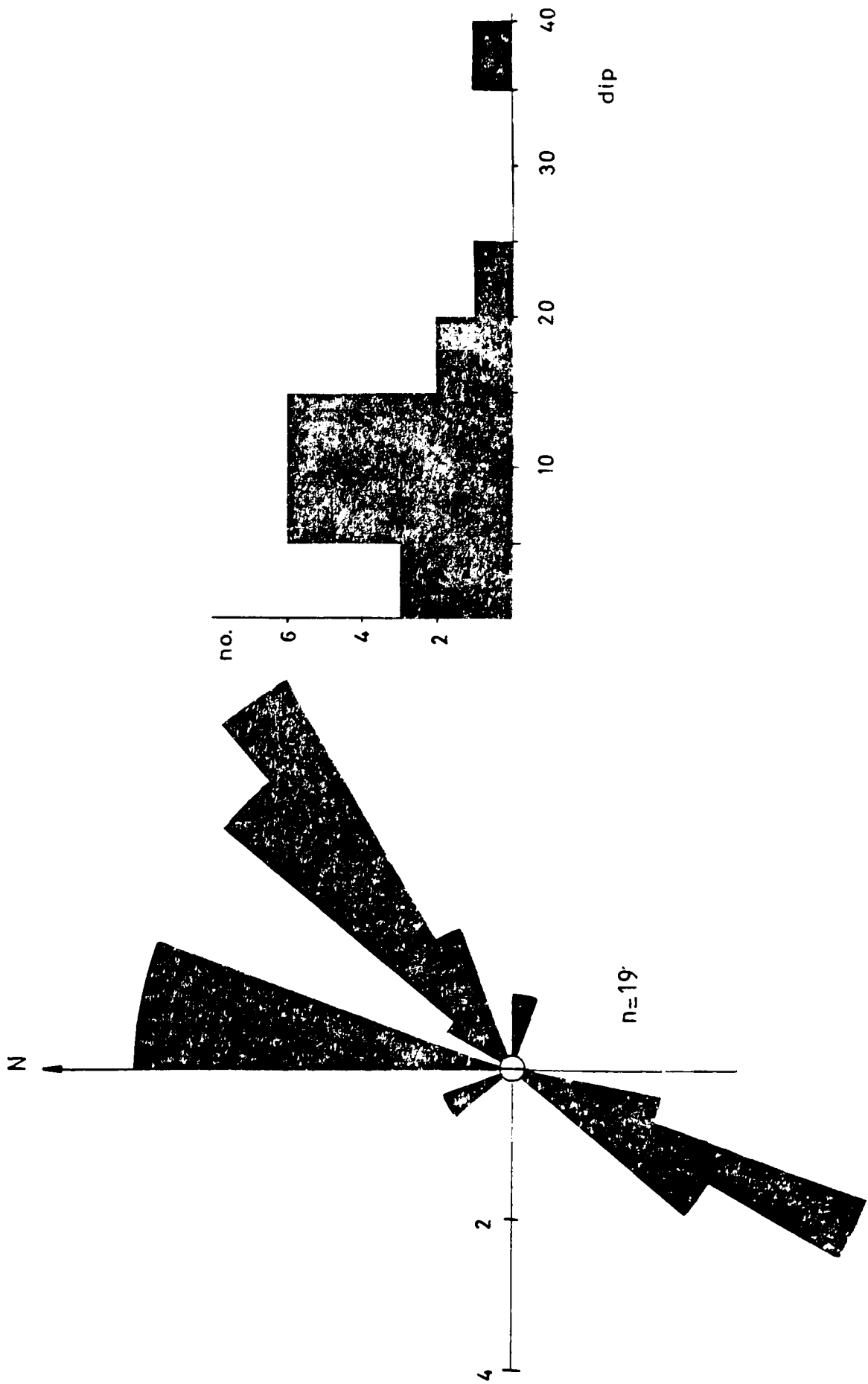


Fig.6.33
Palaeocurrent data obtained from the Dun Boreraig Sst. Member, Facies 16a in Loch Eishort(NG 613161).
Lower thin bedded part.

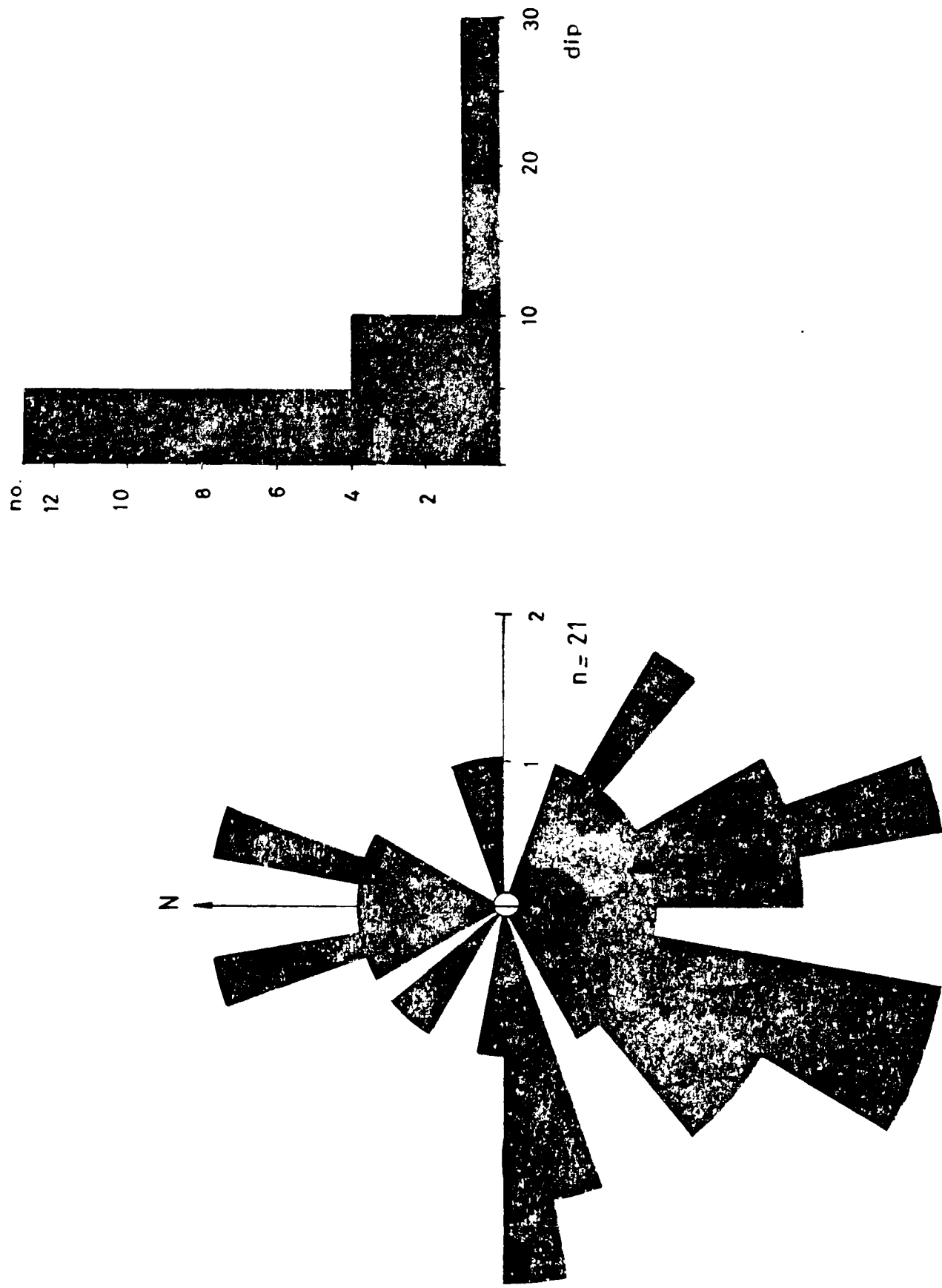


Fig.6.34
Palaeocurrent data obtained from the Dun Boreraig Sst. Member, Facies 16a in Loch Eishort(NG 613161).
Upper medium bedded part,
(see also Fig.6 34a).

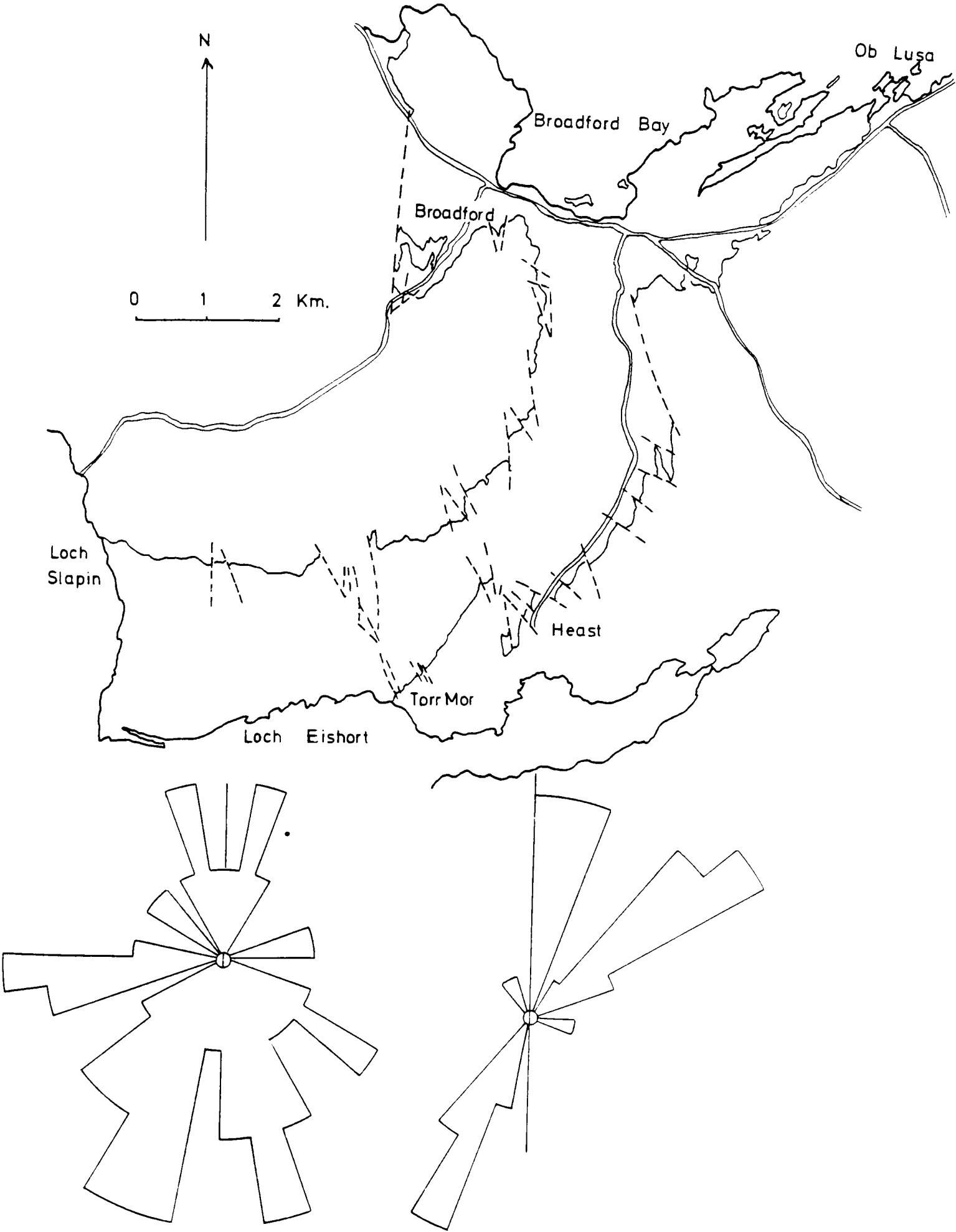


Fig. 6.34a Palaeocurrent data obtained from the Dun Boreraig Sst. Member, Facies 16 in Strath (Skye).

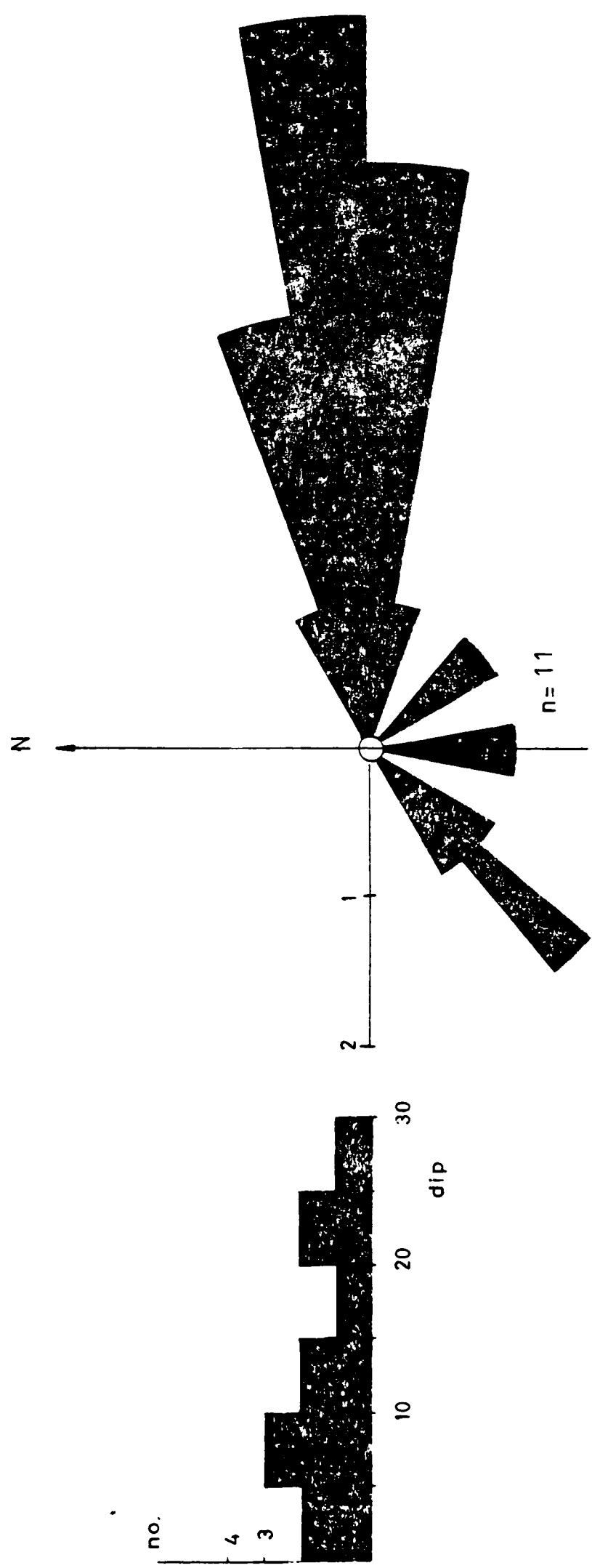


Fig. 6.35

Palaecurrent data obtained from the Dun Boreraig Sst. Member, Facies 17a in Loch Eishort(NG 613161).

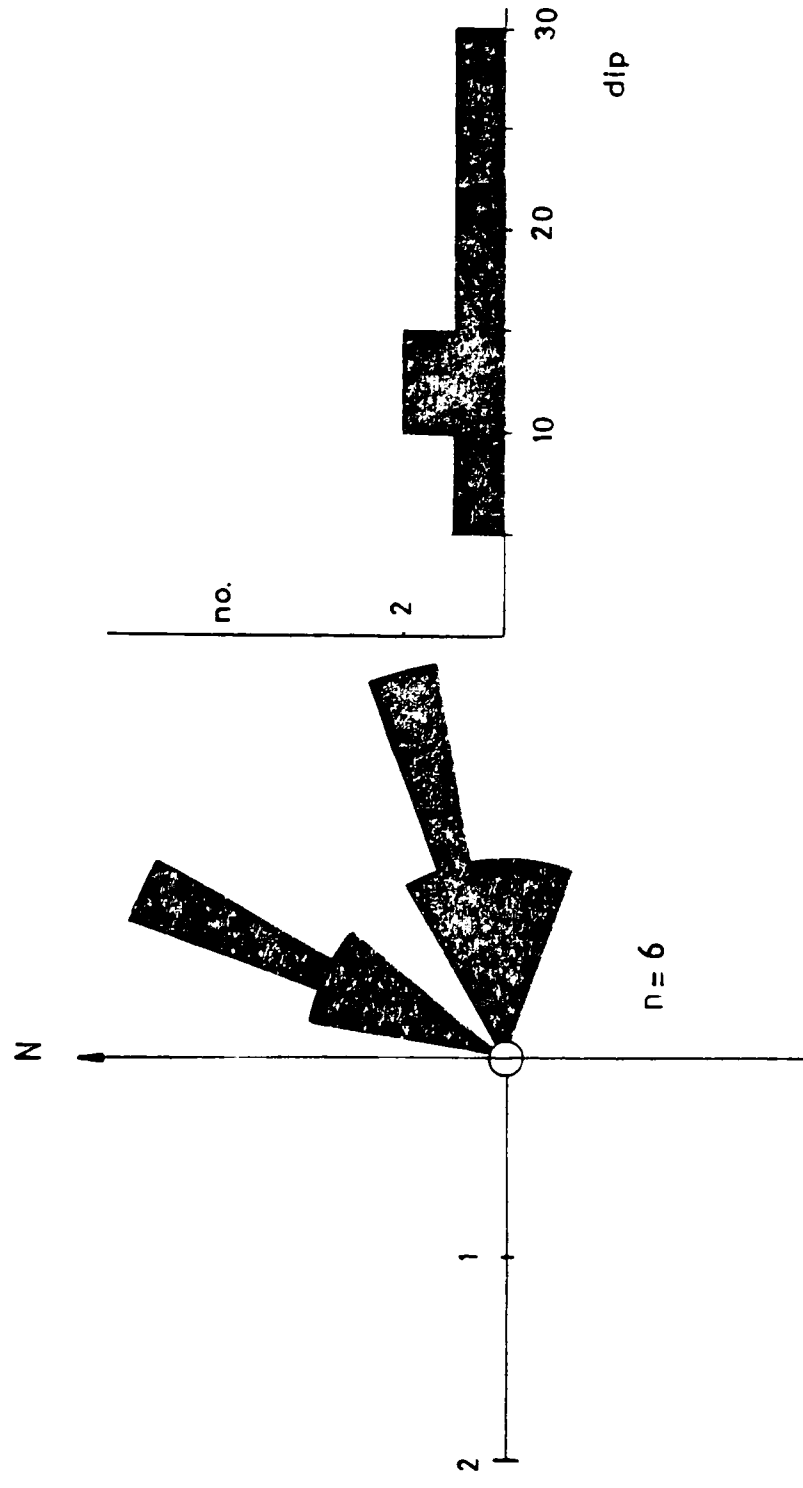


Fig. 6.36
 Palaeocurrent data obtained from the Dun Boreraig Sst. Member, Facies 17-18 in Loch Slapin(NG 578176).

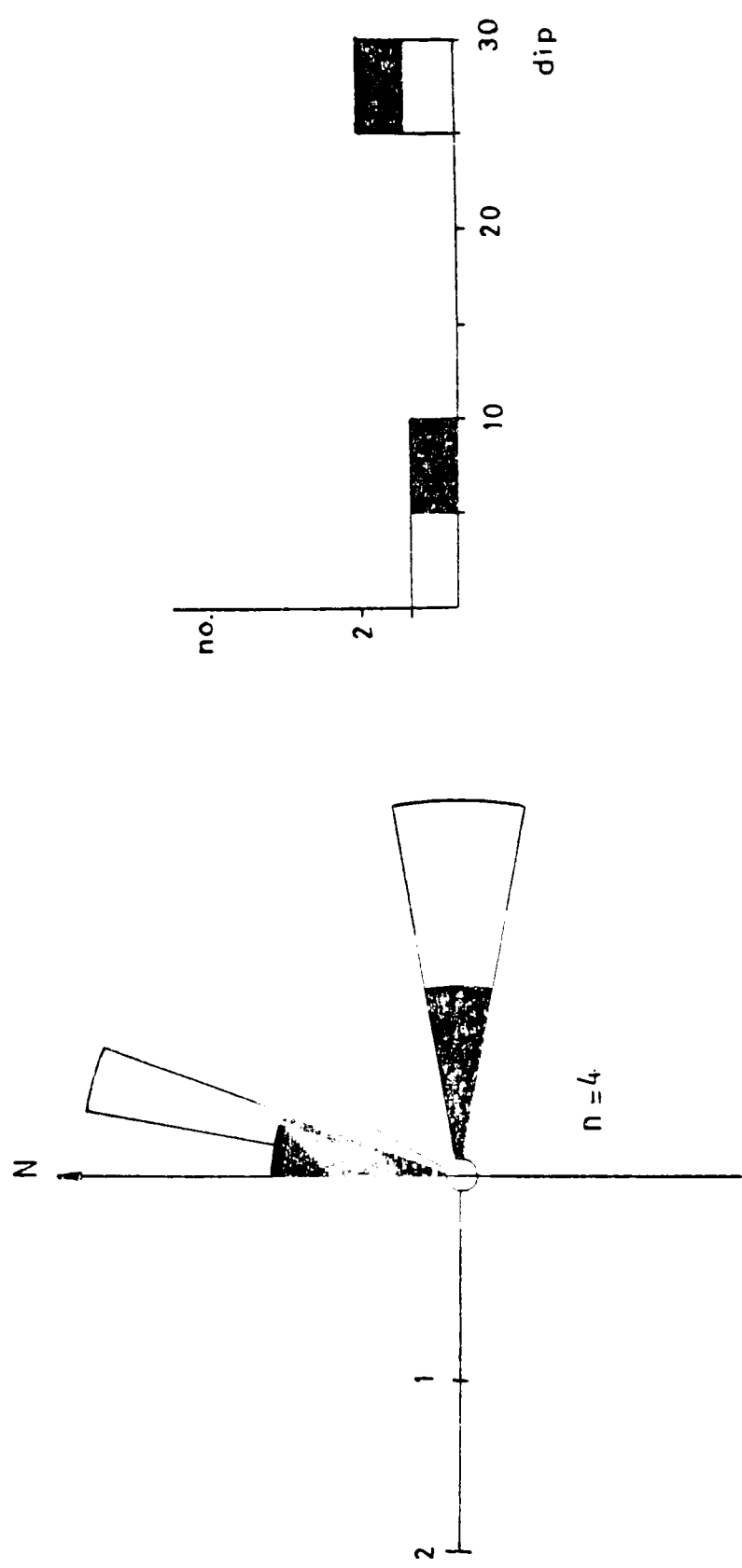


Fig. 6.37

Palaecurrent data obtained from the Dun Boreraig Sst. Member, in Loch Slapin(NG 578176).

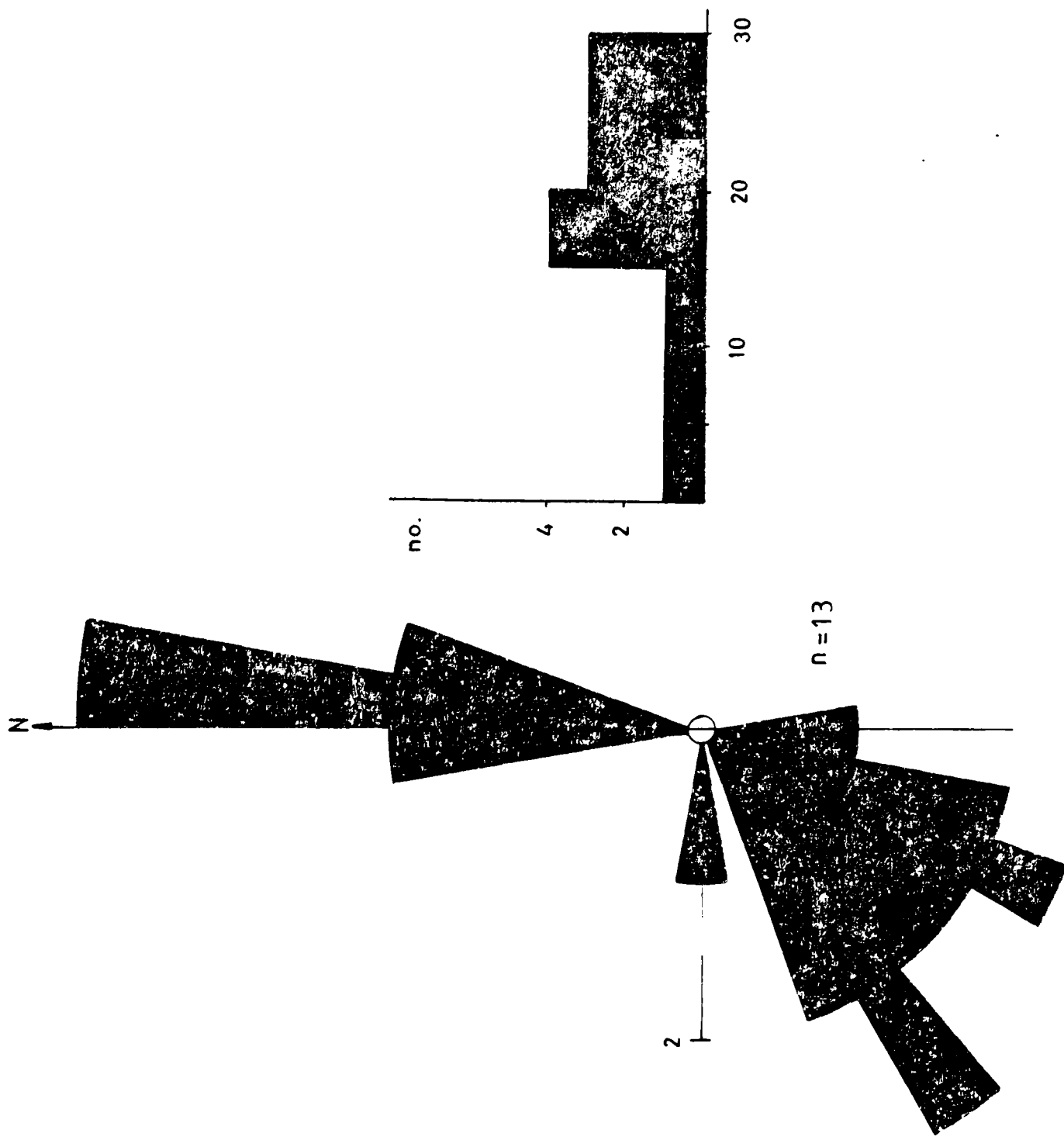


Fig.6.38
Palaeocurrent data obtained from the Dun Boreraig Sst. Member, Facies 17a in Rubh an Eireannaich
(NG 248646).

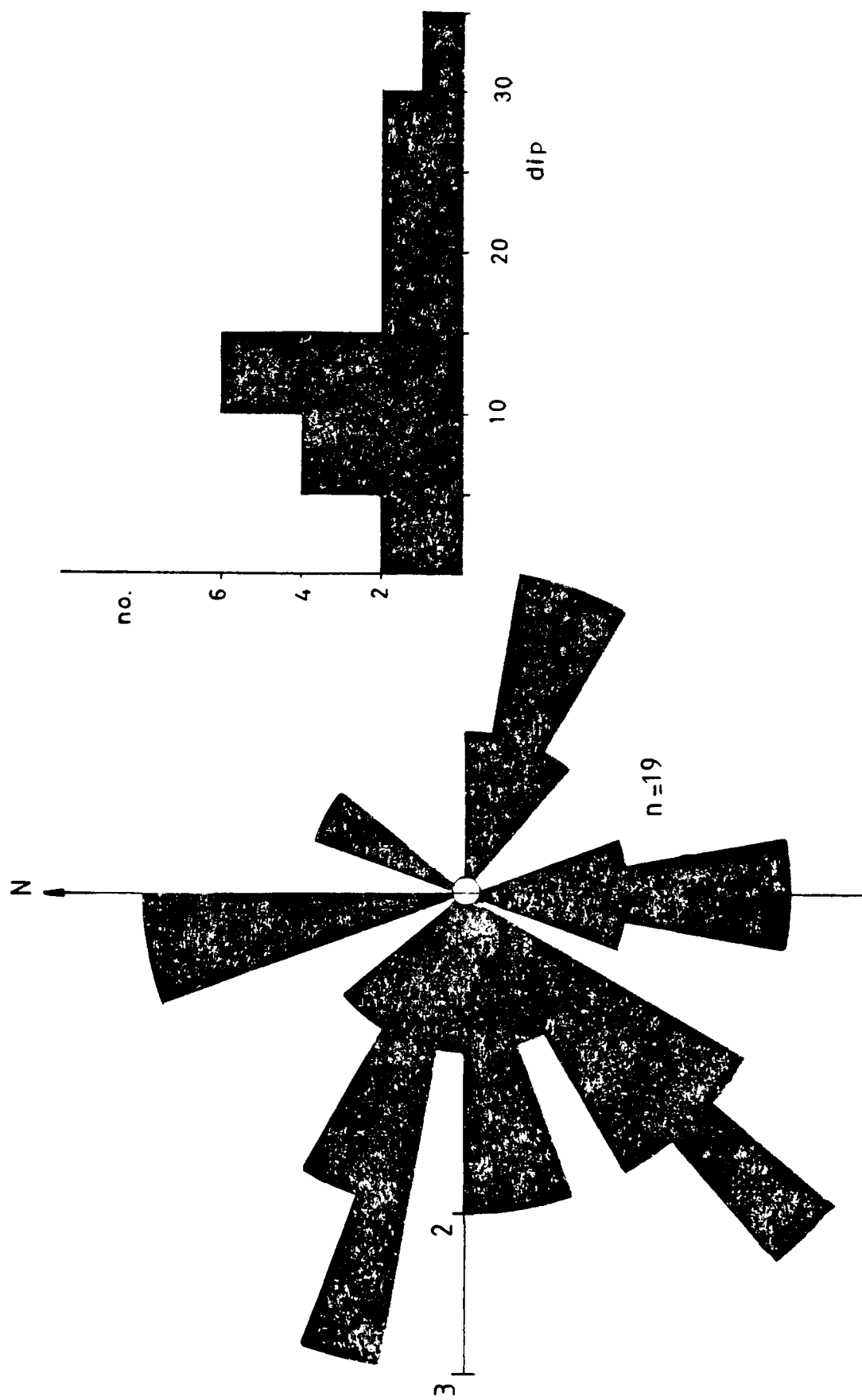


Fig. 6. 39
Palaeocurrent data obtained from the Dun Boreraig Sst. Member, facies 17a in Rubh an Eireannaich
(NG 248646).
(see also Fig. 6.39a)

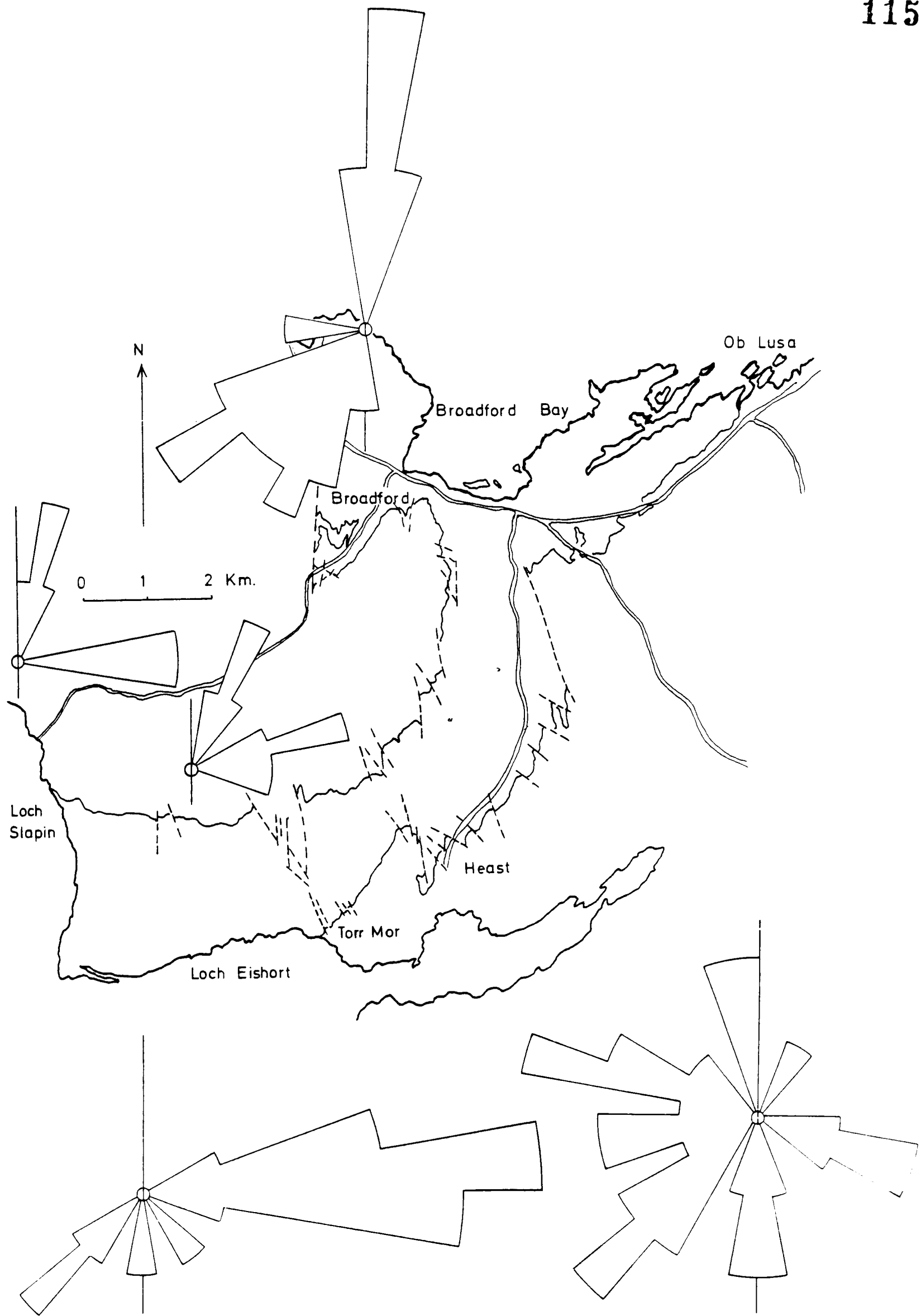


Fig.6.39a Palaeocurrent data obtained from the Dun Boreraig Sst. Member, facies 17 in Strath (Skye).

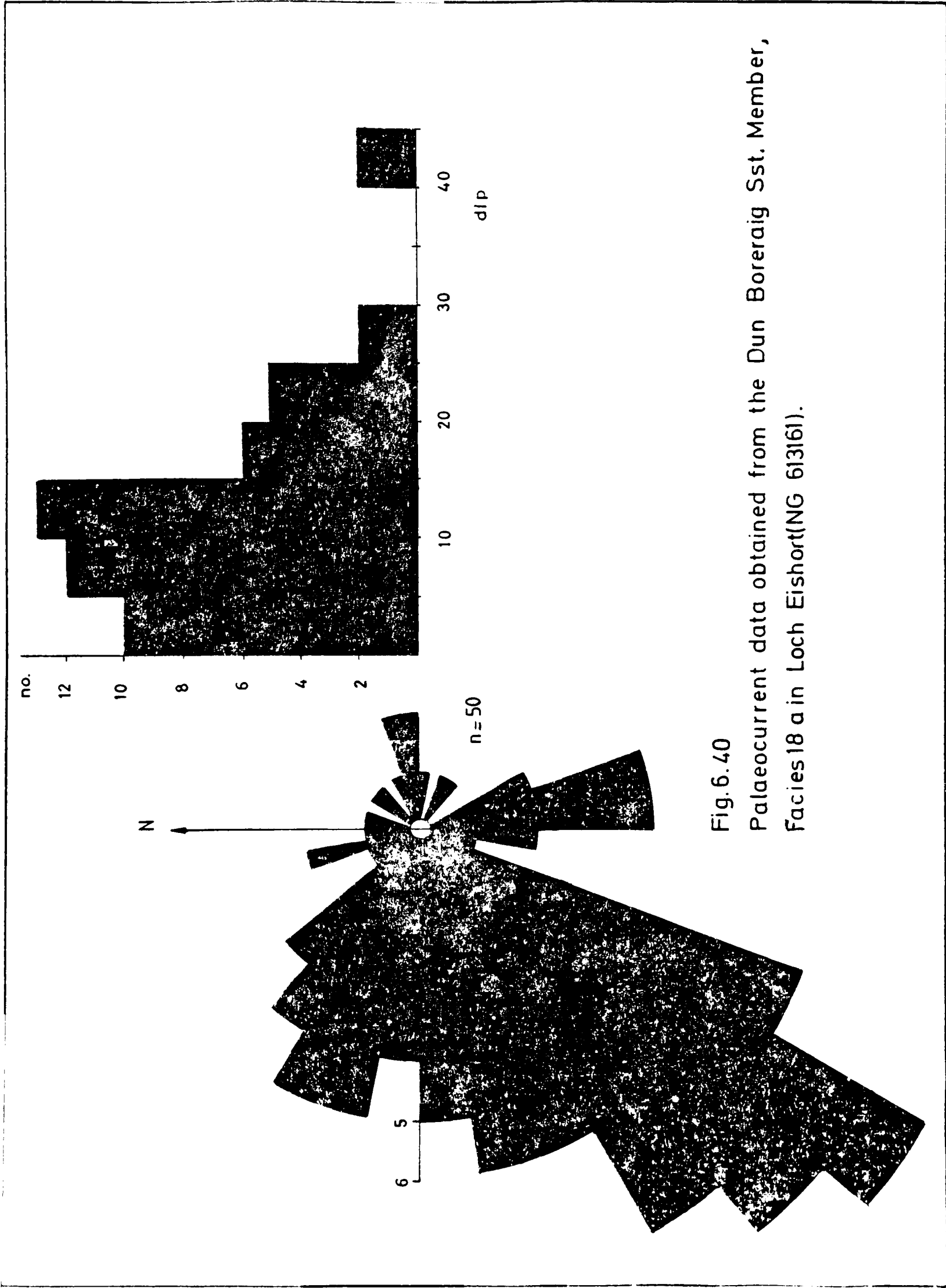


Fig. 6.40
Palaeocurrent data obtained from the Dun Boreraig Sst. Member,
Facies 18a in Loch Eishort (NG 613161).

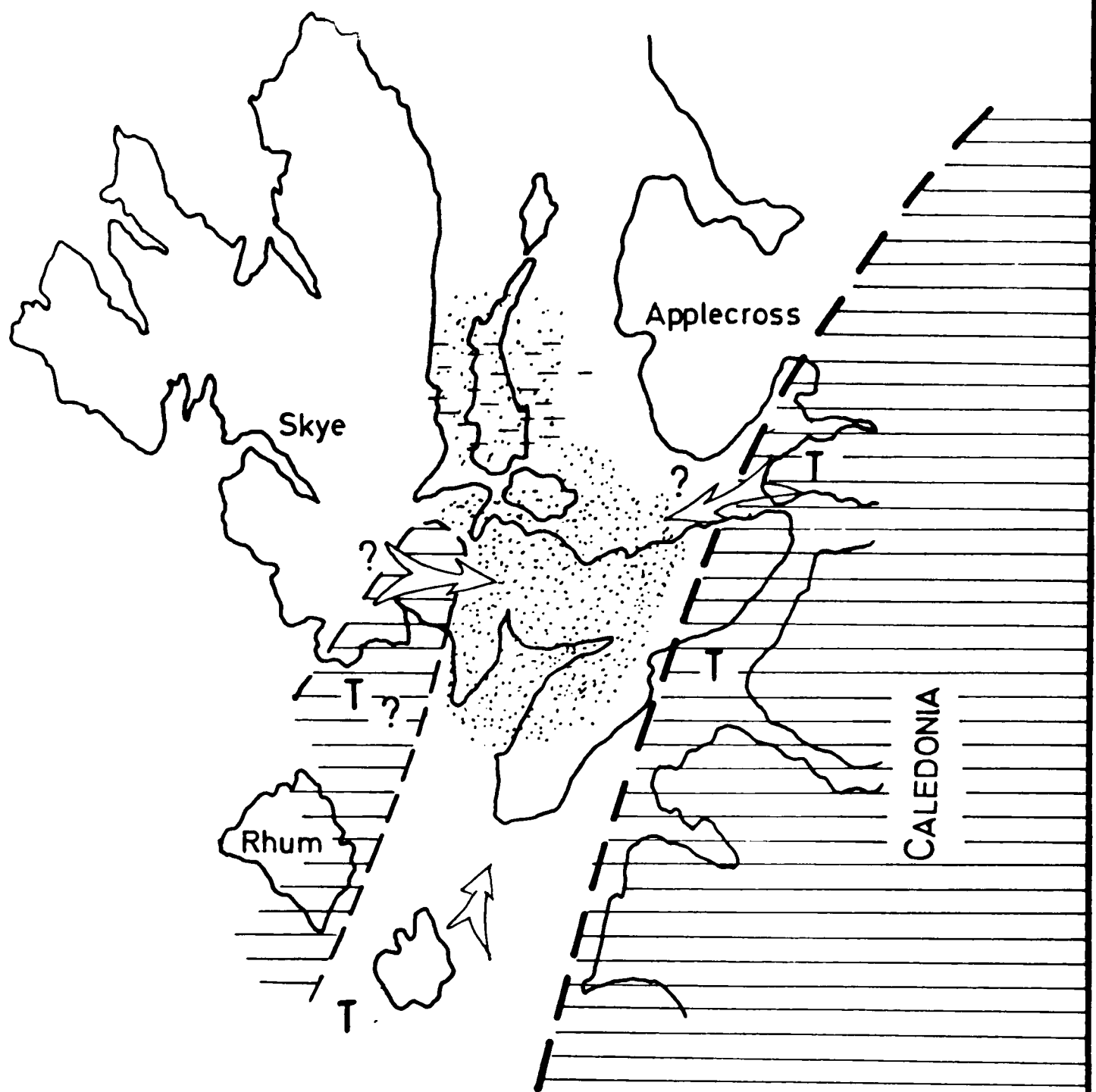


Fig. 6.41

Facies distribution in the northern area of study during the Turner Zone (Facies I6, I7, I8). The symbols are explained in Table 12.1

Fm.	Member	Facies			
STRATH FORMATION	Dun Boreraig	S.Strath	Raasay		
		Crossbedded facies 18a	Sh./Sst. facies 18b		
		Purple Sst. facies 17a	Sst. facies 17b		
		Ferrug. Sst. facies 16a	Sst./Sh. facies 16b		
	Upper Teampull Chaon	Sandy argill. facies 15			
STRATH FORMATION	Breakish Ironst.	Ironst. facies 14			
	Lower Teampull Chaon	Calcareous argillaceous facies 13			
MILTON FORMATION	Breugh Pebble	Rippled Sst. facies 12		7 D facies Nodular Limestone	
		Pebbly Sst. facies 11			
		Bedded Sst. facies 10			
	Upper Sandst.	Sst./Lst. facies 9b			
		Lst. facies 9a			
	Breakish Coral	Coral facies 8			
	Lower Sandstone	Oolitic Sst. facies 7a2	Sst./Oolite facies 7b2		Marlst./Oolite facies 7c2
		S.SKYE	N.SKYE		APPLECR.
		Sst. facies 7a1	Lst./Oolite facies 7b1		Shale/Oolite facies 7c1
	Lusa Coral	Coral facies 6			
	Applecross House	Oolitic facies 5			
		Shaly facies 4			
	Torr Mor	Calc. Sst. facies 3			
		Pebbly Sst. facies 2			
		Conglomer. facies 1			

Table 6.1

Facies in the Broadford Beds Arenaceous Group

Gp.	Form.	MORVERN	MULL	Zone
Broadford	Group			
	Leacach Formation	Micaceous shale facies 22a	Thin bedded marlstone facies 22b	Turneri
			Bedded marlstone facies 22B	Semicost.
	Argillaceous Beds	Nodular lst. facies 21a	Sandst./Lst. facies 21b	Bucklandi
		Nodular lst. facies 20		Angulata
Broadford	Loch Aline Formation	Lst. / Shale facies 19		Liasicus
				Planorbis

Table 6.2

Facies in the Broadford Beds Argillaceous Group

Plate 6.1. Rounded, micritic pellets found in the calcilutite
beds underlying the Torr Mor Member in Applecross.
x 100.

Plate 6.2. Spherical to subspherical calcareous forms with
outward radiating arms (?Thalassinoides) found in the
basal beds of the Torr Mor Member (Ob Lusa).

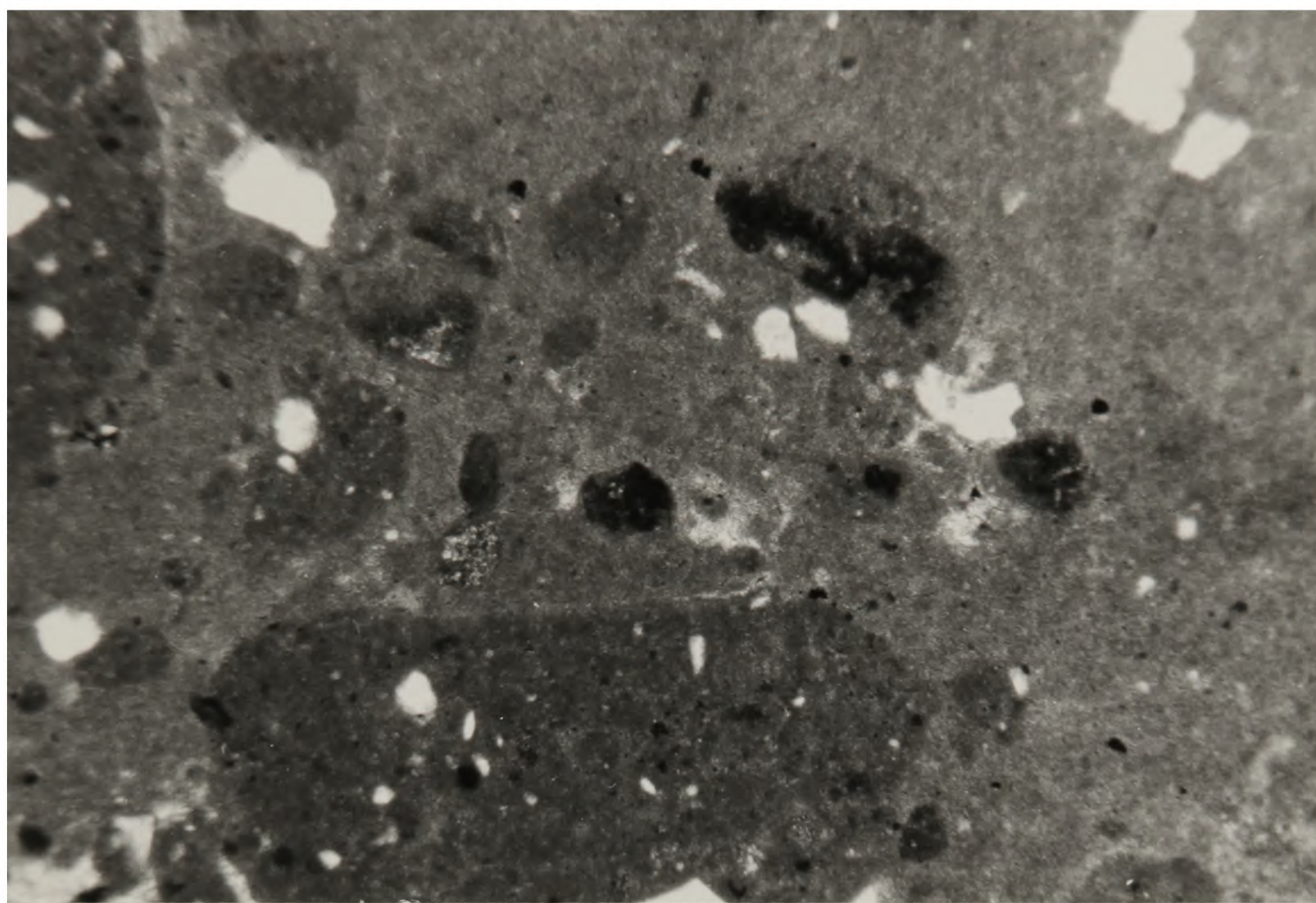


Plate 6.3. Steeply dipping silty shales with lenses of cross laminated, coarse, sub angular sandstones. Basal beds of the Liassic succession directly overlying the Durness limestone at Loch Slapin, Skye.

Plate 6.4. Thin section of a specimen obtained from the rocks shown in Plate 6.3, showing the abrupt contact of the sandstones and silty shales. Note very poor sorting.
x 20.

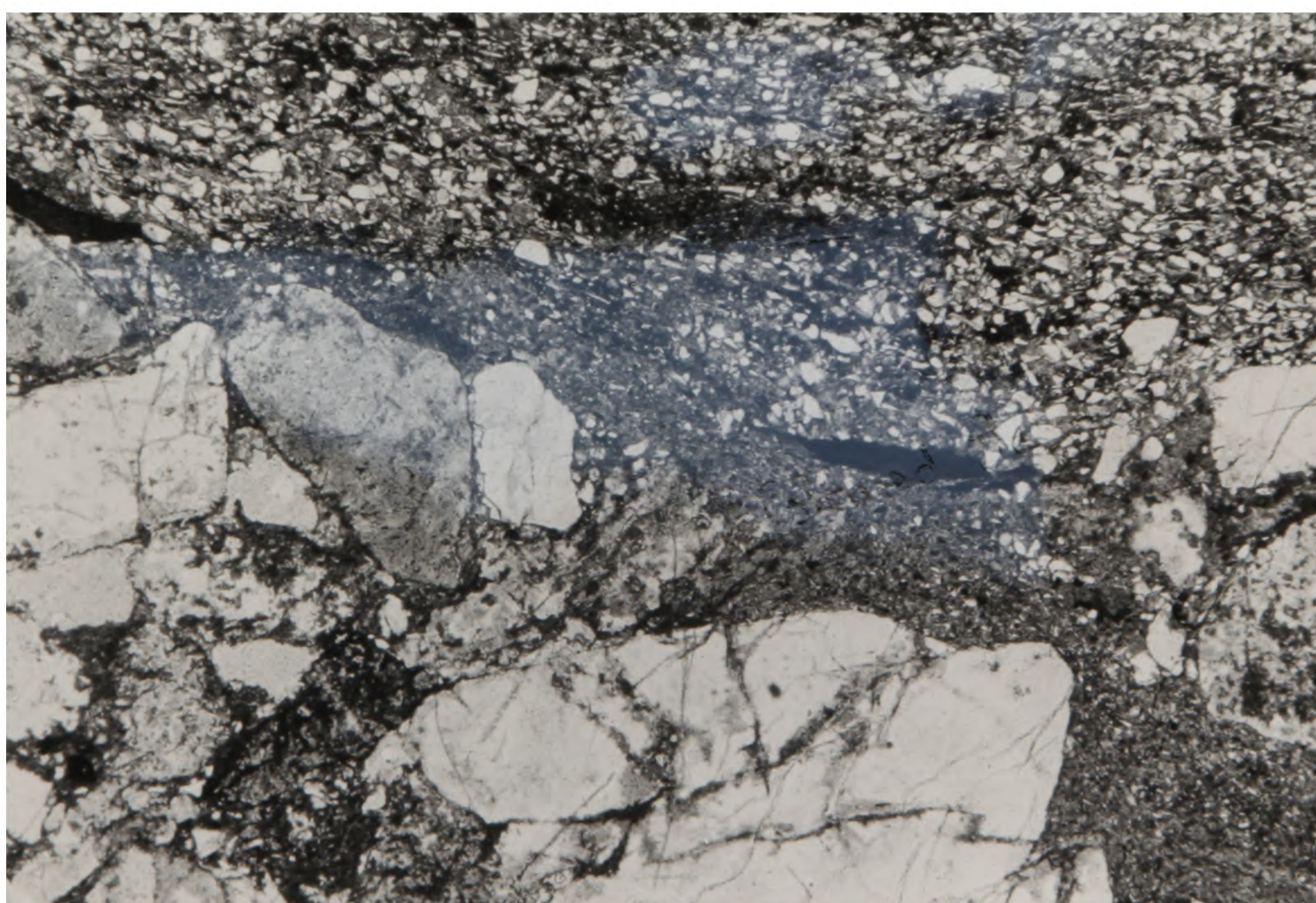


Plate 6.5 Unordered, ungraded, polymodal conglomerate
bed representing Facies 1 of the Torr Mor Member
in southern Strath.



Plate 6.6 Pelletoidal limestone , note elongated micrite

pellets possibly due to compaction.

?Torr Mor Member, Loch Slapin, Skye.

X50

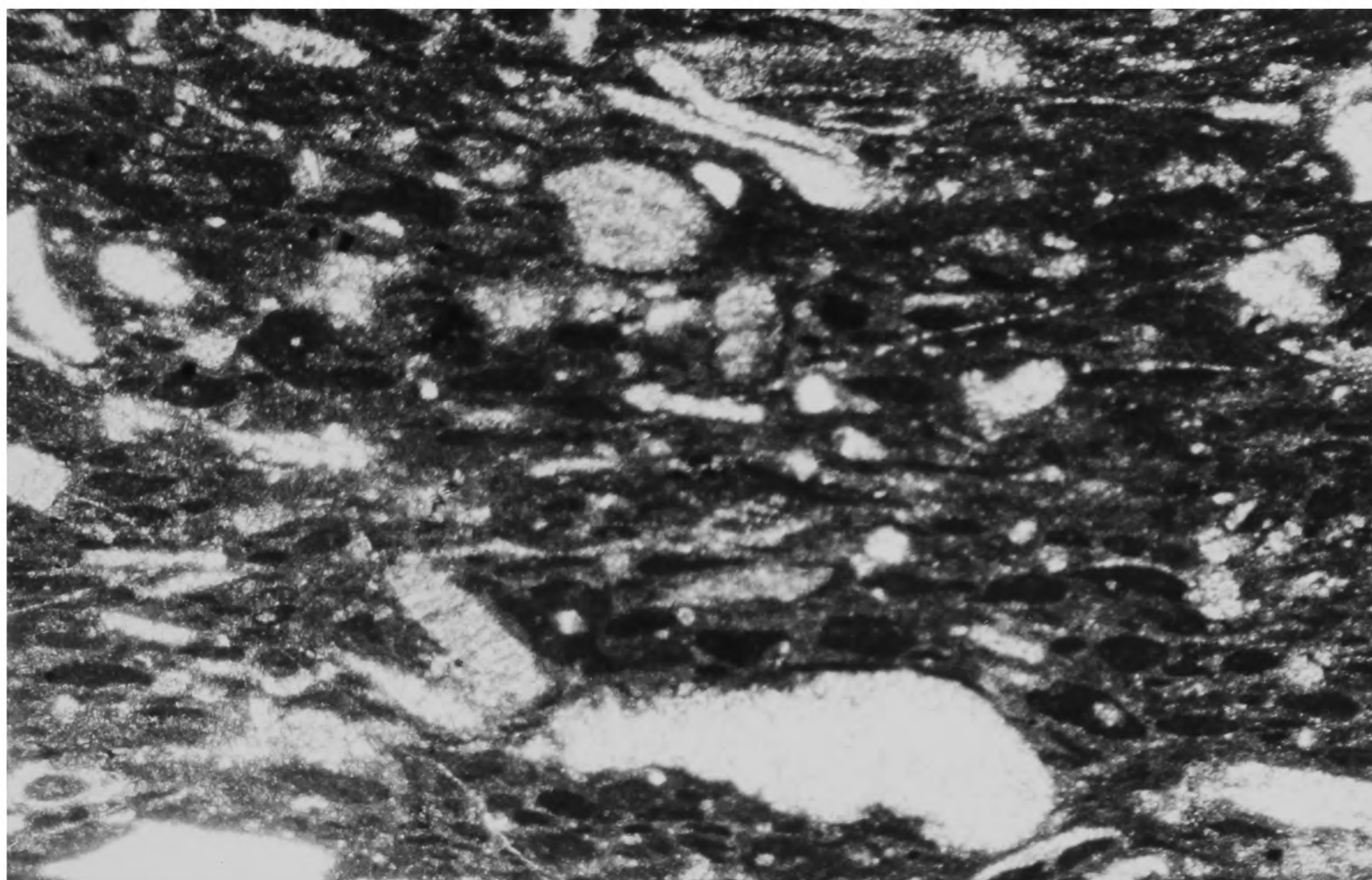


Plate 6.7 Poorly sorted (bimodal) oolite microsparite
packstone of Facies 5 in Applecross.

X50

Plate 6. 8 Silty oolite microsparite wackestone of
Facies 5 in Applecross; most grains show
concentric, second generation coatings.

X50

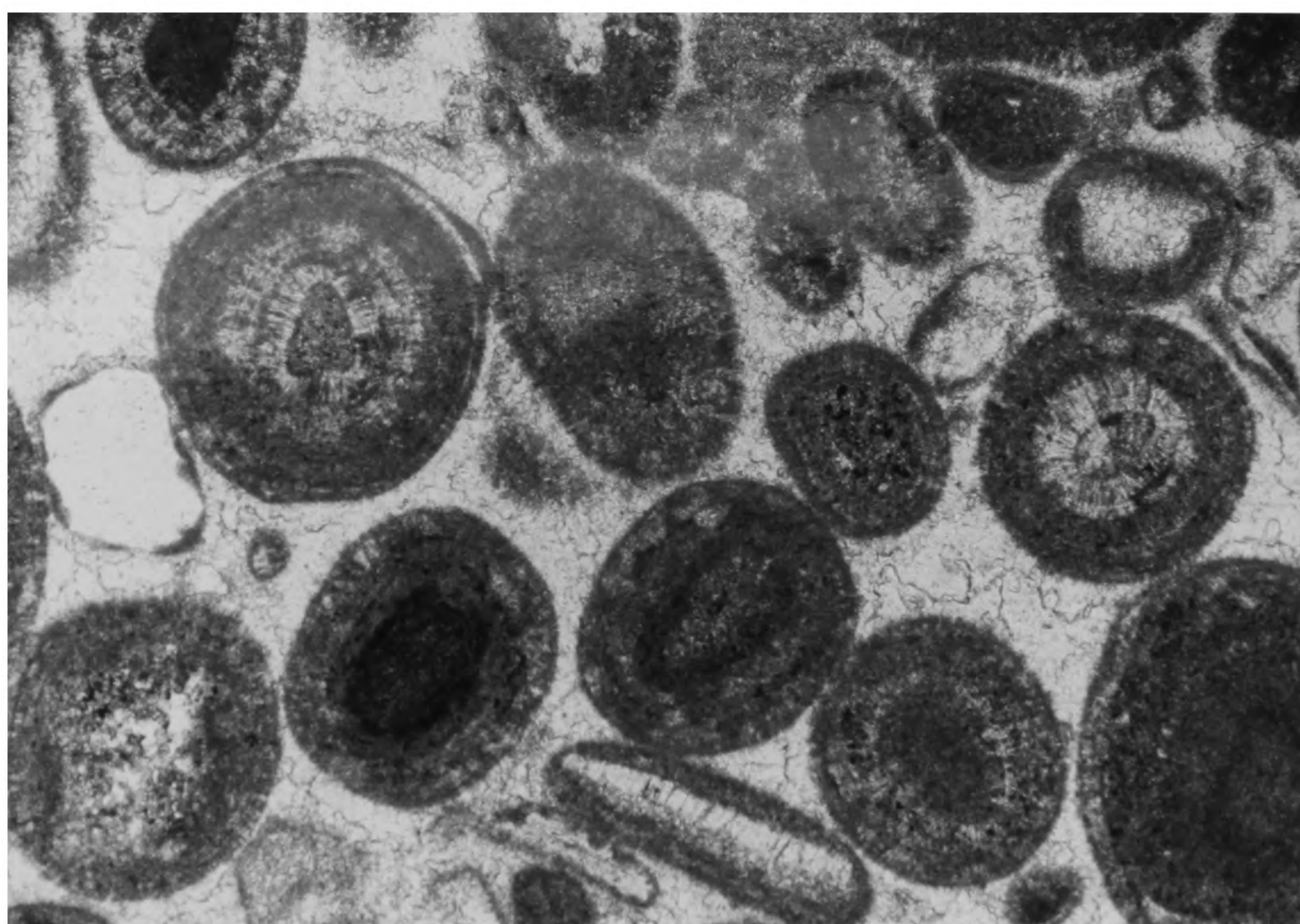
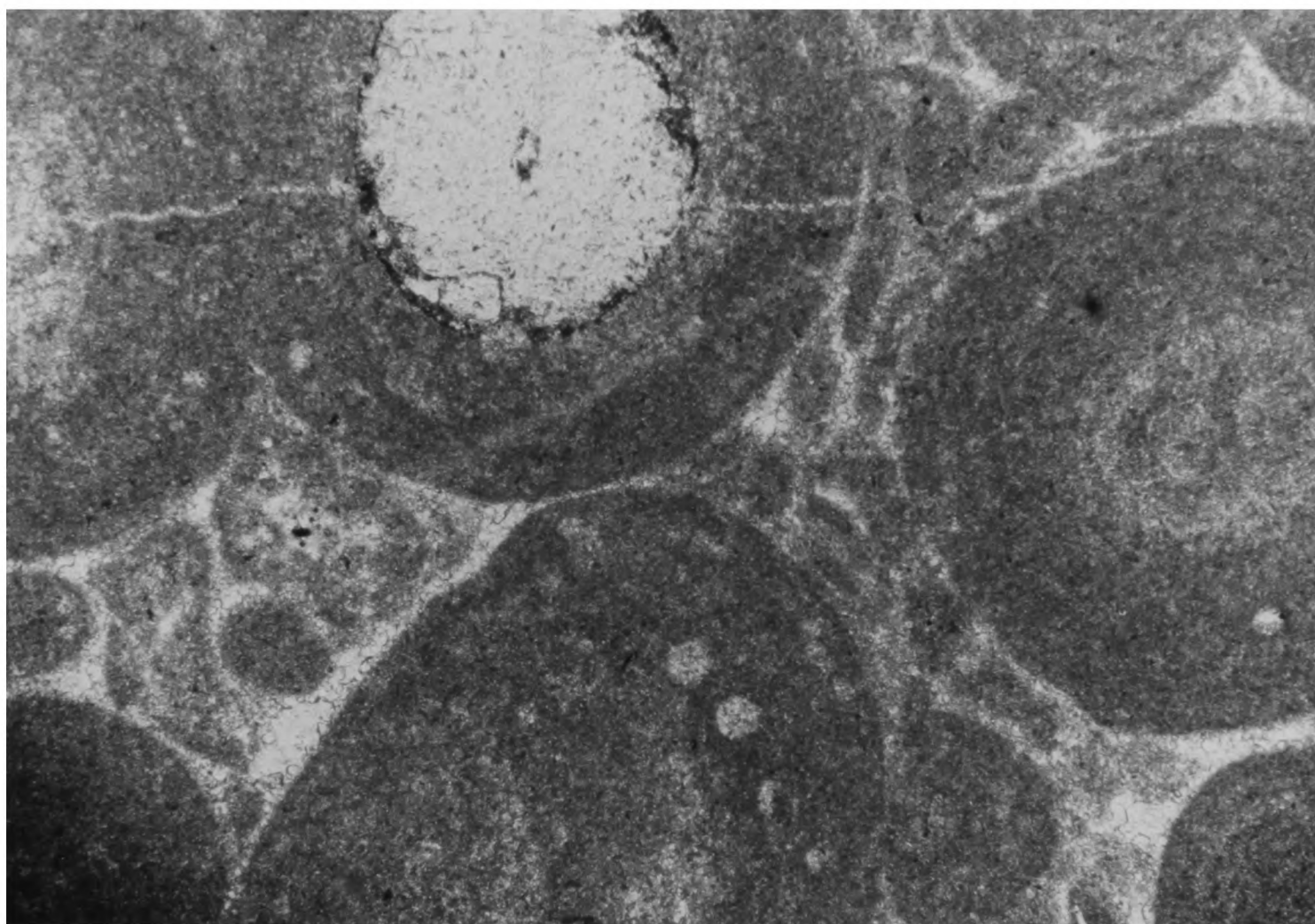


Plate 6.9 Poorly sorted oobio pel microsparite wackestone
with gastropod and ostracod tests. Facies 5,
Applecross.
X4

Plate 6.10 Matrix supported oobiopel microsparite
(partially altered) of Facies 5, showing
recrystallized micritic pellets and grains with
radial oolitic structure in micritic patches.
X50

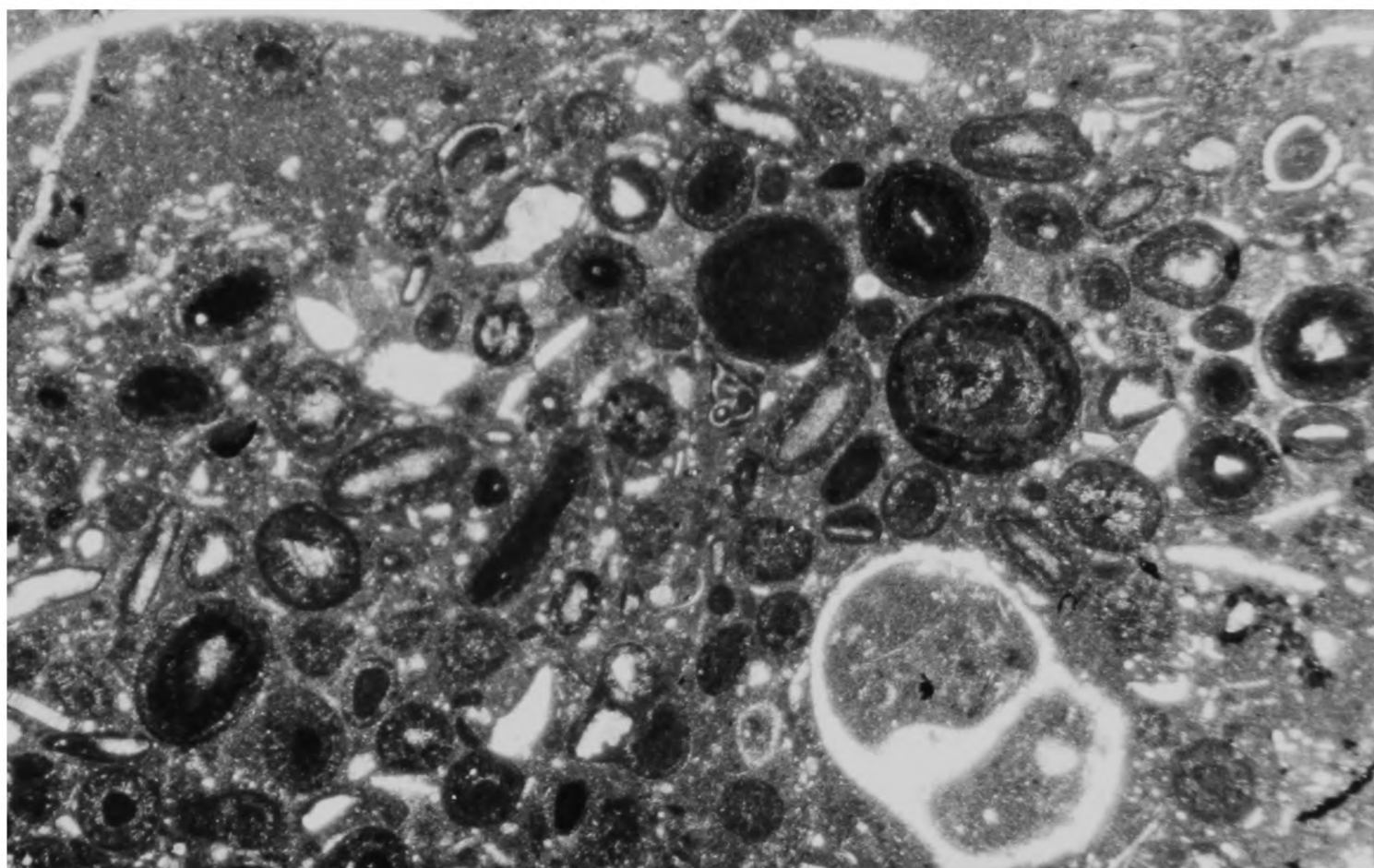


Plate 6.11 Matrix supported oolite occurring
towards the top of Facies 5, showing a multiple
oolite and various grains forming the oolite
nuclei
X50

Plate 6.12 Oolite representing the topmost
part of Facies 5 in Applecross. Note the large
recrystallized shell with a thick micritic
(? algal) mud coating.
X50

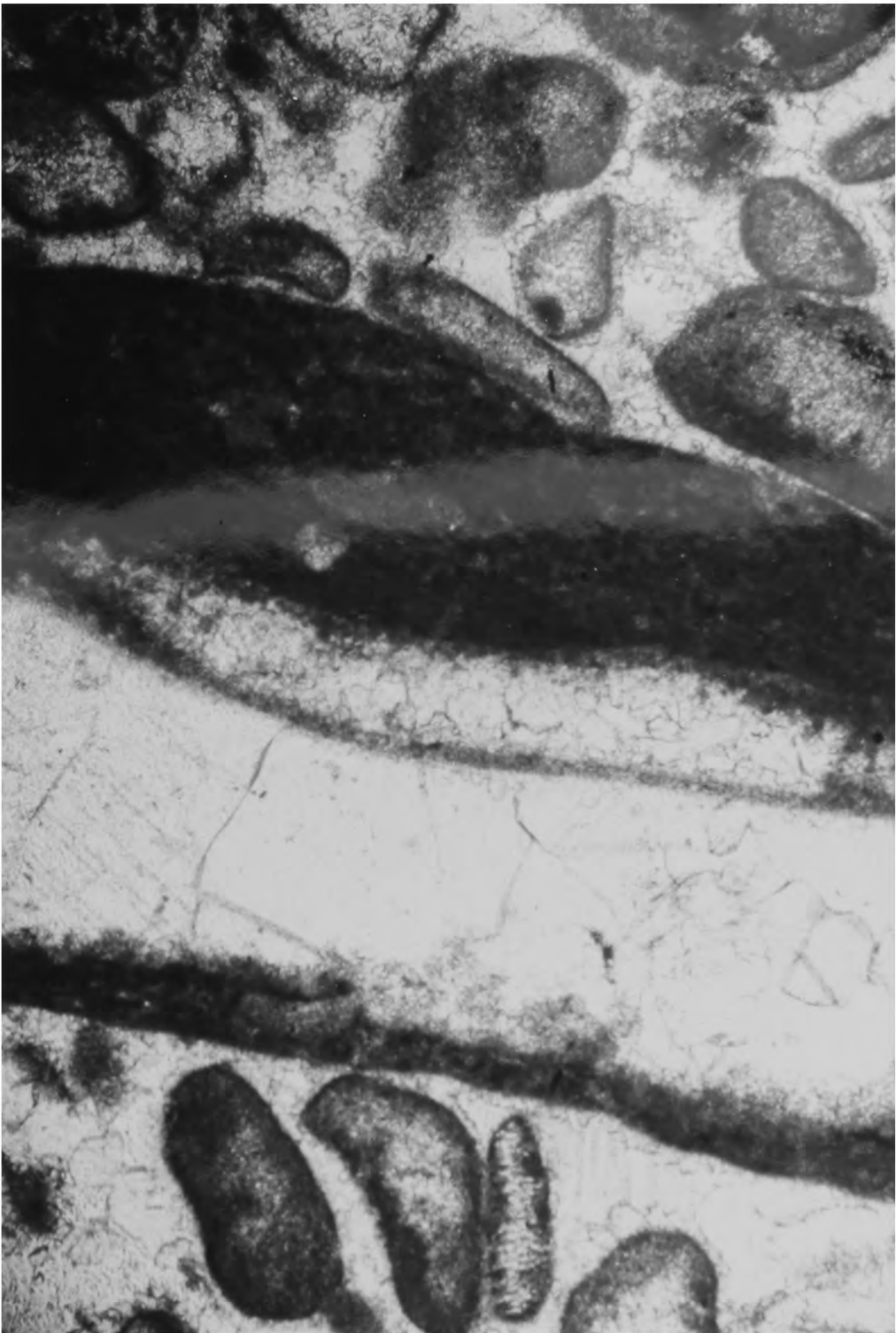
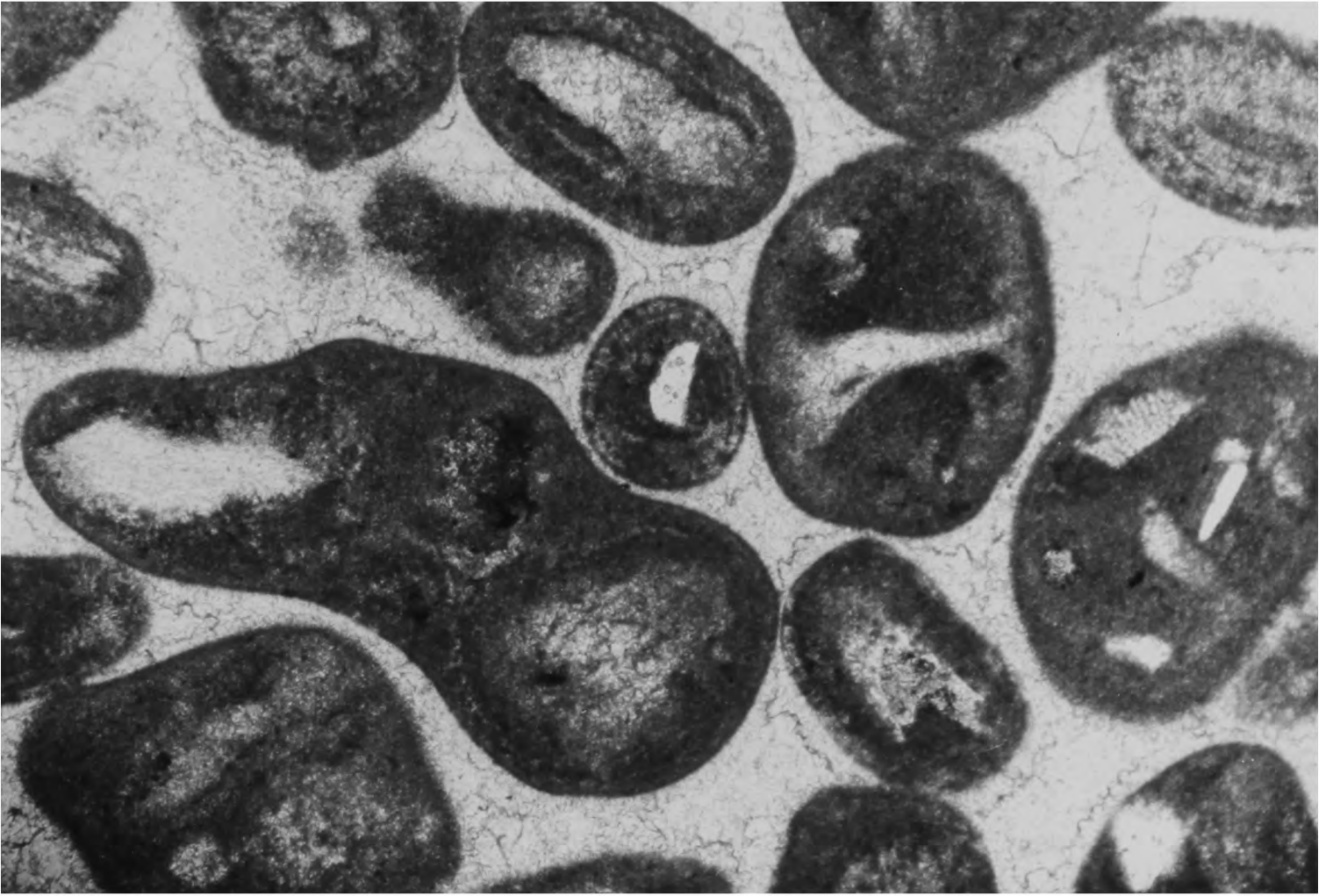


Plate 6.13 Horizontal and vertical burrows

(Thalassinoides) seen in the nodular limestones
and shales (equivalents of Facies 4, 5, 6 and
7D) in Raasay.

Plate 6.14 Thalassinoides burrows seen in the limestones
of Facies 5 in Raasay.



Plate 6.15 Poorly sorted silty oolite sparite with
some asymmetric coating developed on grains.
Facies 5 in Ob Lusa .
X63

Plate 6.16 "Birdseye" structures in the lowermost
beds of Facies 5 at Loch Eishort.
X25

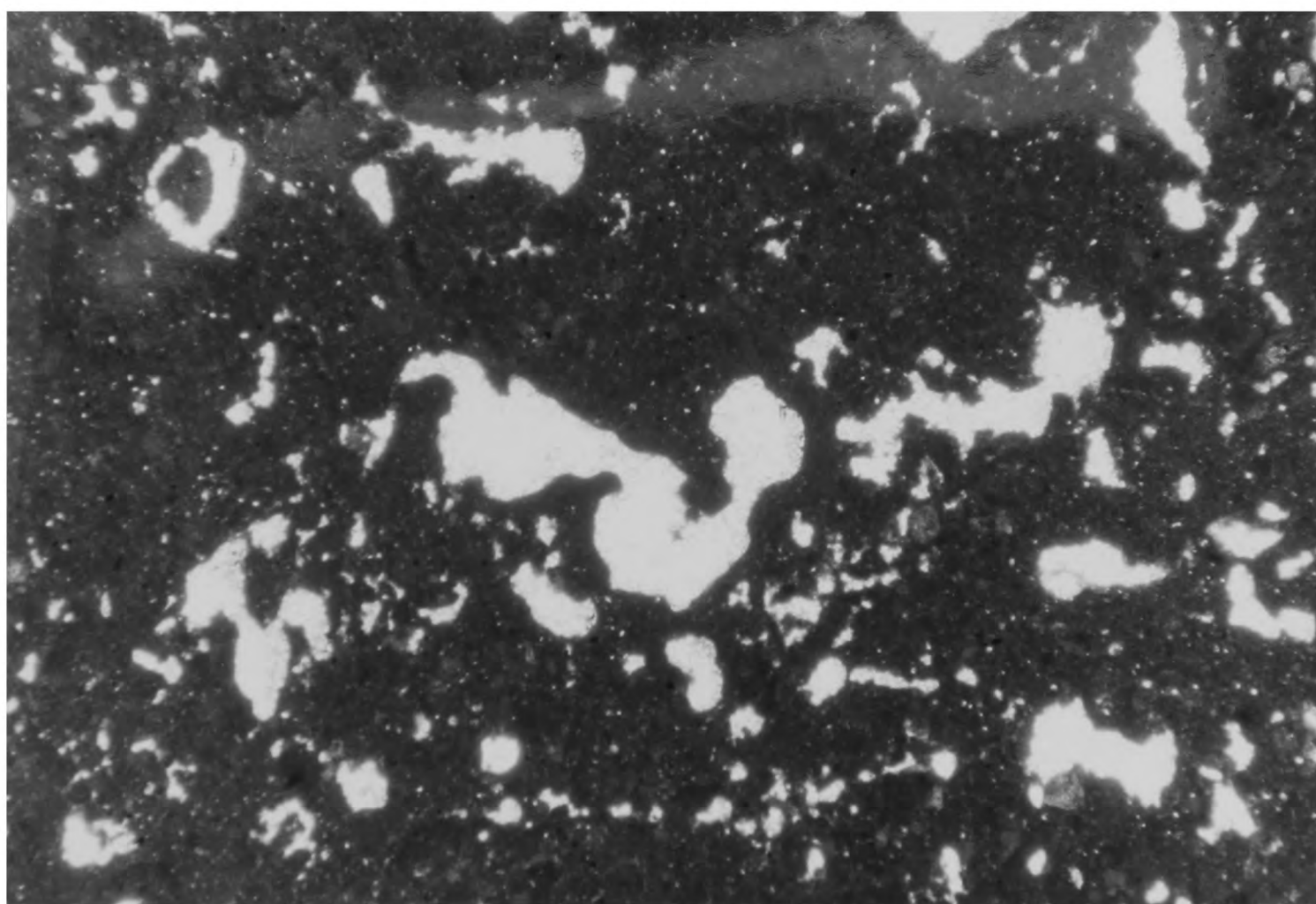
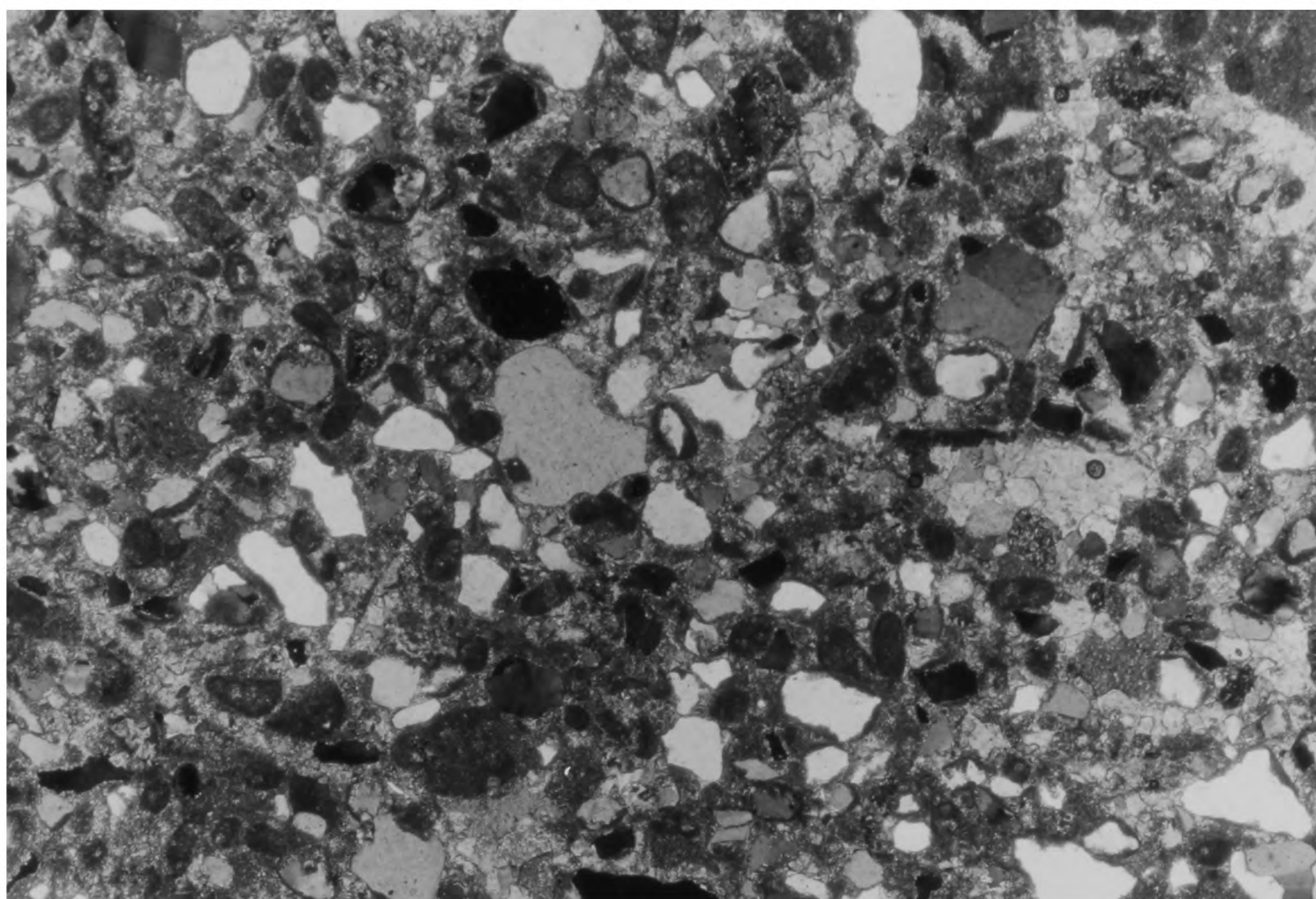


PLate 6.17 Oobiopelmicrite with patches of sparite.

'Base' of Facies 5 in Loch Eishort. Note drusy
mosaic of the sparite patches indicating a
cavity-filling origin

X50

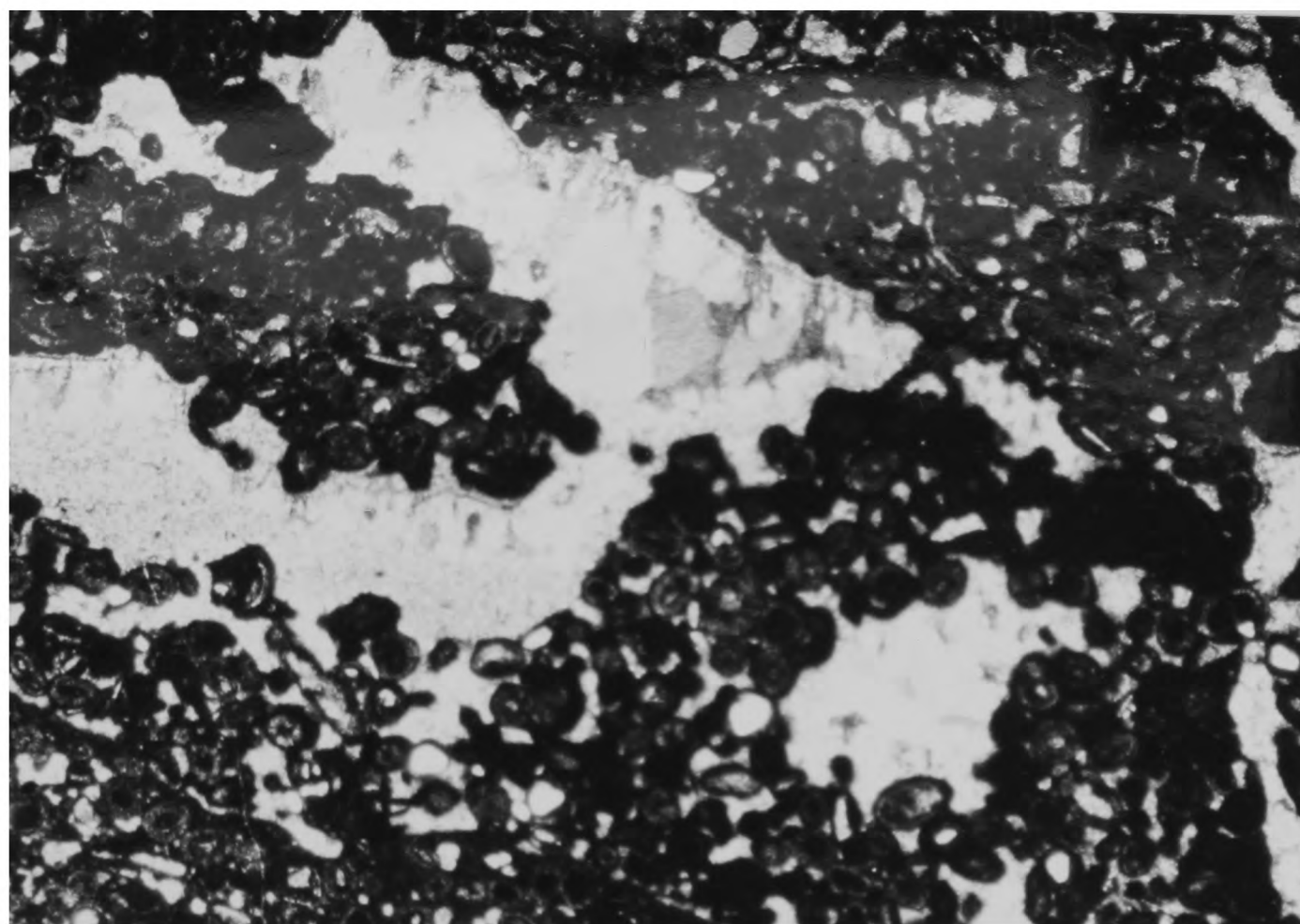


Plate 6.18 Biomicrite representing Facies 4 in
Raasay, note thick coating of mud on brachiopod
shell fragment.
X50

Plate 6.19 Oolite showing evidence of a two-generation
origin. Facies 5 in Applecross.
X50

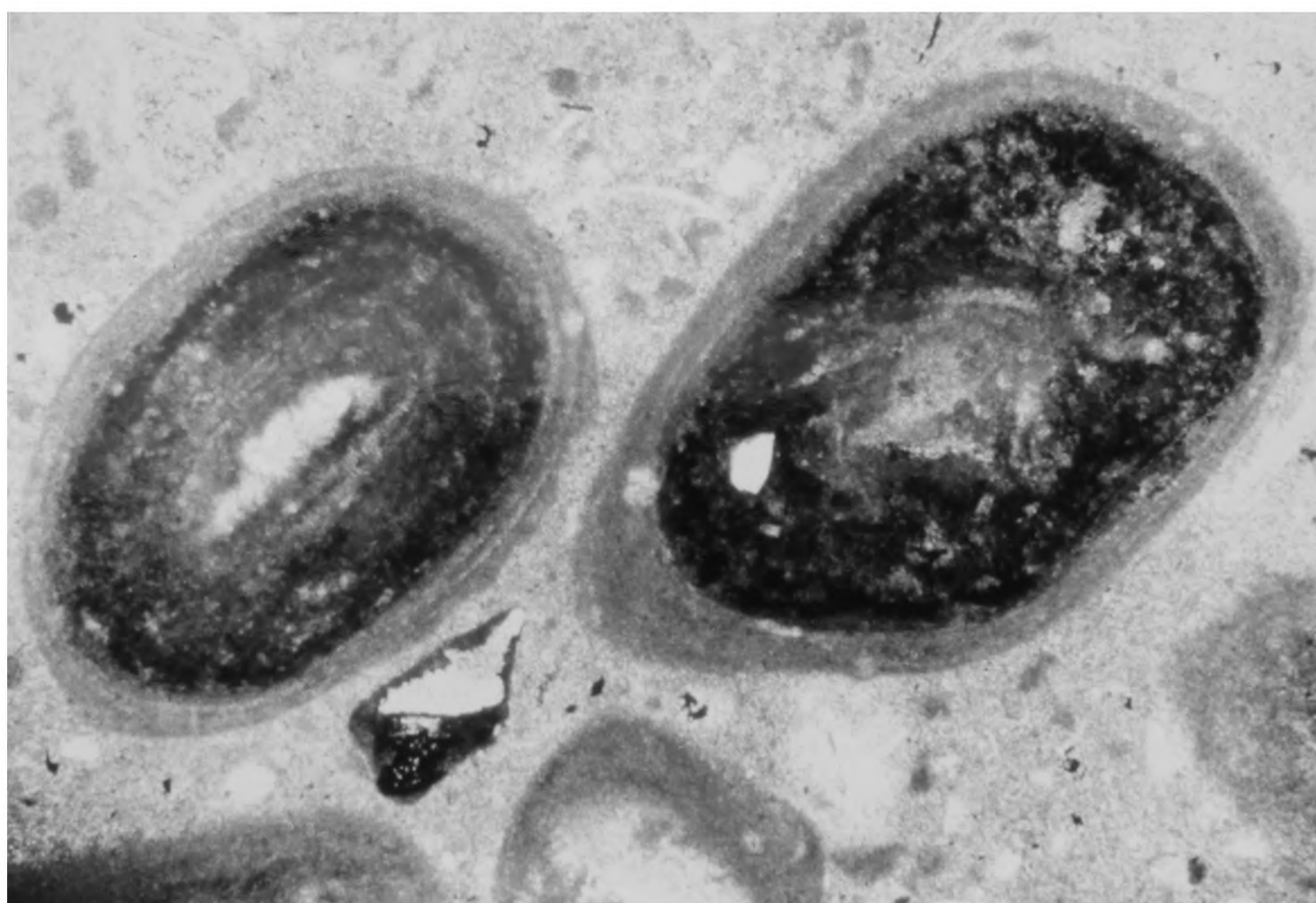


Plate 6.20 Rounded micritic mud pellet in the beds of
Facies 5 in Applecross showing evidence of ?algal
remains (?borings; ?tubes).

X50

Plate 6.21 Oobiomicrite with "inverted" texture, Facies 5
in Applecross.

X40

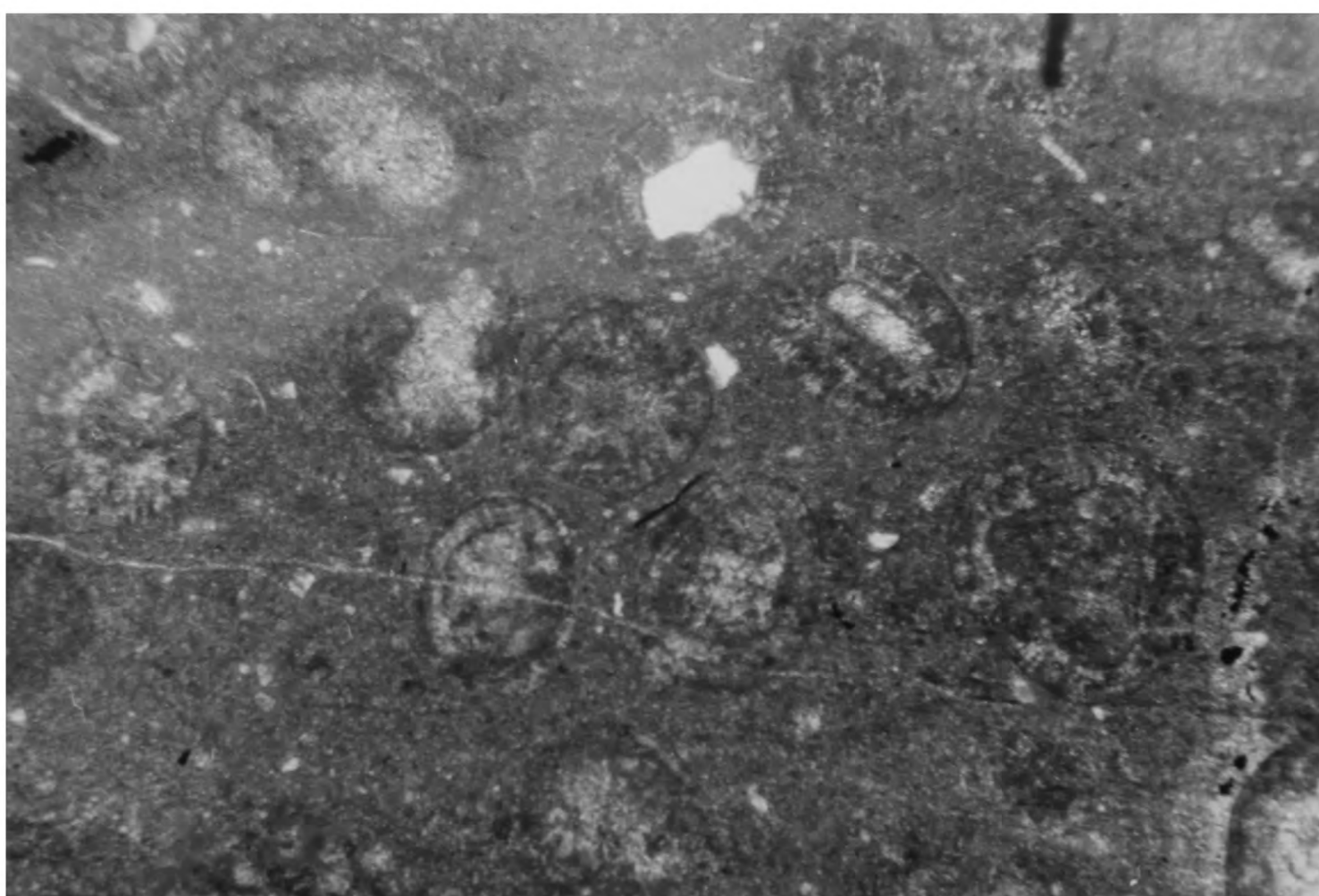
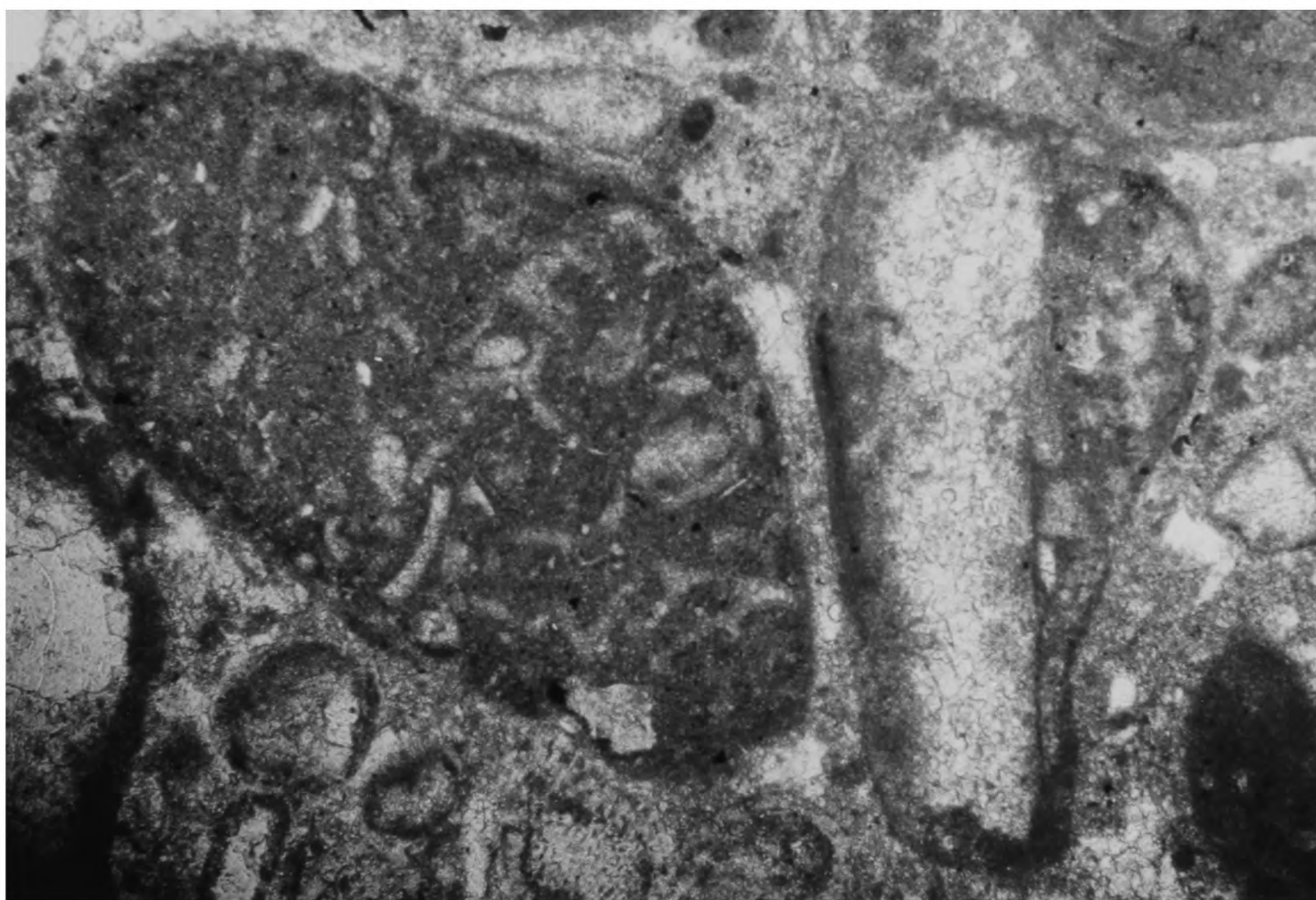


Plate 6.22 Isastrea murchisoni found in the beds of
the Lusa Coral Member of northern Strath. Sample
length is 25 cm.

Plate 6.23 Micritic limestone with thin-shelled
ostracods, bivalves and ?echinodermal fragments.
?Facies 6 in Loch Eishort.
X40

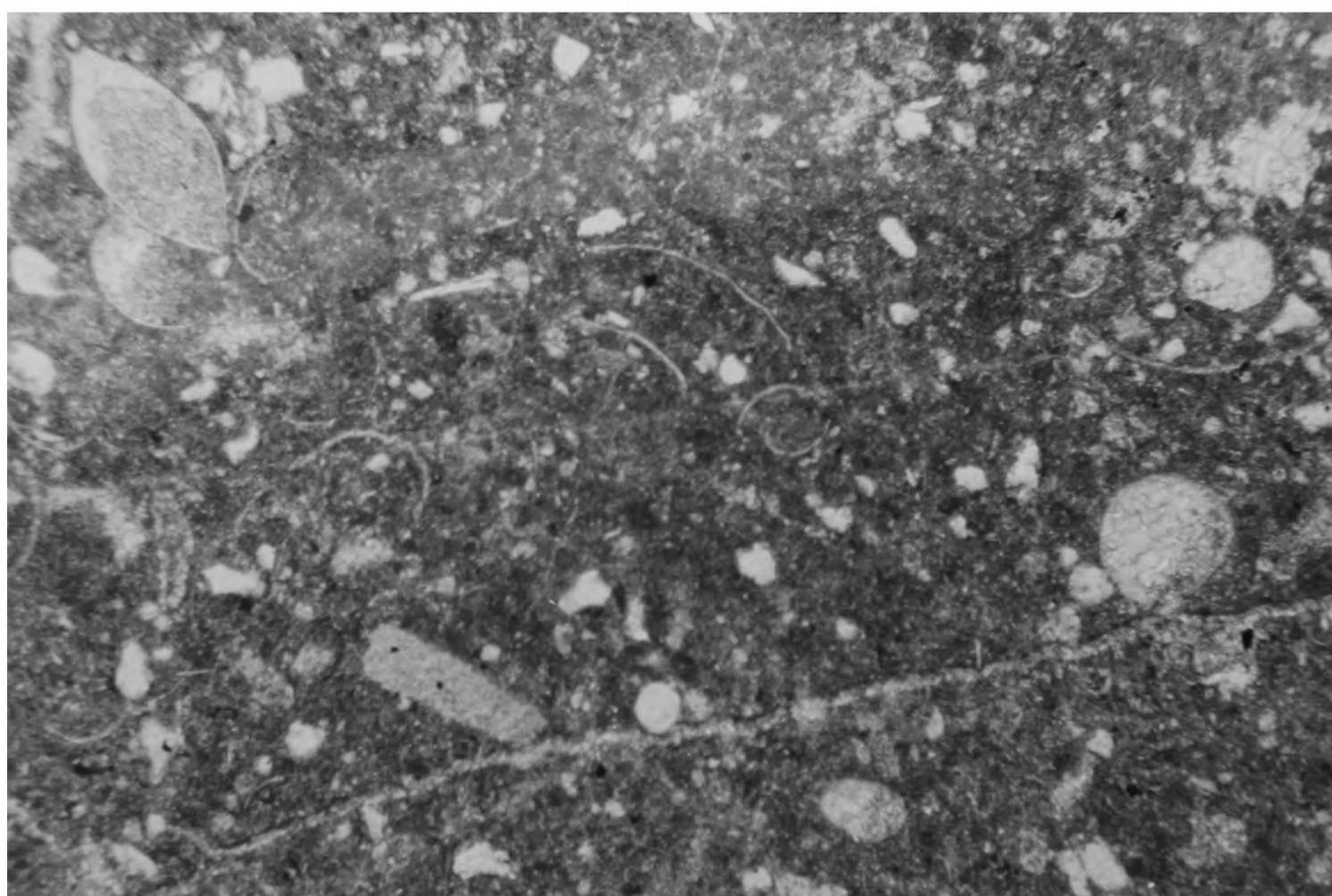


Plate 6.24 .a Lower sand Member, Facies 7a, in Loch Eishort.

Plate 6.24.b Sandy limestone lenses alternating with wavy sandy sheets at the base of Facies 7a, Loch Eishort.

Plate 6.24.C Trough cross laminated calcareous sandstones with coalified material and occasional pebbles, non-erosively overlain by a faintly parallel laminated bed 5-7 cm thick. This is succeeded by small scale lenticular bedded sand. Facies 7a, Loch Eishort.



Plate 6.25 Tabular cross laminated, well washed fine
siltstones at the top of Facies 7a, Loch Eishort.

Plate 6.26 Trough cross stratified well washed white
siltstone at the top of Facies 7a, Loch Eishort.



Plate 6.27 Well washed fine siltstones at the top of Facies
7a 1, Loch Eishort.
X50

Plate 6.28 Oosparite wackestone showing compound and
multiple generation ooliths, Facies 7a2 , Loch
Eishort. Note stylolite cutting across the ooliths.
X16

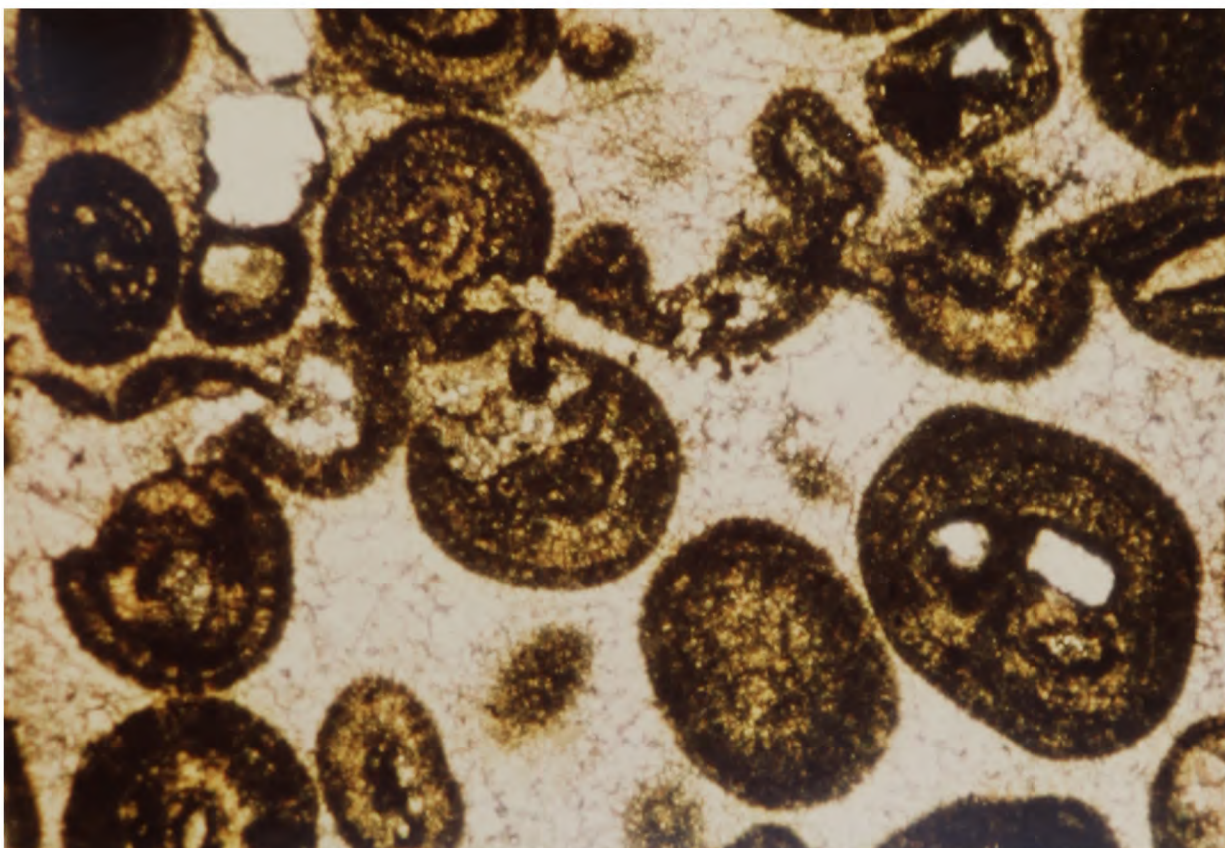
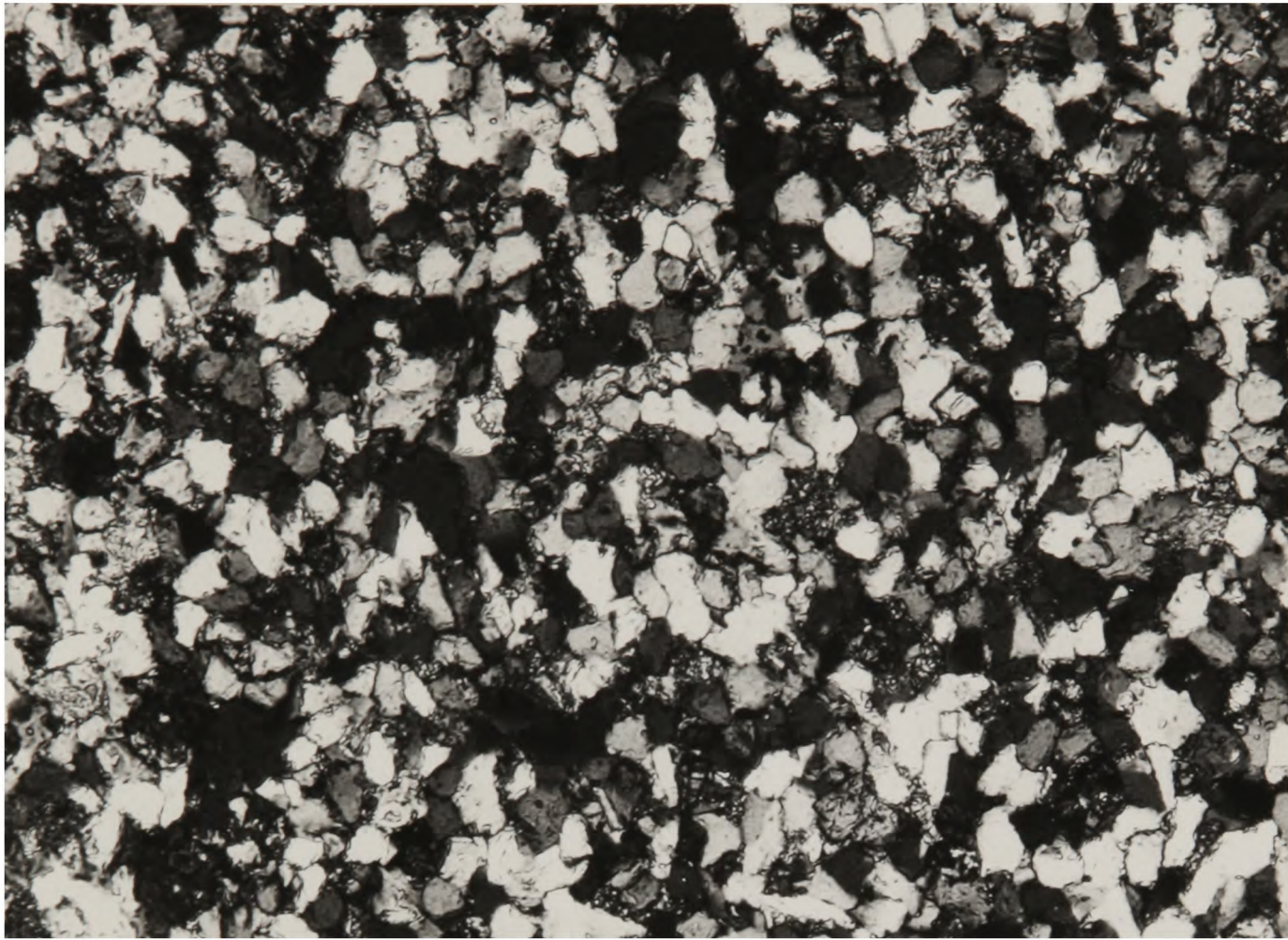


Plate 6.29 Bed crowded with Cardinia concinna. Facies 7,
Ob Lusa.

Plate 6.30 Asymmetric oolite found in the limestone/
oolites of Facies 7b 1 of Ob Lusa, northern Strath.
X50

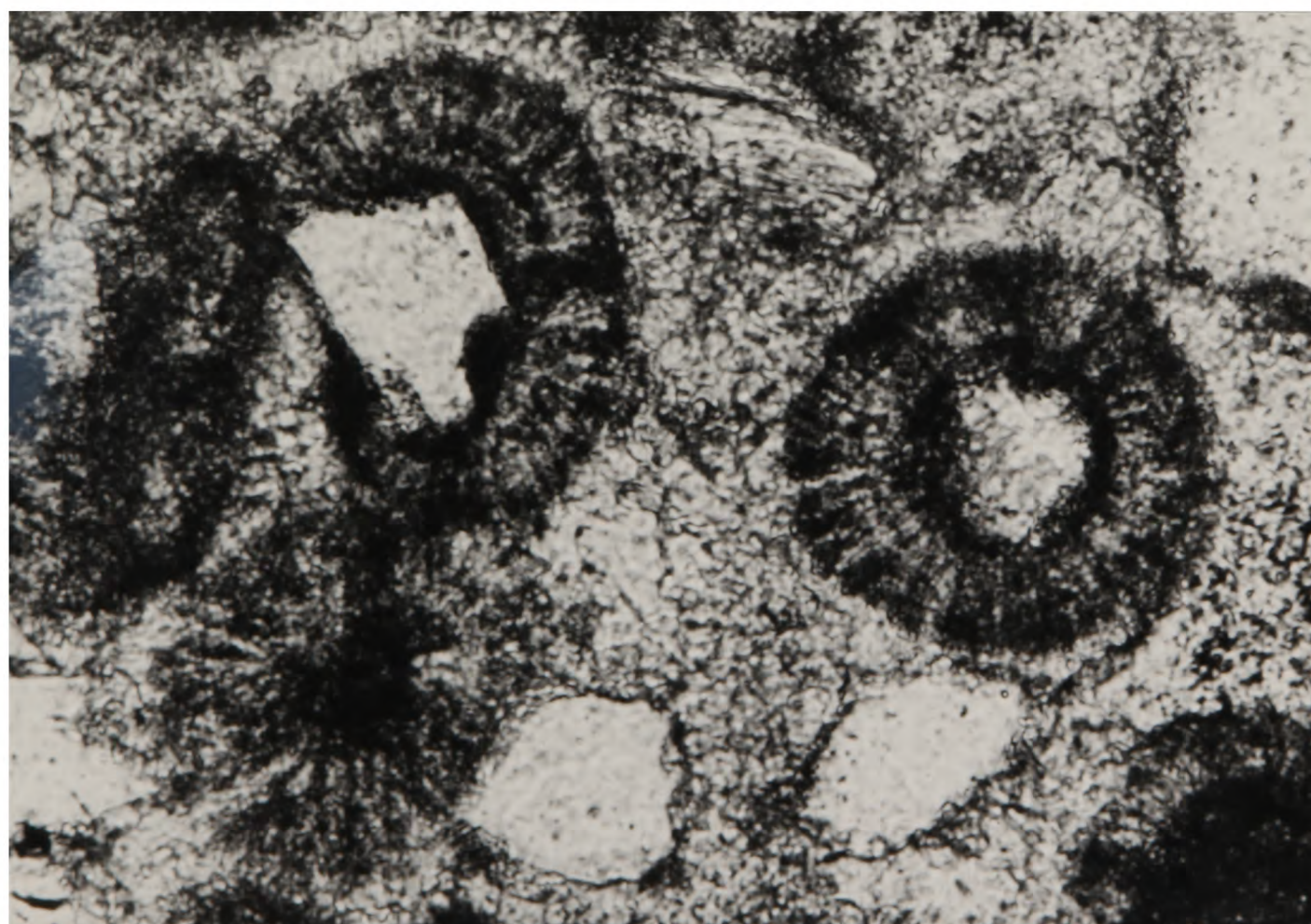


Plate 6.31 Coalified wood remains showing cellular structure.

Facies 7b1 , 0b Lusa.

X6.3



Plate 6.32 Opel micrite of Facies 7C 1, showing second generation ooliths, Applecross. Note inverted texture.

X50

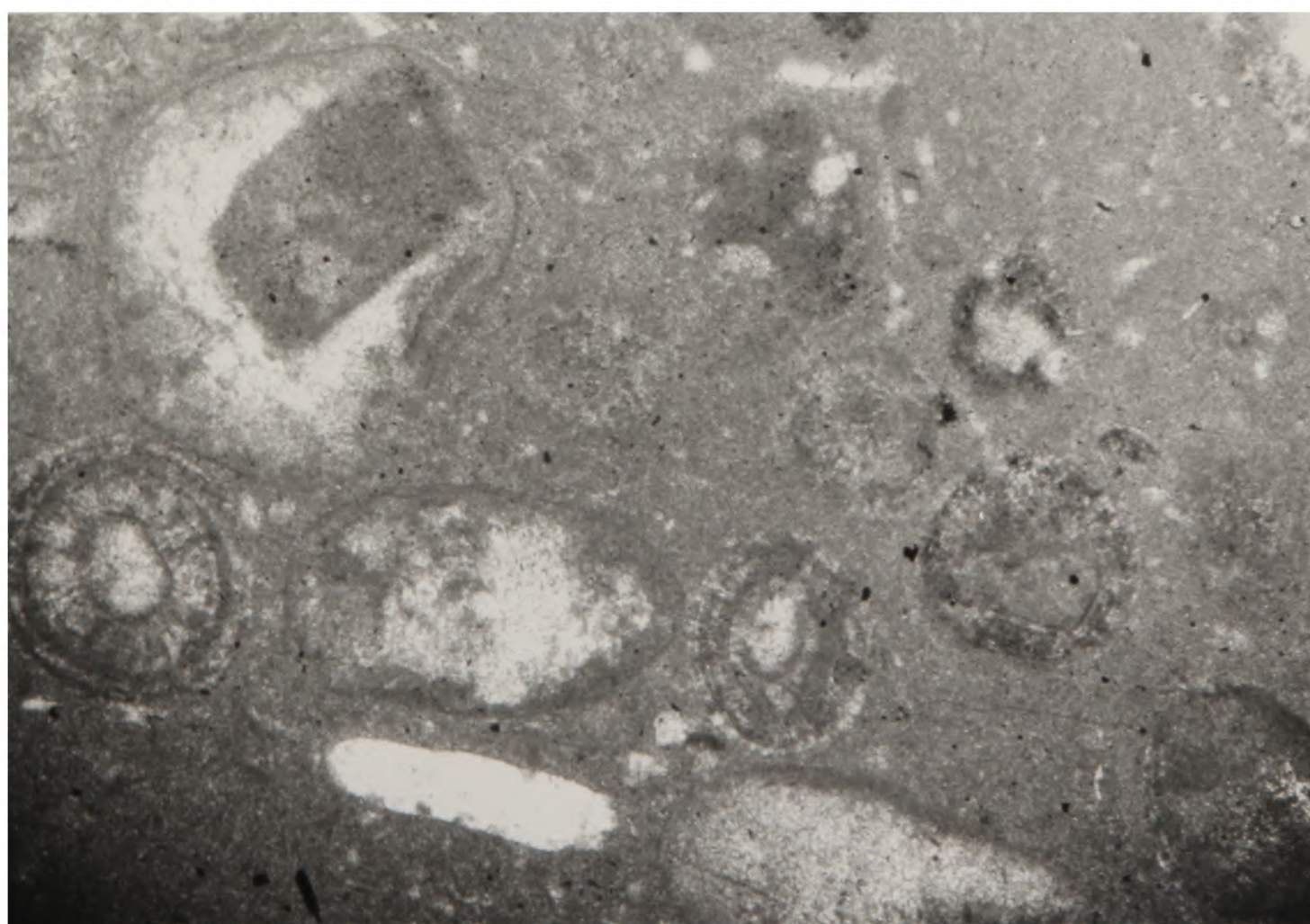


Plate 6.33 Large bivalve and echinodermal shell fragments
with micritic coating. Together with rounded
pellets containing re worked coalified material.
Facies 7C₁, Applecross.
X50

Plate 6.34 Large ooliths (1 ϕ) with micritic coatings
note apparent outer second generation concentric
coating. Facies 7C₂, Applecross.
X50

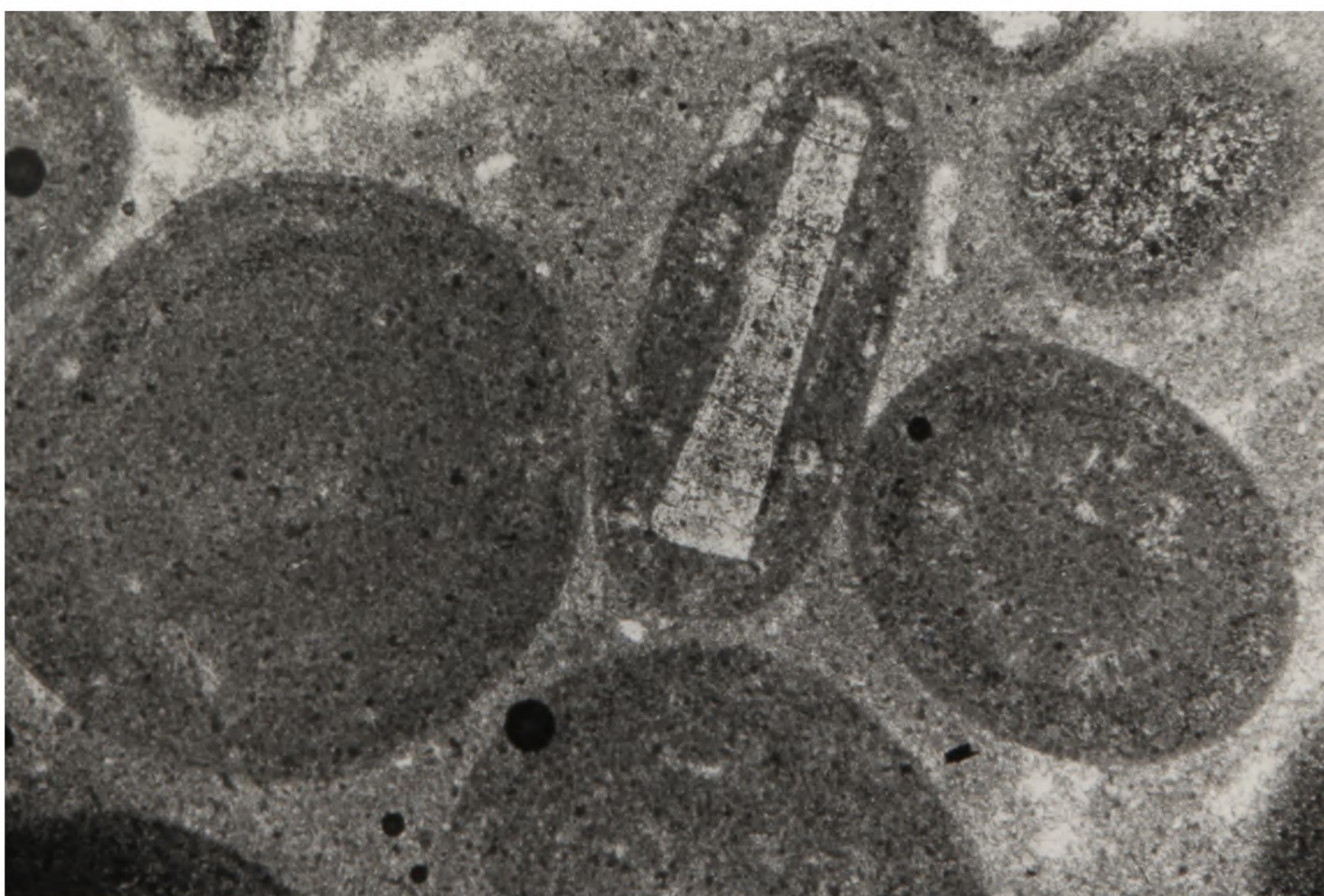
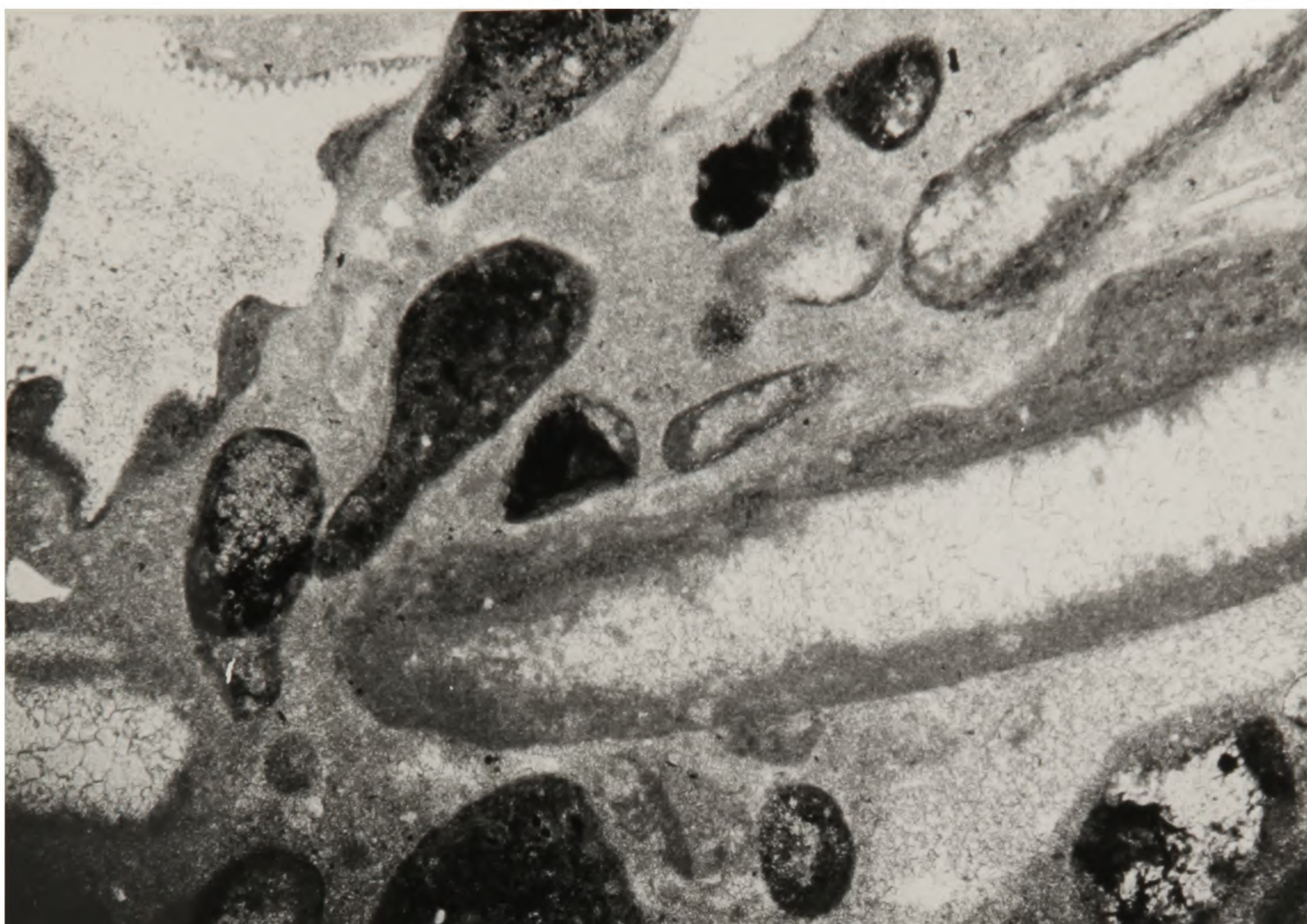


Plate 6.35 Biopelmicrosparite at the base of Facies 7C₂,
Applecross. Note micrite filled gastropod test. The
echinoid spine located left of the centre does not show
a characteristic hollow centre because it was cut
near its top.
X50

Plate 6.36 Oolitic peletoidal limestone at the top of
Facies 7C₂ in Applecross. Note high spired gastropods,
multiple and second generation ooliths and pellets;
echinoid plates and stems which are coated by micritic
mud with ? algal features.
cf. Plate 6.51
X4

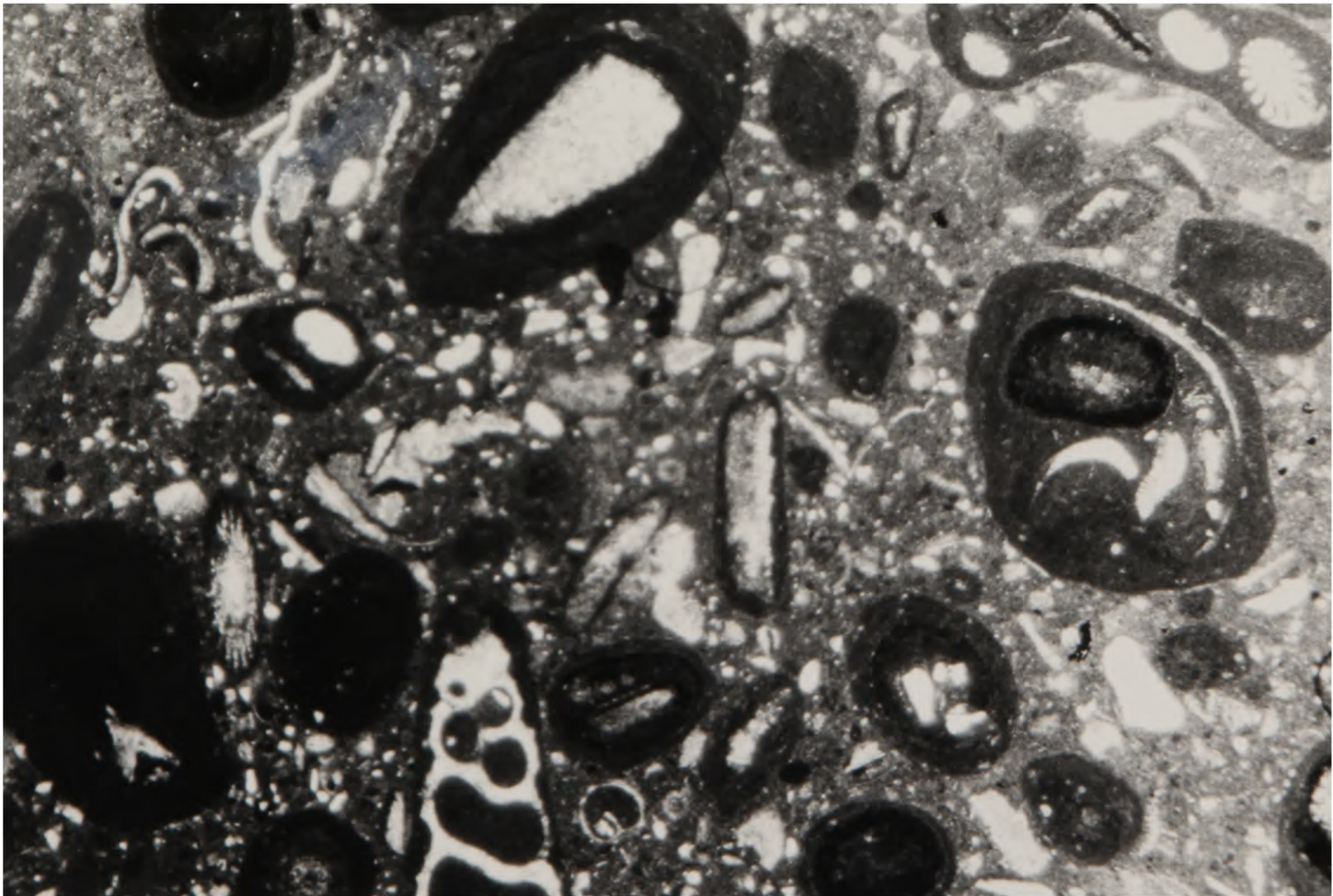
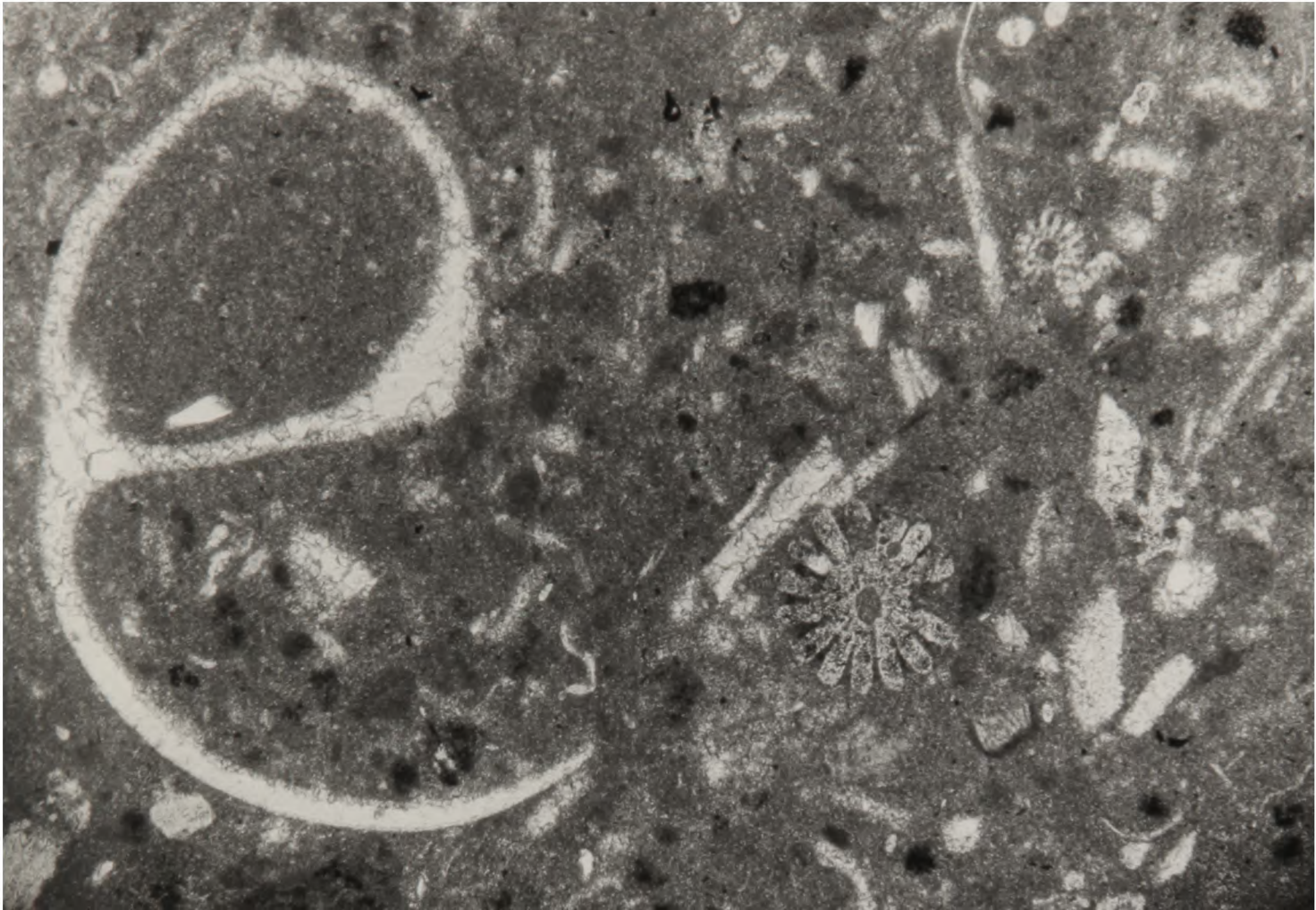


Plate 6.37 As plate 6.36. Note thick algal mud coating
around the grains.

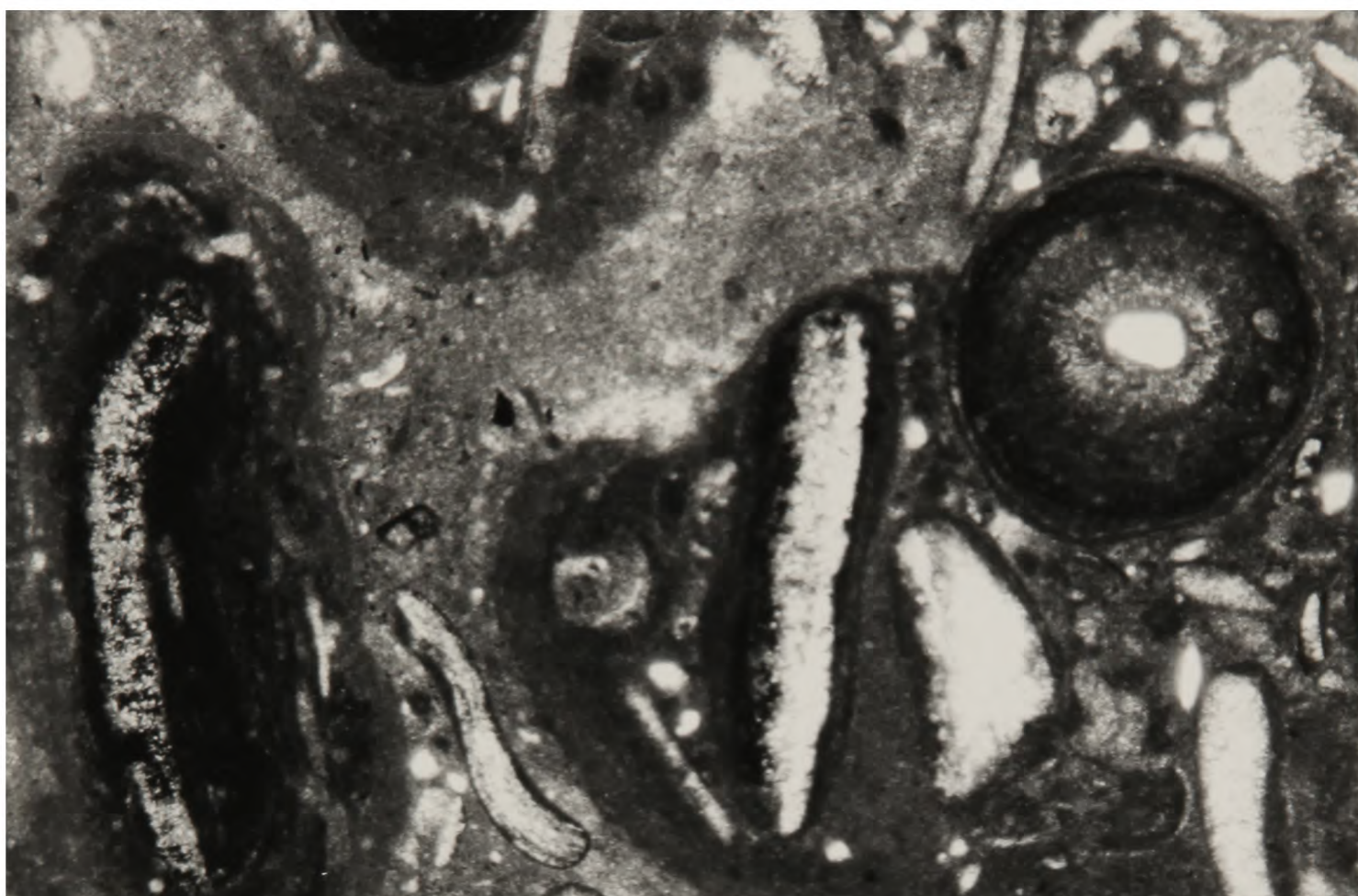


Plate 6.38 Oobiopelsparite of facies 7 indicating deposition in well agitated shoal areas, the presence of rounded micritic grains and mud coated pisolitic grains indicates proximity to ?mud-flat areas. Note second generation ooliths, in particular those with a first generation asymmetric oolith as a nucleus; this together with the perfect oolitic layers of the second generation indicate a progressive increase in environmental agitation.

X 4

Plate 6.39.a Beds of the Breakish Coral Member (Facies 8) in Applecross with wavy lower and upper surfaces. These are interbedded with smectite-rich shales.

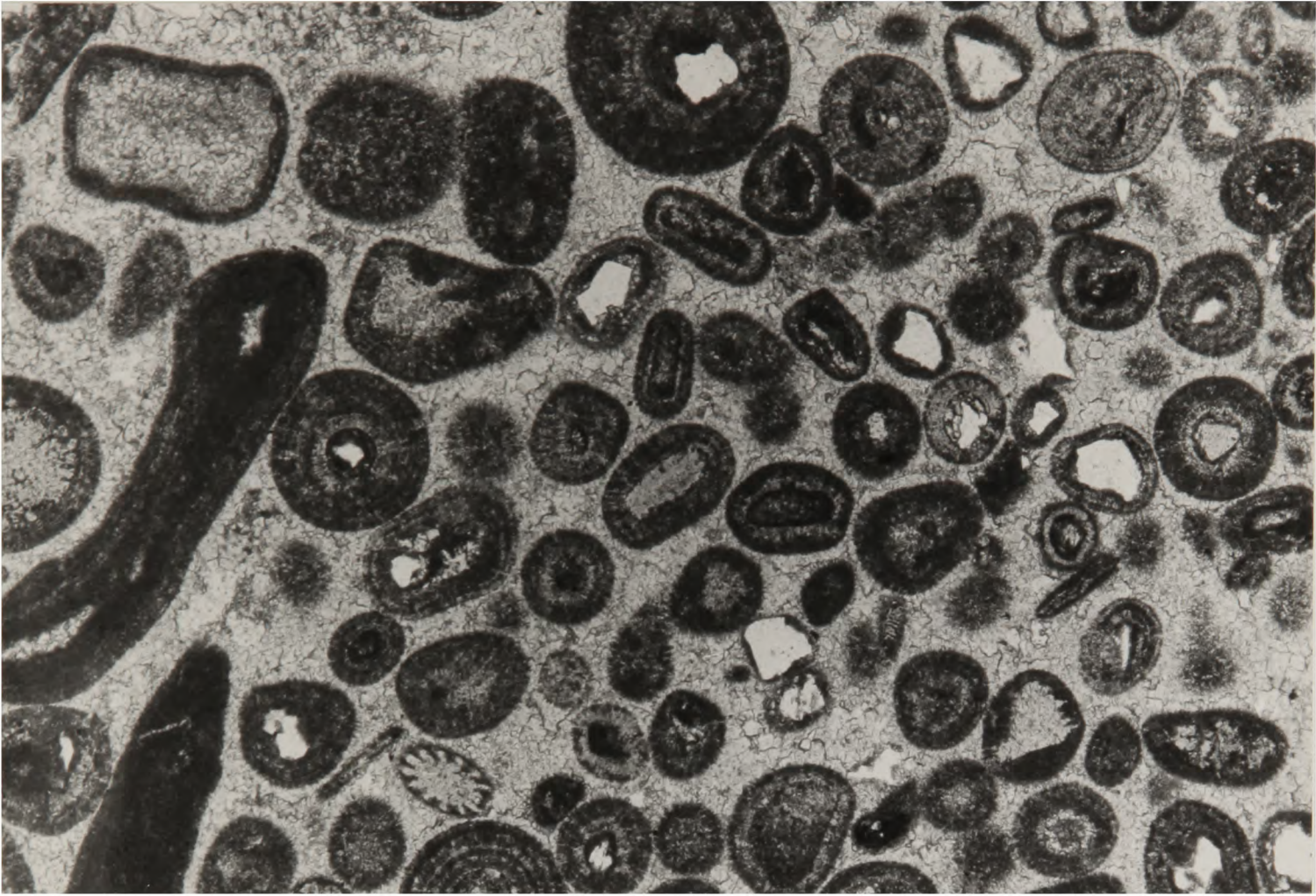


Plate 6.39b. Thecosmilia martini (mostly in life position) in
the Breakish Coral Bed. Ob Breakish.



Plate 6.40. ?algal mud or encrusting foraminifera on
recrystallised Thecosmilia wall surface.
x 50.

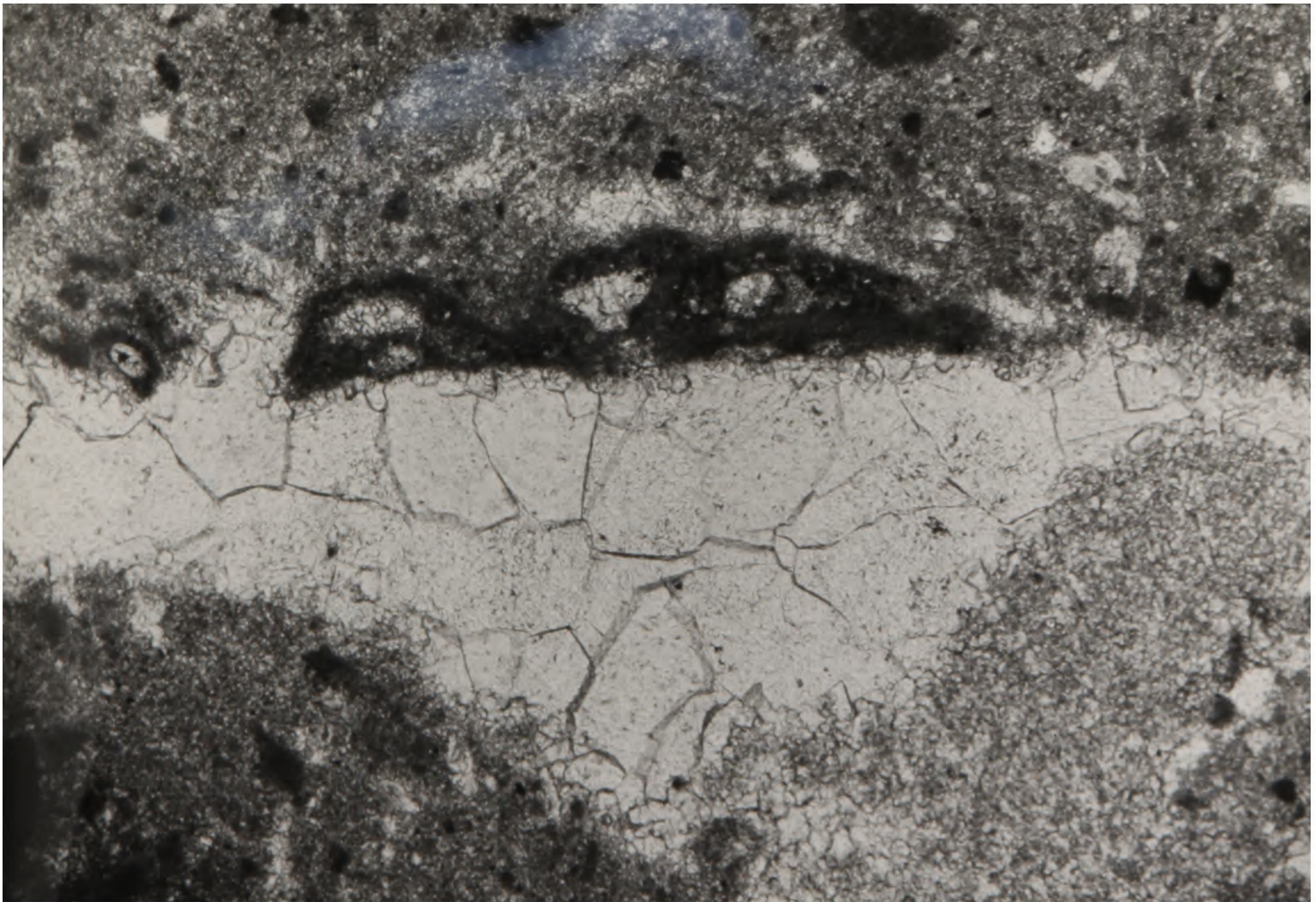


Plate 6.41. Silty biopelmicrosparite with abundant micritic pellets. Facies 9a in Ob Lusa.
x 20.

Plate 6.42. Sandstone sheets interbedded with broad lenses of limestones up to 1 m. long. Note rapid upward diminishing limestone thickness (see also Plate 6.67a).
Facies 9a, northern Strath.

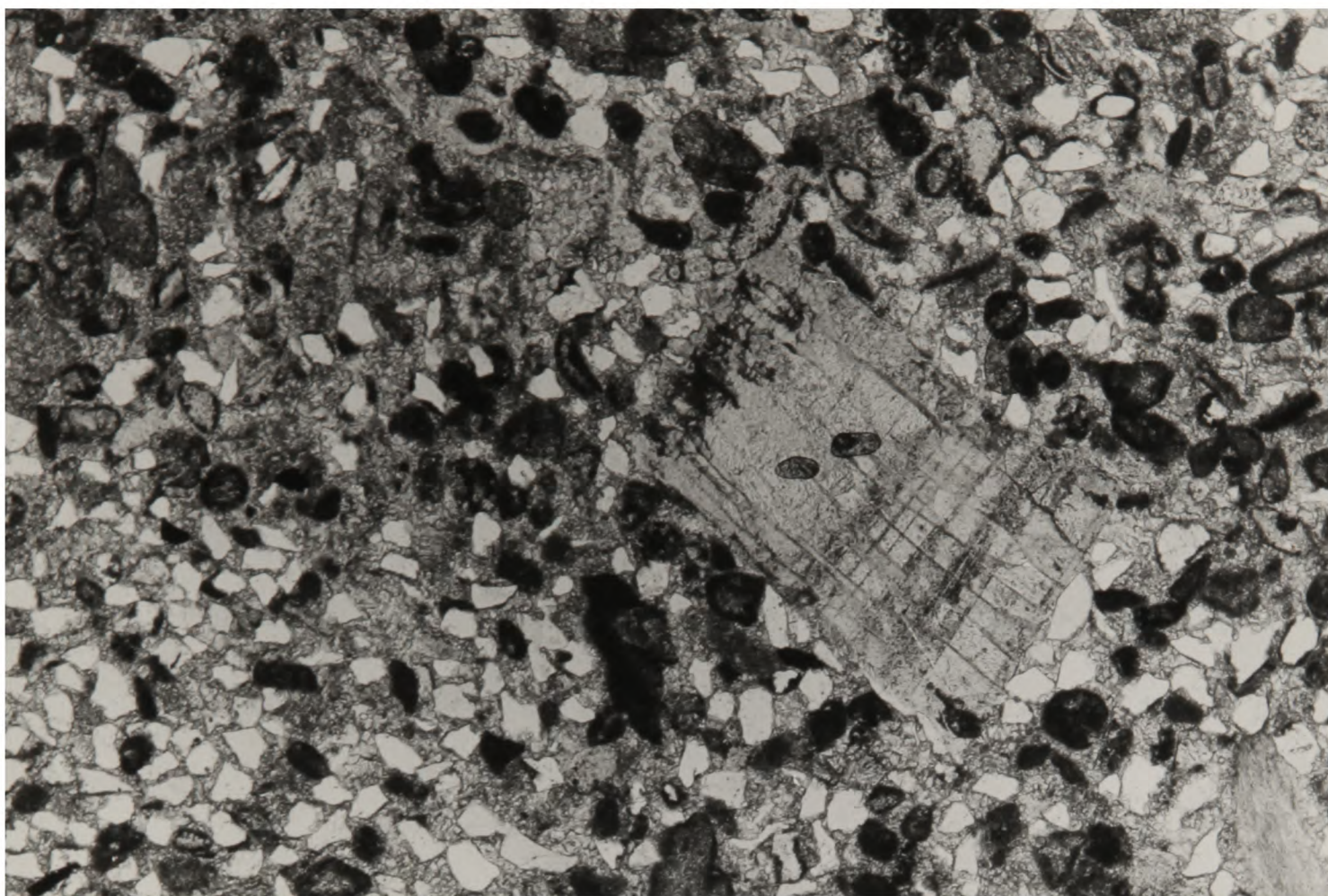


Plate 6.43 . Beds representing Facies 9b along the western flank of Beinn nan Cairn (NG 635787); note cross laminated limestone lenses with pebbles at their base. The average thickness of the sandy interbeddings markedly decreases towards the top of the succession.



Plate 6.44. Pebble bands in the beds of facies 10, Braigh nan Skulamus, Central Strath.

Plate 6.45. Pebble beds of Facies 11 in Applecross; note matrix supported character and general fining upward into cross laminated calcareous sandstones.



Plate 6.46 . Rounded coarse grained pebble and cobble sized constituents of Facies 10 or 11 in Ob Lusa, northern Strath.

Plate 6.47 . Broad, shallow channels formed in the beds of Facies 11 in Applecross.



Plate 6.48 . Lenticular and ripple cross laminated beds
representing the topmost unit of the Breugh Pebble
Member in Applecross.



Plate 6.49. Broad, shallow lenticular calcareous sand bodies forming the top of coarsening upward units of Facies 13 in Loch Eishort, Skye.

Plate 6.50 . Vertically retrusive Rhizocorallium found at the base of the sandy lenses of Facies 13 in northern Strath.



Plate 6.51. Silty shales, densely packed with Gryphaea shells alternating with calcareous sandstones representing the upper parts of Facies 13, Loch Eishort, Skye.

Plate 6.52. Pinna (mostly crushed fragments) on the top surfaces of the silty shales of Facies 13, Loch Eishort, Skye.
 $\frac{1}{2}$ penny for scale.

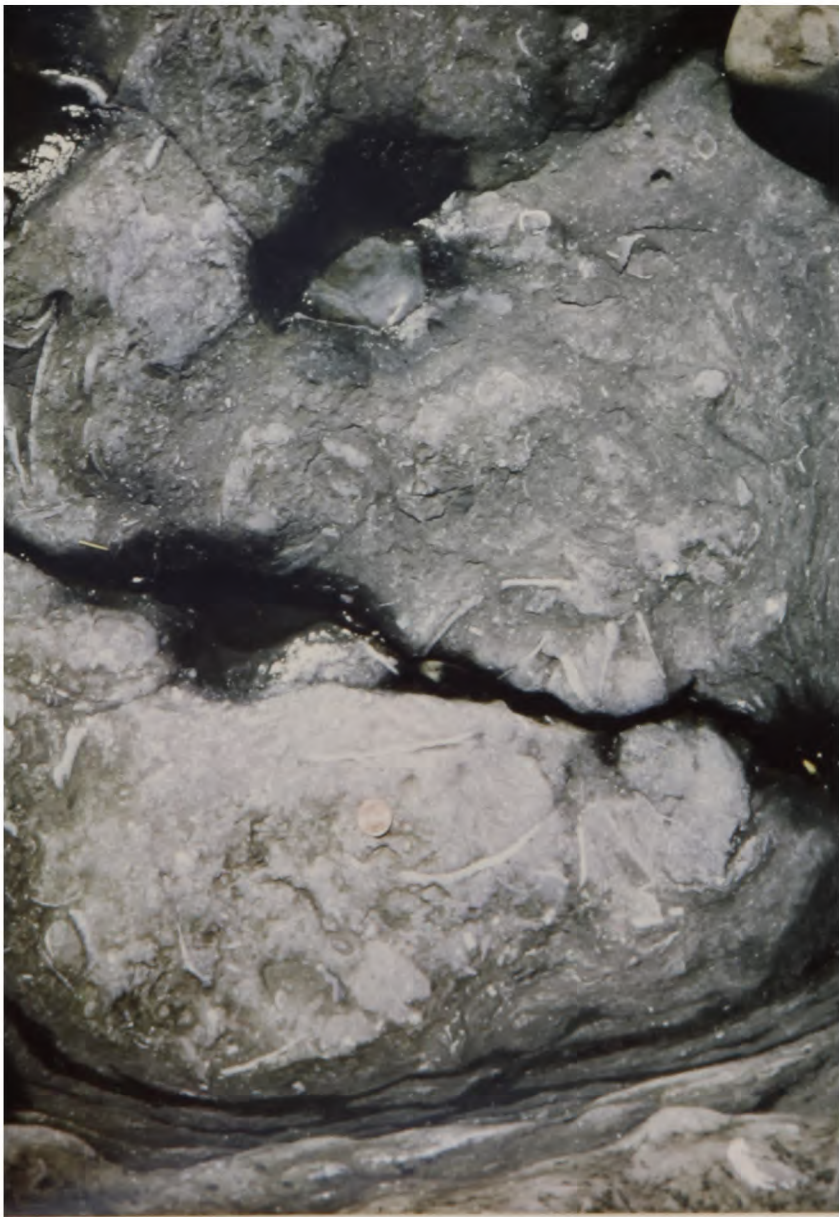
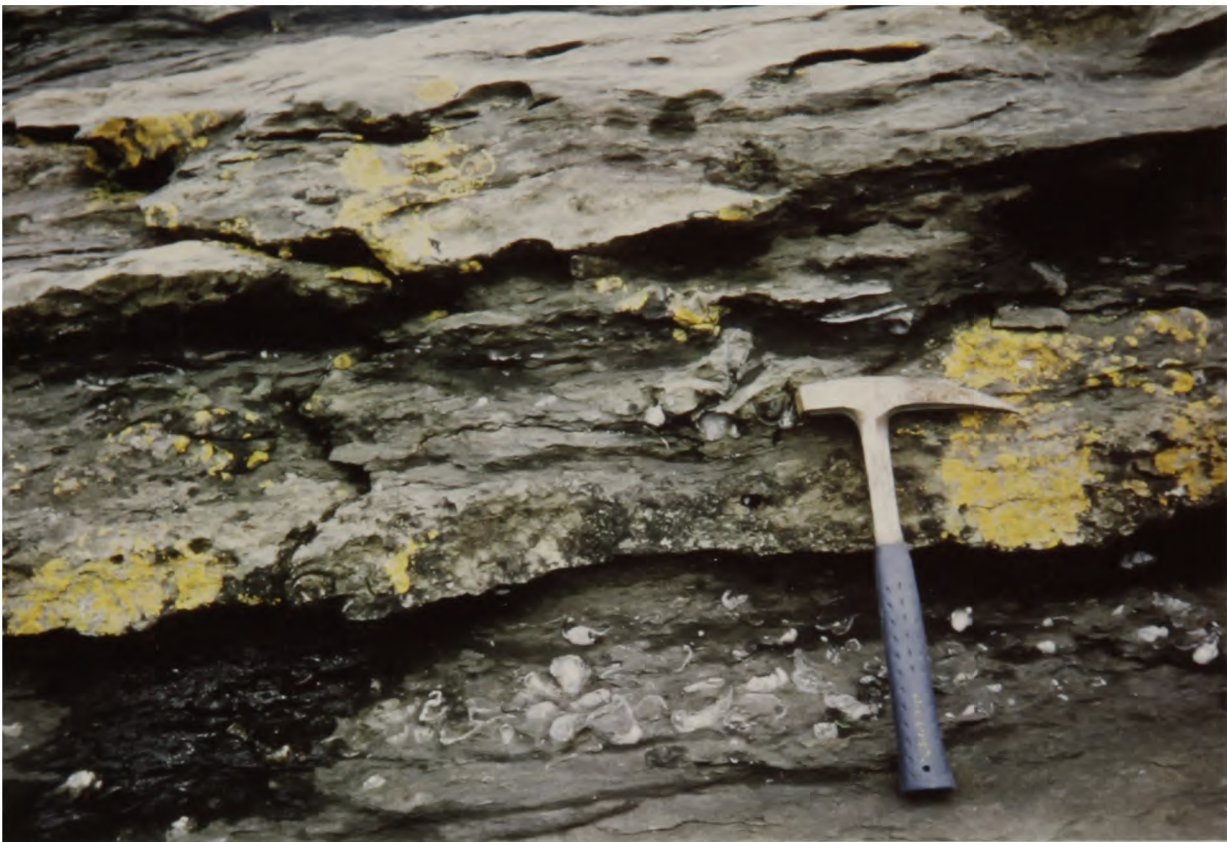


Plate 6.53. Base of the Strath Formation, Rubha nan Leac, Raasay. Note first Gryphaea bed below the thick-bedded sandstones.

Plate 6.54. Echinodermal packstone forming the basal parts of the calcareous micaceous siltstones of the coarsening upward cycles in Facies 13. Rubha nan Leac, Raasay.
x 50.

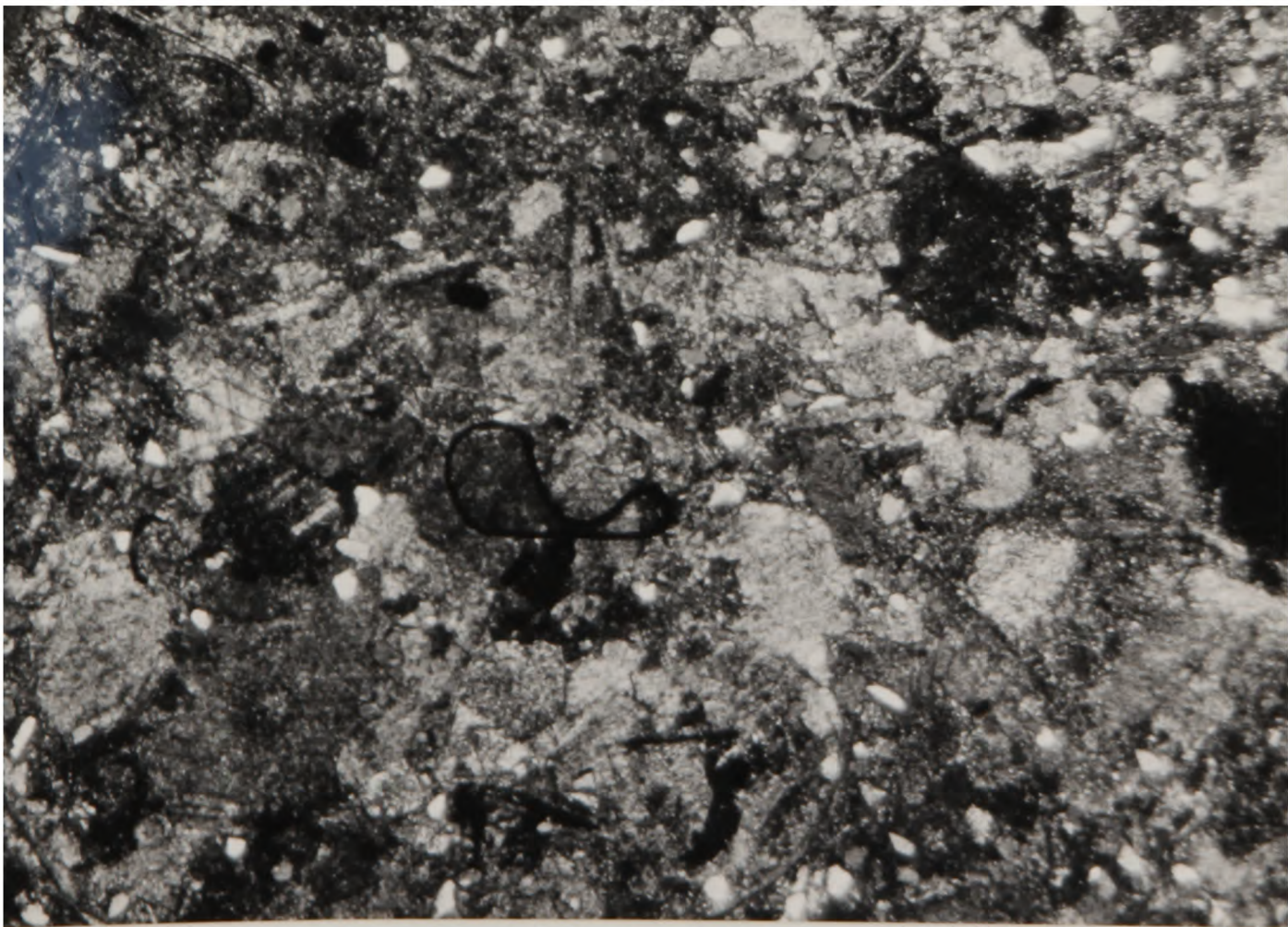


Plate 6.55 Towards the top of the calcareous micaceous siltstones
of the cycles in Facies 13, the silt content increases at
the expense of the echinodermal fragments
Rubha nan Leac, Raasay.

· x 50.



Plate 6.56 . Biomicrosparite consisting of crinoidal debris.

Base of the Lower Teampull Chaon Shale Member, Facies 13,
Loch Slapin, Skye.

x 50.

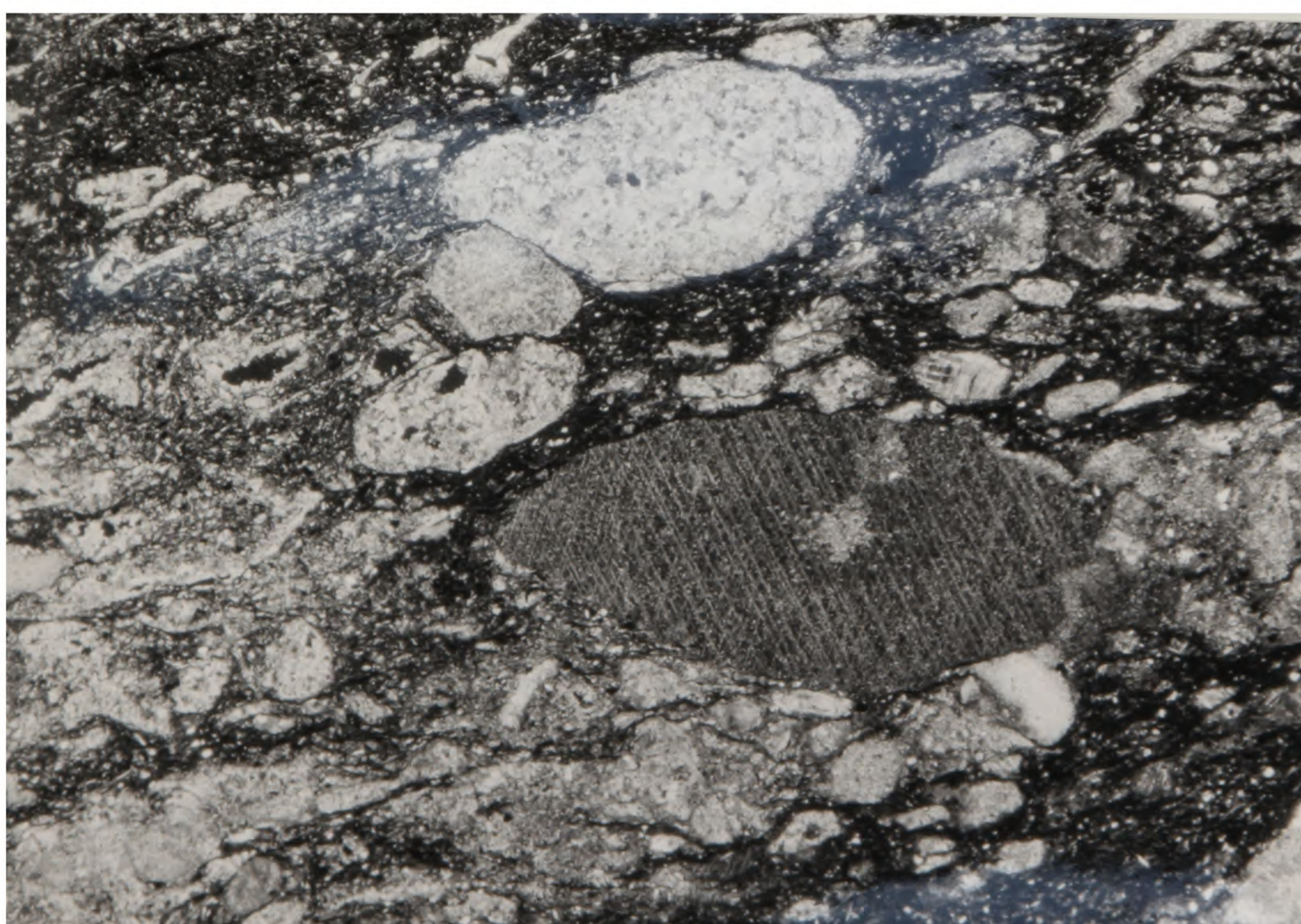


Plate 6.57a. Calcisphere found in the silty calcareous beds of the Lower Teampull Chaon Shale Member (Facies 13) in Ob Breakish. Note apparent geopetal internal feature.
x 100.

Plate 6.57b. Calcisphere with its body chamber infilled with spar, found in the silty calcareous beds of the Lower Teampull Chaon Shale Member, Facies 13 in Ob Breakish. Note lack of inner fine grained layer and the sole preservation of the outer prismatic layer.
x 400.

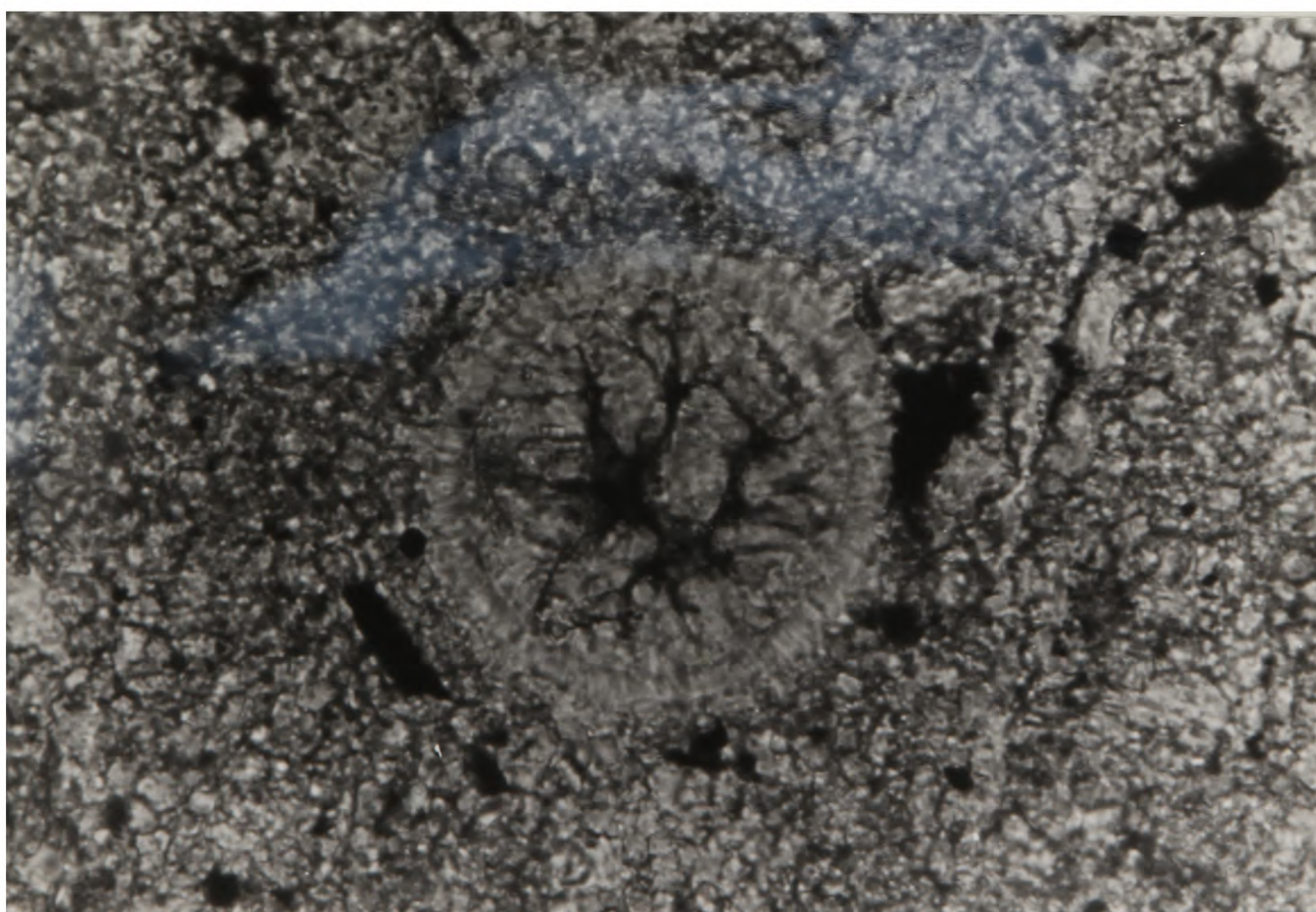


Plate 6.57 c. Calcisphere infilled with microspar with spinose outer wall found in the silty calcareous beds of Facies 13, Ob Breakish, Skye.
x 400.

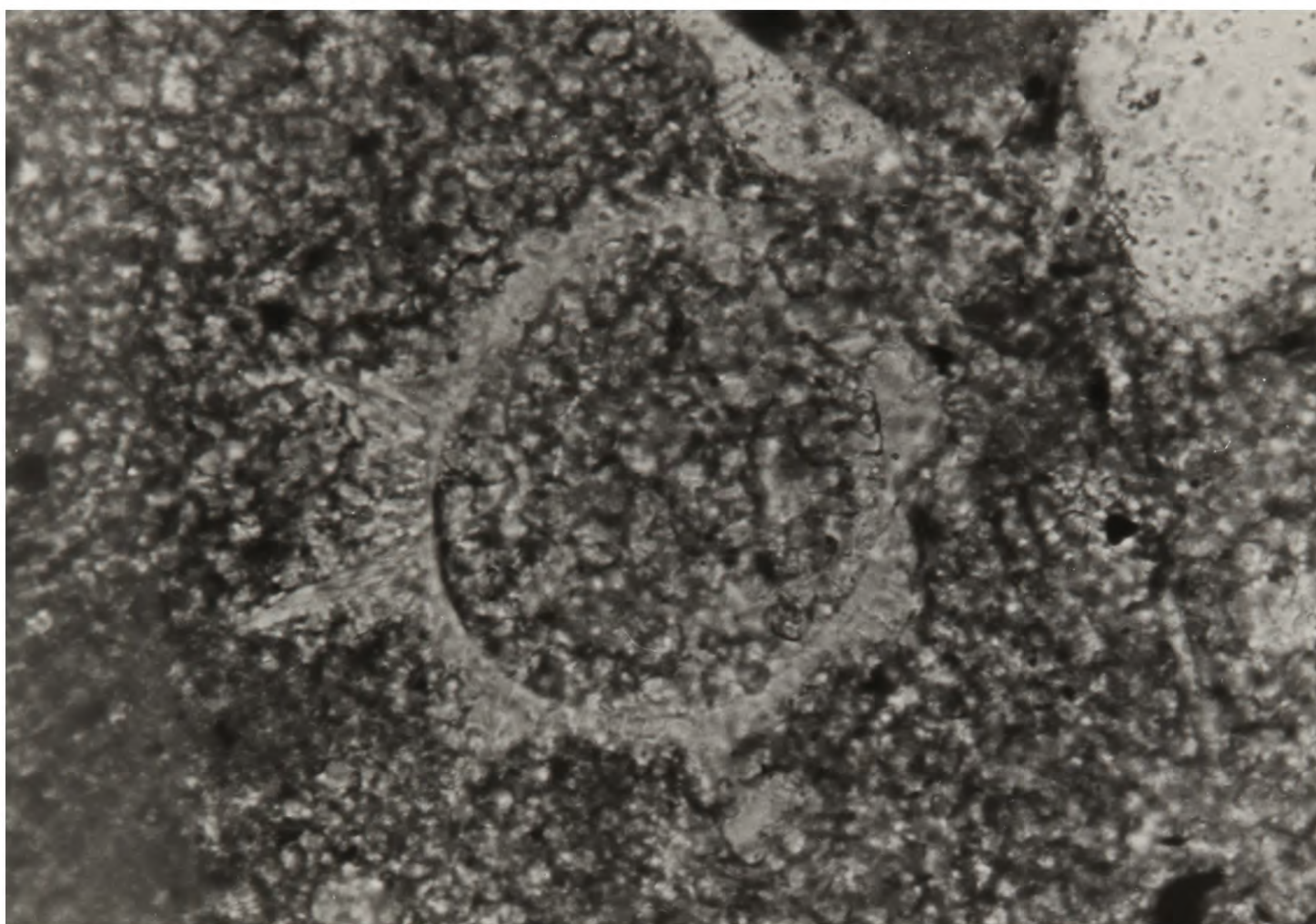


Plate 6.58a. Calcisphere with inner fibrous and outer prismatic
calcitic wall with dendritic outer wall reminiscent of
spines. Facies 13, Ob Breakish, northern Strath.
x 400.

Plate 6.58b. As Plate 6.58a.

x 400

+ nicols

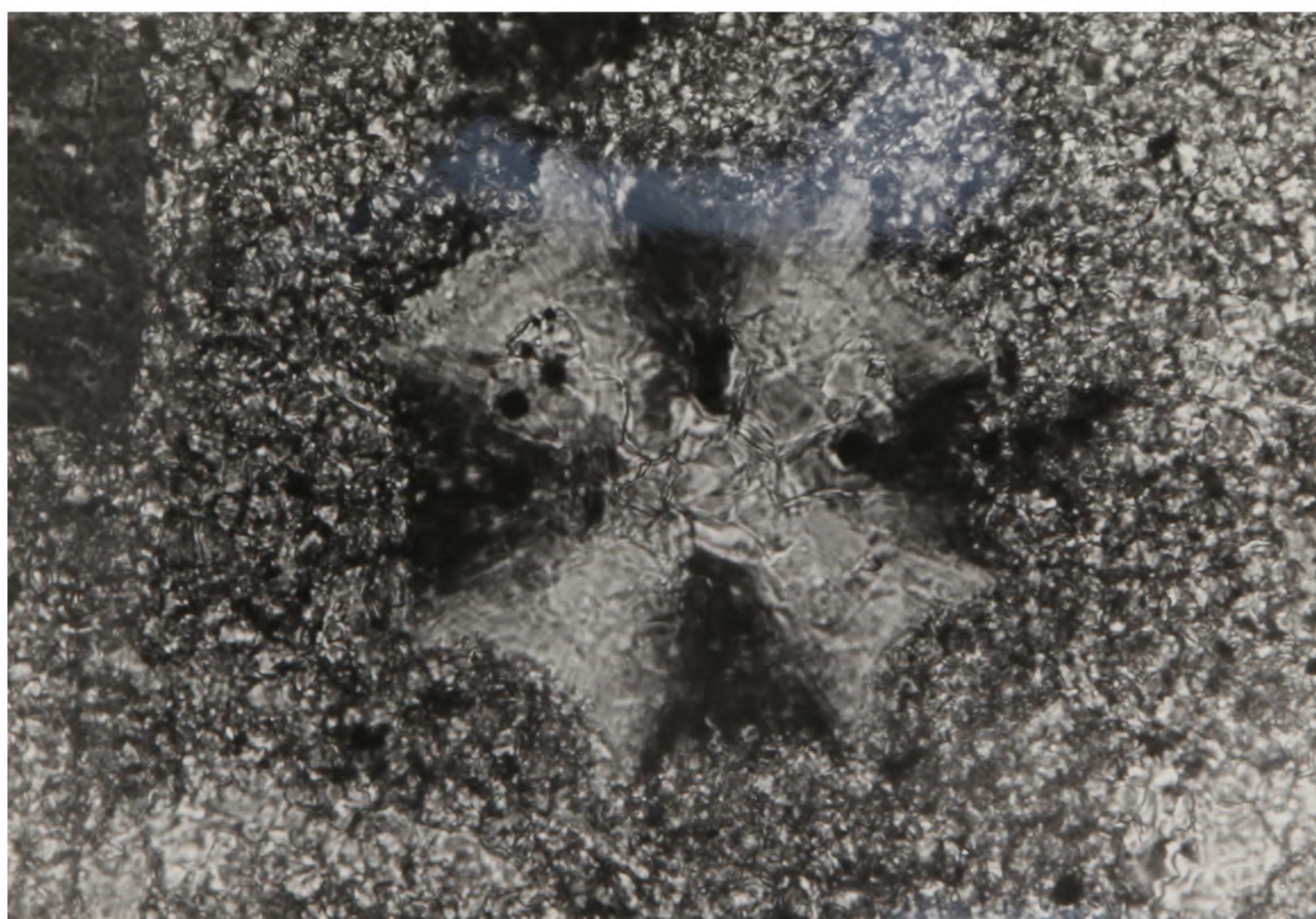
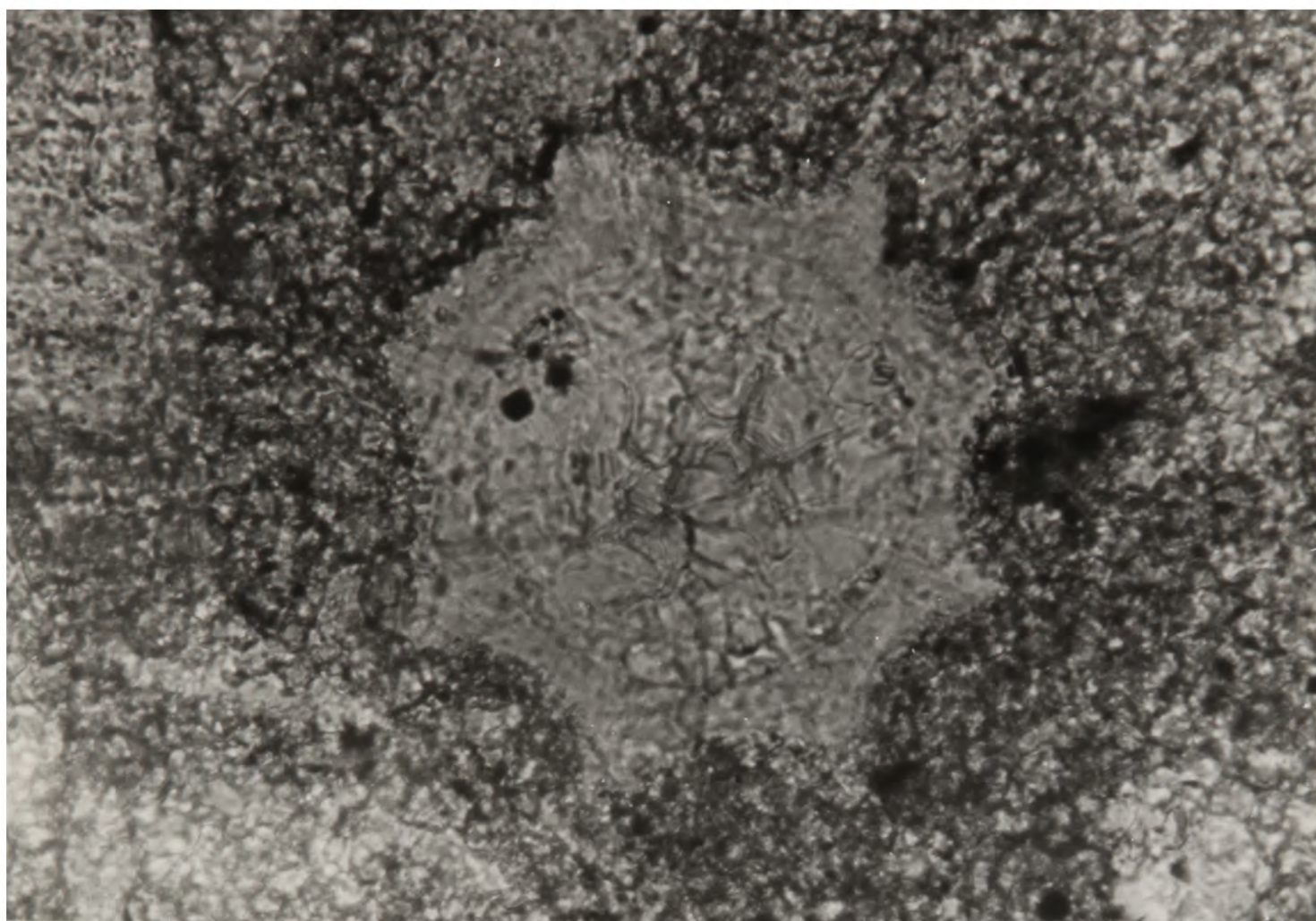


Plate 6.59 . Spiral shaped micro-organism found in the silty
calcareous beds of Facies 13, Ob Breakish, northern Strath.
Cf. Involutina liassica (Jones), cf. Trocholina granosa
Frentzen.
x 100.

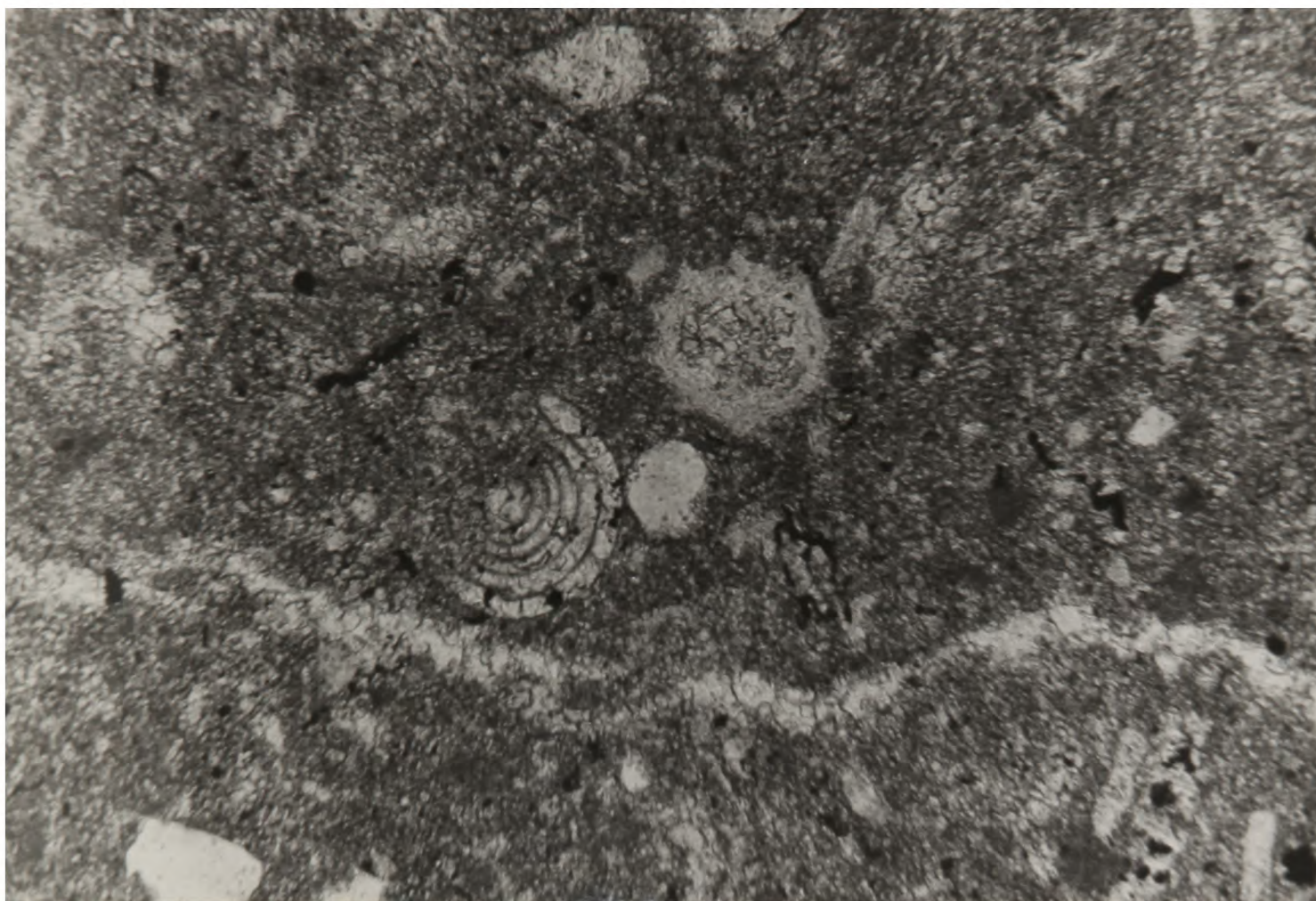


Plate 6.60 a. Sideritic calcareous chamosite oolite with ferroan calcite cement (stained). Breakish Ironstone Member, northern Skye.
x 20.

Plate 6.60 b. As 6.60 a. Note radial extinction brush indicating the orientation of the platy minerals.
x20
+ nicols

Plate 6.60 c. As 6.60 b with quartz wedge. Note "chamosite" flake alignment.
x 20.

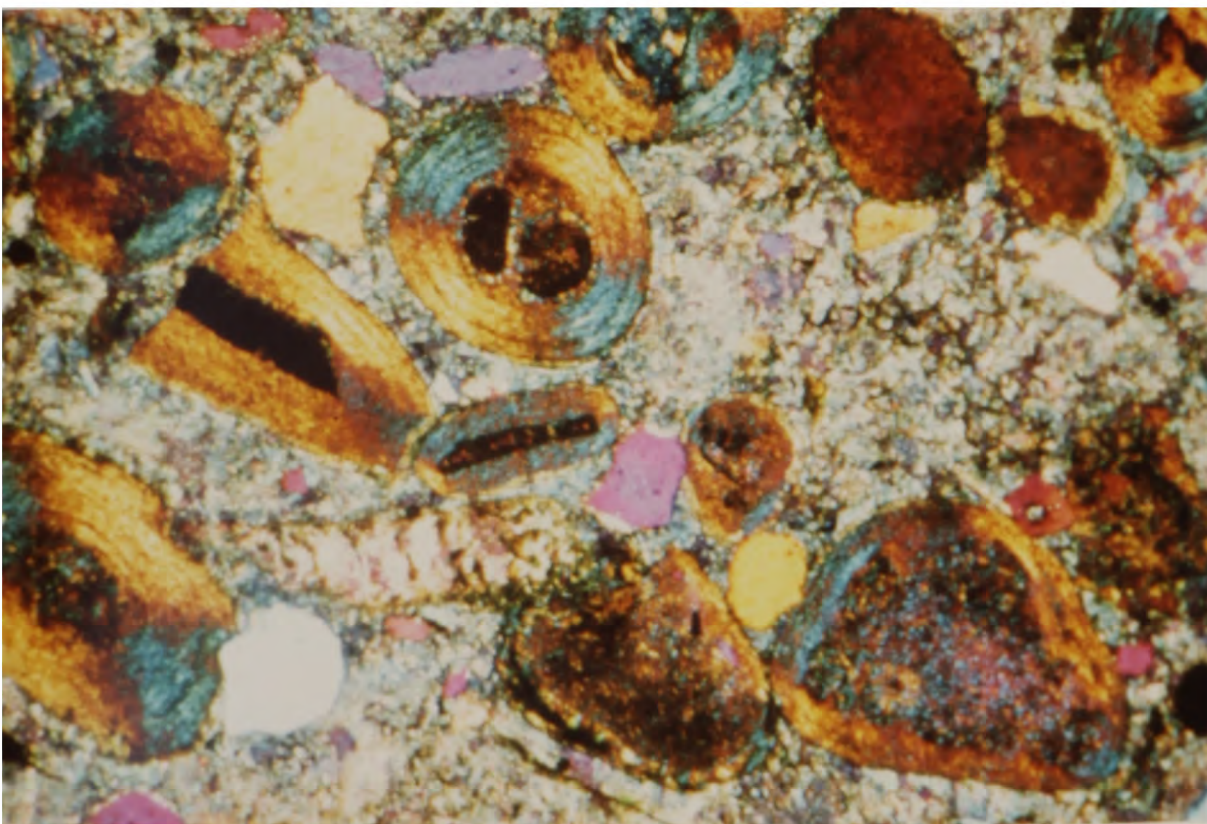
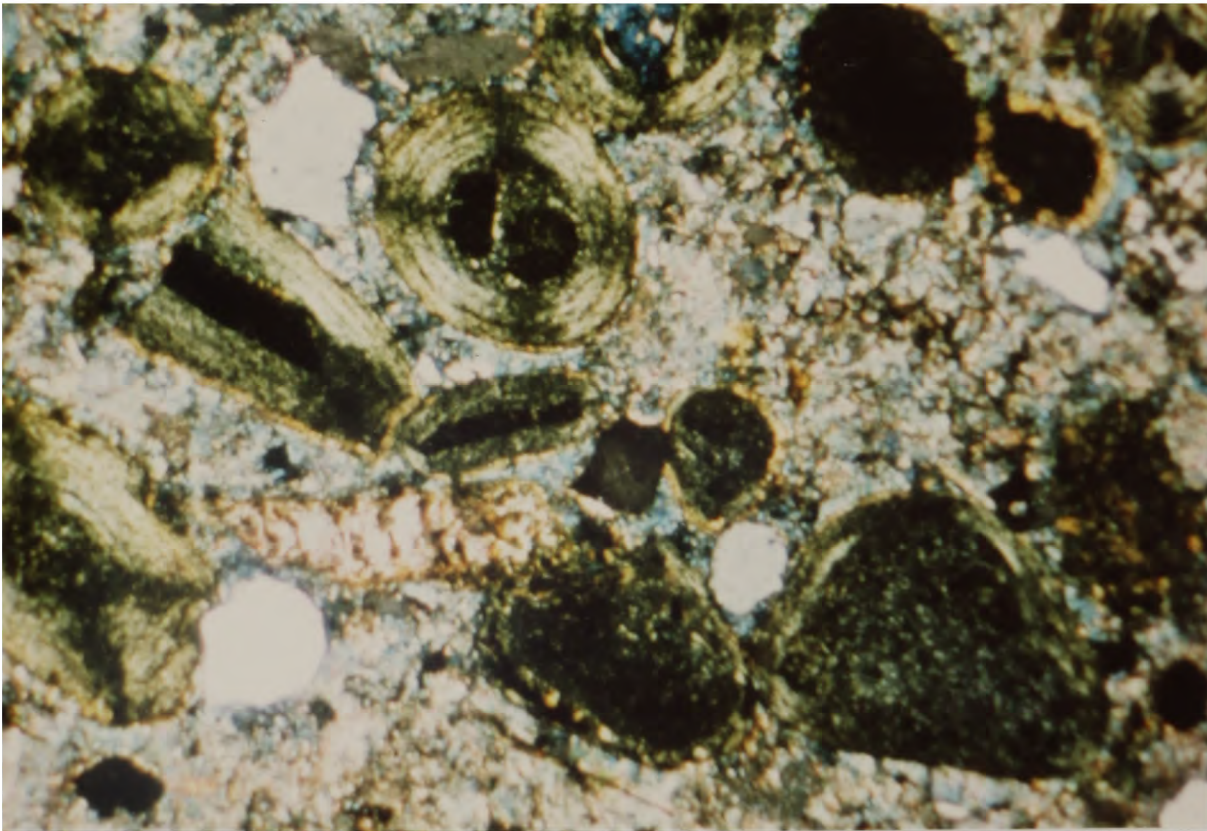
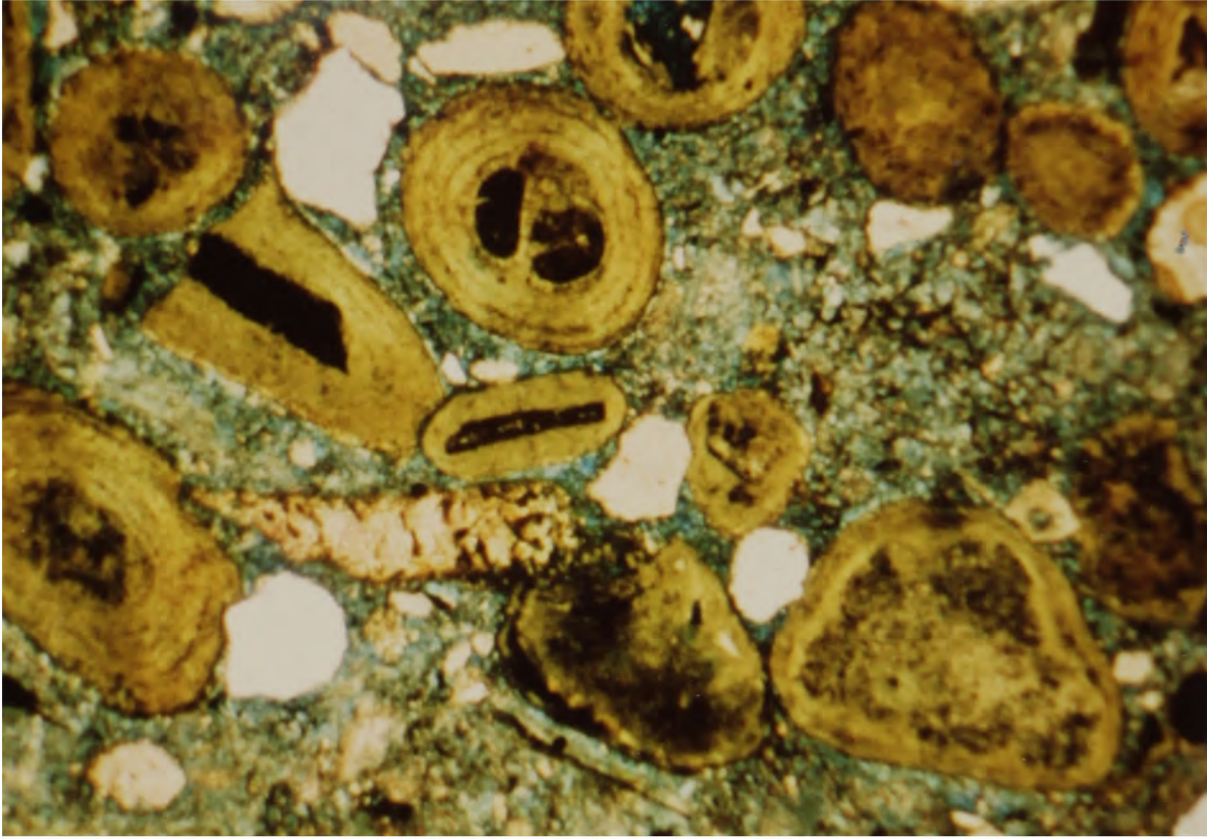


Plate 6.60d. Bivalve shell fragment (stained as non ferroan calcite) in the ferroan calcite cement (blue) of the Breakish ironstone Member. Note the echinoderm plate which has been entirely covered by ferruginous matter.
x 50.

Plate 6.60e. Shell fragments showing boring marks subsequently infilled with the sideritic-"chamosite" cement of the Breakish Ironstone Member.
x 20.

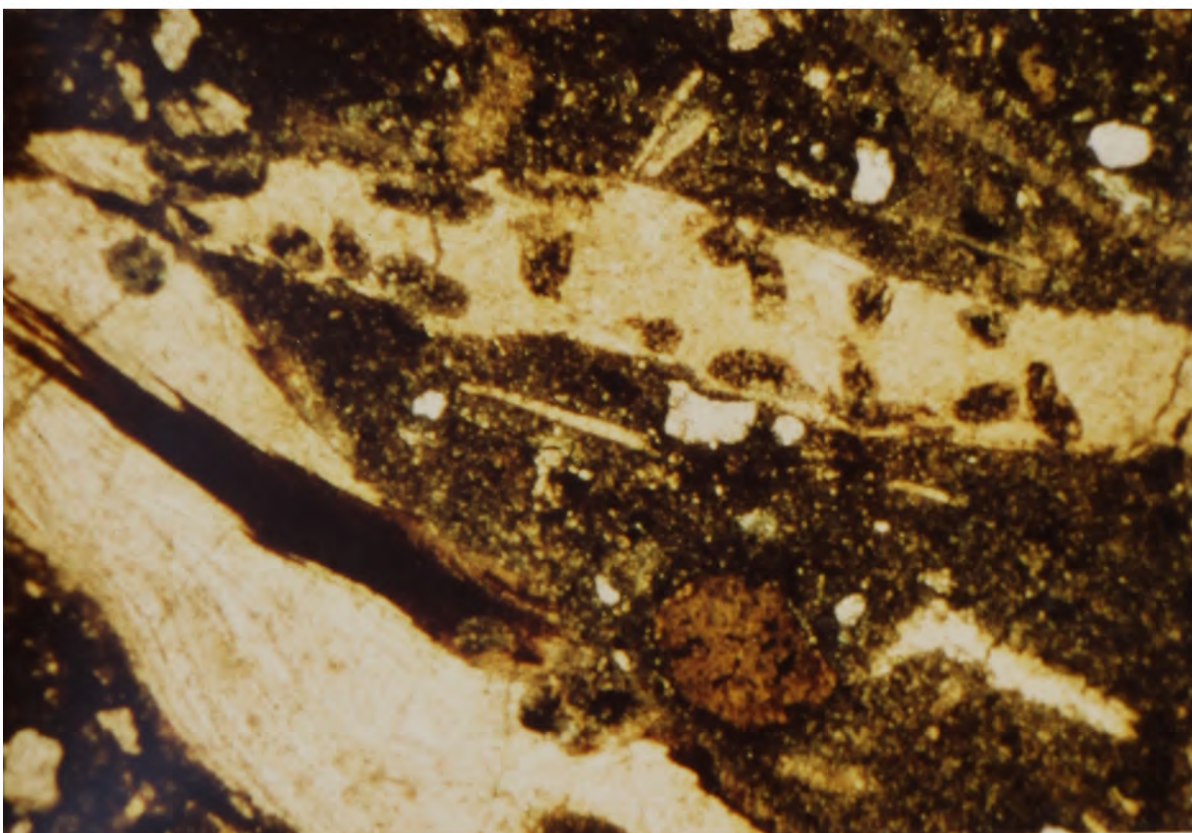
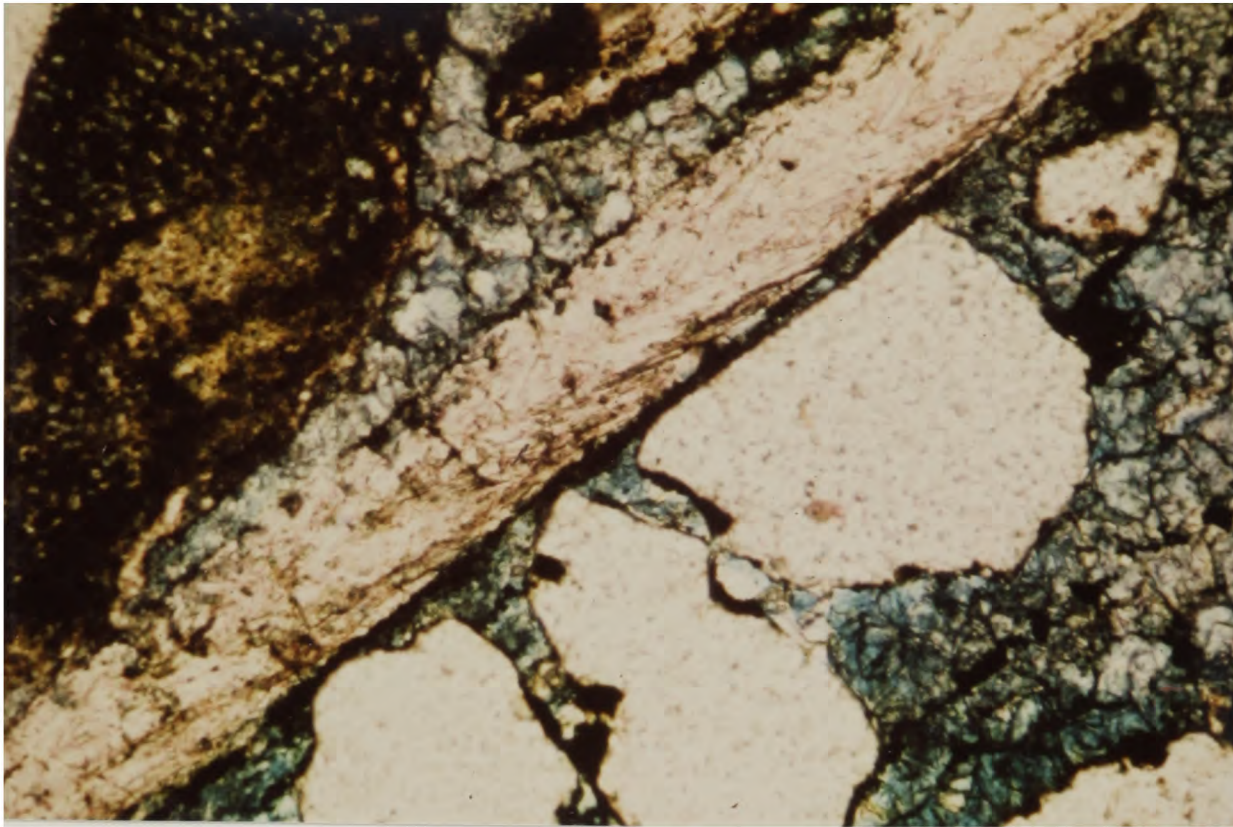


Plate 6.60 f. Gastropod test infilled with goethitized substance containing other oolite and with geopetal structure. Facies 14, Ob Breakish, Skye.
x 25.

Plate 6.60 g. As 6.60 f, with quartz wedge. Note "chamosite" flake alignment seen for the oolite within the gastropod test.
x 25.

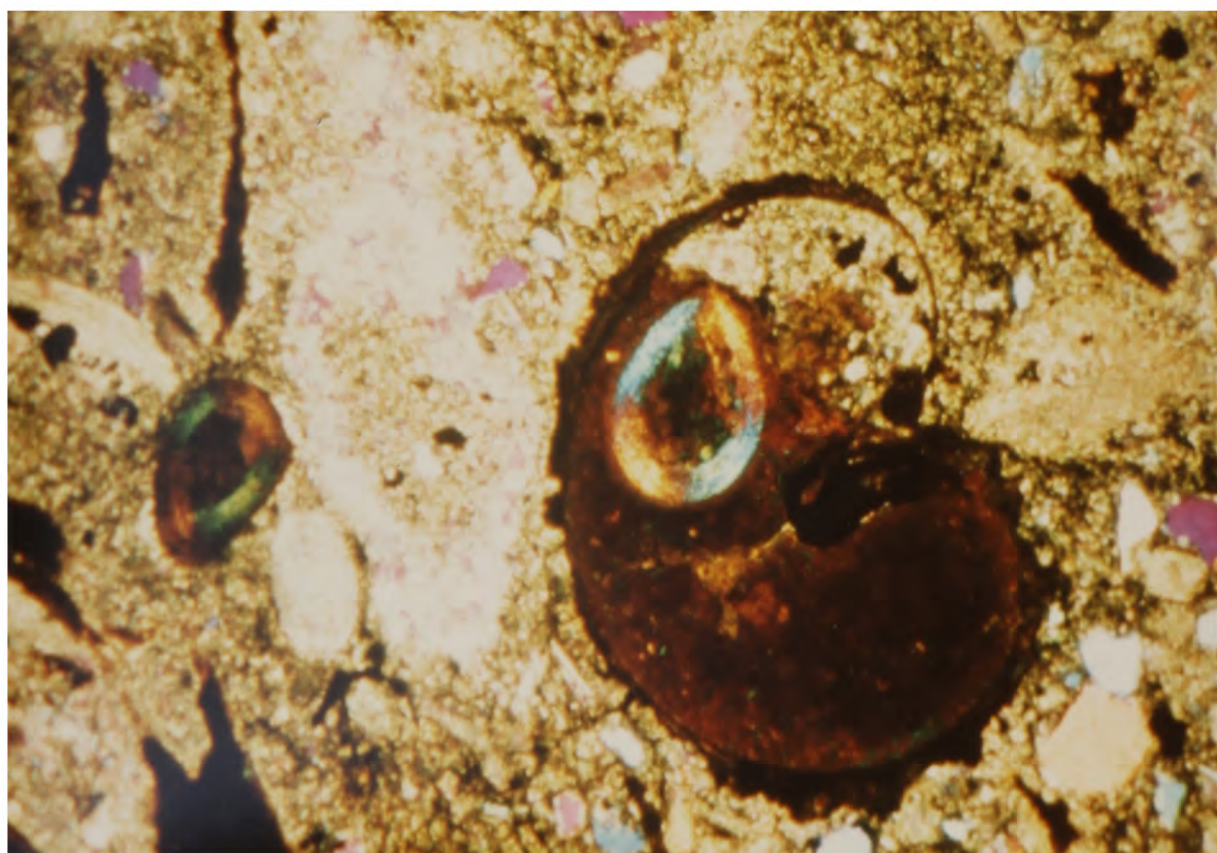
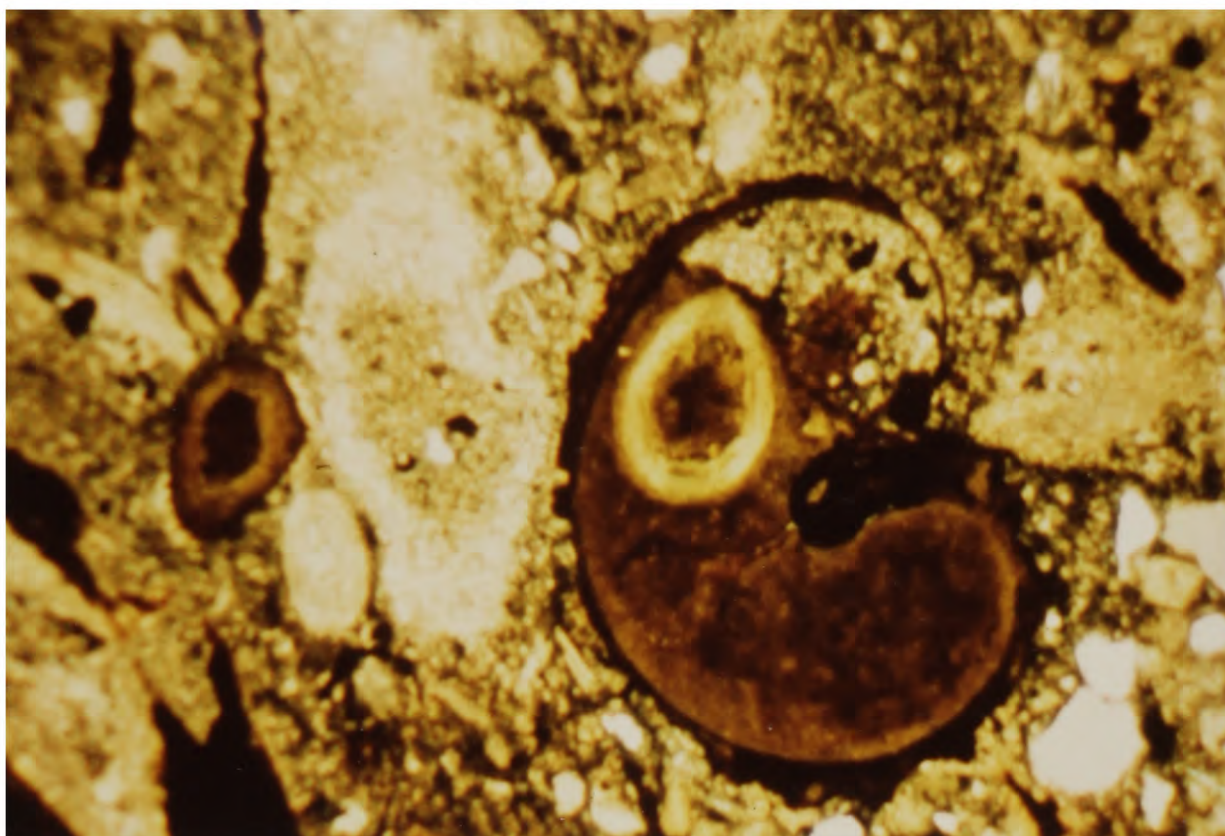


Plate 6.61. Basal beds of Facies 15 in Loch Eishort showing well defined but transitionally occurring calcareous siltstones and micaceous shales . Loch Eishort, Southern Strath.

Plate 6.62 a. Beds at the top of the Upper Teampull Chaon Shale Member. Note the transitional contacts together with goethitized horizontal and vertical burrow features.



Plate 6.62 b. Extensively bioturbated beds showing no internal sedimentary structures. Upper Teampull Chaon Shale Member, Loch Eishort, Skye.

Plate 6.62 c. Silty micaceous limestone of Facies 15 and 16 (Upper Teampull Chaon Shale Member of southern Strath).
x 25.

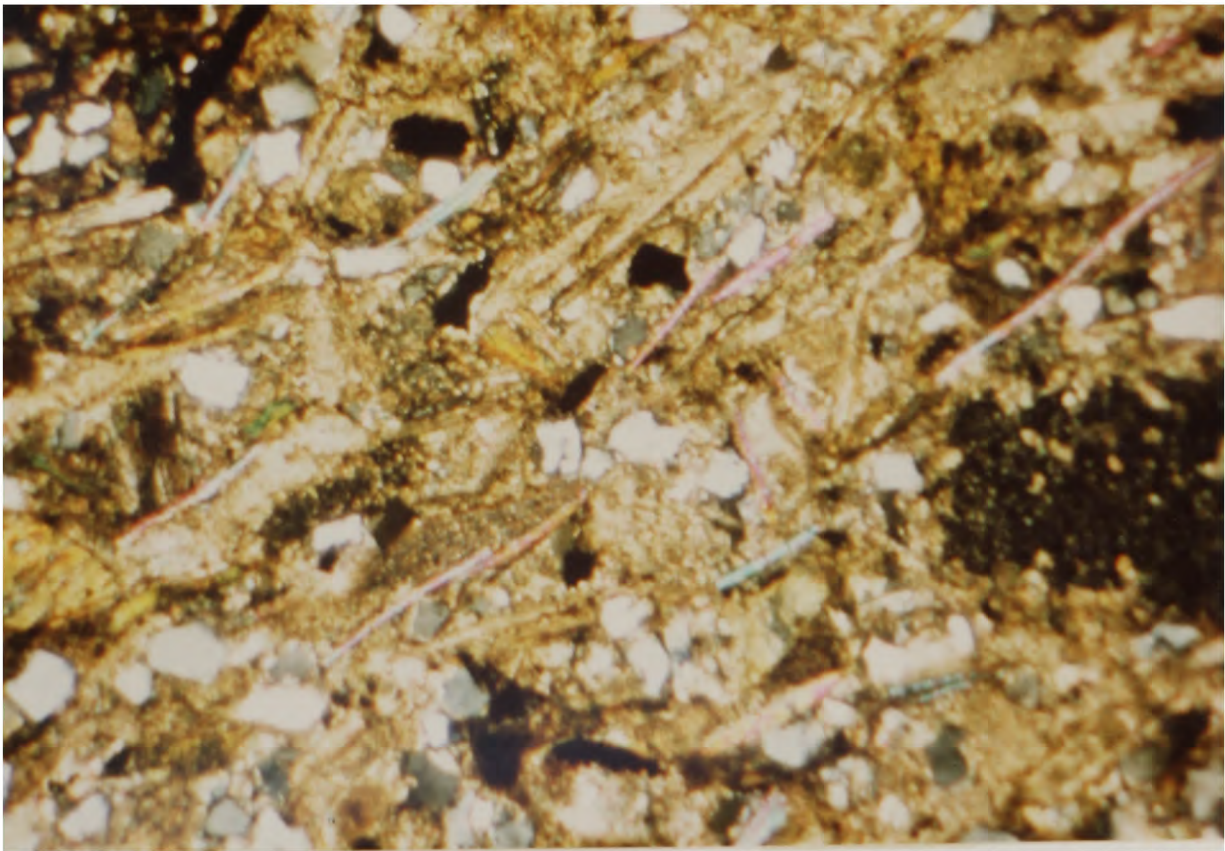


Plate 6.63 a. Annelid worm tubes (cf. Serpula (cycloserpula) socialis Goldfuss). Found in the coarser Members of the Upper Teampull Chaon Member, Loch Eishort, Skye. Note some tubes are infilled by the calcareous sideritic cement.

X 25

Plate 6.63 b. As 6.63 a, in plan view.

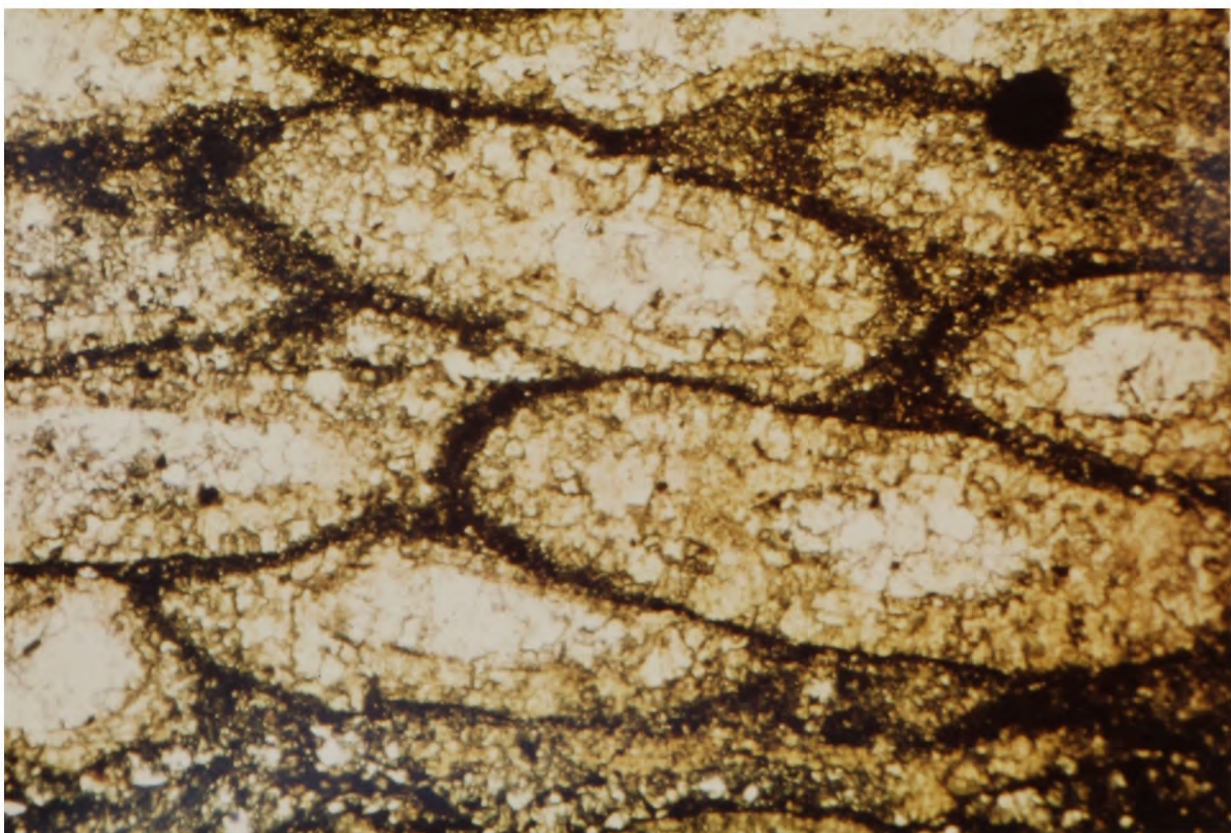
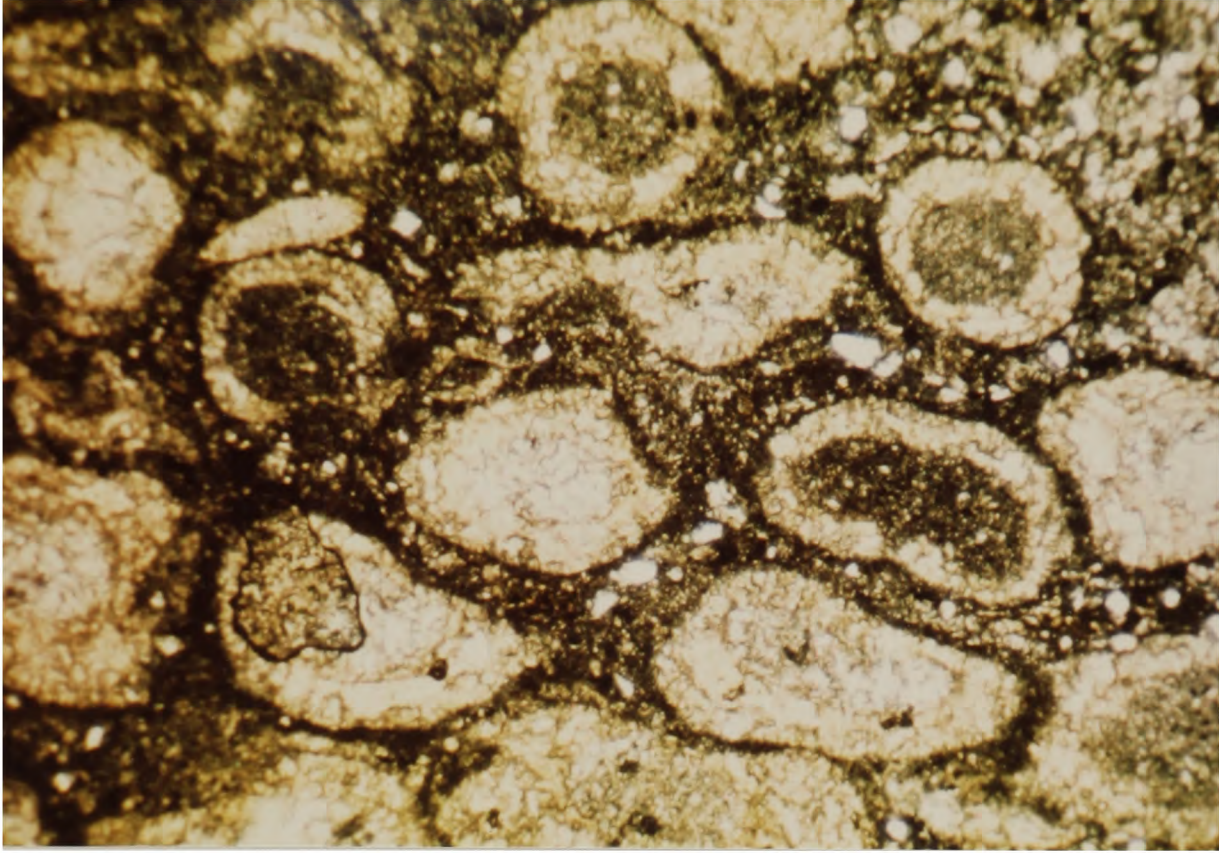


Plate 6.64 . Pinna in life position and small, phosphate-replaced Kulindrichnus langi on the top surfaces of the coarser beds of Facies 15, Upper Teampull Chaon Shale Member, Loch Eishort.

Plate 6.65 . Silty micaceous shales of Facies 15 showing phosphate-replaced horizontal, semi-conical features radiating out from a semi spherical feature.
1 penny piece for scale.



Plate 6.66 . Top surface of the silty calcareous beds of facies
15. In Loch Eishort, showing phosphate-replaced
Thalassinoides burrow.

Plate 6.67 . Top most beds of Facies 15 in Loch Eishort, Skye,
showing phosphatic nodules.



Plate 6.68 . Calcareous sandstone/shale repetitions at the base of Facies 15 in Rubha nan Leac, Raasay. Note the asymmetric development of beds. Gryphaea occurs in the calcareous bed and in general the thickness of calcareous sandstone decreases towards the top of the unit.



Plate 6.69. Phosphatic nodules forming discrete bands at the upper parts of the Upper Teampull Chaon Shale Member. Rubha nan Leac (Hallaig Waterfall), Raasay.

Plate 6.70.a. Calcareous ferruginous sandstone of Facies 16a with calcareous cement and thin ferruginous coating on the grains which are mostly normal quartz with microcline feldspars, glauconite pellets and lithic fragments are also present. Loch Eishort, Skye.
x 125.

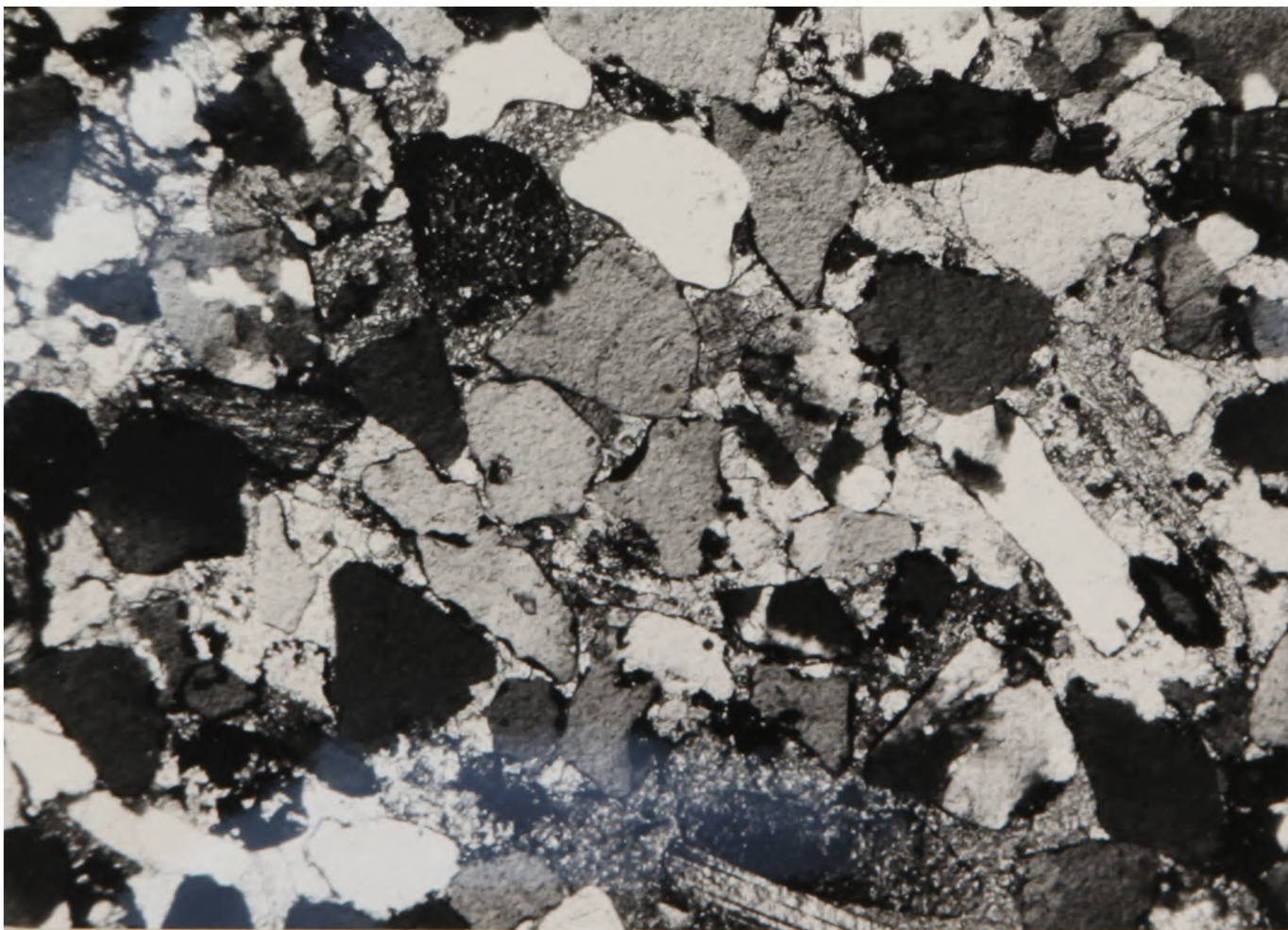


Plate 6. 10.b. Mud pellet showing definite
cellular internal features (?algal).
x 50.

Plate 6.11.a. Chondrites together with other vertical and
horizontal burrowers (?Siphonites) found in the lower and
most beds of Facies 16a in Loch Eishort, Skye.
1 penny piece for scale.

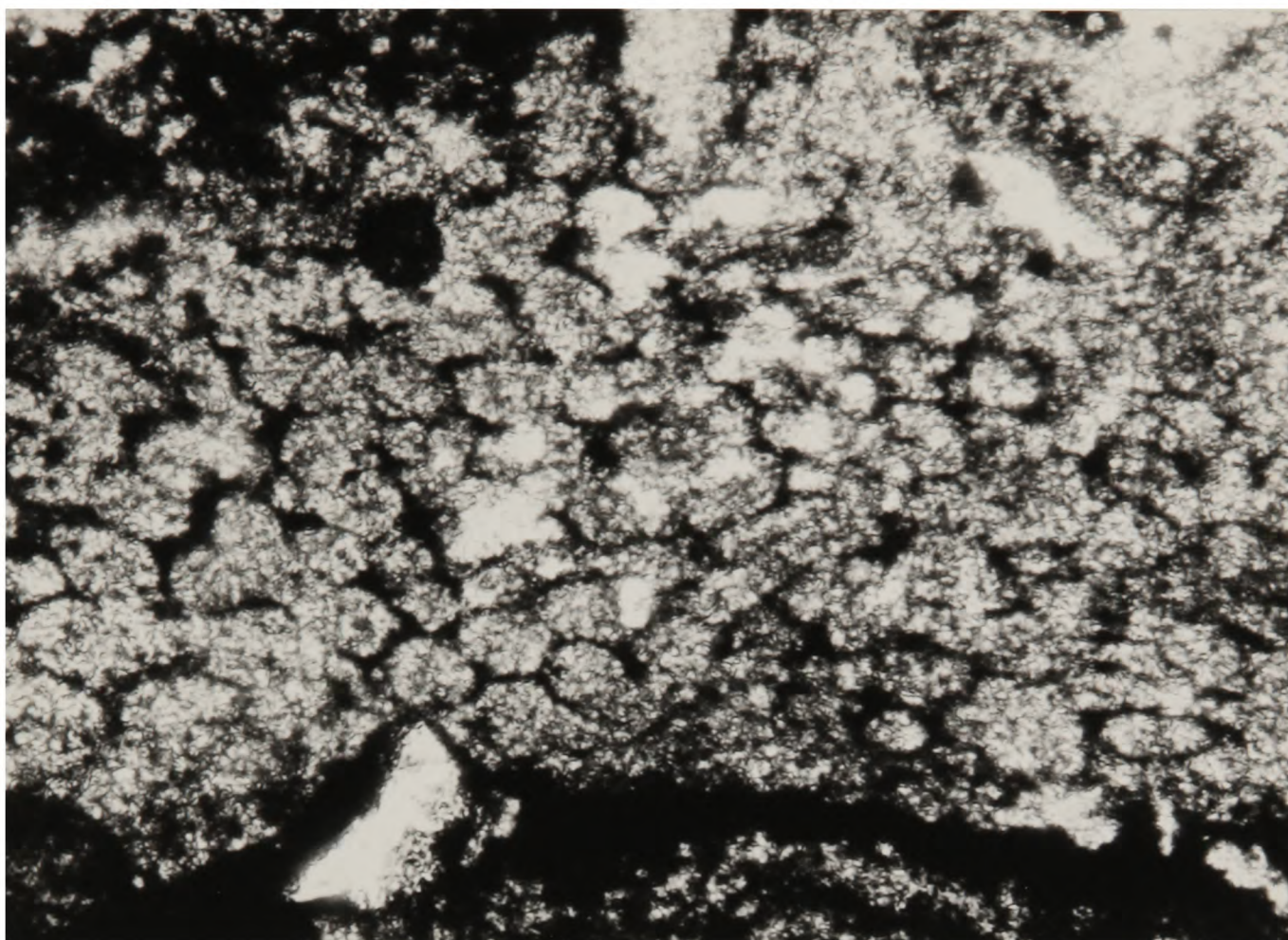


Plate 6. 71.b. Gyrocorde-like markings on top of a sample
obtained from Facies 16a, Loch Eishort, Skye.
Scale = 6 cm.

Plate 6. 71.c. Low Angle cross laminae with tangential bases,
Facies 16a, upper medium bedded unit, Loch Eishort, Skye.



Plate 6. 72. Broad lenticular well indurated, purplish sandstone lenses, some with convex-upward tops and flat bases. Note some lenses form small convex downward bases; flat tops are also common. Facies 17a, Loch Eishort, Skye.



Plate 6. 73. Collapsed phosphatic pebble with banding and fibre texture in the beds of Facies 17a, note echinoderm spine.
x 4.

Plate 6. 74. Ferruginous pellets and silicified shell fragments in sandy limestones of Facies 17a, Loch Eishort, Skye.
Cf. 6. 73 and note echinoid spines and higher mud pellet content together with thick grain coatings.
x 25.

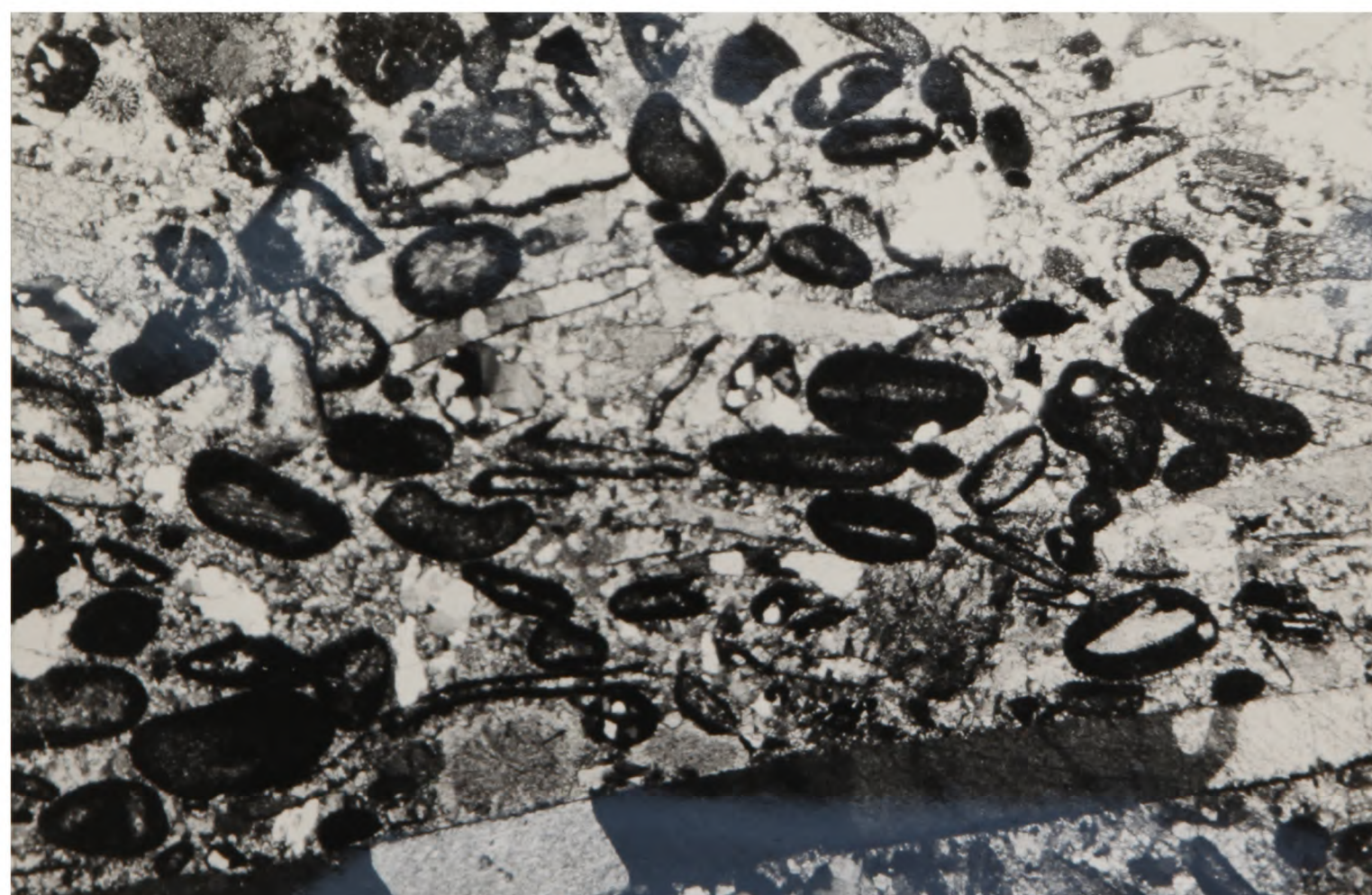
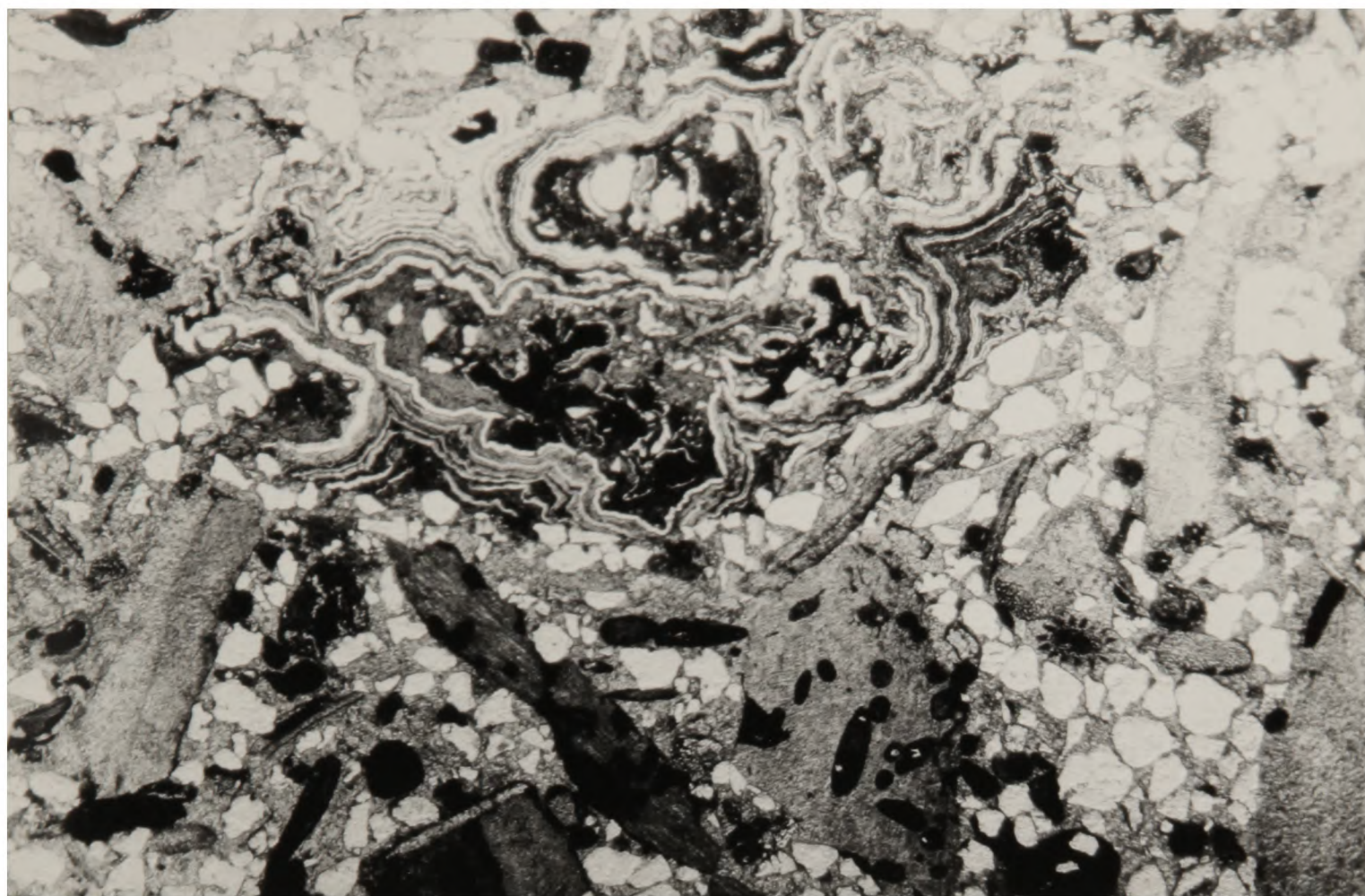


Plate 6.75 Beds of Facies 17^b in Raasay (Rubha nan Leac).



Plate 6.76a Large lenticular calcareous (fine) sandstone
beds showing abrupt (?erosive) contacts with the under-
lying beds. Facies 18a, Loch Eishort, Skye.

Plate 6.76b Lower part of the lenticular, cross laminated beds
of Facies 18a in Loch Eishort, Skye.



Plate 6.77 . Topmost beds of Facies 17b, basal (basal Facies 18b) micaceous calcareous siltstone, extensively burrowed by vertical and horizontal siphonites. Rubha nan Leac, Raasay.

Plate 6.78 Calcareous siltstones and ferruginous shale coarsening upward cycles in the beds of Facies 18b (Raasay):



Plate 6.79 Burrows on top of a sandy ferruginous bed
developed in the beds of Facies 18b within the ferruginous
shales, note the (lengthened) Rhizocorallium-like feature.
Rubha nan Leac, Raasay.



Plate 6.80 . Quartz-free calcilutites alternating with Gryphaea-
bearing shales (Strath Formation) in Suisnish, Raasay.



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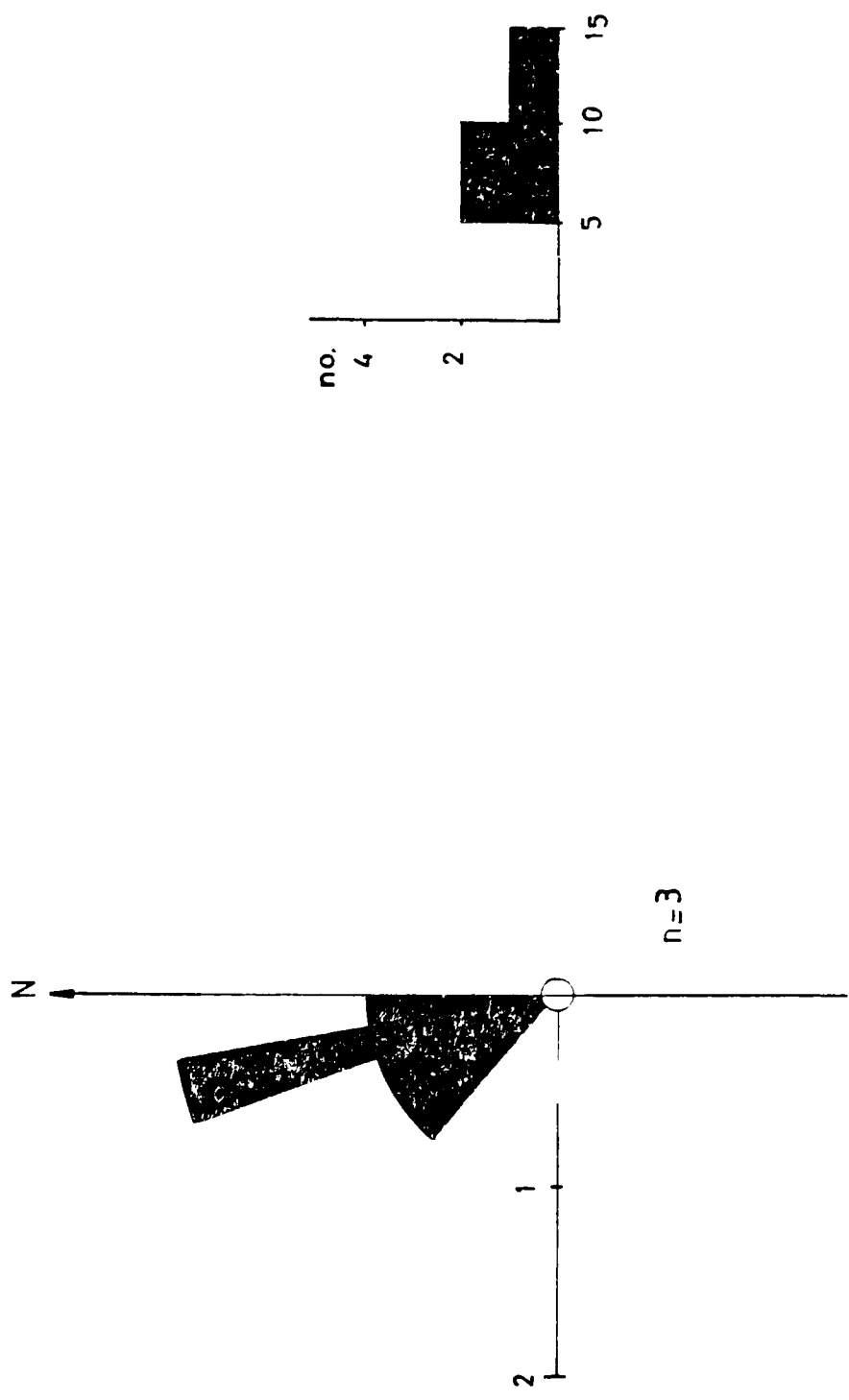


Fig.7.1
Palaeocurrent data obtained from the Breugh Pebble Member in Ardnamurchan (NM 708534),
(Mingary Castle).

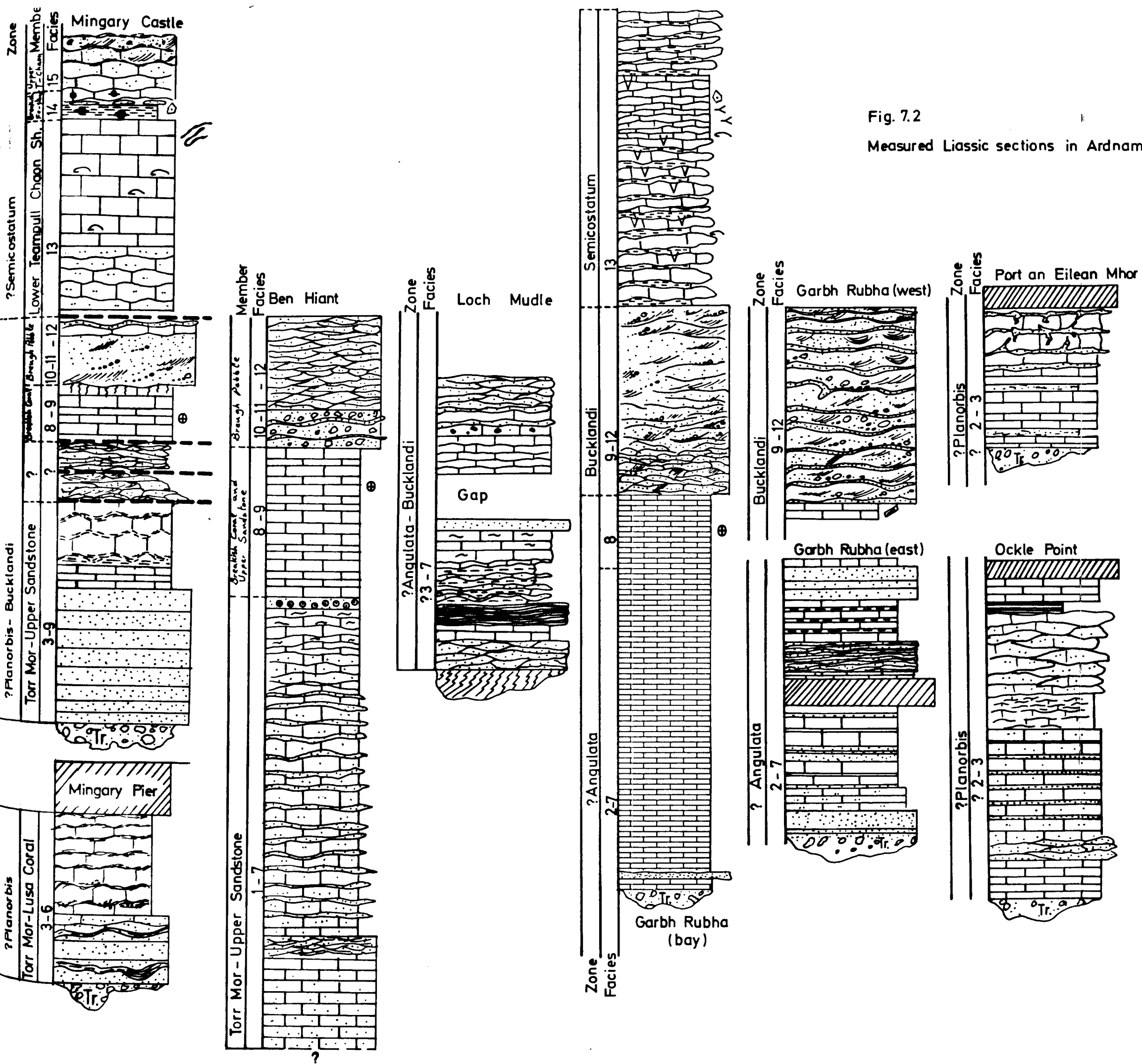


Fig. 7.2

Measured Liassic sections in Ardnamurchan (see text for grid references).

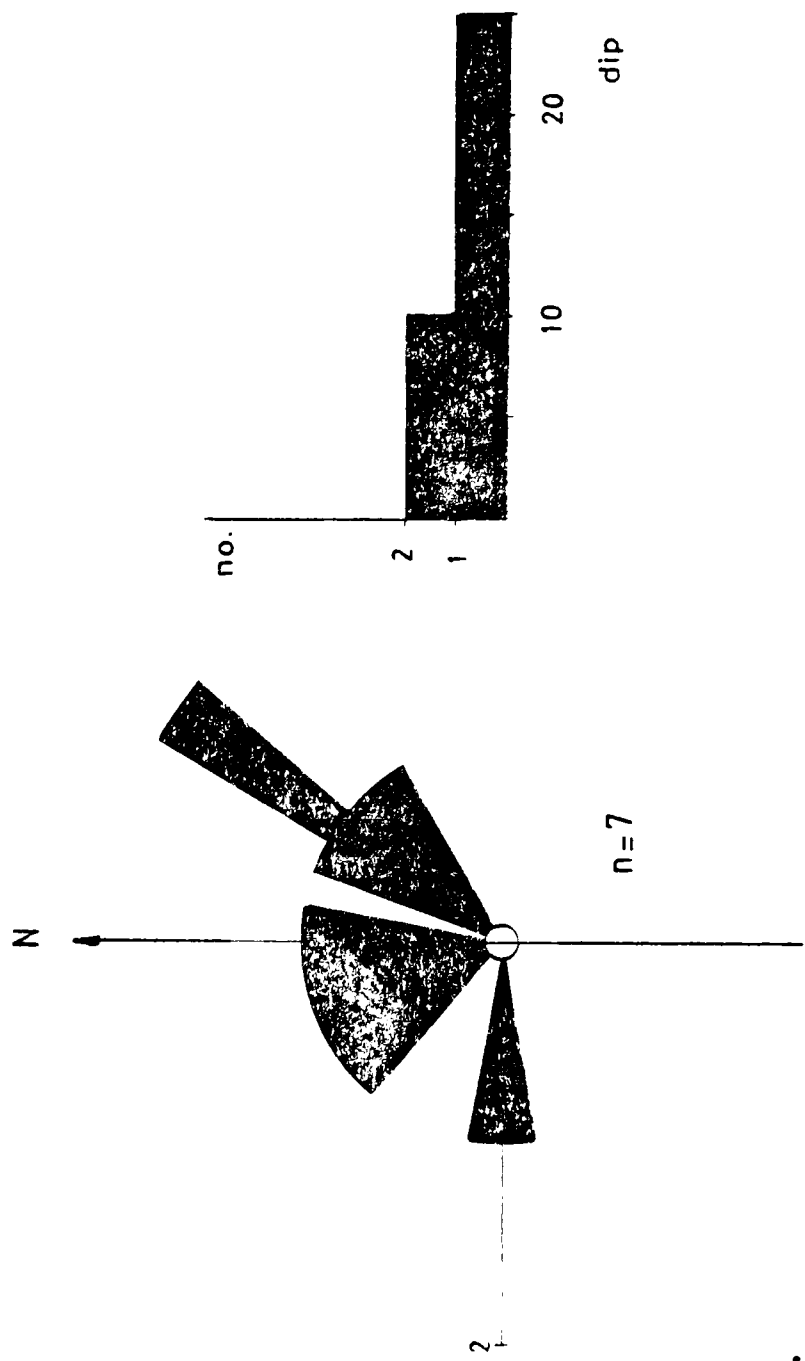


Fig.7.3
Palaeocurrent data obtained from the Breugh Pebble Member in Ardnamurchan (NM 708534),
(Garbh Rubha bay).

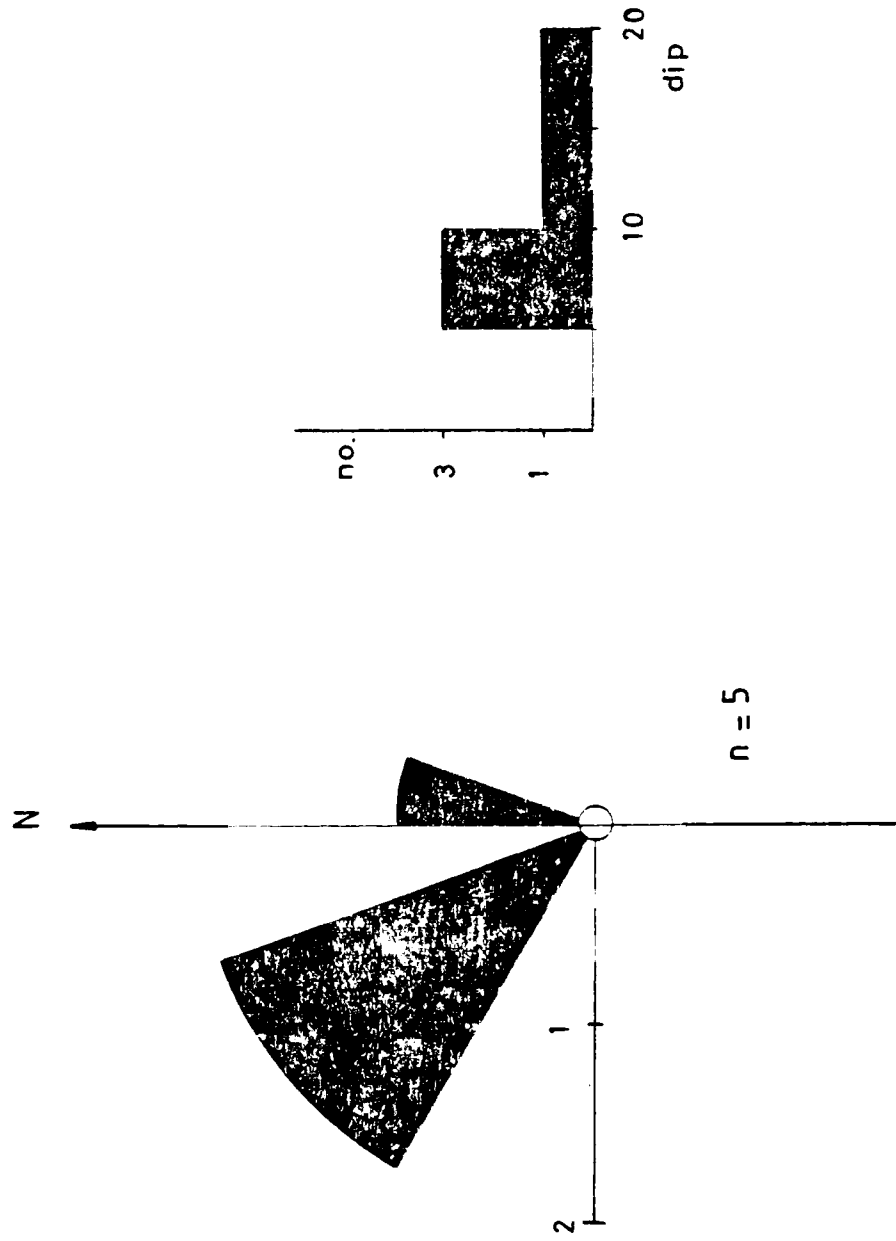


Fig. 7.4
 Palaeocurrent data obtained from the ?Breugh Pebble Member in Ardnamurchan (NM 709530),
 (west of Garbh Rubha bay).

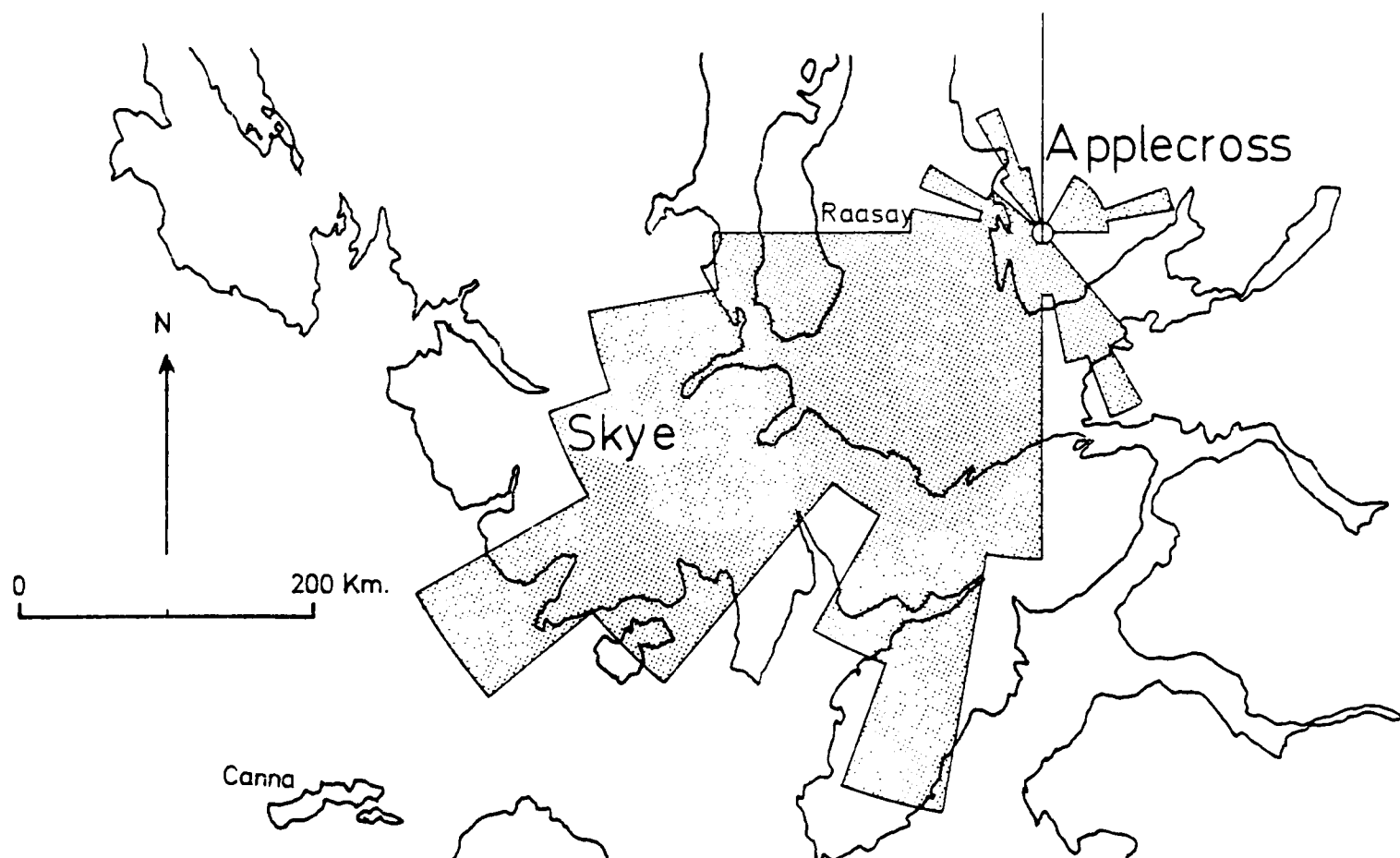


Fig.7.5

Palaeocurrent data obtained from the Breugh Pebble Member, facies 11, 12.

Plate 7.1. Blue micritic limestone beds at the base of the Liassic succession at Mingary Pier, Ardnamurchan, interbedded with pebbly calcareous shale. Note the erosive contact and upward incomplete grading.



Plate 7.2. Cross laminated calcareous sandstone erosively overlying limestones, note pebbles at the base and wavy bedding towards the top. Ardnamurchan, Mingary Castle.

Plate 7.3. Wavy cross laminated and disturbed cross laminae towards the top of the beds shown in Plate 7.2 , note lack of pebbles and wavy top surface.



Plate 7.4.a. Echinodermal silty shale (packstone) Semicostatum
Zone beds Mingary Castle Ardnamurchan.
x 20.

Plate 7.4.b. Photomicrograph of the beds overlying those shown
in plate 7.4a. (Echinodermal packstone) note larger shell
fragments and syntaxial rim around most. Note prismatic
shell structure of Pinna shell fragments and Echinoid
spines with radial pore structure.
x 20.

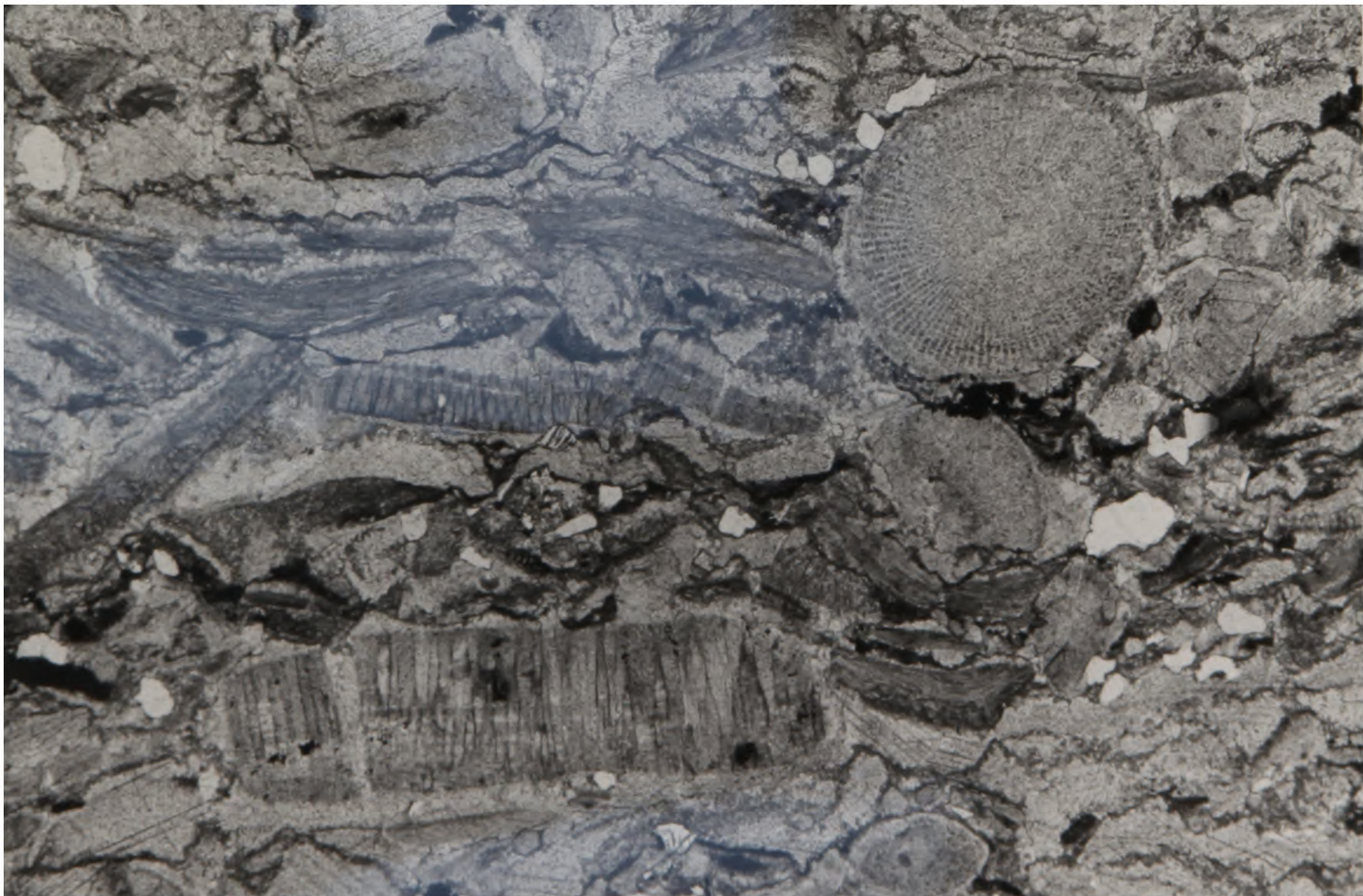


Plate 7.5. Ferruginous oolitic bed found in the Sauzeanum Subzone of Mingary Castle, Ardnamurchan. Note large echinoid plate with its oolitic rim. Elongate ooliths and round ooliths with tangential arrangement of the oolitic laminae (?Chlorite flakes showing the characteristic extinction brush under + nicols.

x 50

Plate 7.6. Slender, branching. Thecosmilia individuals in fine grained calcilutite beds found at Garbh Rubha (Ardnamurchan.
(Facies 8).

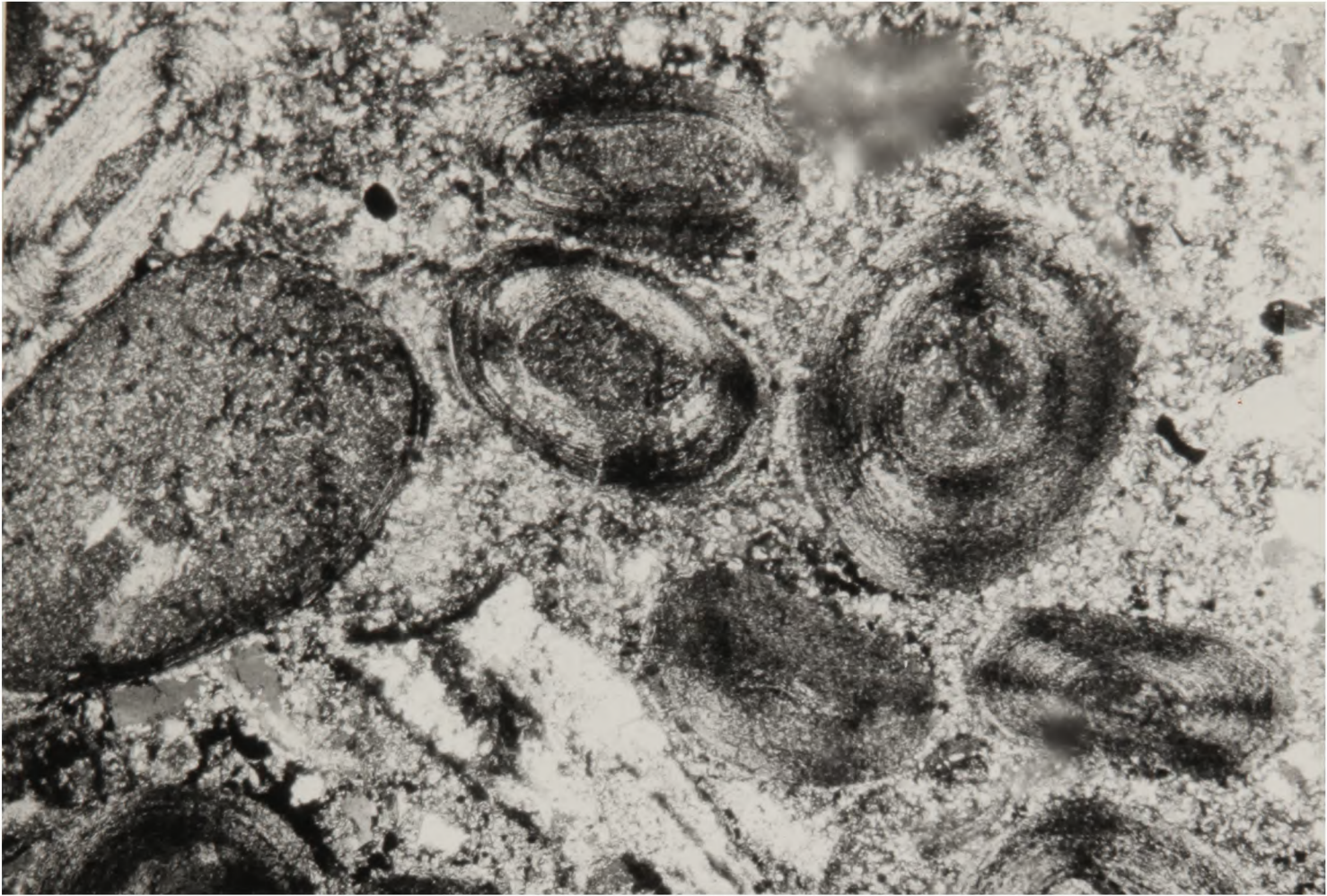


Plate 7.7. Calcilutite beds with Thecosmilia martini showing three distinct types of beds (see text) at Garbh Rubha, Ardnamurchan. CF. beds of the Breakish Coral Member in Applecross (Facies 8), note wavy contacts of beds and lack of shale interbeddings.

Plate 7.8. Crossbedded poorly sorted pebbly calcareous sandstone succeeding the sandstone which overlies the micritic limestone with Thecosmilia in Garbh Rubha Bay, Ardnamurchan. CF. Plate 7.2 and the beds of the Breugh Pebble Member of Applecross.



Plate 7.9. Sandy biomicrosparites interbedded with silty shales with uneven contacts; these overlie the Pebble beds shown in Plate 7.8. Note lack of pebbles and cross lamination. Garbh Rubh, Ardnamurchan.

Plate 7.10. Silty shale bed crowded with broken , reworked fragments of shells occurring at the Corybeari/Rotiforme Subzone boundary at Garbh Rubha, Ardnamurchan.



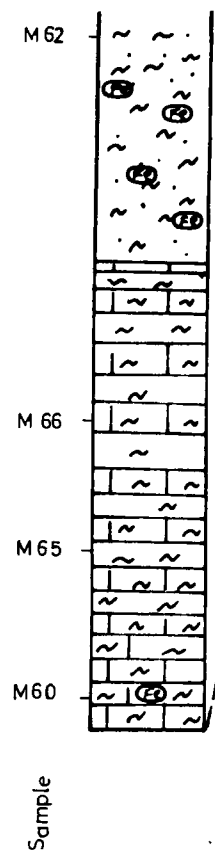
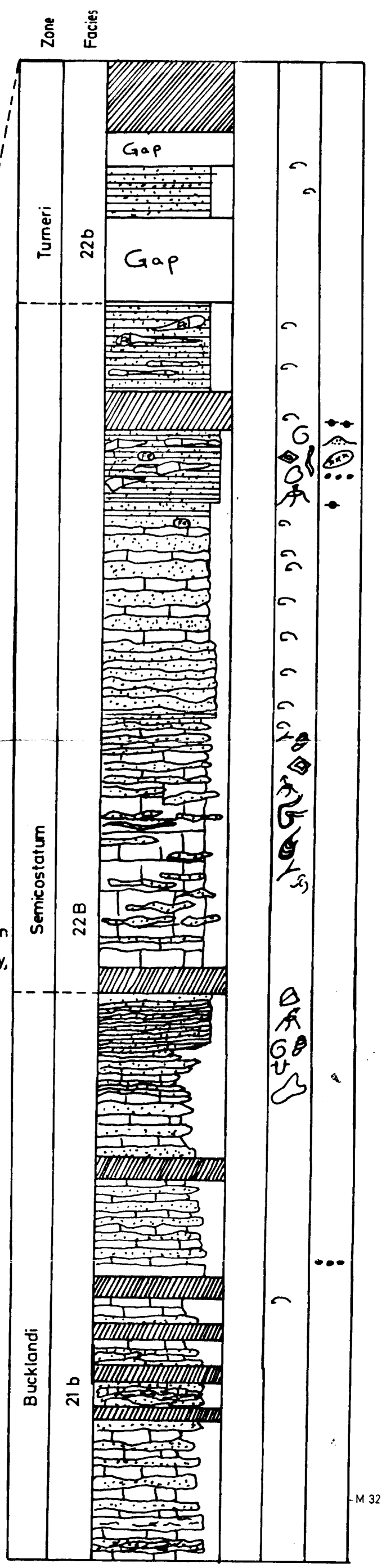


Fig. 8.1
Liassic succession
at Craignure Bay,
Mull.



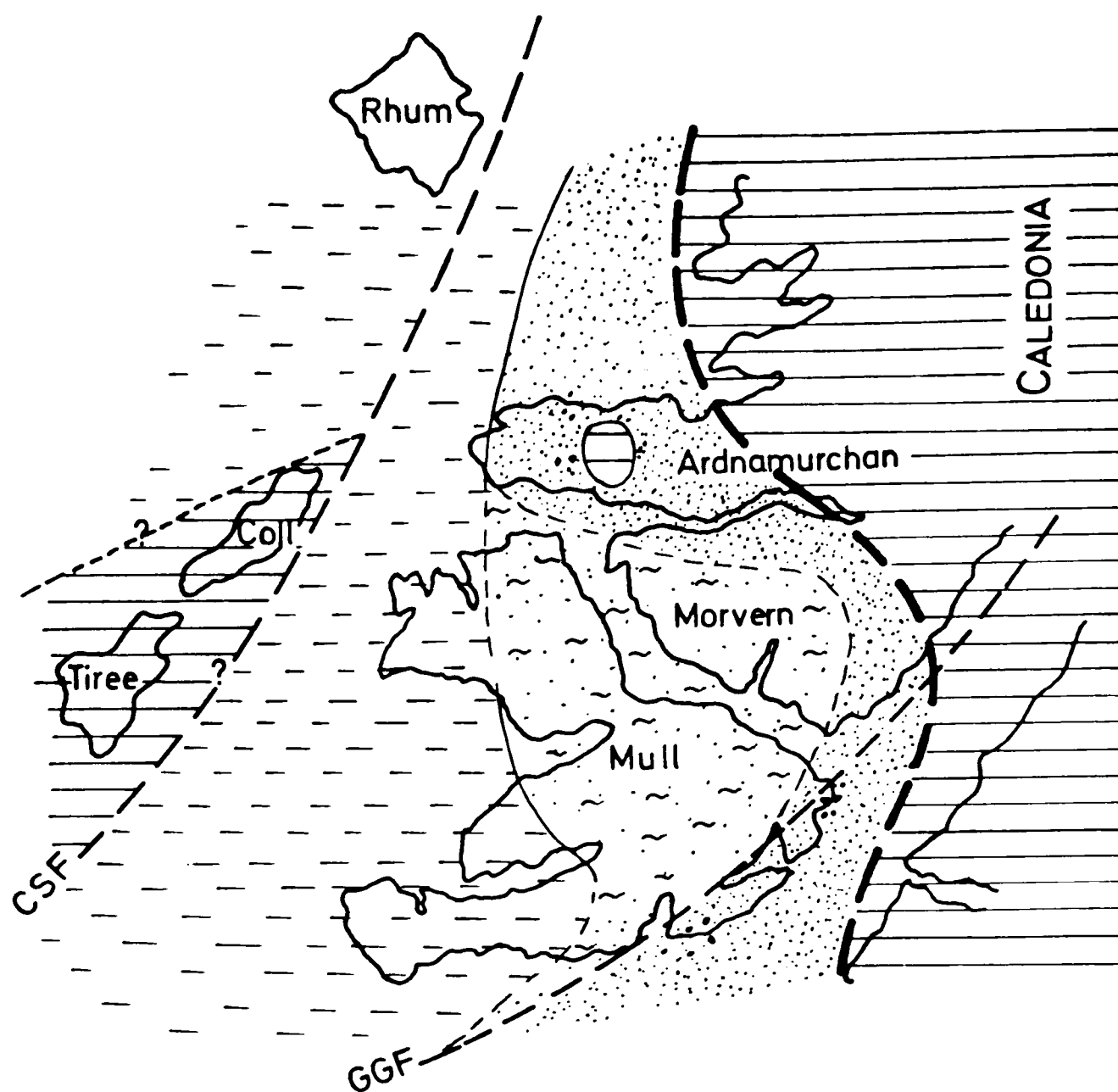


Fig.8.2

Facies distribution in the southern area of study during the Planorbis-Angulata Zones (Facies I9). The symbols are explained in Table12.1.

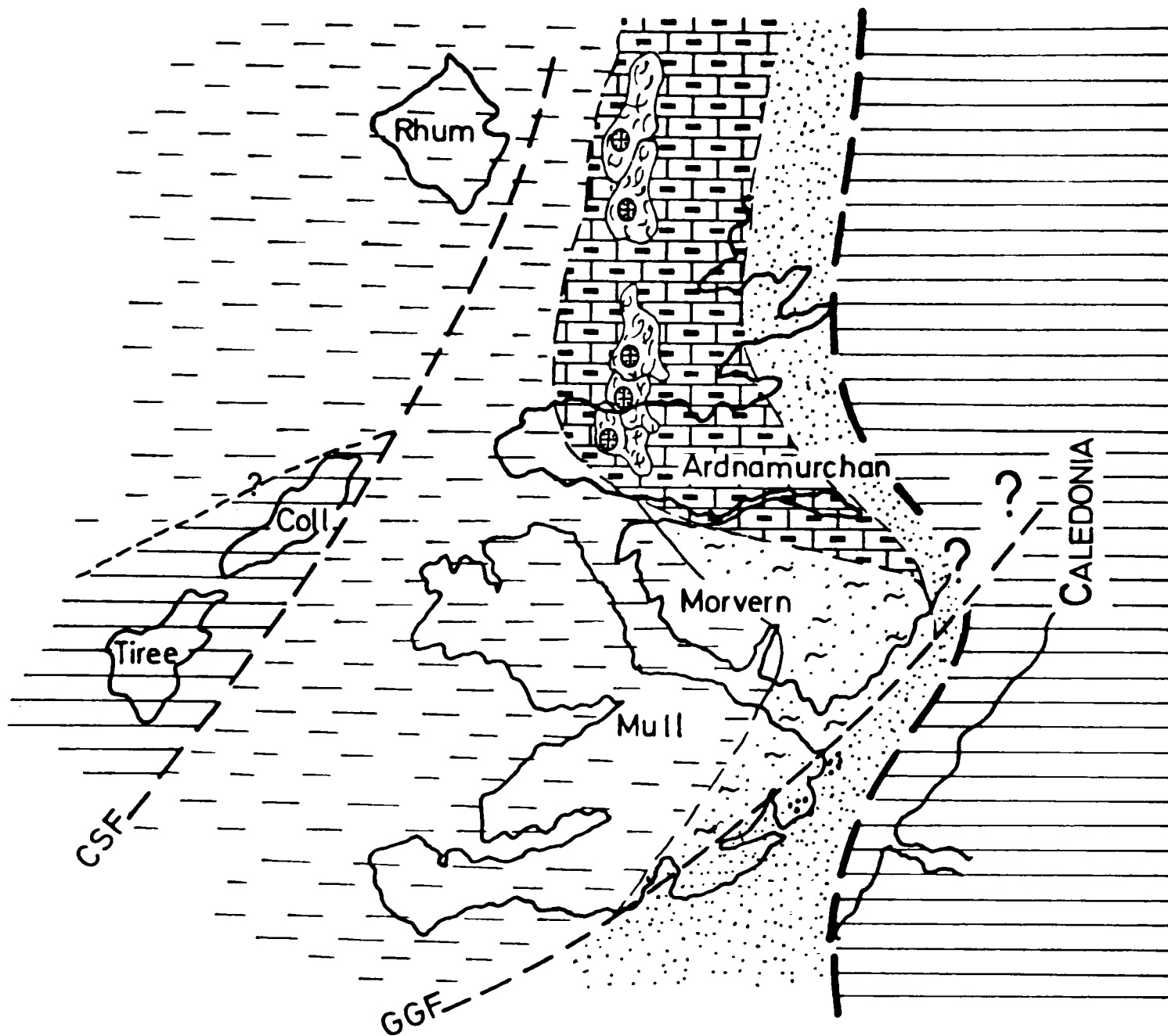


Fig. 8.3
Facies distribution in the southern area of study during the Angulata Zone (Facies 20). The symbols are explained in Table 12.1

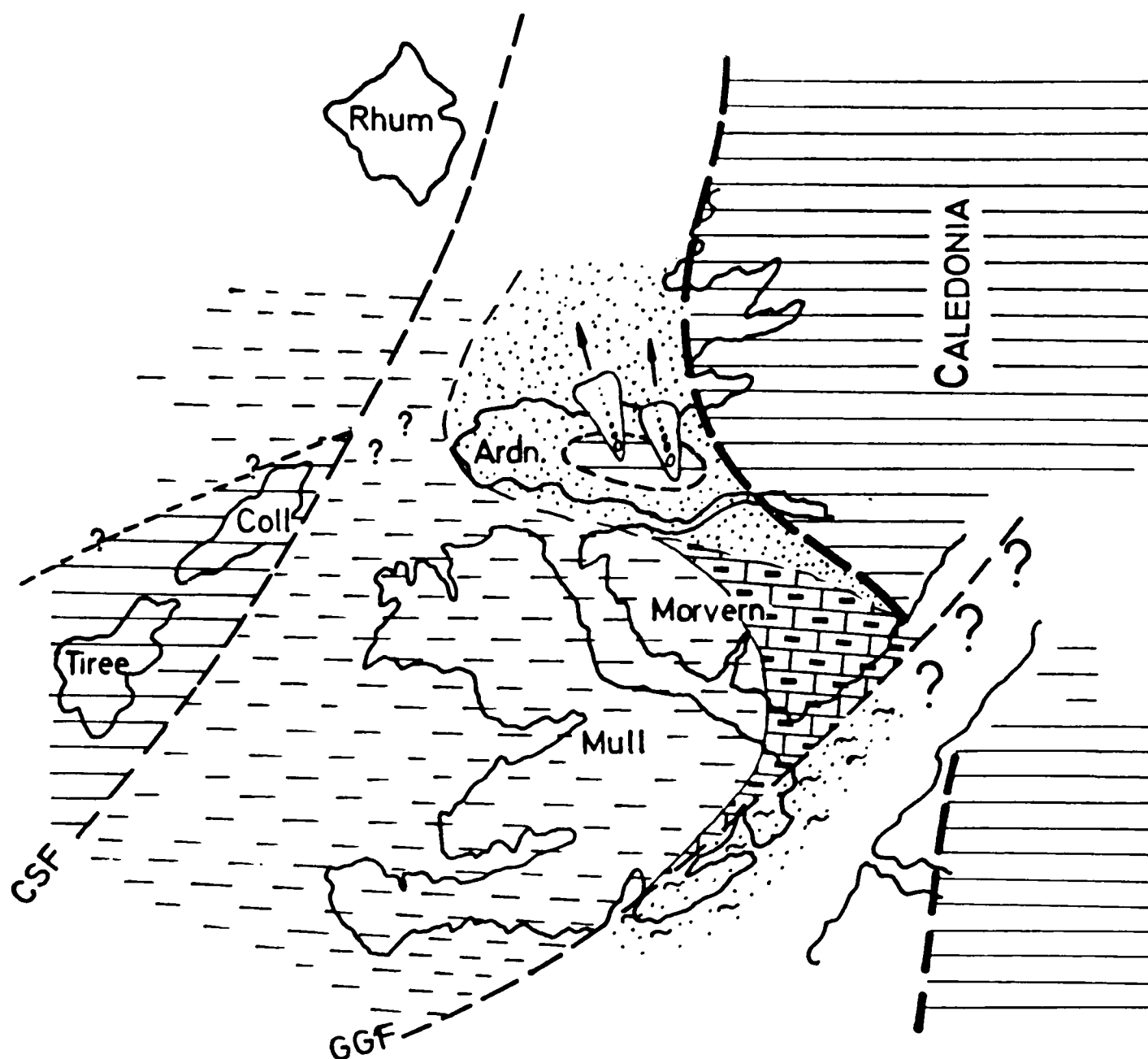


Fig. 8.4

Facies distribution in the southern area of study during the Bucklandi Zone (Facies 2Ia & 2Ib). The symbols are explained in Table 12.1

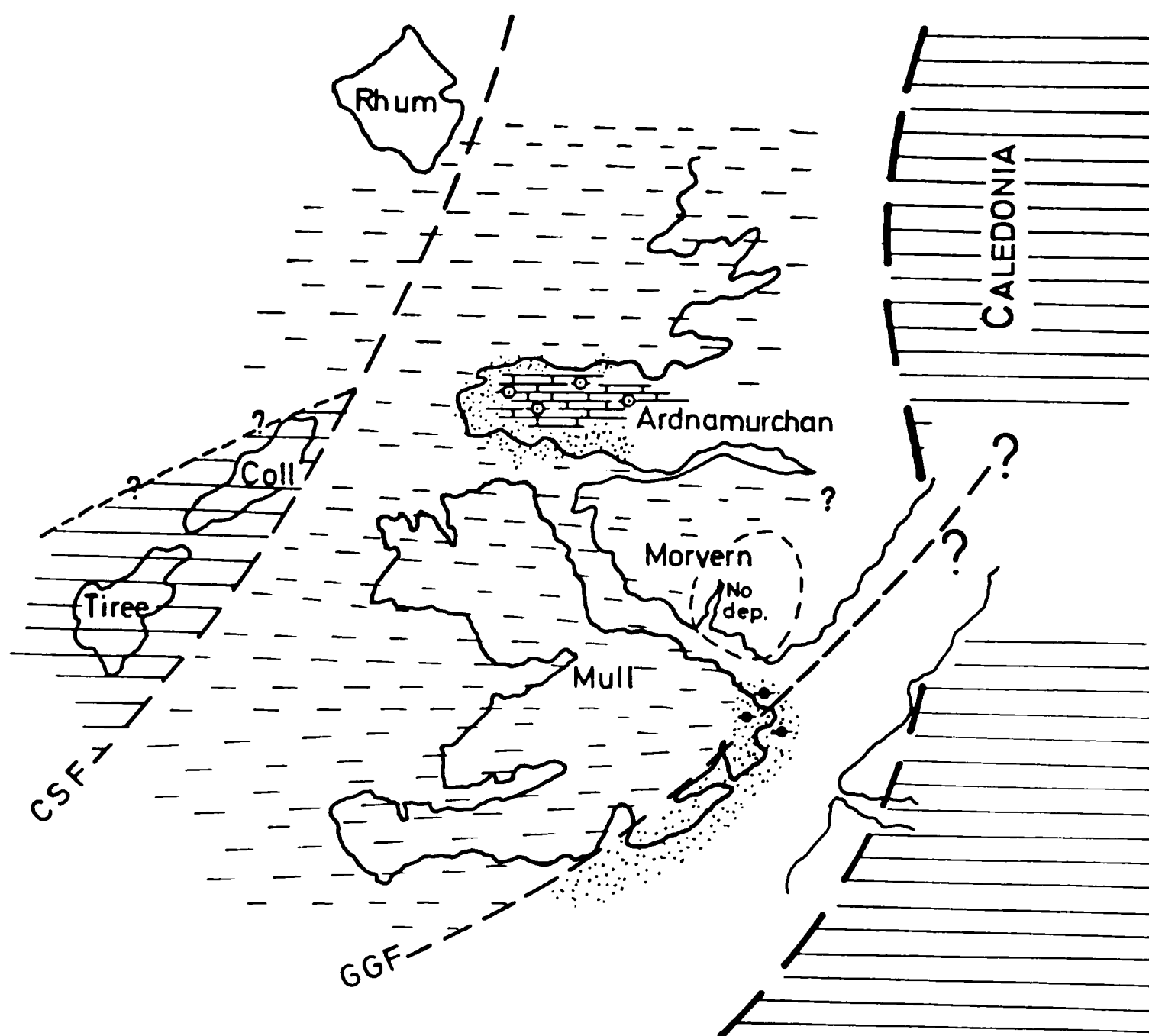


Fig.8.5

Facies distribution in the southern area of study during the Semicostatum Zone (Facies22a & 22B). The symbols are explained in Table 12.1

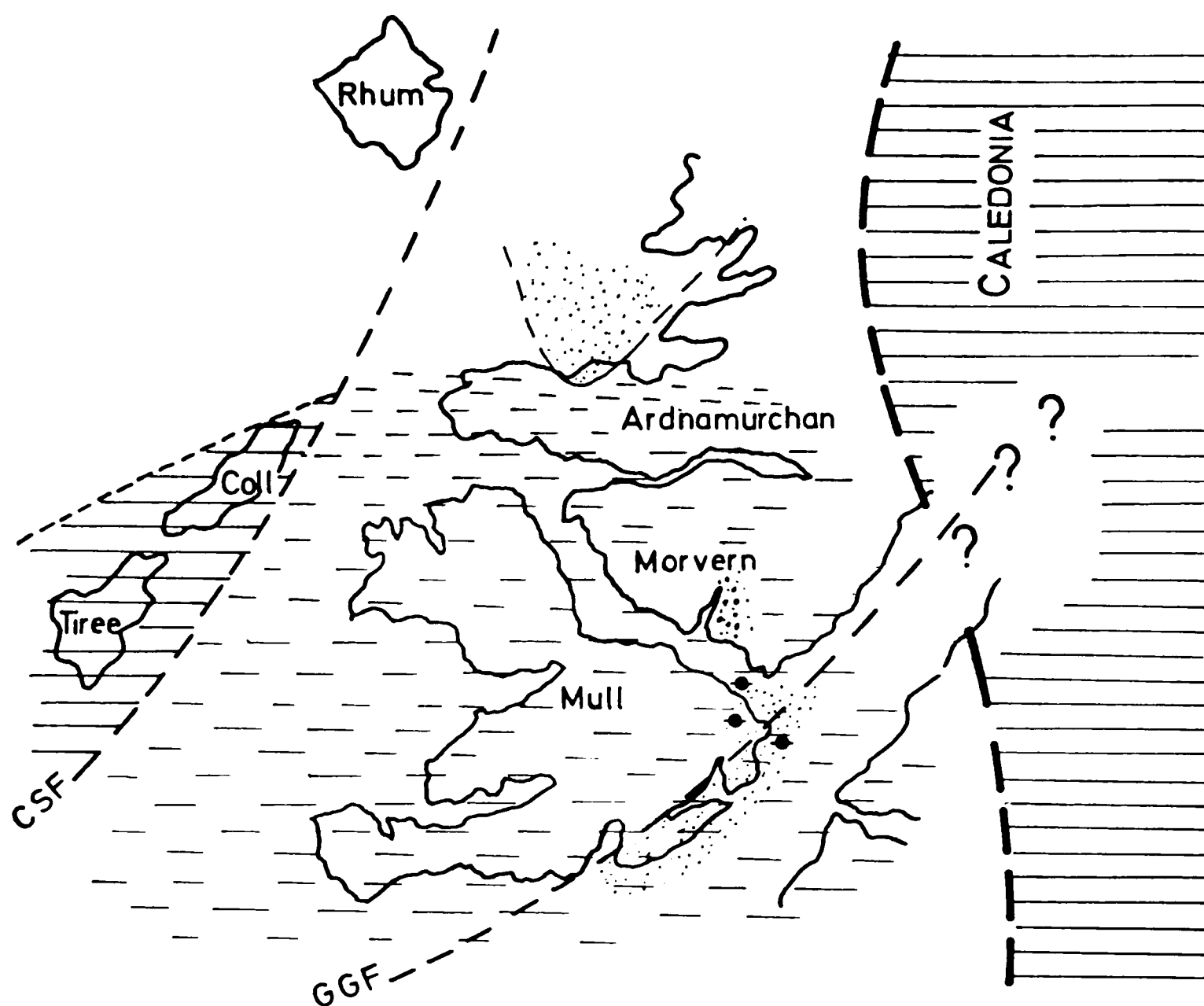


Fig.8.6

Facies distribution in the southern area of study during the Turner Zone (Facies 22b). Symbols are given in Table 12.1

Plate 8.1.a. Wilderness Shale Member consisting of alternating limestones and shales at Rubha nah' Iolaire Ardmeanach, Western Mull. Note collapse structure in lower bed (see text).

Plate 8.1.b. Well preserved specimens of Psiloceras planorbis found at the base of the Wilderness Shale Member, Western Mull.



Plate 8.2.a. Marly beds, bioturbated by shallow infaunal
burrowing e.g. normal and vertically retrusive Rhizo-
corallium Wilderness Shale Member, Mull.

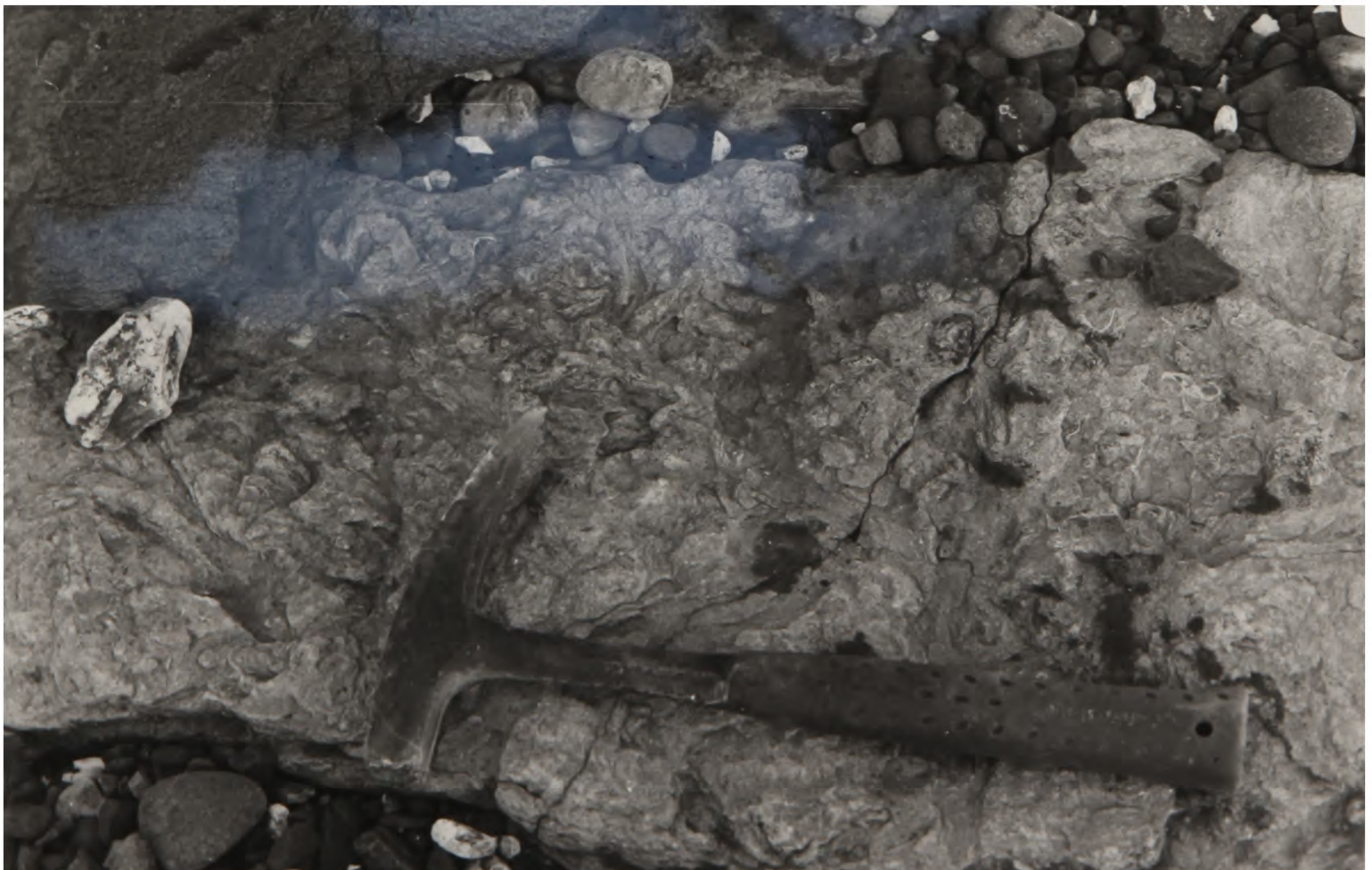


Plate 8.2.b. Vertical burrow features seen in the silty
calcareous beds of the Wilderness Shale Member, Mull.
(see Plate 8.1). Scale = 6 cm.

Plate 8.3.a. Alternating limestone and shales representing
parts of Facies 21a along Allt Leacach, Loch Aline.



Plate 8.3.b. Thin section obtained from the beds of facies 21a.

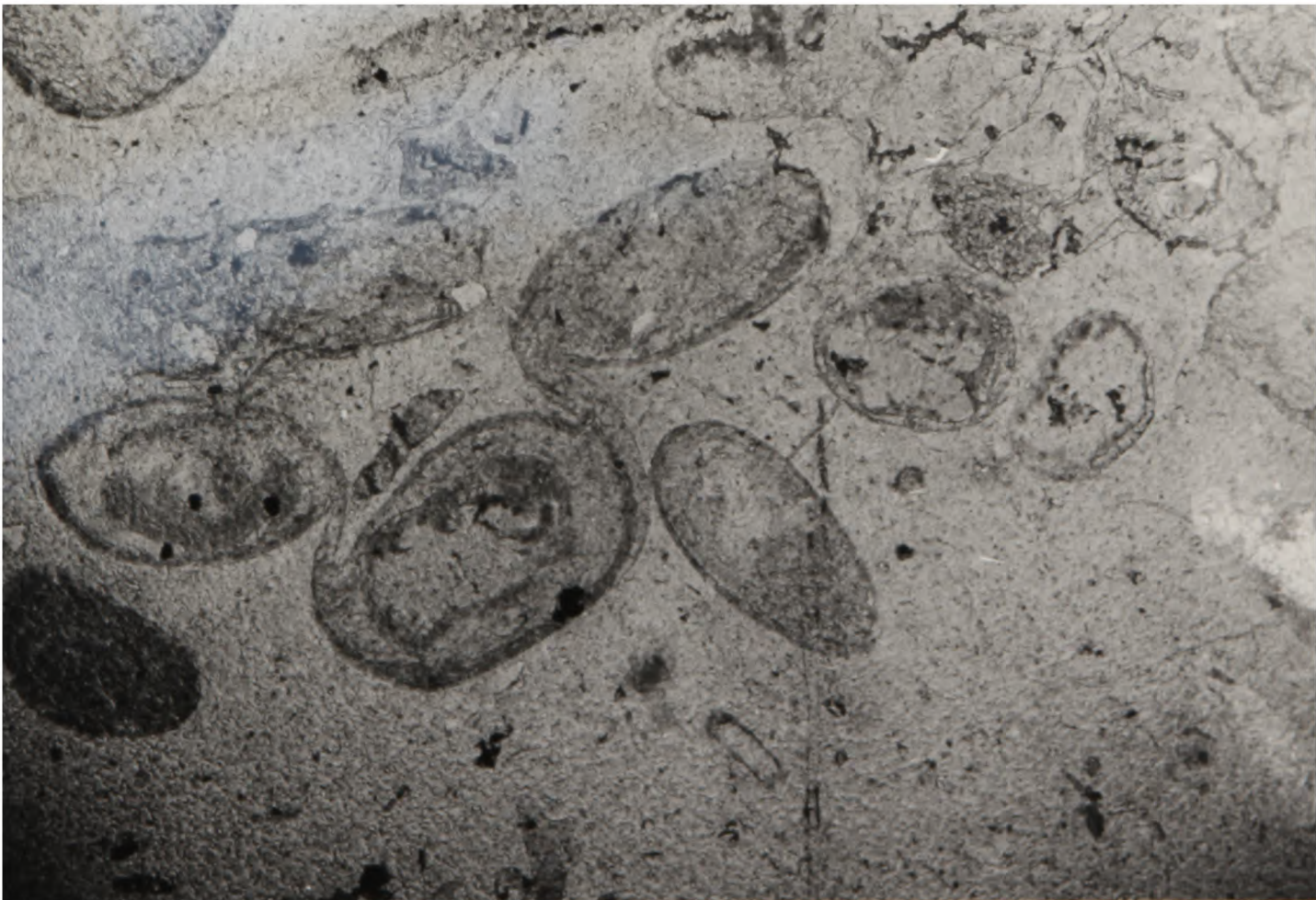
Note totally recrystallized echinoderm plates, large bivalve shell fragments and some ostracods.

x15

Plate 8.4.a. Rounded calcareous bodies in carbonate apatite cement taken from the phosphatic nodules in the Sauzeanum oolitic ferruginous bed of Mingary Castle Ardnamurchan.

Note distorted spheres and some with apophyses interconnections, also calcareous ooliths with radial structures at the bottom corner.

x 50.



Plates 8.4.b. Spherical elliptical and distorted calcareous bodies in collophane cement formed in a phosphatic nodule in the Semicostatum limestones of Loch Aline (sample provided by Dr. M.J. Oates) cf. plate 7.5 a,b,c. Note interconnecting apophyses. x 50.

Plate 8.5. Metamorphosed, thin calcareous sheets overlying pebbly calcareous sandstones (Triassic) in Craignure Bay.

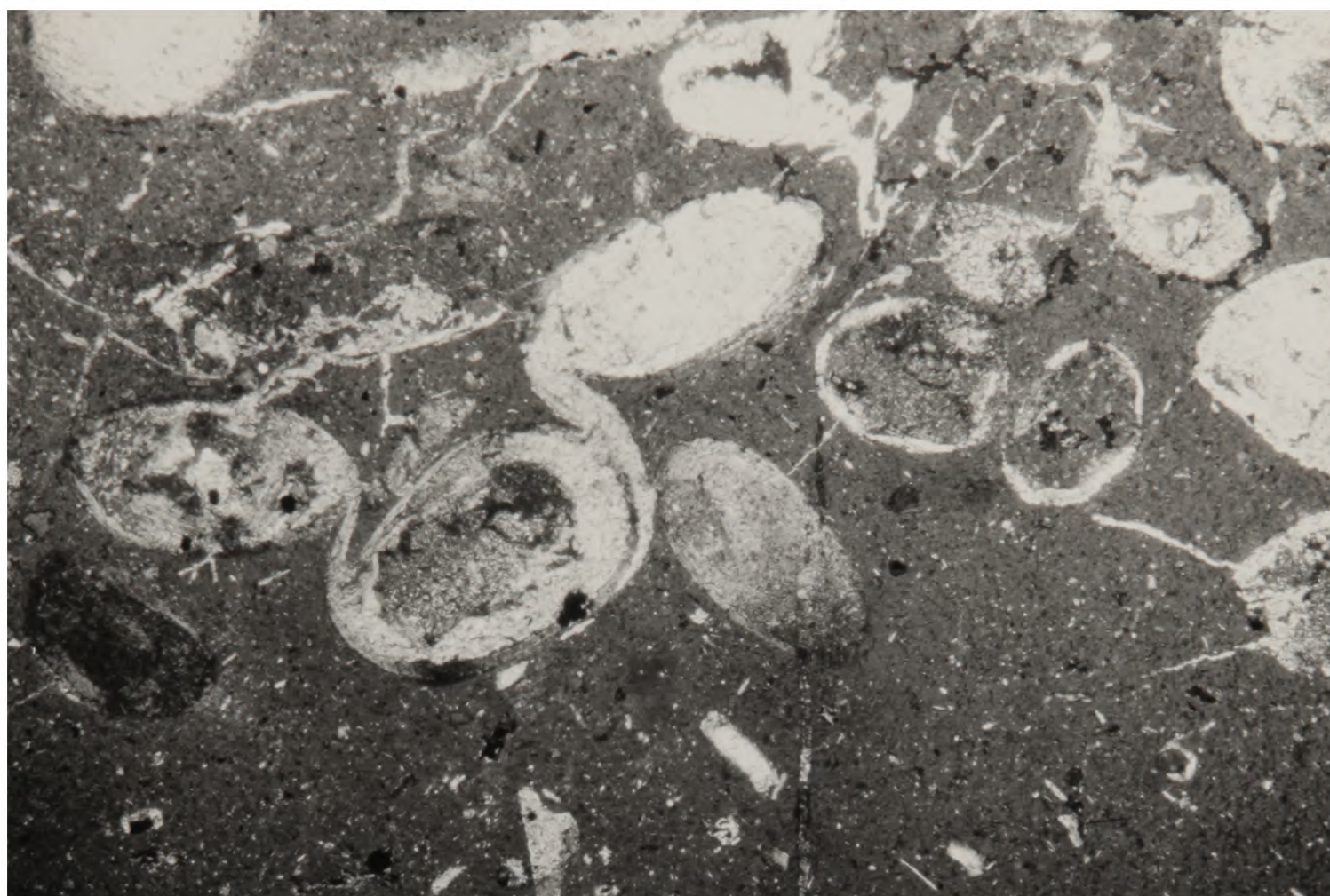


Plate 8.6. Micaceous calcareous shales with thin laterally persistent calcareous nodules, facies 22a, Leacach. Shale Member, Loch Aline.

Plate 8.7. Sandy micaceous shales with abundant limestone pebbles forming the Leacach Pebble Member, overlying the Leacach Shale Member in Allt nan Leach, Loch Aline.
Scale = 6 cm

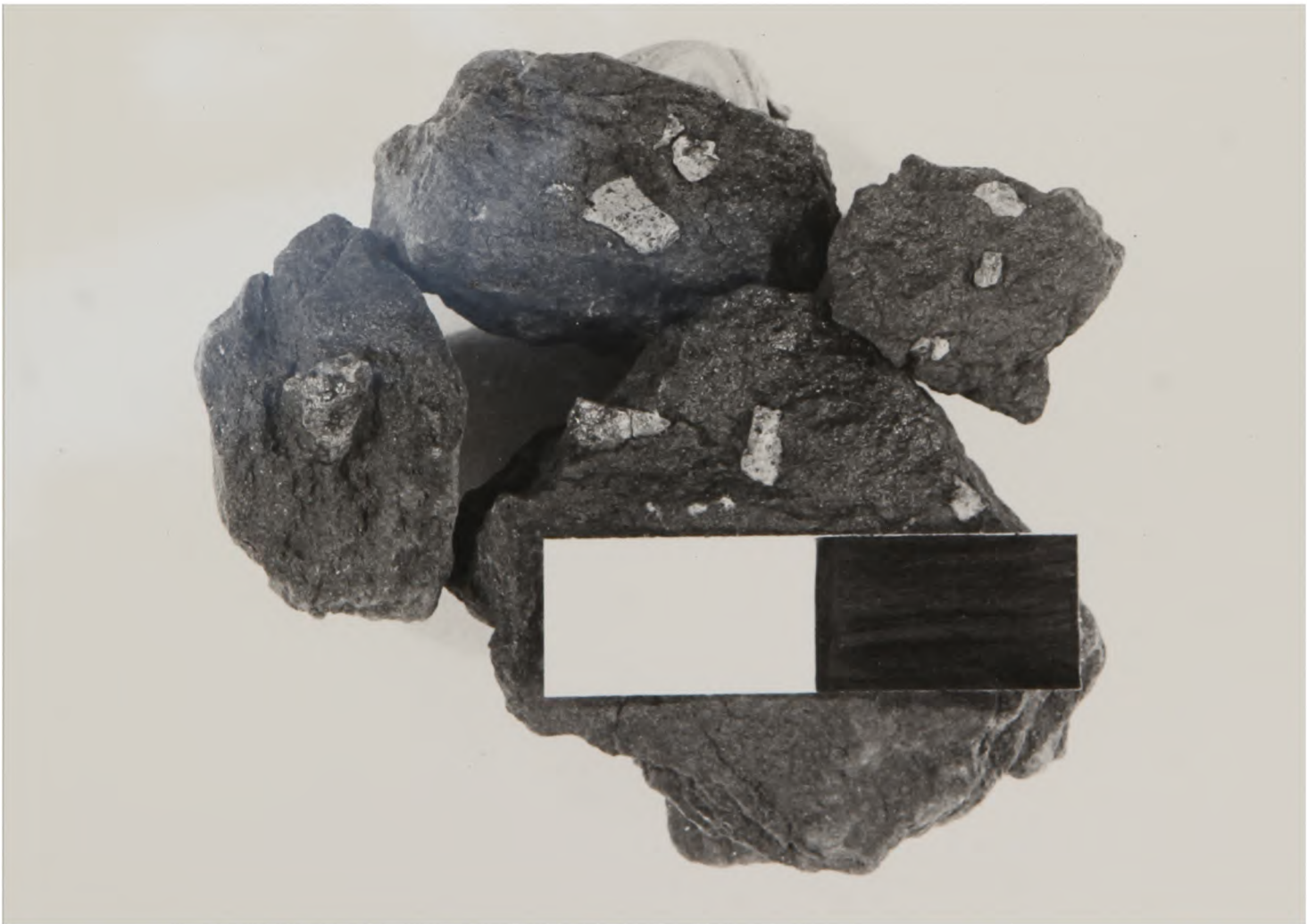


Plate 8.8. Top surface Thalassinoides markings on the marlstone beds comprising Facies 22b, Leacach Shale Member, Caignure Bay, Mull.

Plate 8.9. Bioturbated, bedsurface of Facies 22B showing Rhizocorallium and simple meandering tubes, Caignure, Mull.

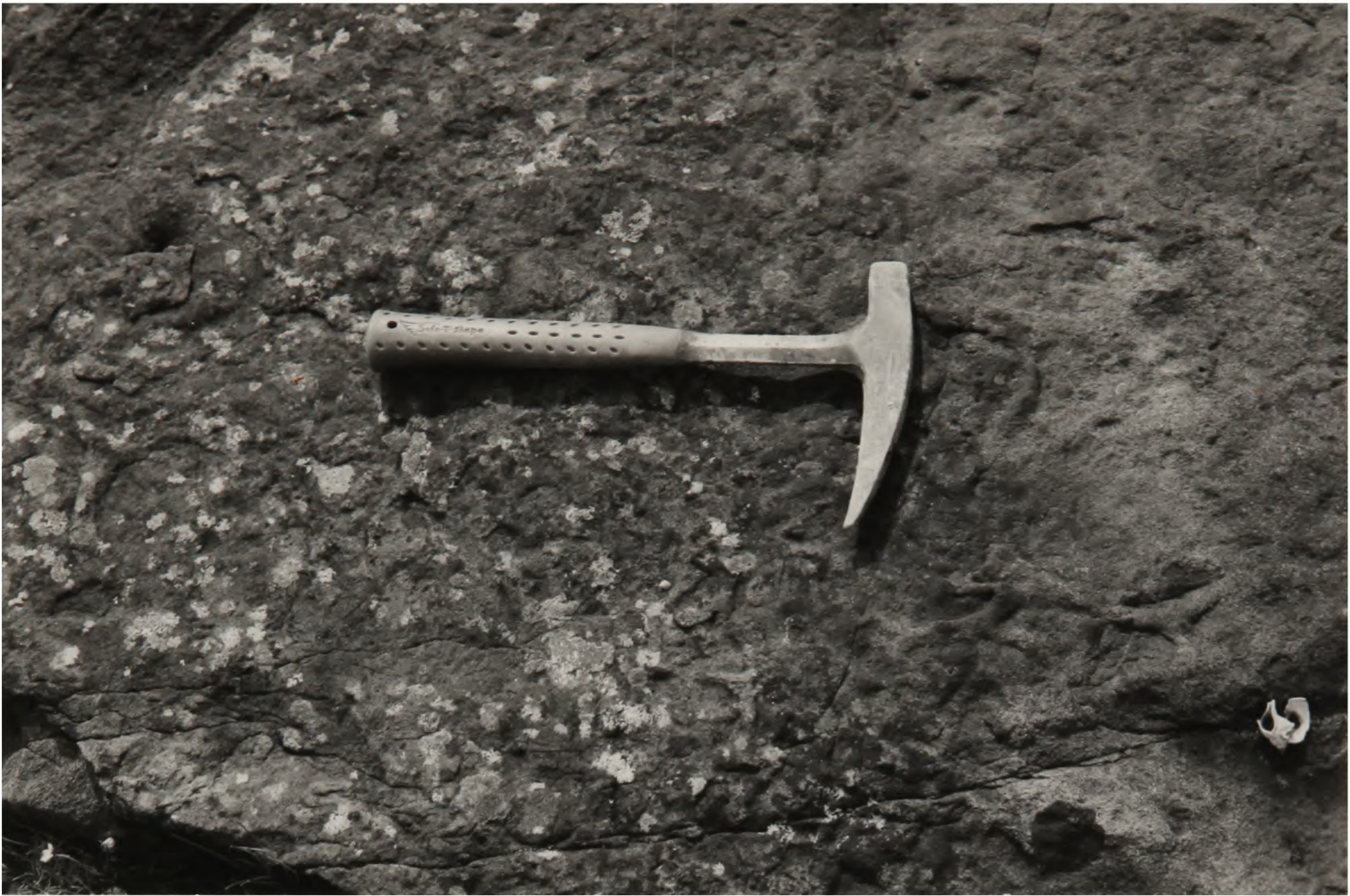


Plate 8.10.a. Bivalve shell together with echinoderm spine in silty ferruginous phosphatic beds of Facies 22B, Leacach Formation, Craignure, Mull.
x 10.

Plate 8.10.b. Plate 10a under + Nicols. Note nearly isotropic Cement.
x 10.

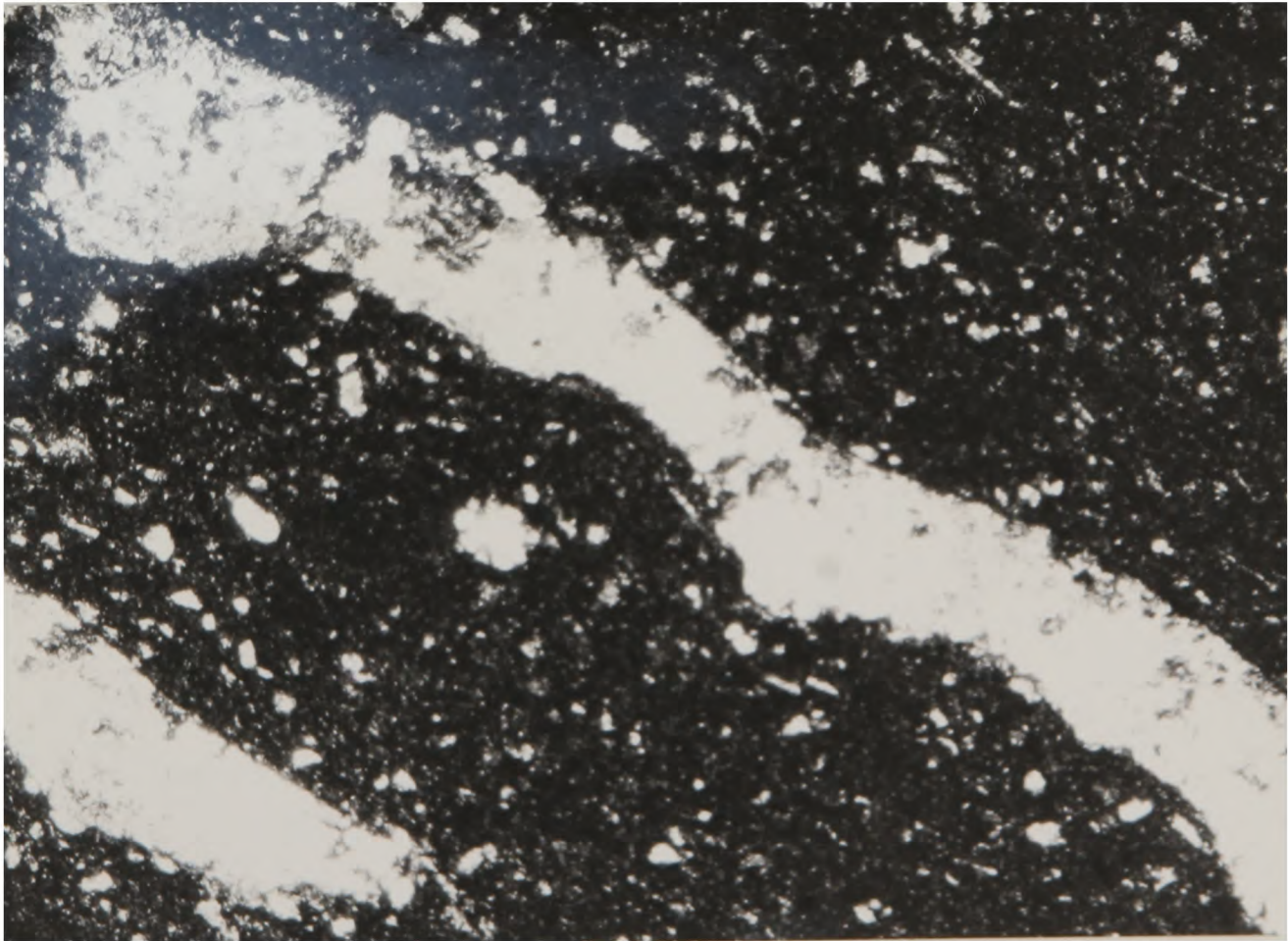
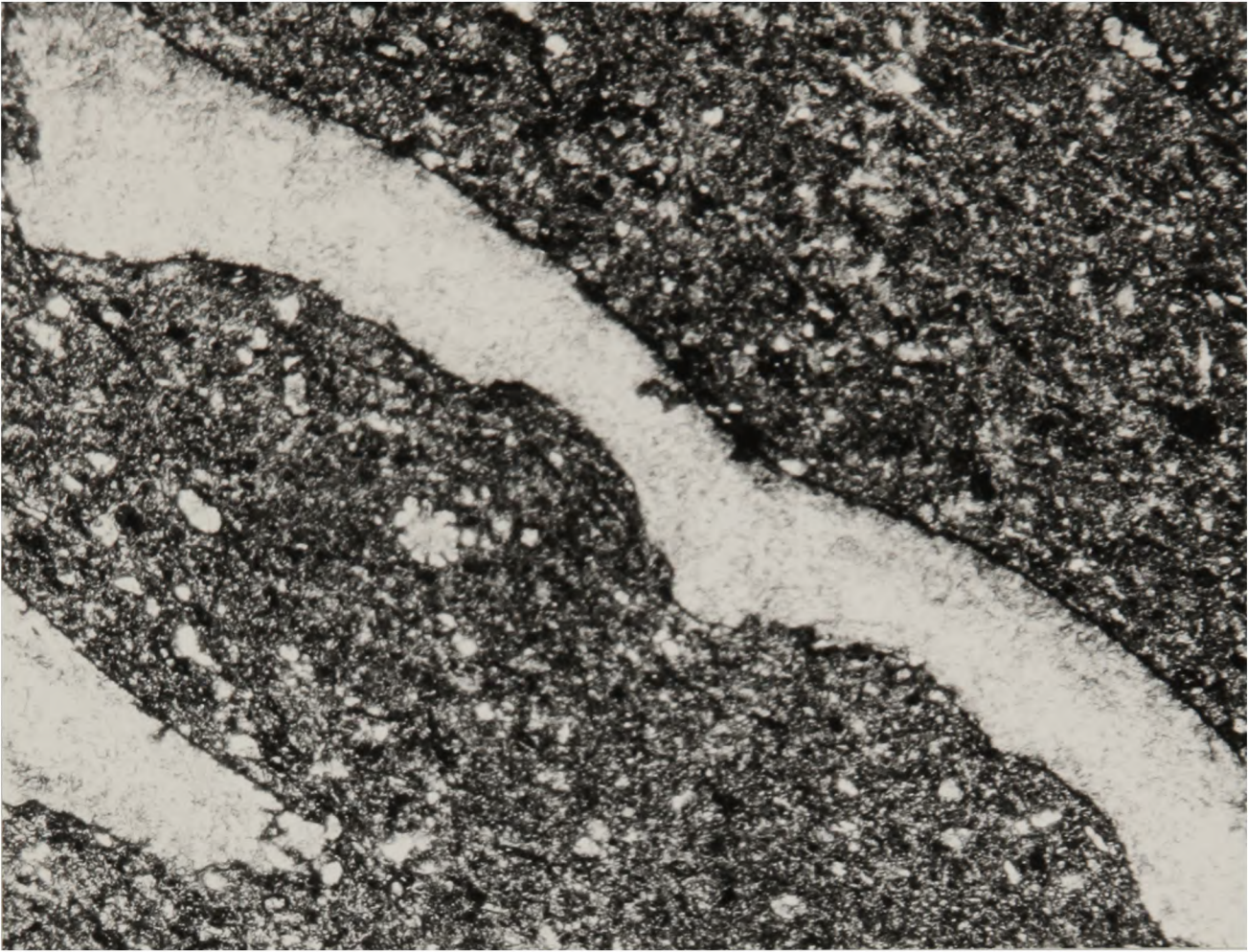


Plate 8.11.a. Mound-like features seen in the more resistant
marlstones of Facies 22B, Craignure, Mull.



Plate 8.11.b. Internal features of the mound-like structure of Plate 8.11a, note crushed shell fragments rounded pebbles and meandering worm-like burrow features surrounding it. Craignure Bay, Mull.



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Tables 9.1 - 9.5	205-209
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ASTM

Samples*

Cronstedtite 17-470	Chamosite Iron-Chlorite 7-329	Cham. Chlorite 7-315	Cham. II Ch1.7-339	Ra B8	A _D 5 ⁸	Am66-1	Amb72	Am79	Am68	Am155	Am88-2	Am88-22
dÅ I				dÅ I	dÅ I	dÅ I	dÅ I	dÅ I	dÅ I	dÅ I	dÅ I	dÅ I
7.09 100	7.06 100	7.05 100	7.12 100	7.08 2	7.052 4	7.09 1	7.07 1	7.081 4	7.052 1	7.036 2	7.172 1	7.201 4
4.75 10	4.59 60	4.67 20	4.68 50	3.49 1	3.454 1	3.54 2	3.53 3	3.446 1	3.529 2	3.462 1	3.550 4	3.479 1
4.34 6	3.53 100	4.58 20	4.30 20	1.84 3	2.625 4	3.43 4	2.49 2	2.625 2		2.630 3	2.640 3	2.651 2
3.95 6	2.63 70	4.28 5	3.93 30		1.839 3	2.41 4	1.908 5	1.837 3		1.841 3	1.843 2	1.844 3
3.54 85	2.46 80	3.90 10	3.55 100			1.91 3						
3.17 1	2.11 60	3.52 100	3.07 20									
2.830 1	1.752 50	2.80 ?	2.71 50									
2.722 50	1.517 70	2.68 40	2.53 100									
2.558 10	1.486 40	2.52 90	2.15 70									
2.439 40	1.465 40	2.40 40	1.779 60									
2.358 6	1.398 40	2.34 5	1.563 70									
2.305 10		2.27 5	etc									
2.172 2		2.14 60										
2.036 16												
1.972 6												
1.908 6												
1.793 6												
etc												

* Peak intensities in decreasing order 1-10.

TABLE 9.1. Chlorite (?Chamosite) peaks

XRD analysis of spot samples taken from phosphatic nodules and iron-rich beds of the Strath and Leacach Formations (Lower Lias) of northwest Scotland.

ASTM				Samples*									
Hydroxyl apatite 9-432	Carbonate apatite 19-272	Carb. apatite 21-145	Carb. fluor. apatite 21-141	Fluor. apatite 15-876	Ra 32	ADSB	Am66-1	Am672	Am79	Am68	Am155	Am88-2	Am88-22
dR	dR	dR	dR	dR	dR	dR	dR	dR	dR	dR	dR	dR	dR
1.17	3.46	8.13	8.04	8.12	3.84	2.801	3.43	3.43	3.173	3.85	3.46	3.46	3.479
5.26	3.17	4.69	4.67	5.25	3.45	2.778	2.80	2.80	3.063	3.44	3.037	3.08	3.096
4.72	2.780	4.06	4.04	4.684	2.80	2.706	2.78	2.78	2.80	2.80	2.809	2.81	2.801
4.07	2.680	3.43	3.86	4.055	2.77	2.625	2.72	2.70	2.77	2.77	2.785	2.78	2.722
3.88	2.622	3.08	3.43	3.872	2.70	2.253	2.67	2.49	2.699	2.70	2.714	2.713	2.253
3.51	2.474	2.811	3.16	3.494	2.629	1.937	1.94	2.625	2.625	2.630	2.630	2.640	1.944
3.44	2.285	2.774	3.05	3.442	2.253	1.839	1.94	2.446	2.446	3.46	3.46	2.261	2.261
3.17	2.231	2.717	2.79	3.167	2.253	1.839	1.94	2.248	2.248	1.945	1.945	1.941	1.941
3.08	2.124	2.627	2.769	3.067	2.253	1.839	1.94	1.937	1.937	1.841	1.841	1.888	1.888
2.814	2.069	2.526	2.692	2.800	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.778	2.004	2.793	2.619	2.772	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.631	2.929	2.261	2.506	2.702	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.528	1.858	2.149	2.284	2.624	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.296	1.838	1.941	2.210	2.517	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.262	1.783	1.889	2.134	2.289	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.228	1.754	1.841	2.021	2.250	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.148	1.736	1.805	1.931	2.218	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.134		1.781	1.887	2.140	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.065		1.757	1.855	2.128	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.040		1.720	1.834	2.061	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
2.000			1.790	2.028	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.943			1.783	1.997	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.890			1.754	1.937	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.871			1.720	1.884	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.841				1.862	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.806			Dahlite	1.837	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.760			15-0100	1.797	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.754			3.479	1.771	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
1.722			2.822	1.748	2.253	1.839	1.94	1.837	1.837	1.841	1.841	1.843	1.843
				etc.	2.22	2	2.22	2	1.722	16			
1.684													
1.644													
1.587													
1.542													
etc													

* Peak intensities in decreasing order 1 - 10.

TABLE 9.2 Apatite peaks

XRD analysis of spot samples taken from phosphatic nodules and iron-rich beds of the Strath and Leacach Formations (Lower Lias) of northwest Scotland.

Zone	Ref	Ironstone	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	S ₂ Fe	SFe	S	C	SO ₃	CO ₂	H ₂ O ⁺	H ₂ O ⁻
Hettangian	1	Turneri	5.15	4.49	1.05	69.93	0.95	2.48	1.05	.57	0.01	0.32	1.23	-	-	-	0.41	-	0.48	11.89	2.07
	2	"	3.90	3.34	-	19.4	11.31	1.58	1.3	26.3	-	-	0.77	-	-	-	-	-	-	-	-
	3	"	9.25	4.6	-	24.86	10.66	1.4	1.83	21.1	-	-	.85	-	-	-	-	-	-	-	-
	4	Breakish	25.39	8.64	0.43	3.07	19.07	0.13	2.49	0.17	6.23	0.04	.48	-	-	-	-	-	-	5.31	CaCO ₃ 29.50
		Bucklandi																			
		Angulata																			
	5	Rodingberg	42.76	7.82	0.50	12.47	16.29	0.091	0.61	1.44	0.12	0.63	0.30	-	-	*0.043	0.98	-	3.37	7.23	5.66
Hettangian	6	Kurremolla	9.09	7.11	2.44	2.34	44.90	0.20	0.53	2.37	0.01	0.34	0.81	-	-	*0.013	0.28	-	19.78	3.73	0.80
	7	Kurremolla	8.20	5.84	0.39	3.25	42.72	0.36	0.84	3.94	0.05	0.51	0.21	-	-	*0.19	0.62	-	29.41	1.78	1.43

Zone	Ref	Ironstone	(CO,Ni)O	Sub Total	Less O	Total	%CO ₂
Sinemurian	1	Frodingham	0.03	100.11	-	100.11	
	2	"	-	-	-	-	
	3	"	-	-	-	-	
	4	Breakish	-	100.95	-	100.95	14.90
Hettangian	5	Rodingberg	-	100.31	0.02	100.29	
	6	Kurremolla	-	99.74	-	99.74	
	7	Kurremolla	-	99.74	0.10	99.64	

Table 9.3. Available analyses of European Lower Liassic ironstones

1. - Analyses of separated goethite ooliths (Hallimond, 1925).
2. - Whole-rock, "Appleby bore 2" (Hallimond, 1925).
3. - Whole-rock, "Yarborough pit" (Hallimond, 1925).
4. - Whole-rock, (this study).
5. - Whole-rock, Arenaceous chamosite (Palmqvist, 1935).
6. - Whole-rock, Ilmenite-bearing chamosite oolite (Palmqvist, 1935).
7. - Whole-rock, Dense sideritic rock (Palmqvist, 1935).
* - Reported as Sz.

	Ra32	AD58	Amb72	Am79	Am68	Am155	Am88-2	Am88-22	Am88-2ω
SiO ₂	15.01	13.40	23.53	20.05	20.02	18.23	34.44	35.78	51.11
TiO ₂	0.17	0.12	0.2	0.12	0.14	0.14	0.28	0.30	0.41
Al ₂ O ₃	4.87	3.94	5.44	3.68	5.08	4.36	2.93	2.61	5.39
FeO	2.59	5.08	3.29	2.67	3.64	5.78	2.77	3.79	4.20
Fe ₂ O ₃	0.91	0.86	0.32	0.00	5.59	0.77	0.18	0.00	2.01
MnO	0.58	0.22	0.09	0.06	0.08	0.09	0.07	0.07	0.05
MgO	0.94	0.98	1.02	0.57	0.98	1.21	0.80	0.50	0.84
CaO	15.58	21.83	15.55	30.02	17.93	18.13	26.83	27.30	1.40
K ₂ O	0.59	0.86	0.71	0.76	0.18	0.32	0.50	0.60	1.00
Na ₂ O	0.00	0.17	0.76	0.17	1.64	0.17	1.43	0.19	0.17
P ₂ O ₅	12.17	19.24	11.97	22.51	13.95	13.47	20.05	19.94	0.09
CaCo ₃	43.20	35.25	33.86	20.48	22.84	31.14	7.20	6.56	0.00?
H ₂ O	3.04	0.02	2.59	0.19	7.95	5.40	2.11	2.13	32.60
Tot.	99.65	101.97	99.33	101.28	100.02	99.21	99.59	99.71	99.27
Tot. vol.	22.05	15.53	17.49	9.20	10.00	19.10	5.28	4.99	32.60
CO ₂ %	14.90	15.51	14.90	9.01	10.05	13.70	3.17	2.86	23.13

TABLE 9.4 Major-element geochemistry of phosphatic nodules: Strath and Leacach Formations, northwest Scotland.

Stage	Zone	Locality	Thickness	Character	Remarks	References
Sinemurian	Obtusum	Frodingham Lincolnshire, England.	~9 m.	Mainly limon. oolite cha.		Whitehead <u>et al.</u> (1952) Hallam (1963a)
	Turneri					
	Semicostatum	Ardnish, Isle of Skye, Scotland.	~50 cm.	Calcareous, sideritic, "chamosite", goethite, siderite oolite.	Thin, impersistent lenses.	This study.
	Bucklandi					
Hettangian	Angulata	Fredricke Basin, Germany.	Few met.	Oolitic limon. & cham.	Lias α -3, a few beds in the L. Sinemurian.	Kolbe (1952)
	Liasicus					
	Planorbis	Austria. Scania, Sweden.	Many met.	Clay ironstone. Sandy siderite, some chamosite & limonite oolite.	Oldest Jurassic ironst. in Europe.	Kern (1952) Palmqvist (1935) Hadding (1929, 1933)

Table 9.5 Reported Lower Liassic ironstones of Europe.

Plate 9.1. Horizontal surface burrows infilled with reddish-brown compounds found at the surface of the ferruginous beds of Mull.
(Length is 25cm).

Plate 9.2. Distinctive surface appearance of the ferruginous beds of Facies 22B in Mull. Note horizontal, non branching tubes together with the wavy surface.

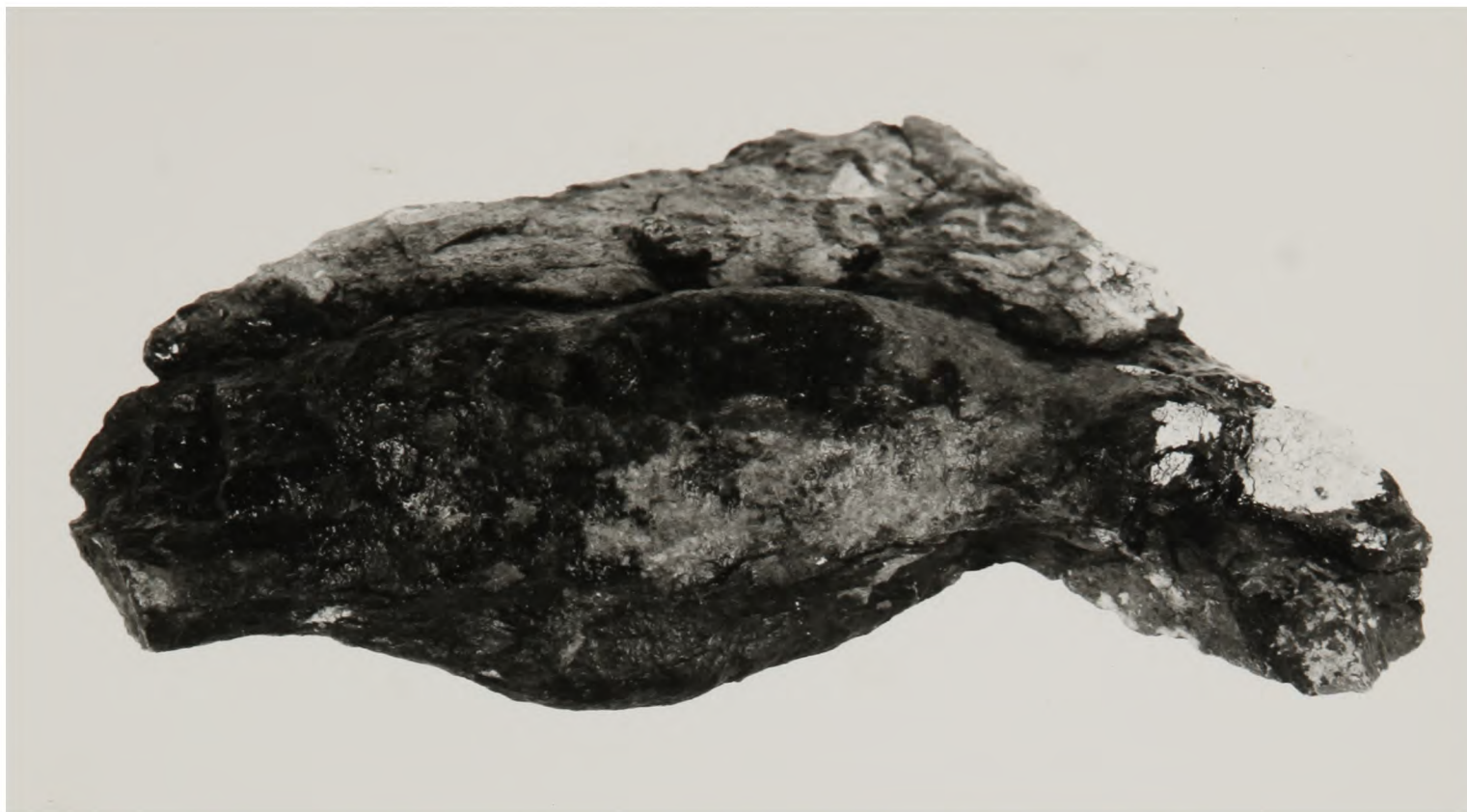


Plate 9.3. Silty ferruginous bed in Raasay, note lack of ooliths and the presence only of pellets and gastropod fillings.
x 16.



Plate 9.4.a. Breakish oolitic(N. Strath) ironstone, note
microsparite cement, flattened ooliths, echinoderm plates
and infilled gastropod test surrounded by tangentially
oriented ?chloritic flakes.
x 16 plane polarized light.

Plate 9.4.b. As plate 94a + Nicols. Notice extinction brush.

Plate 9.4.c. As plate 94a.
+ Nicols
+ quartz wedge,
Note chlorite flake orientation.

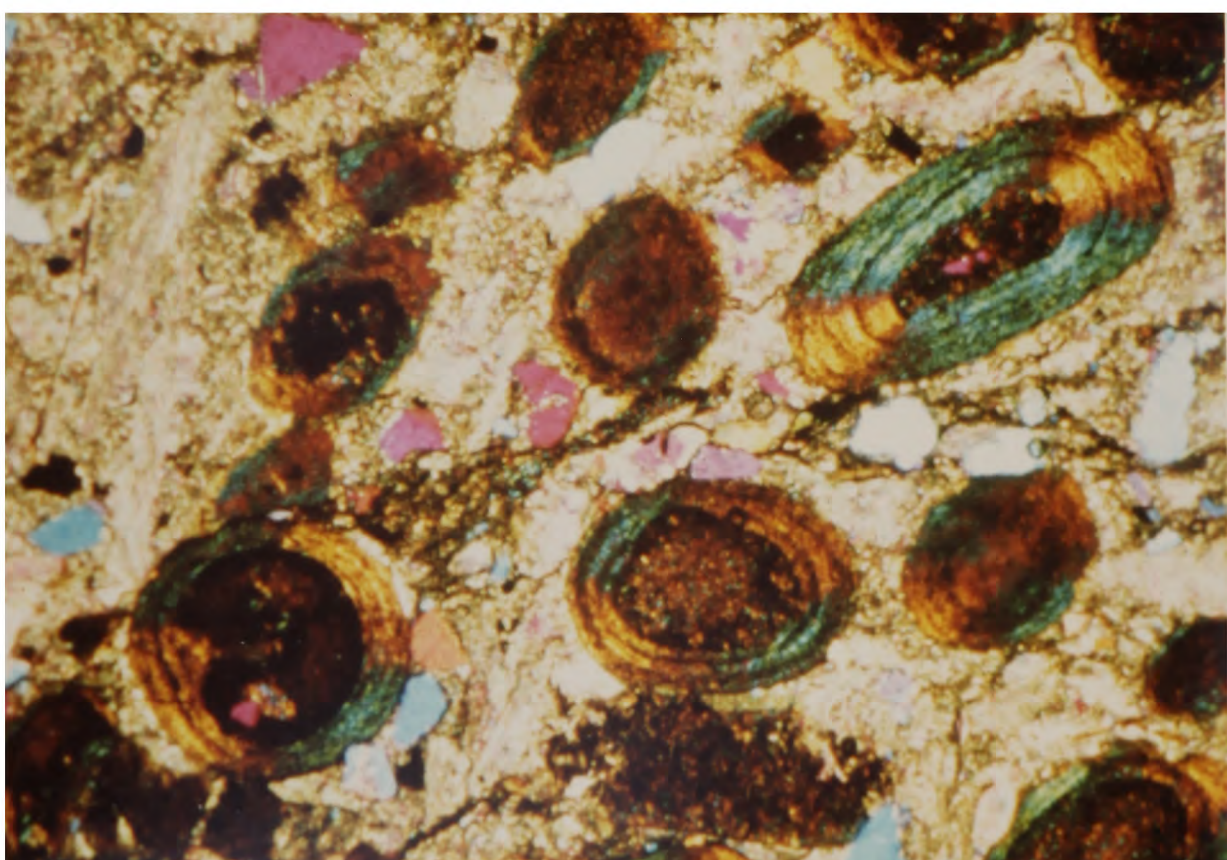
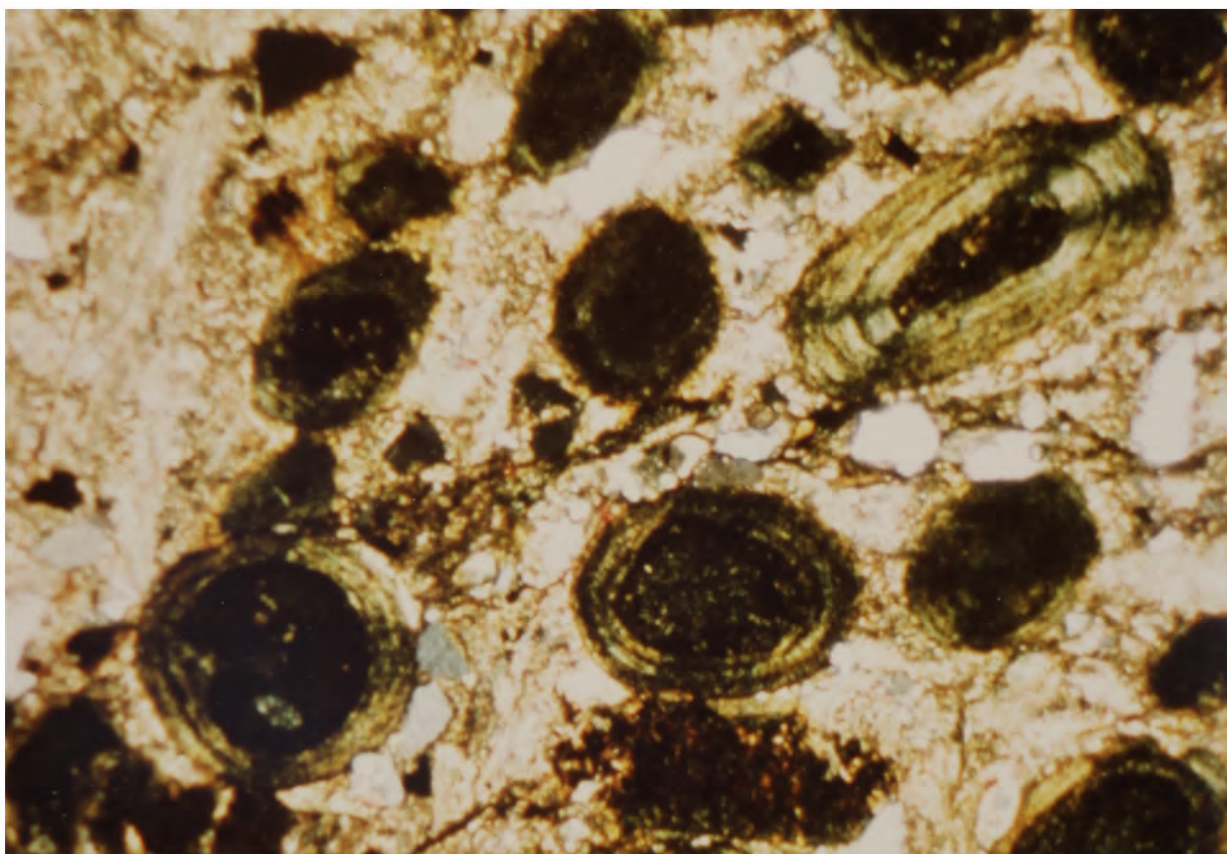
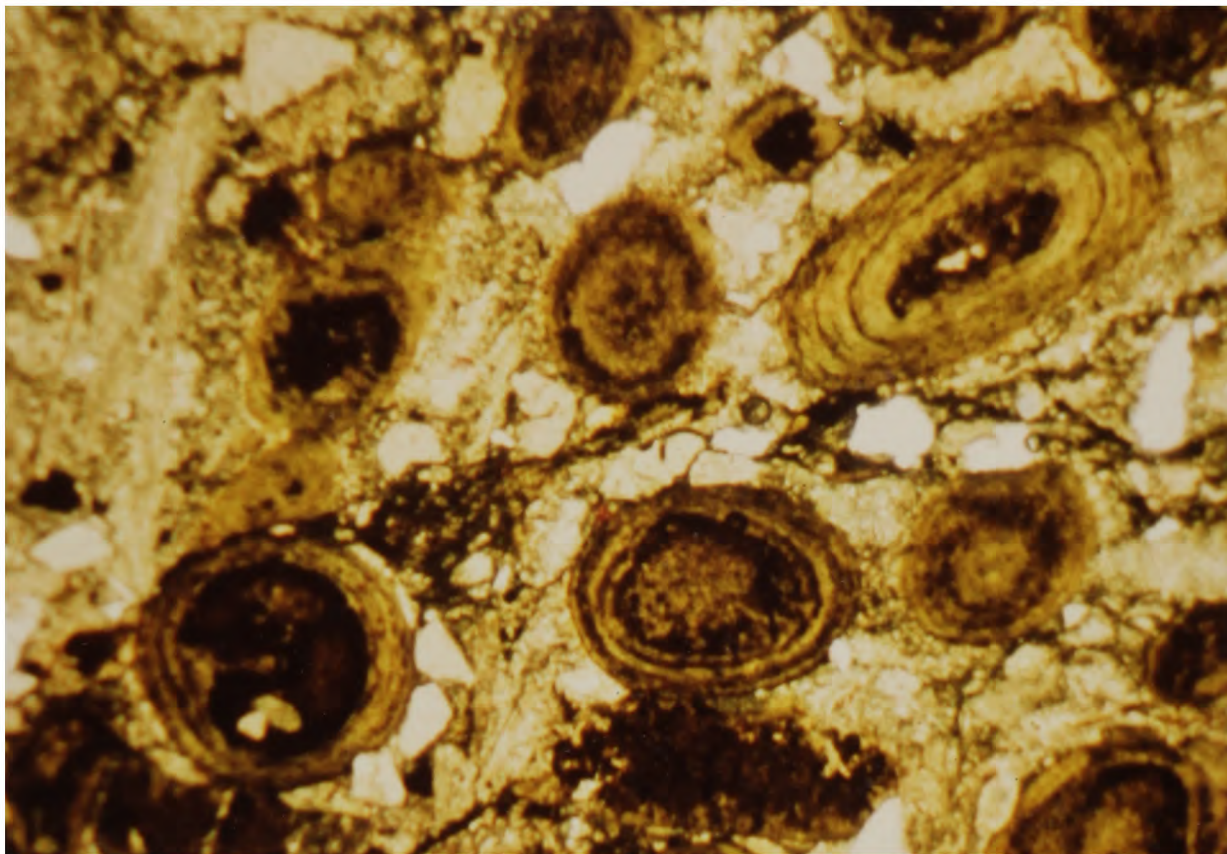


Plate 9.5. Compressed ooliths signifying probable post depositional compaction prior to lithification, note that the grains do not penetrate the oolith and the centre is clearly stretched, ferroan calcite cement (stained) is present; ?microboring marks in the internal laminations towards the centre. Breakish Ironstone Member, Skye.
x 40.

Plate 9.4d. Tangential chlorite flake orientation shown by radiaxial extinction brush; banding is a result of non-chlorite minerals ?limonite and calcite. Breakish Ironstone Member, Skye.
x 16.

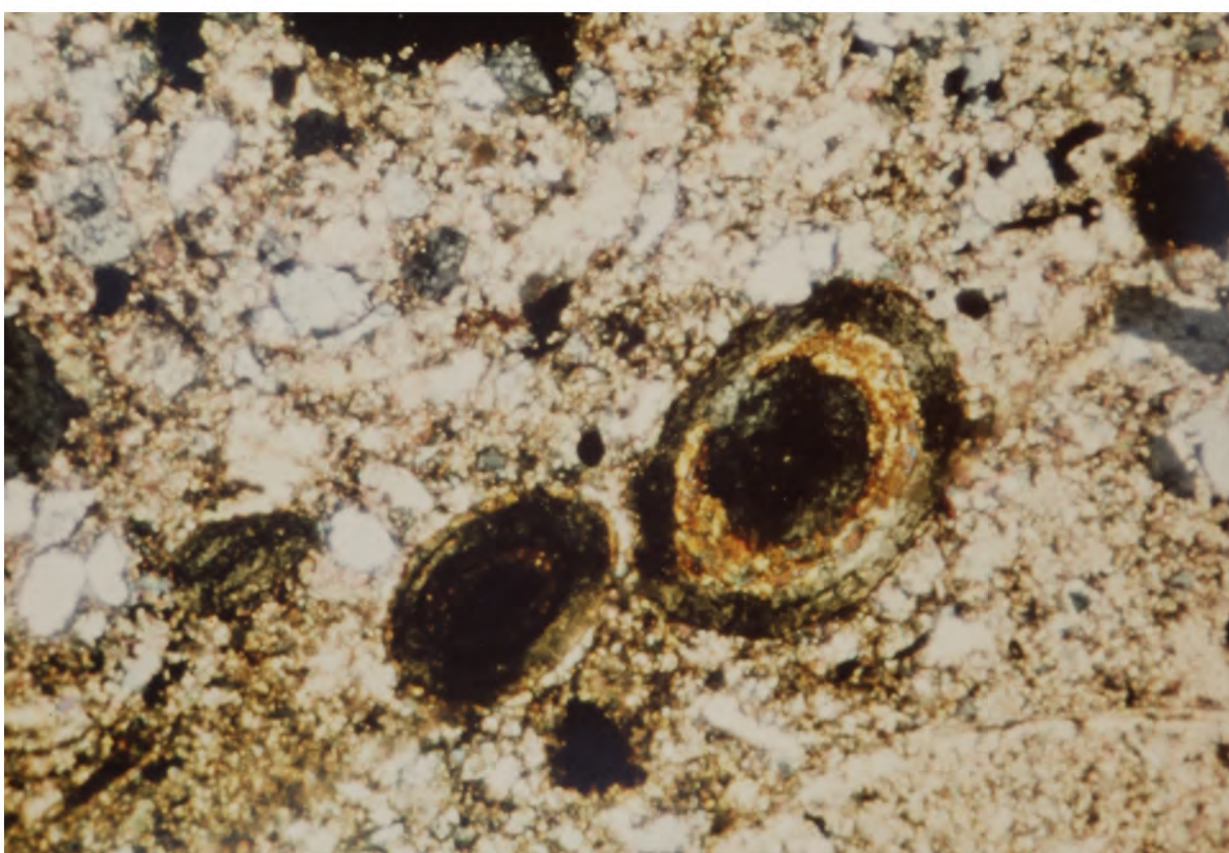
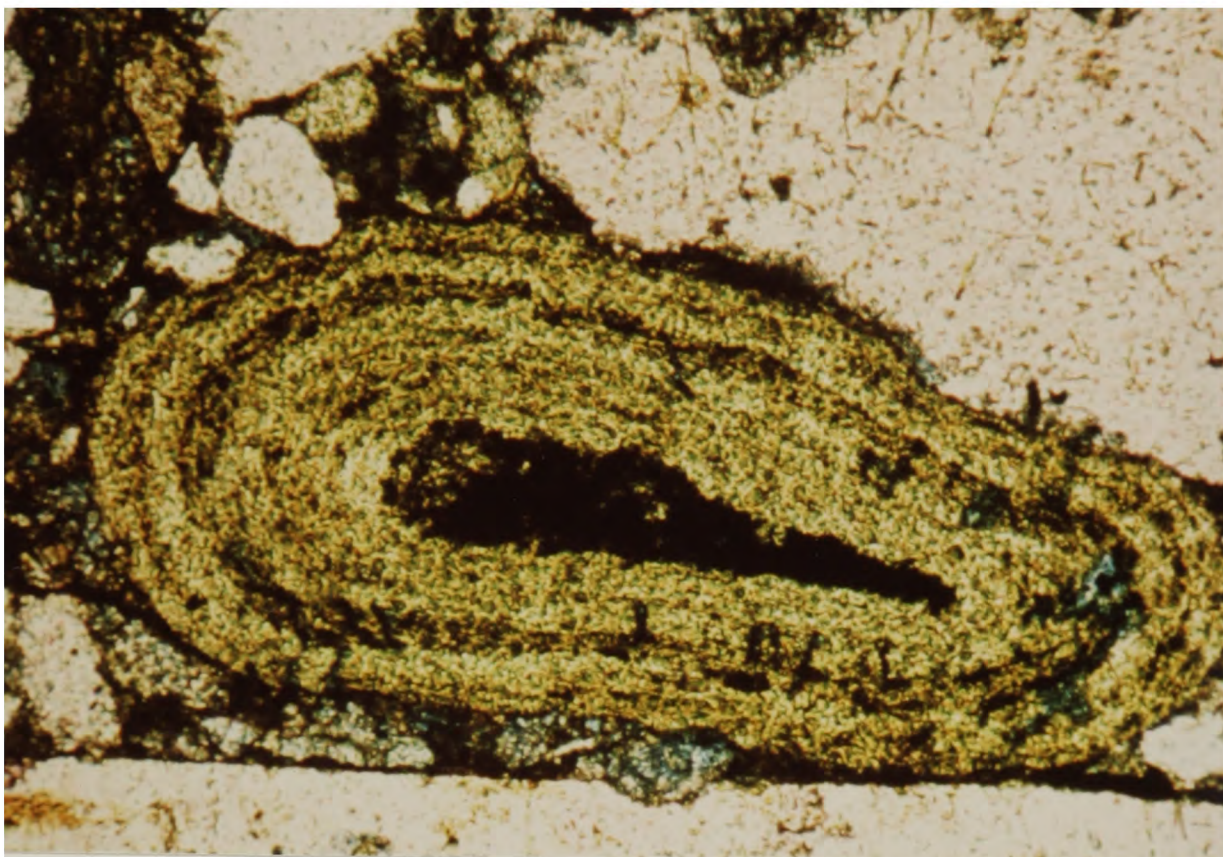


Plate 9.6.a. Photomicrograph of part of the Breakish Ironstone Member in Skye showing microsparitic ferroan cement (stained blue) containing quartz fragments and chloritic-mud infilled ostracod test. Note that the ostracod shell is non ferroan calcite (pink stain); thick organic coating covers one quartz grain (top left).
x 50.

Plate 9.6.b. As 9.6a. Note altered margins of non coated quartz fragment.
x 50.
+ nicols

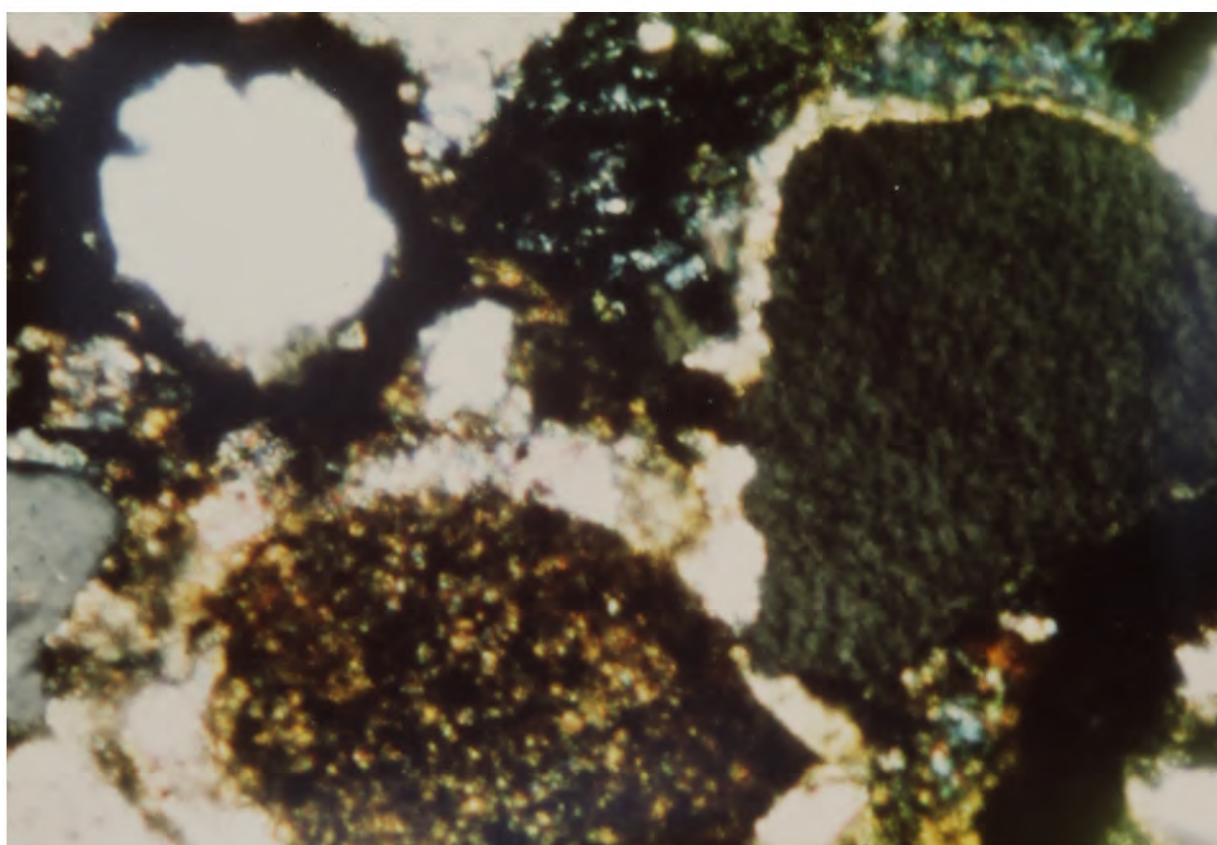
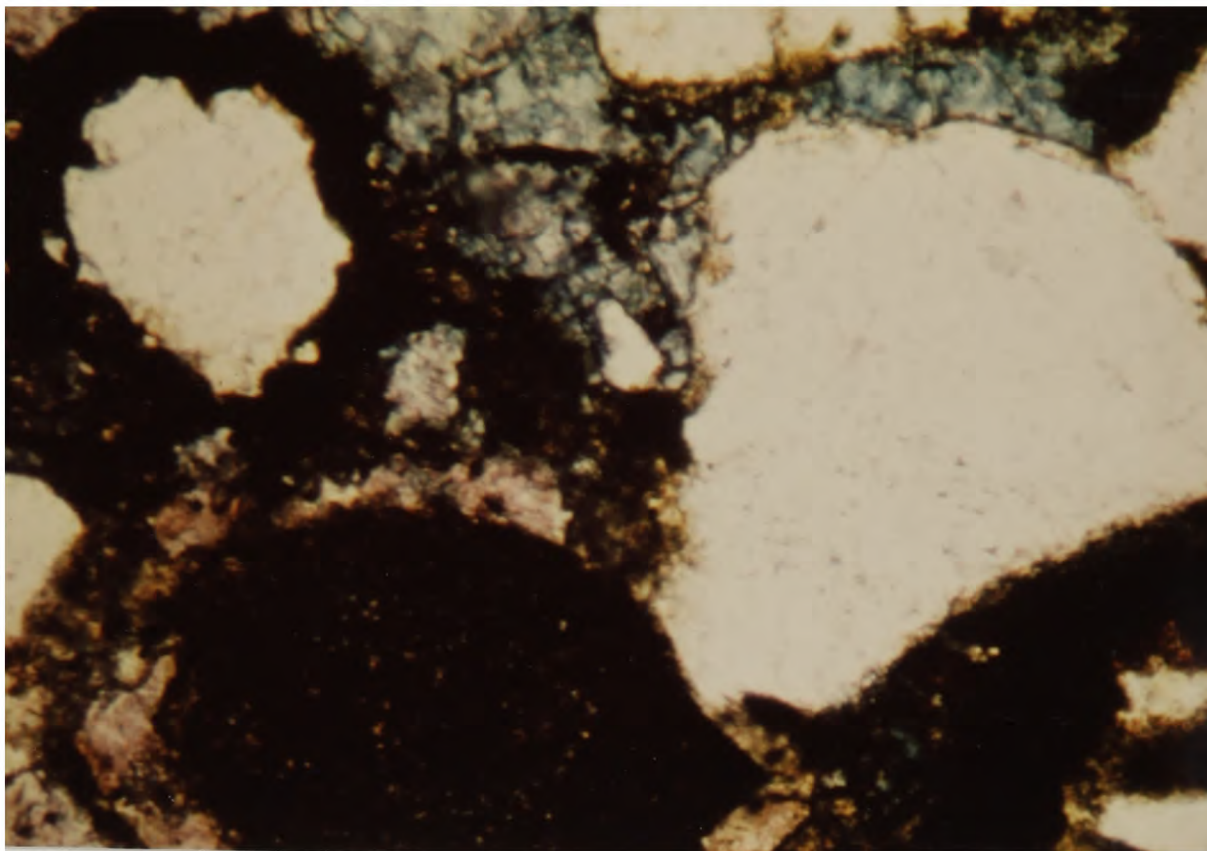


Plate 9.7. Photomicrograph of calcareous chamosite oolite with compressed oolith and echinoid plate with a thin oolitic film (Cf. Plate 7.5 x 50) note tangential plate orientation.

Semicostatum Zone, Ardnamurchan.

X 50

Plate 9.8a. Chloritic siltstone/sandstone of Facies 22B, Craignure Bay, Mull. Note poor sorting, bivalve and echinoid shell fragments.

x 4.

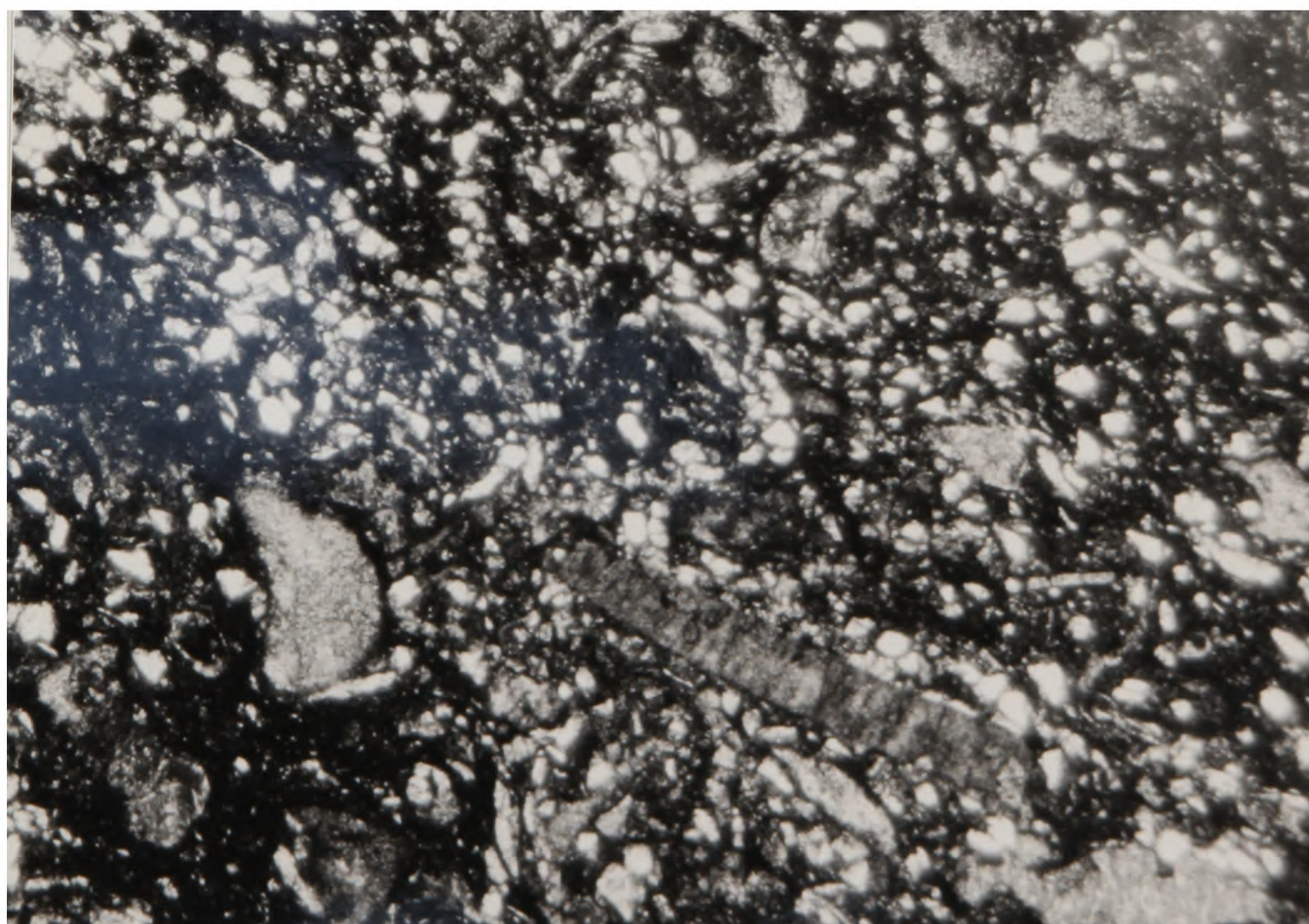
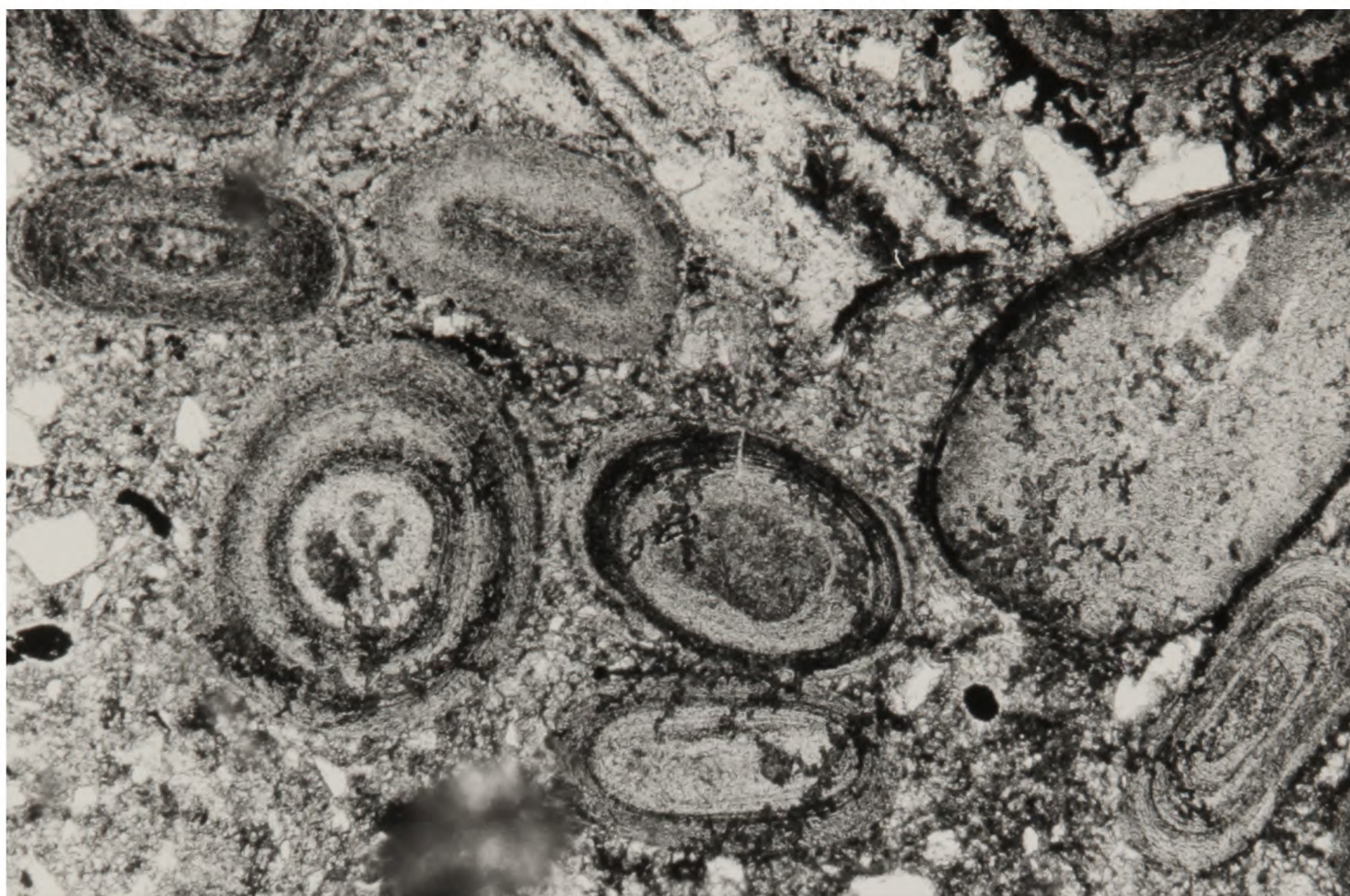


Plate 9.8.b. Same area as 9.7a + Nicols.

Plate 9.9. Chloritic/calcareous fine sandstone/siltstone of Facies 22b of Craginure Bay Mull. Note better sorting than that of Plate 9.7a and subparallel alignment of mica flakes and the development of wavy laminations (pyrite).
x 10.

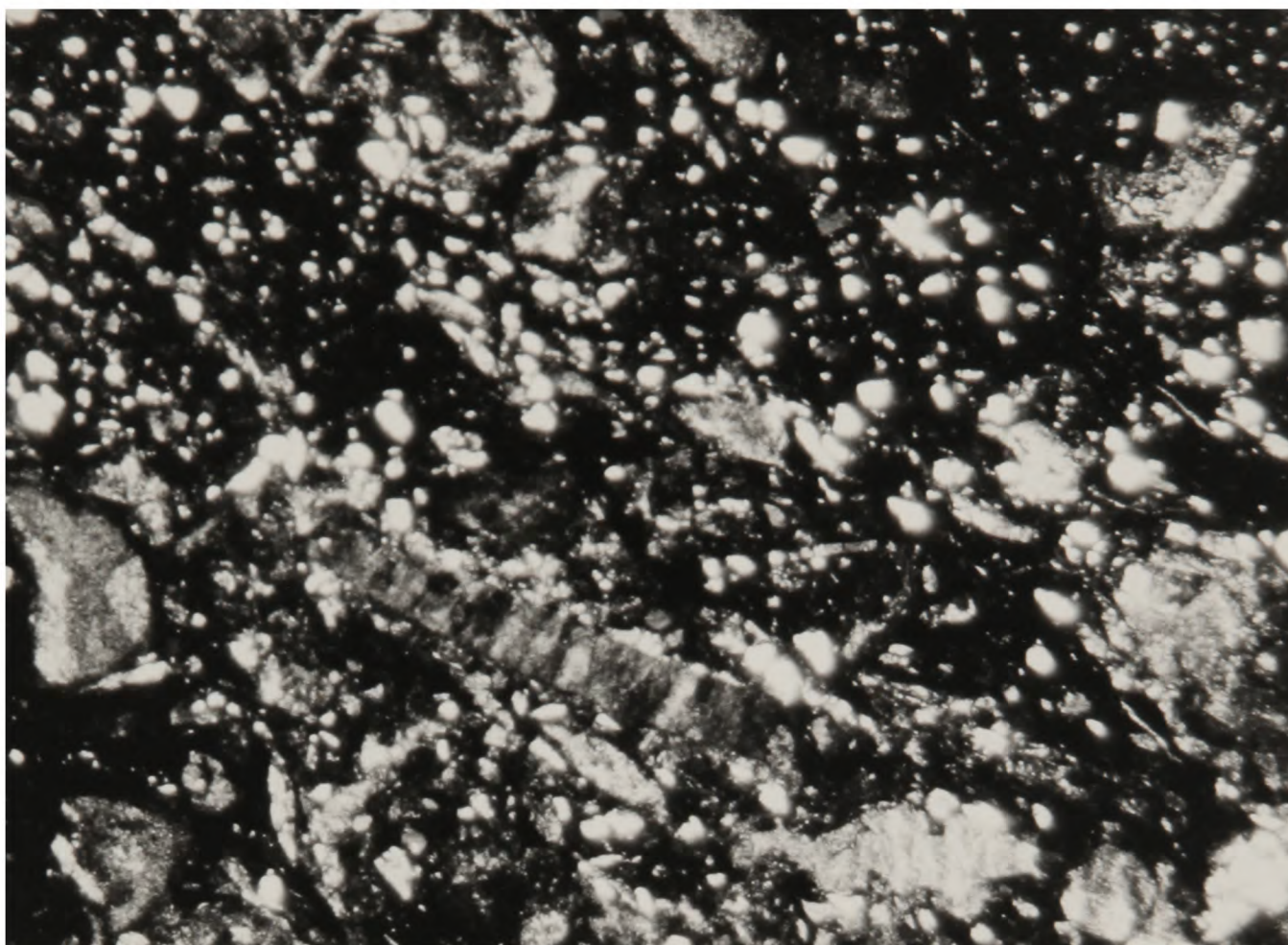
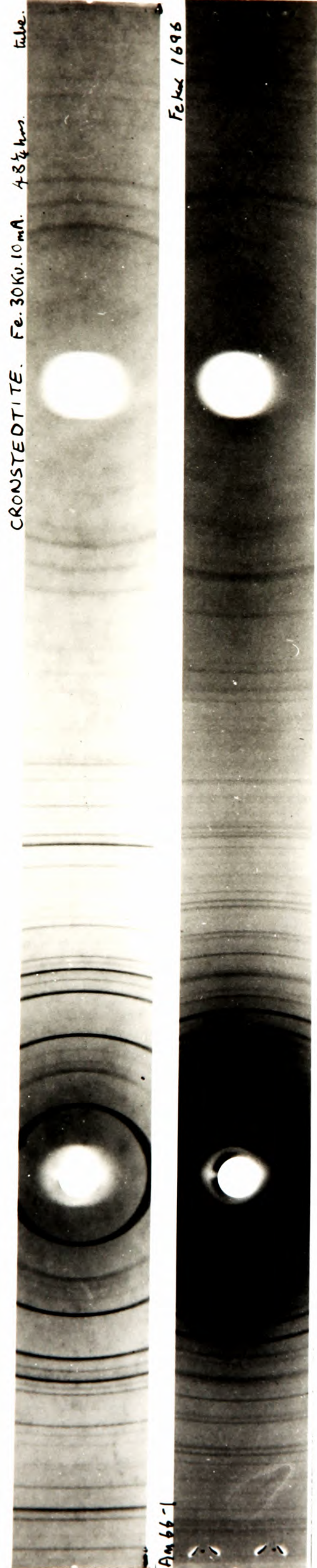
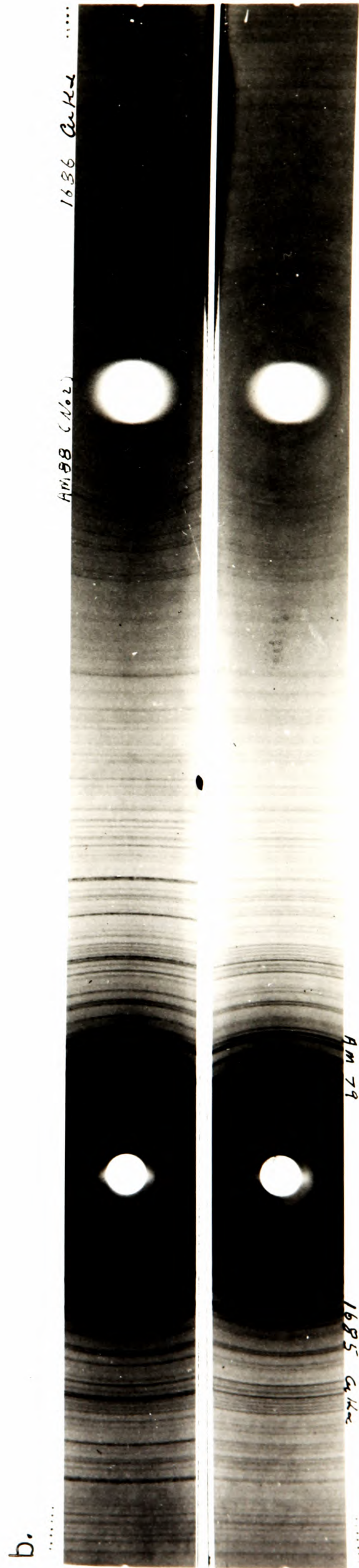


Plate 9.10a. X-ray powder photograph obtained from individual ooliths in the Breakish Ironstone Member (lower photograph). Note similarity of 7.09Å and 3.54Å lines to those of cronstedtite (upper photograph).

Plate 9.10b. X-ray powder photograph obtained from the phosphatic nodules of the Strath Formation. Note 3.08Å, 2.81Å and 2.71Å lines characteristic of carbonate apatites.



a.



b.

Plate 9.11. Reniforme, distorted calcareous (?Collophane) bands found in phosphatic nodules obtained from the Semicostatum Zone beds of Ardnamurchan. Note the presence of an apparent calcareous oolith at lower left part of plate. Rounded, distorted colloform bodies which are connected by a narrow apophyses can be seen. The cement is crypto crystalline carbonate apatite.

Cf. Plate 7.5 and 8.4 a,b.

x 50.

Plate 9.12. Spherical and ovoid bodies formed from the progressive narrowing and eventual detection of the apophyses which connect the bodies shown in Plate 9.11. Note the previously formed oolith within an ovoid body at the top of the plate and also a compressed ovoid body showing remnants of a ?oolitic concentric banding. Sauzeanum Subzone, Mingary Castle.

x 50.

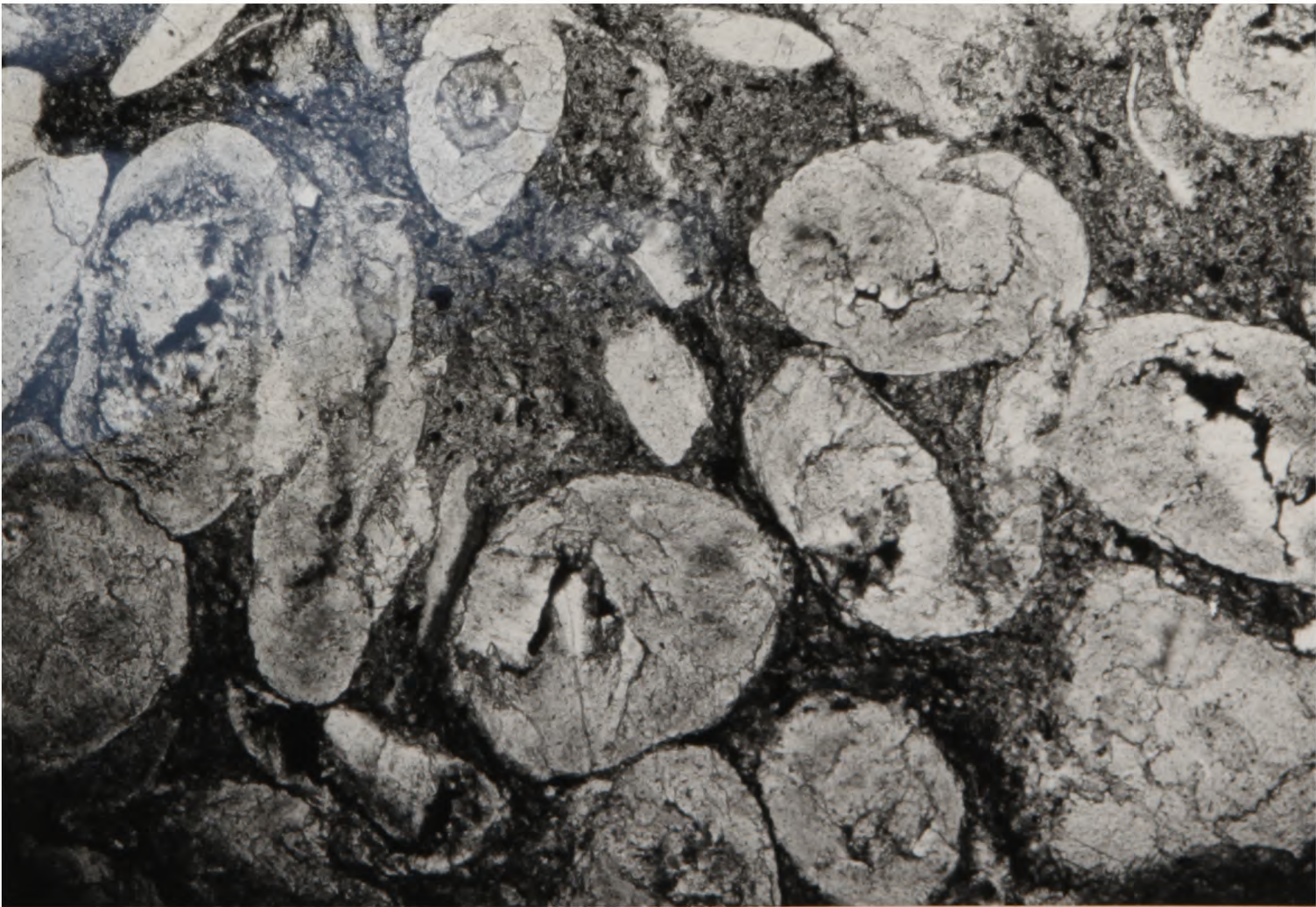


Plate 9. 13.a. Angular grain of feldspar forming the nucleus of oolith. Note altered margins of feldspar grain, apparent aggregate massive inner coating and outer oolitic coat. Breakish Ironstone Member, Ob Breakish, Skye.

x 100

Plate 9.13.b. Same area as plate 9.13a under cross nicols, note original outline of altered angular feldspar, round aggregate ?vermicular kaolinite coating followed by tangentially oriented chloritic flakes showing a characteristic radial extinction brush.

x 100.

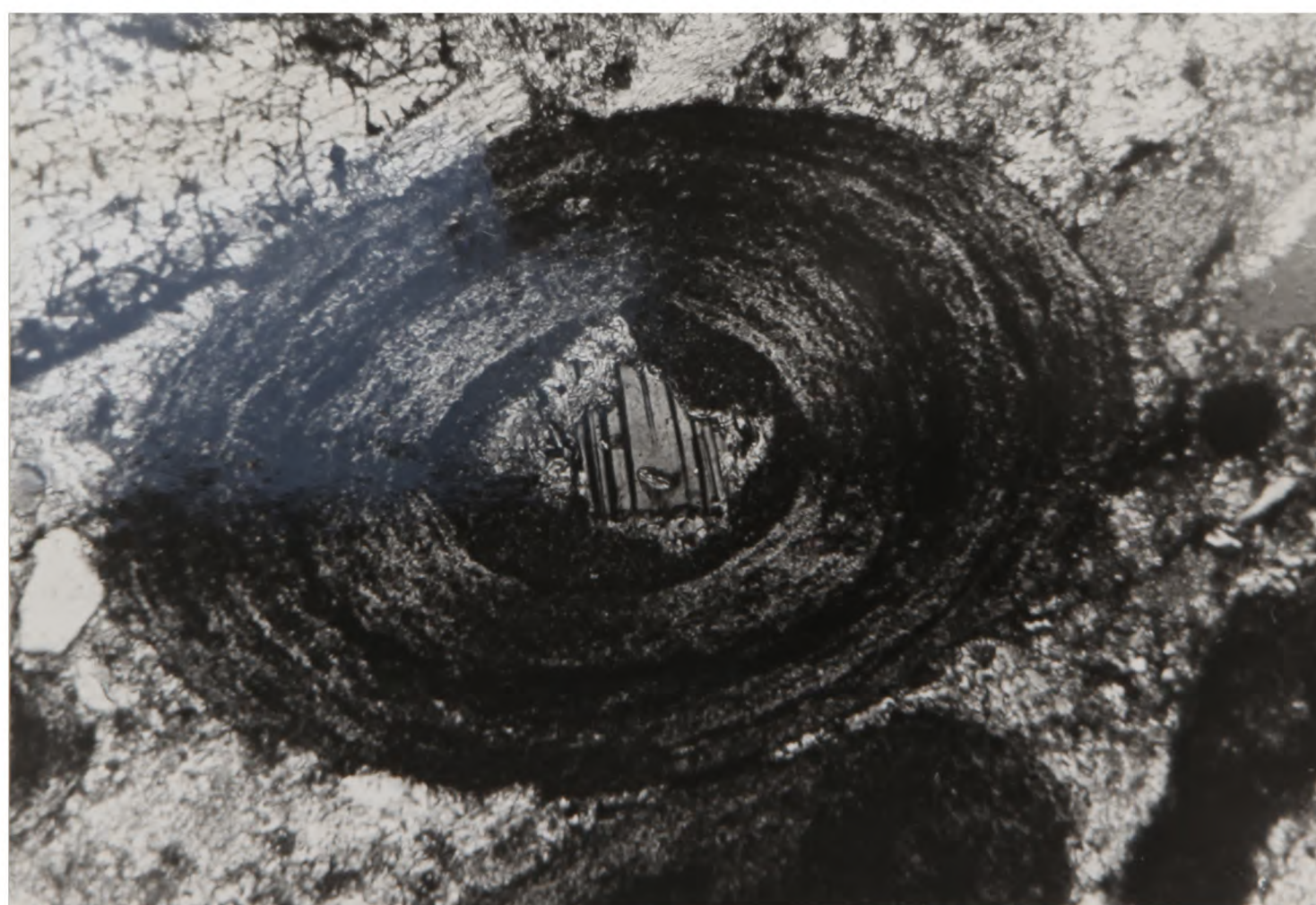
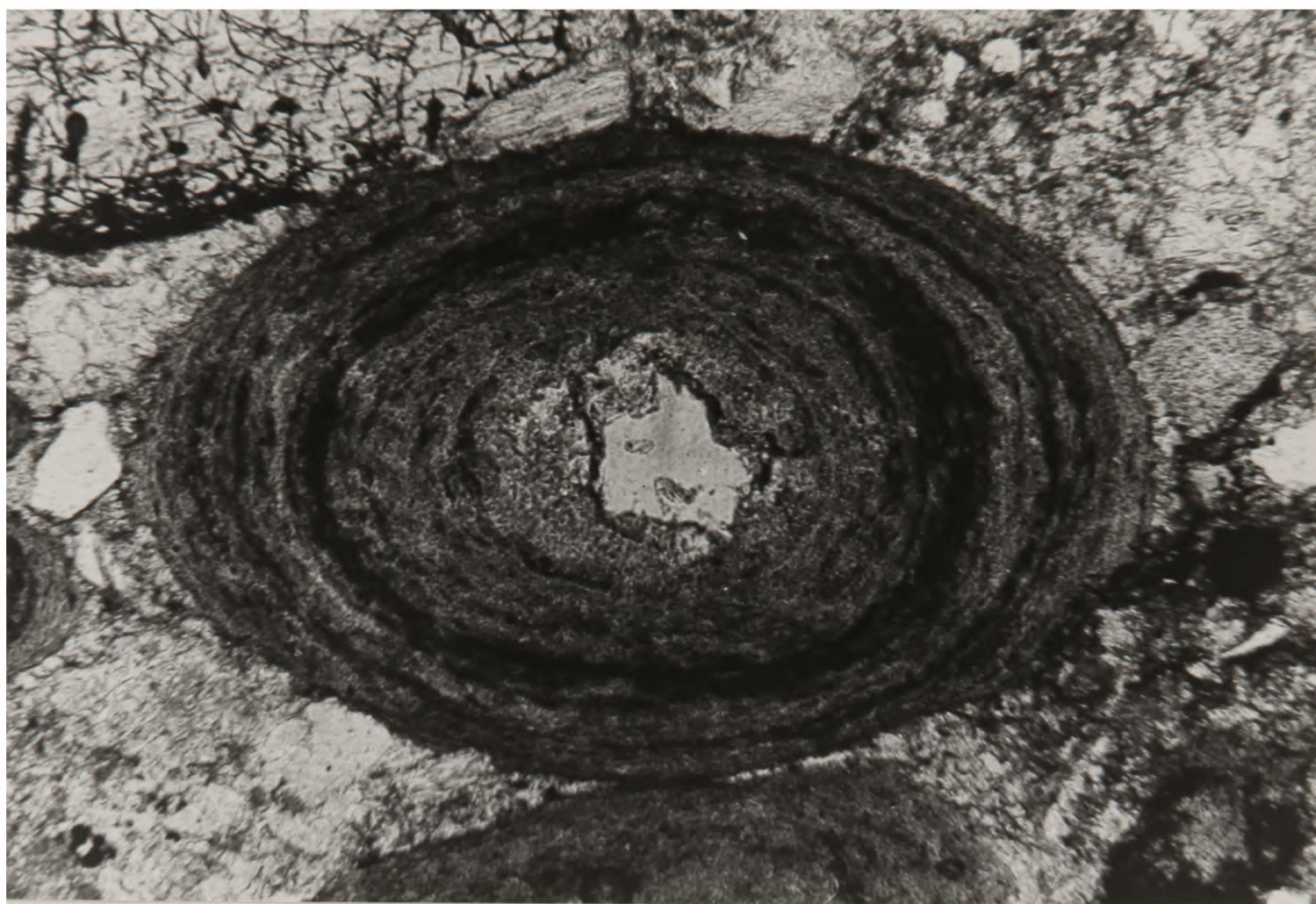
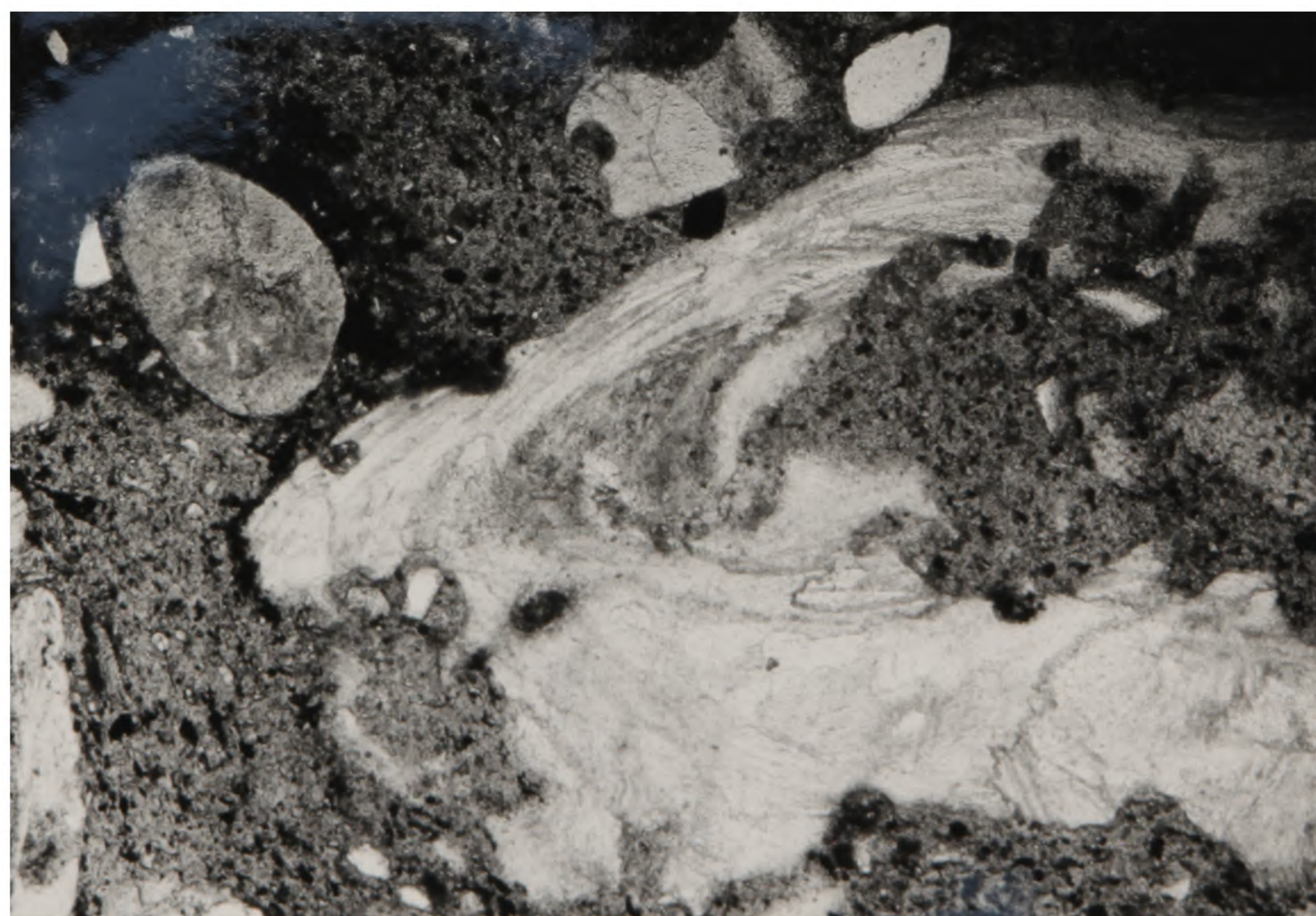


Plate 9.13.C. Same sample as Plate 9.13a. Angular feldspar grain showing altered margin with rounded vermicular kaolinite coating covered by tangentially oriented chloritic flakes.
x 400.

Plate 9.14. Photomicrograph of phosphatic nodule showing apparently digested shell fragments in phosphatic cement.
Semicostatum Zone, Mingary Castle, Ardnamurchan.
x 50.



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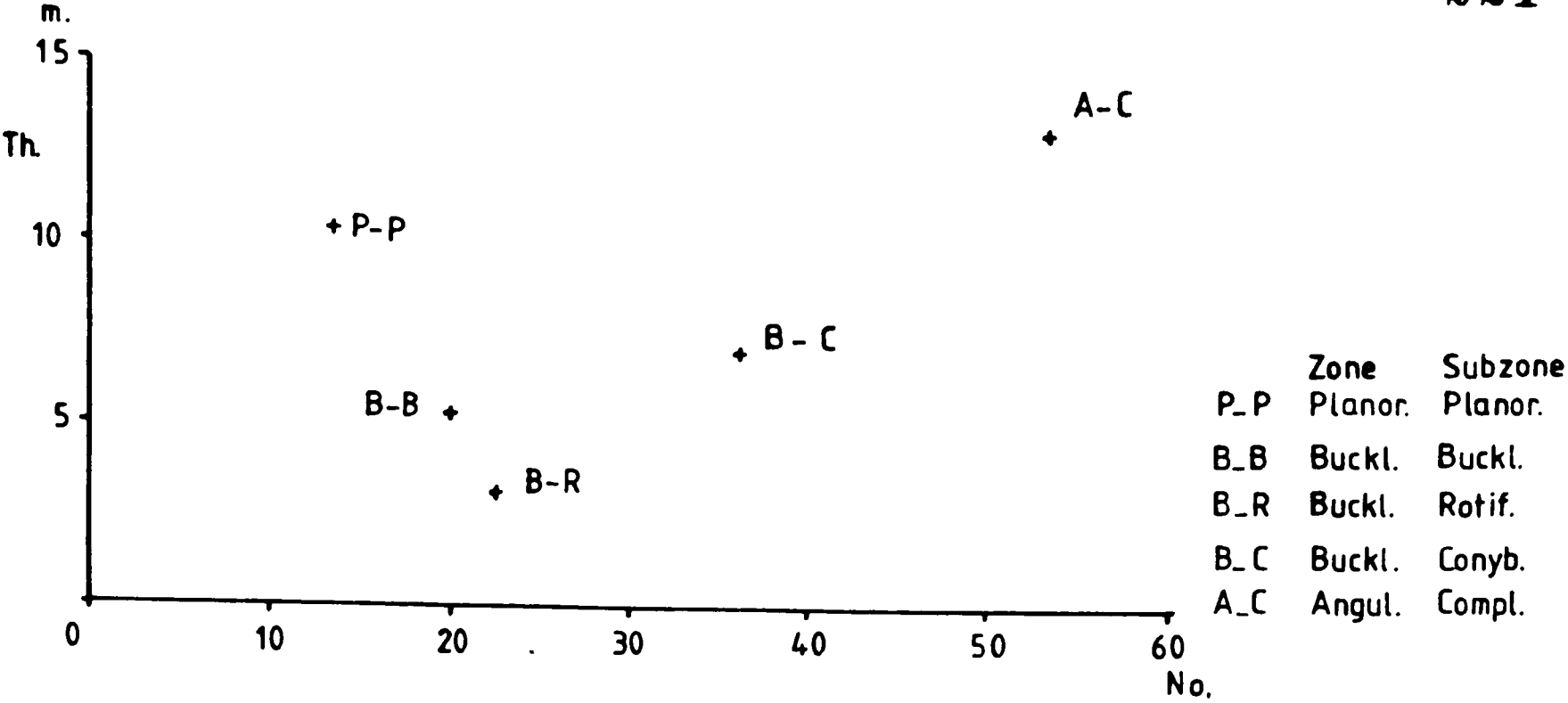


Fig.10.1 Zone thickness vs. number of limestone beds in the Broadford Beds Argillaceous Group.

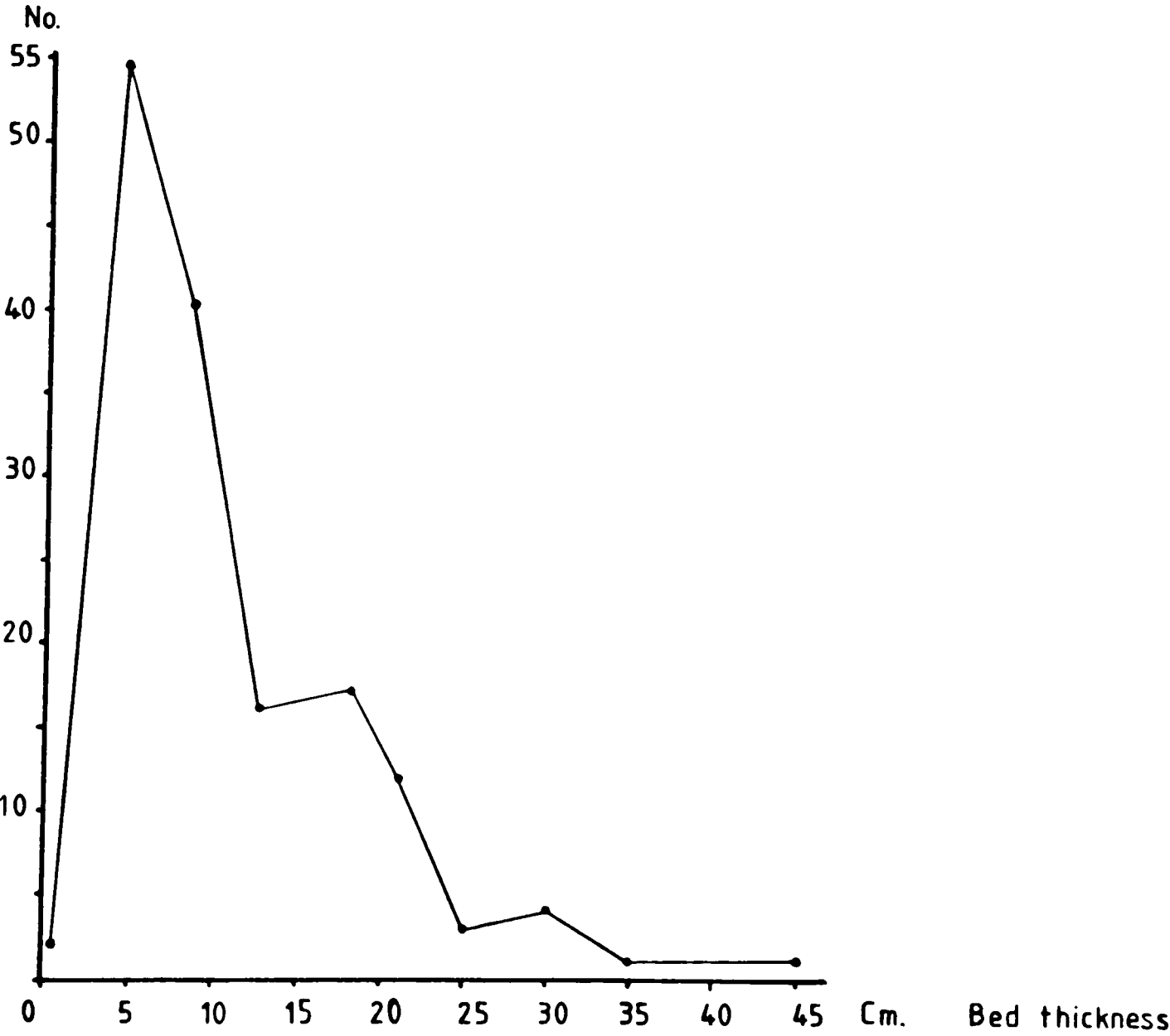


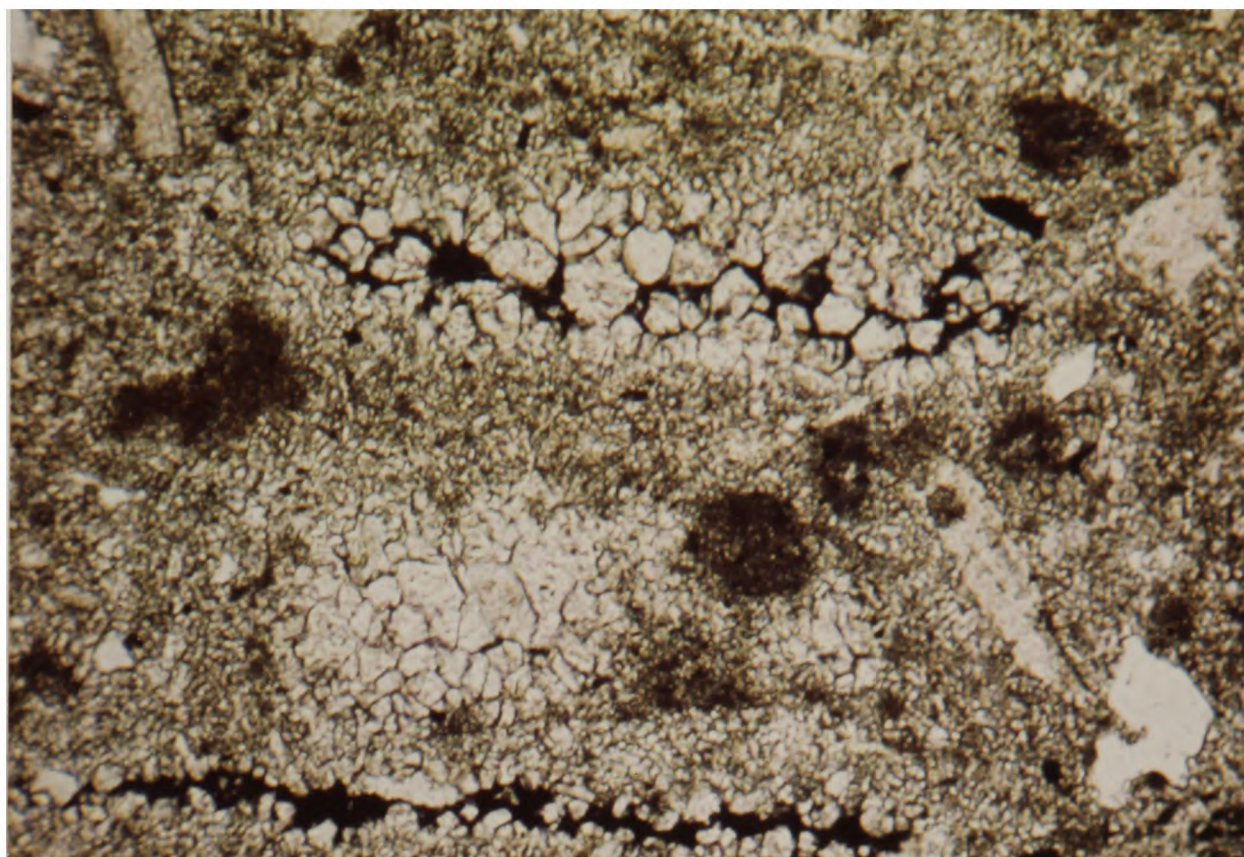
Fig.10.2 Bed-thickness vs. number of limestone beds in the Leacach Formation.

Plate 10.1. Photomicrograph showing masses of sparry calcite which may have formed due to pore infilling (note the size increase of the crystals towards the centre of the ?cavity).

x 50

Plate 10.2. Photomicrograph showing large calcite crystals with sutured boundaries and bent twin lamellae which are typical of strained calcite and late diagenetic stage origin.

x 50. Angulata-Bucklandi Zone, northern Strata.



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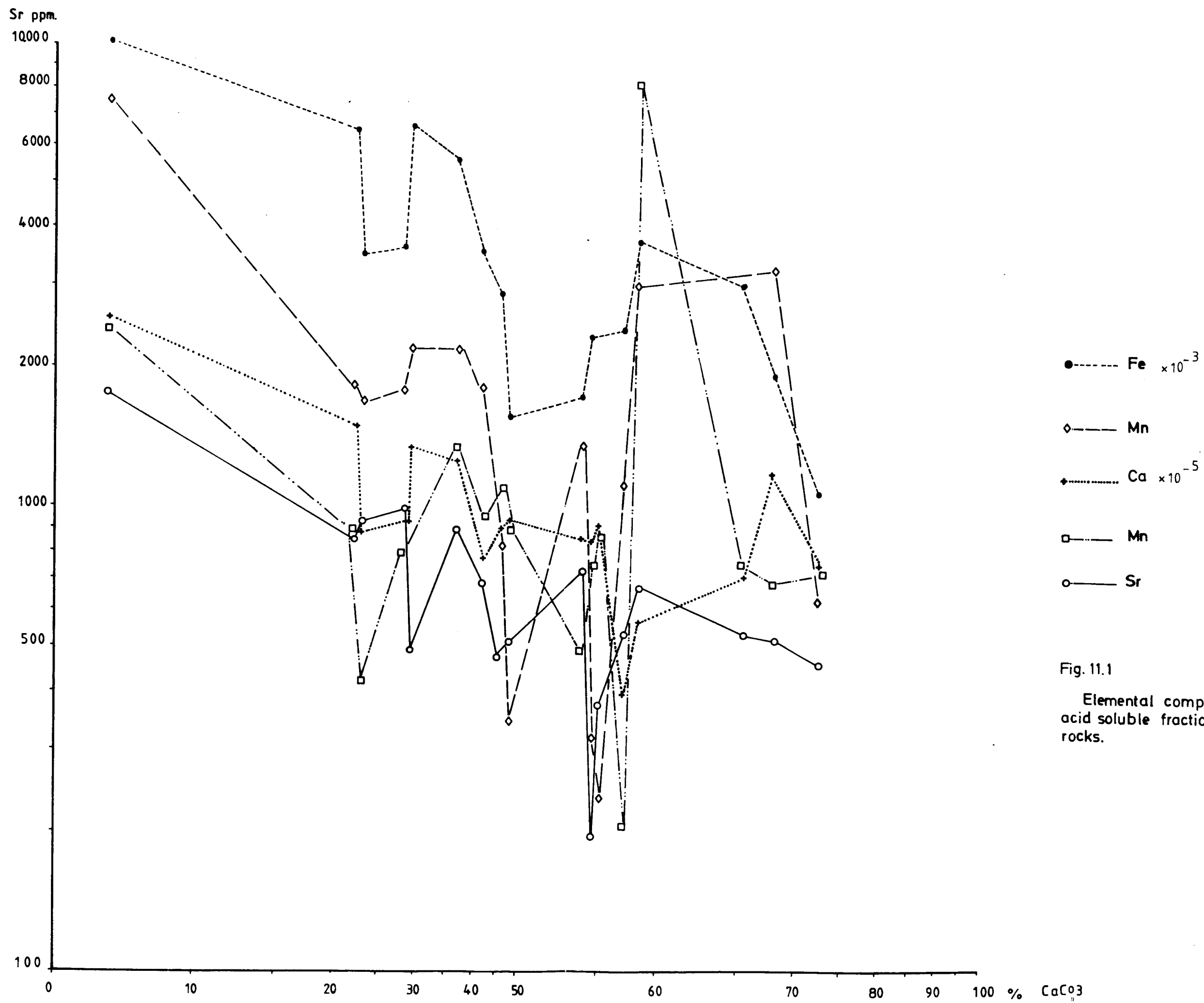


Fig. 11.1

Elemental composition of the acid soluble fraction of the studied rocks.

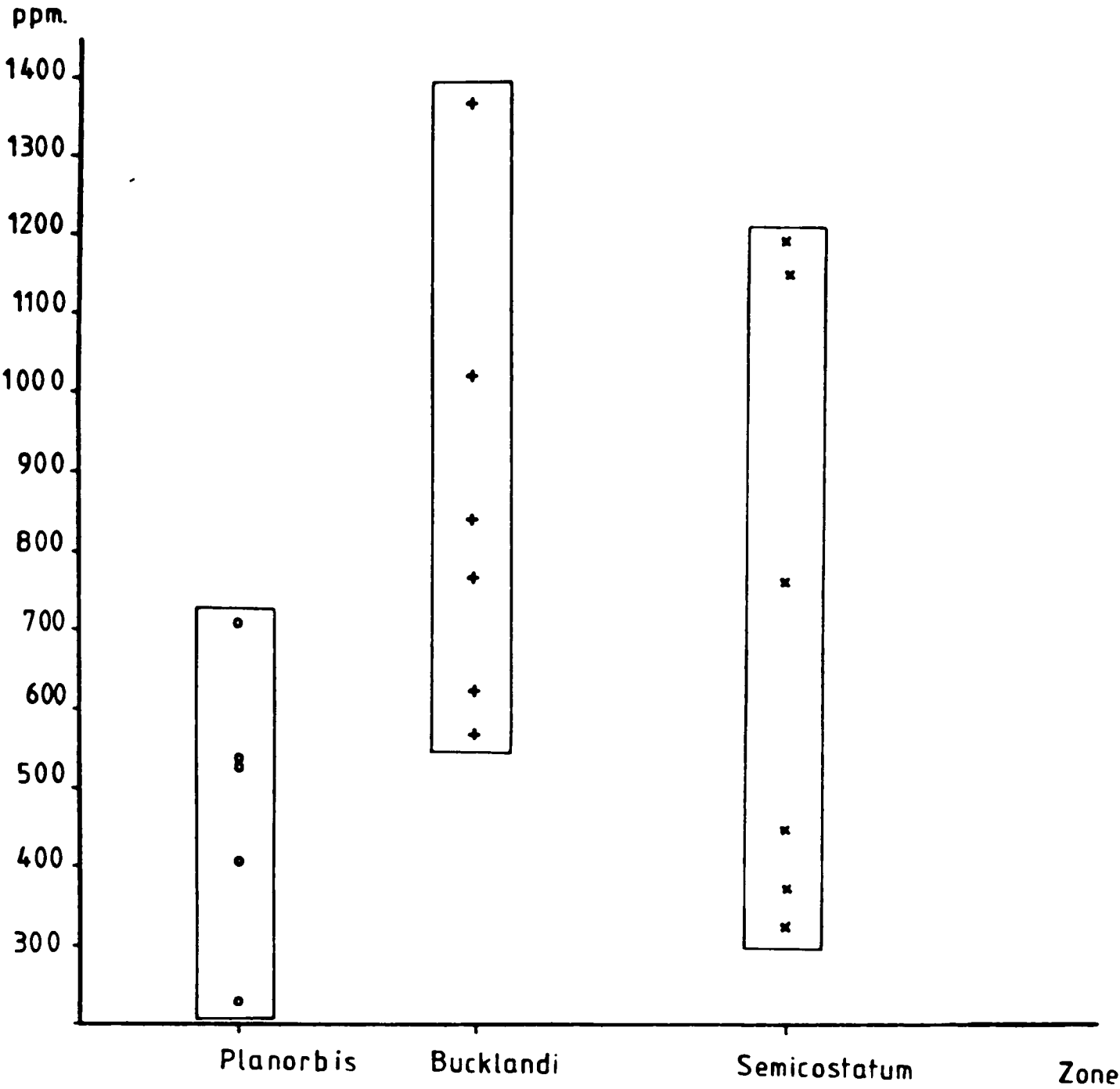


Fig.11.2 General Sr^{++} concentration variation in the studied rocks.

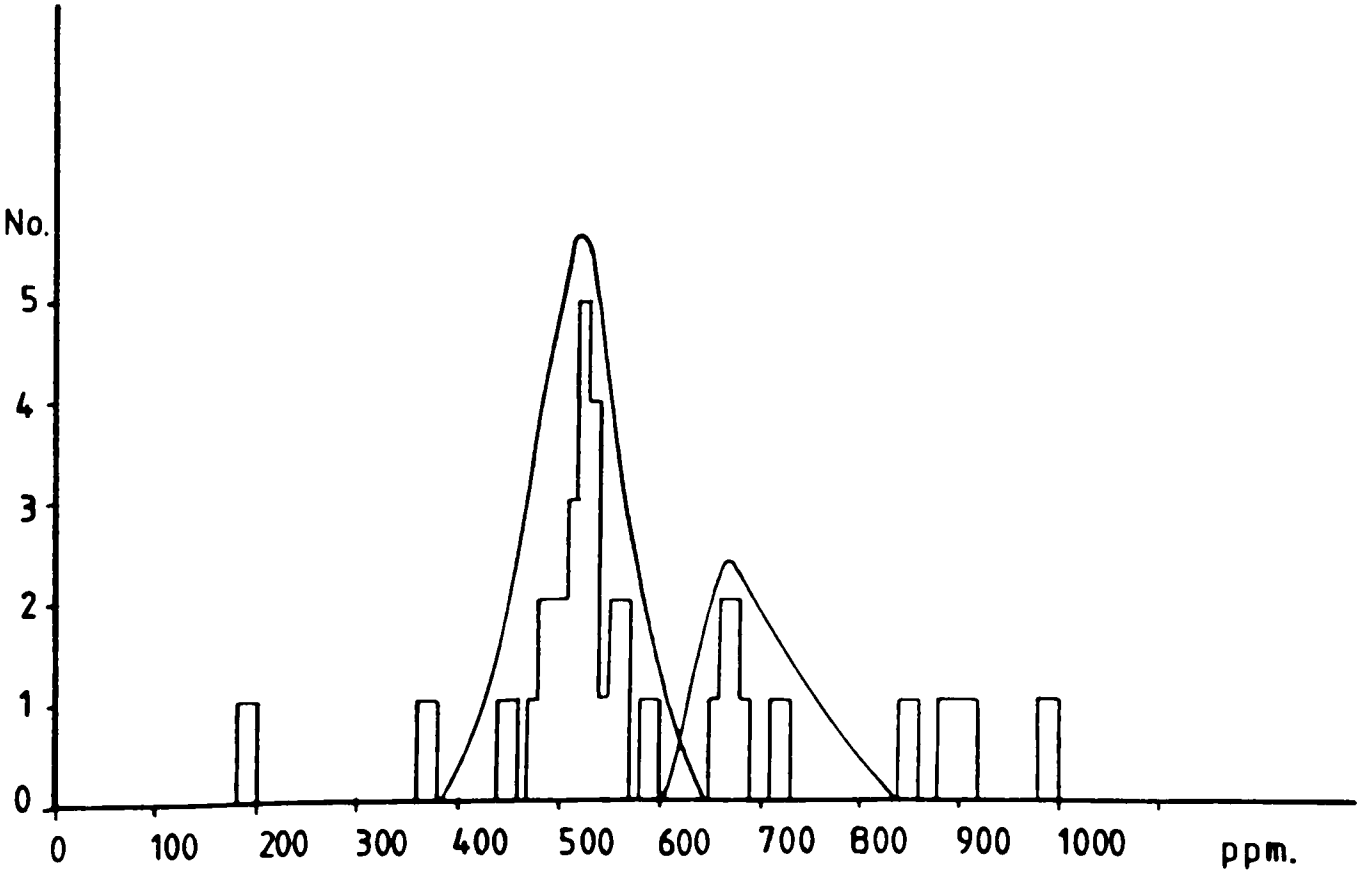


Fig.11.3 Histogram of Sr^{++} ppm. distribution in the studied rocks.

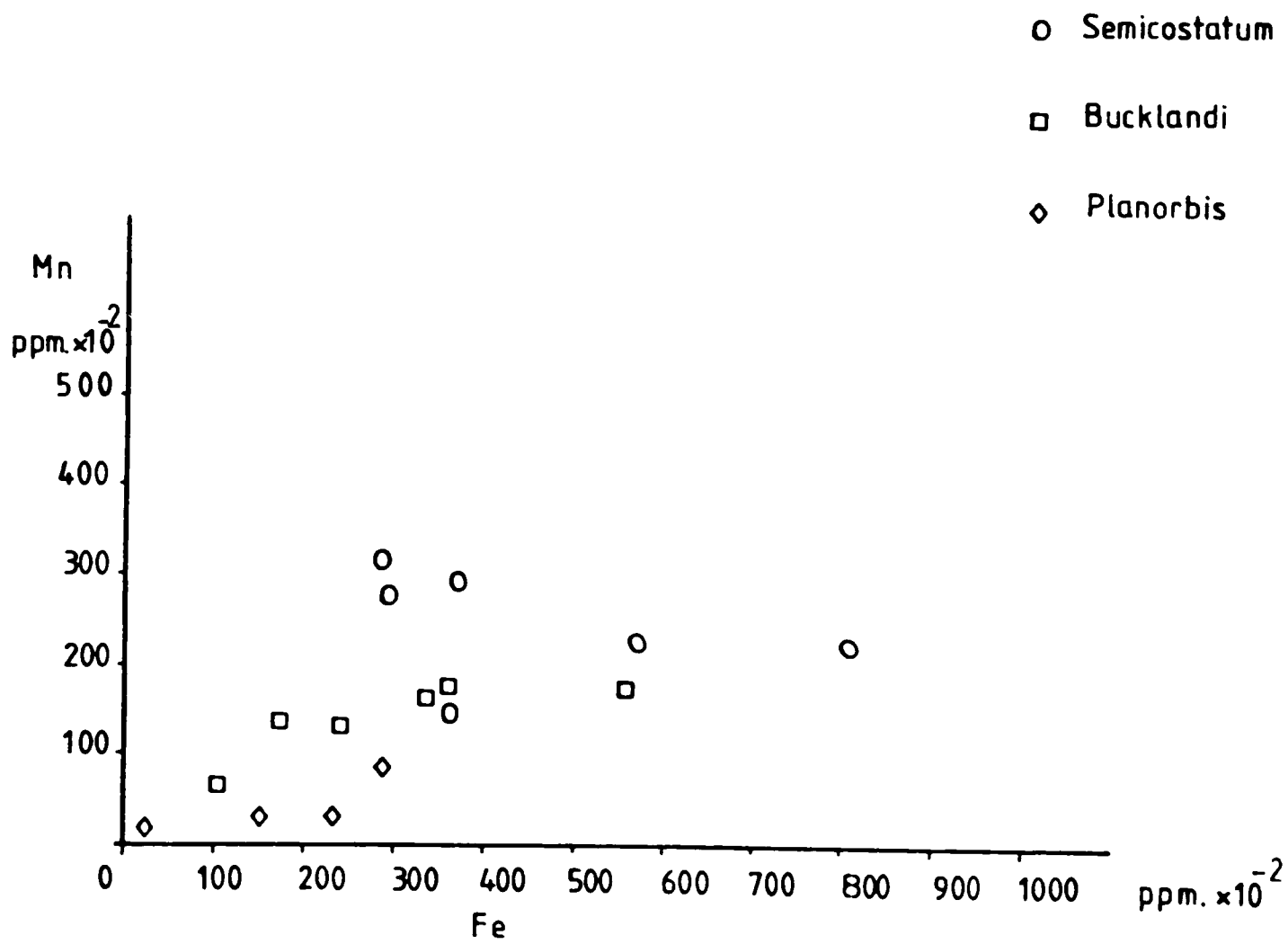


Fig.11.4 Mn. vs. Fe concentration in the carbonate fraction of the studied beds.

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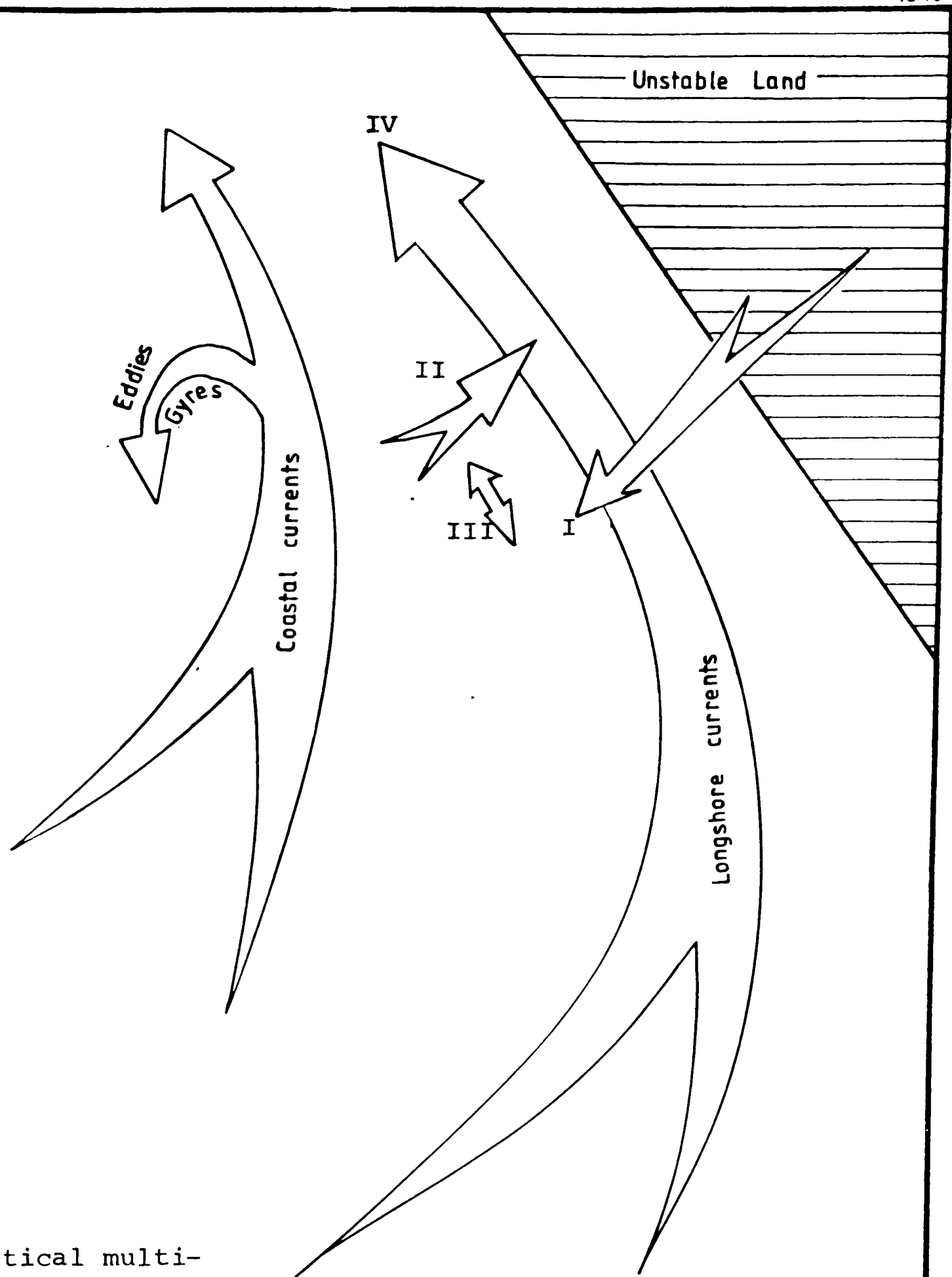


Fig 12. I
Hypothetical multi-component depositional system which controlled the sediment distribution patterns, during the L. Lias in NW Scotland.
Transportation direction.

- a. Offshore.
- b. Onshore.
- c.. Longshore.

- Possible mechanism.
- 1. Uplift, regr., lowering of sea level.
 - 2. Downwarp, transgr., rise of sea level.
 - 3. Stillstand.
 - 4. Longsh. & coastal cur.

Effects:
1=I-a>b>c ; 2=II-b>a>c
3=III-c>a>b; 4=IV-c>a>b

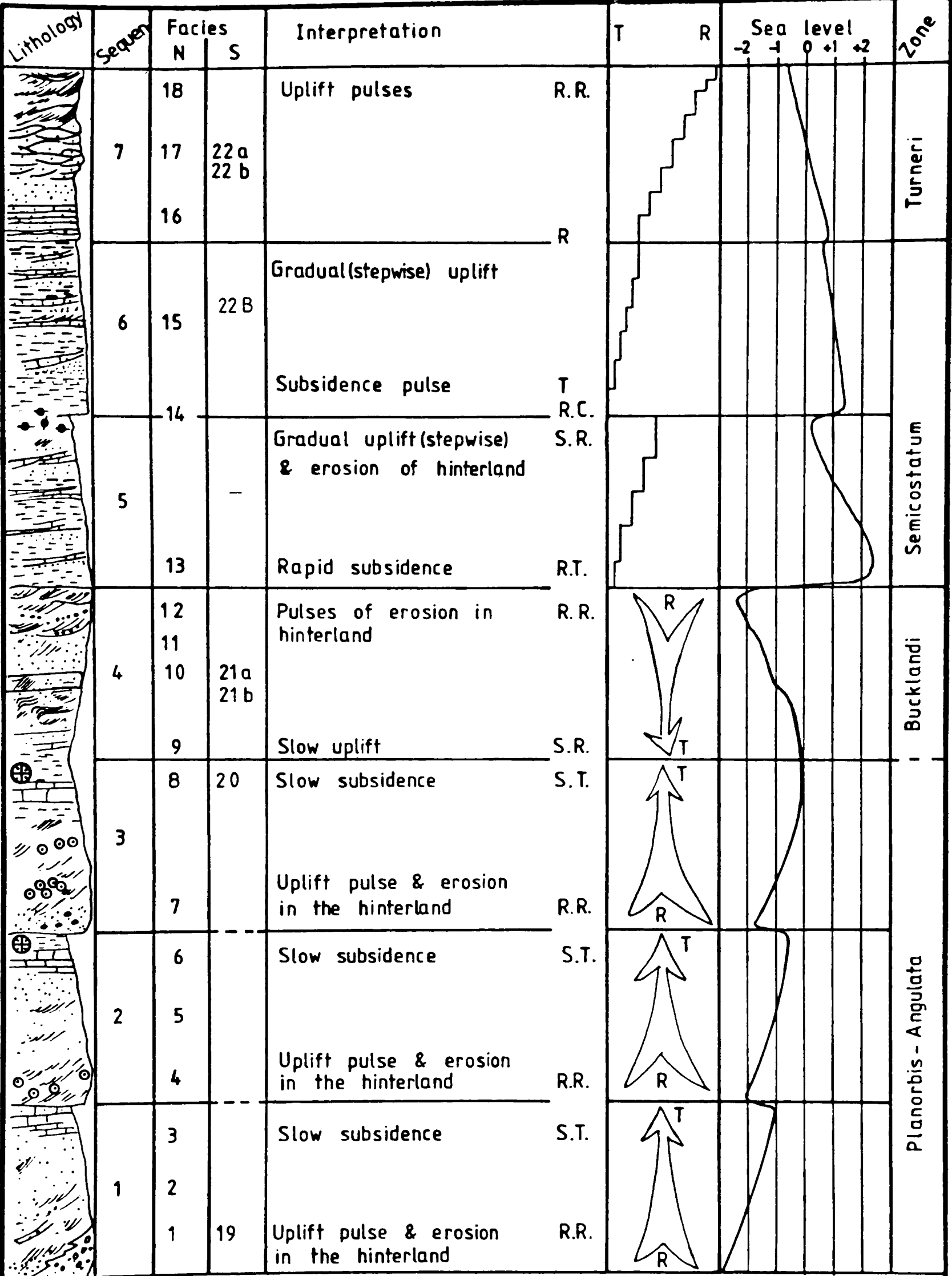


Fig. 12.2

R = Regression R.R. = Rapid regr. S.R. = Slow regr.
T = Transgression R.T. = Rapid trans. S.T. = Slow trans.
R.C. = Regression culmination

Possible sea-level-facies relationships in the Lower Lias of NW Scotland.

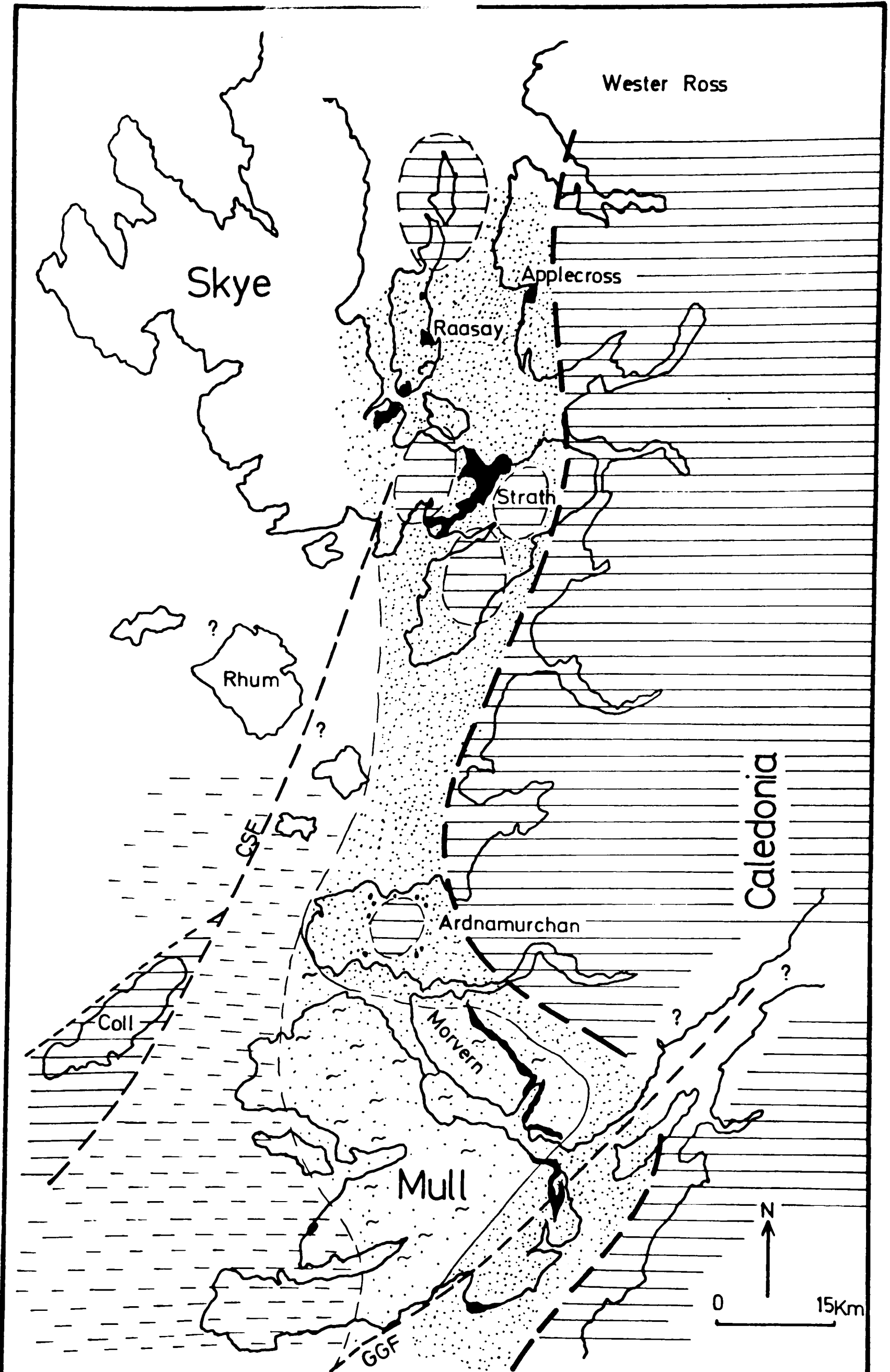


Fig. 12.3 Development of facies during sequence I (Plan.-Buck. Zones), in the studied area. Symbols explained in Table 12.1

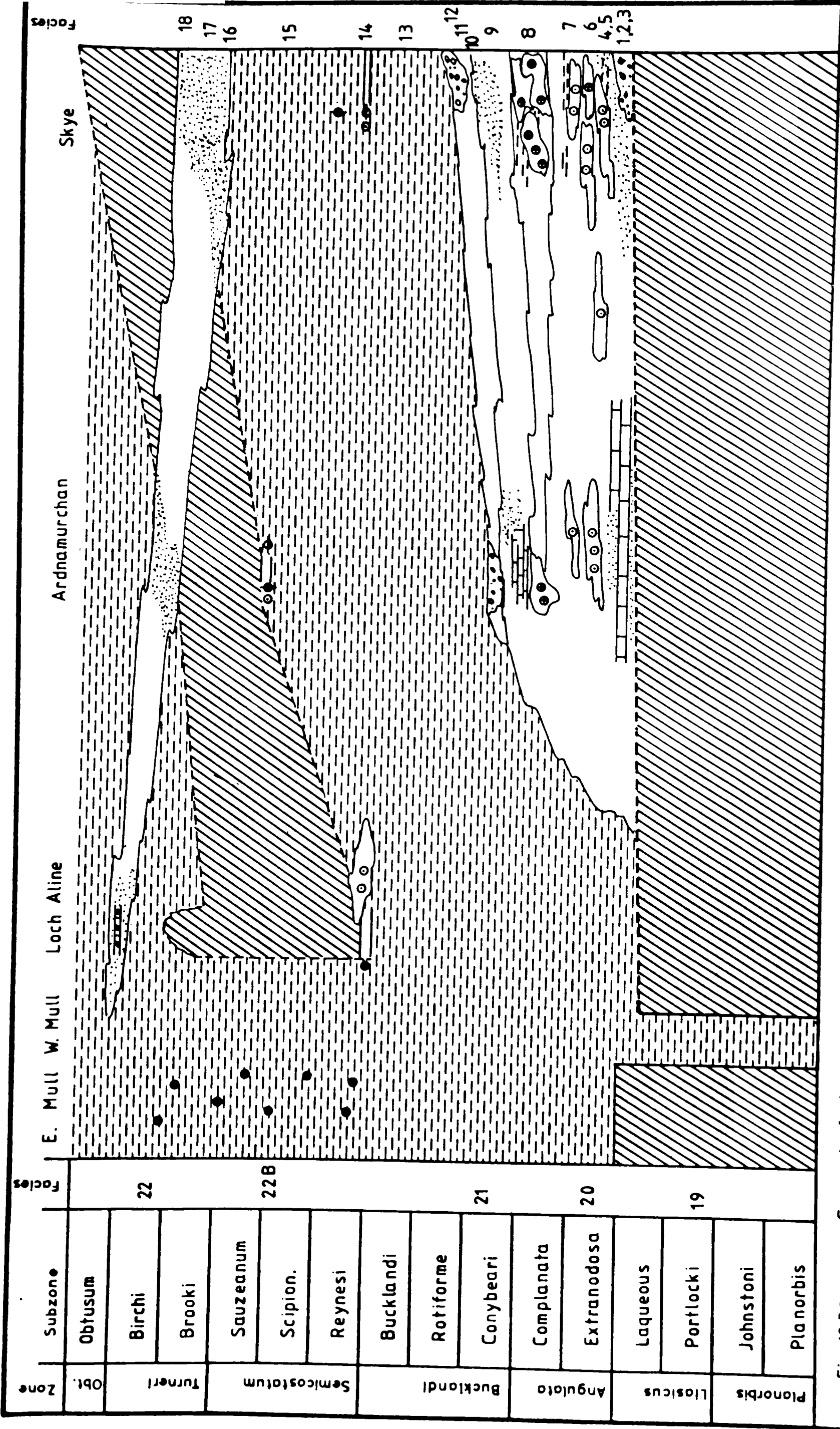


Fig. 12.3a General facies correlation

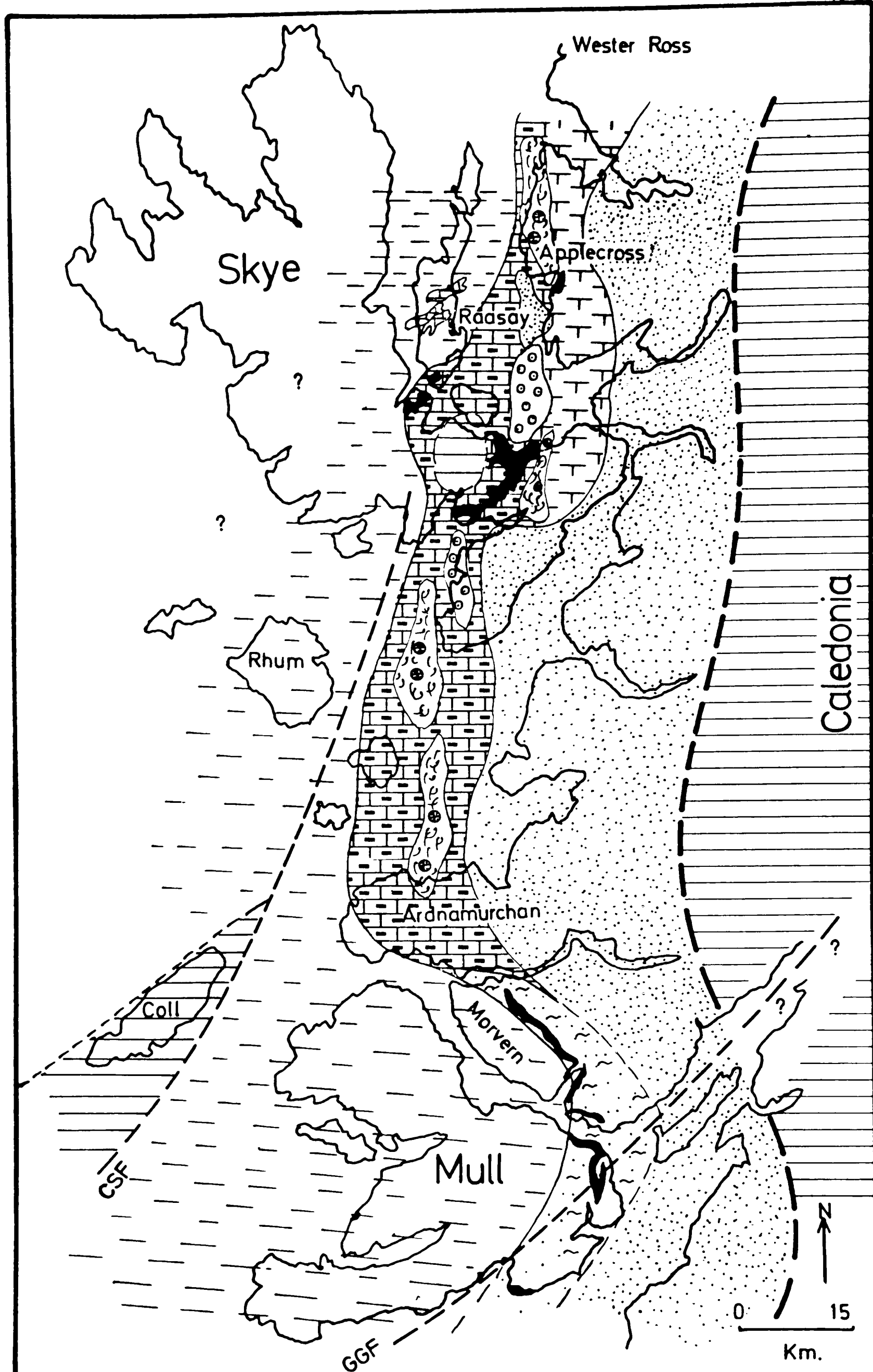


Fig. 12.4 Development of facies during sequences 2 & 3 (Angul. Zone), in the studied area. The symbols are explained in Tab.12.1

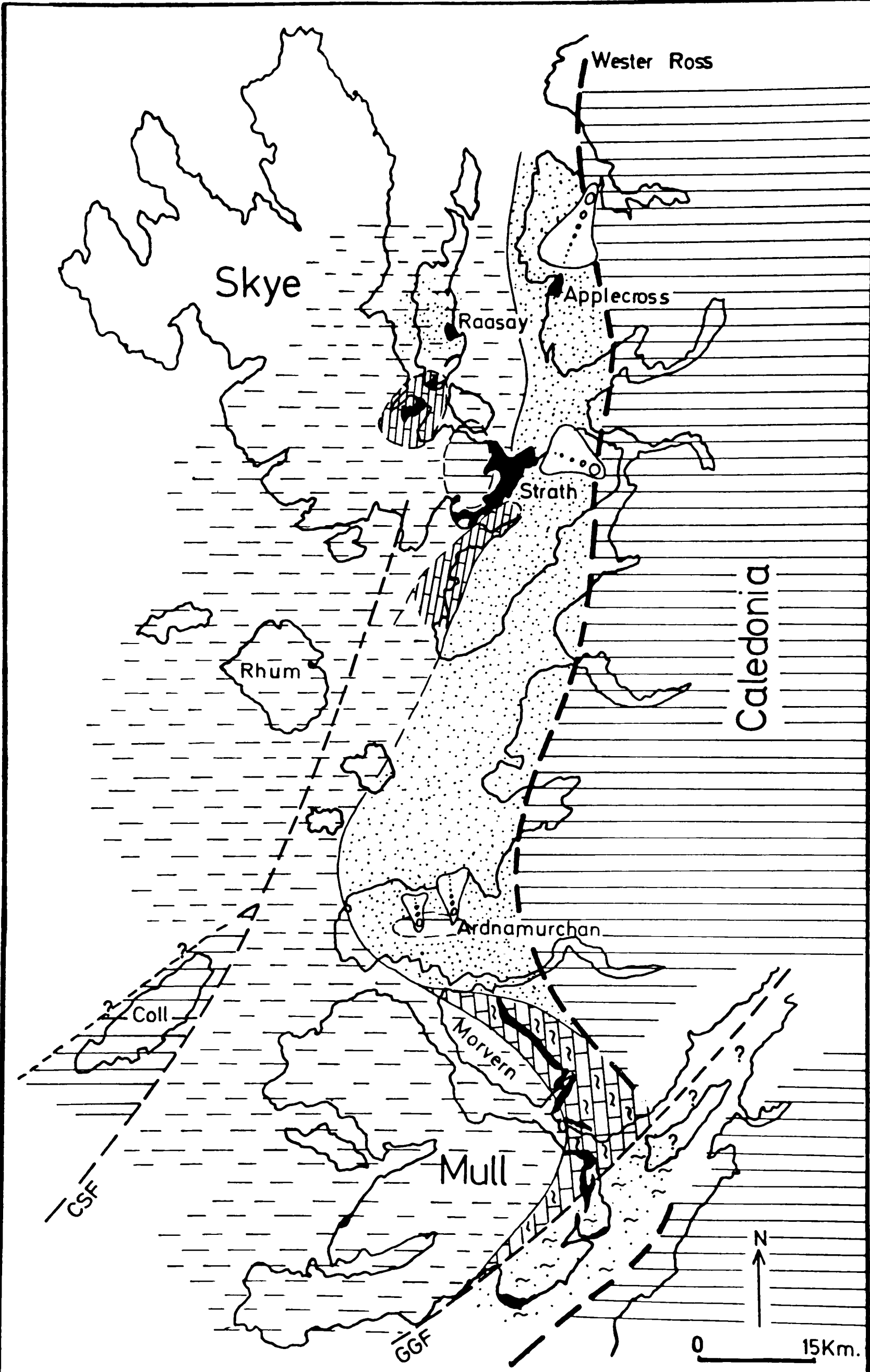


Fig. 12.5 Development of facies during sequence 4 (Buck. Zone), in the studied area . The symbols are explained in Table 12.1.

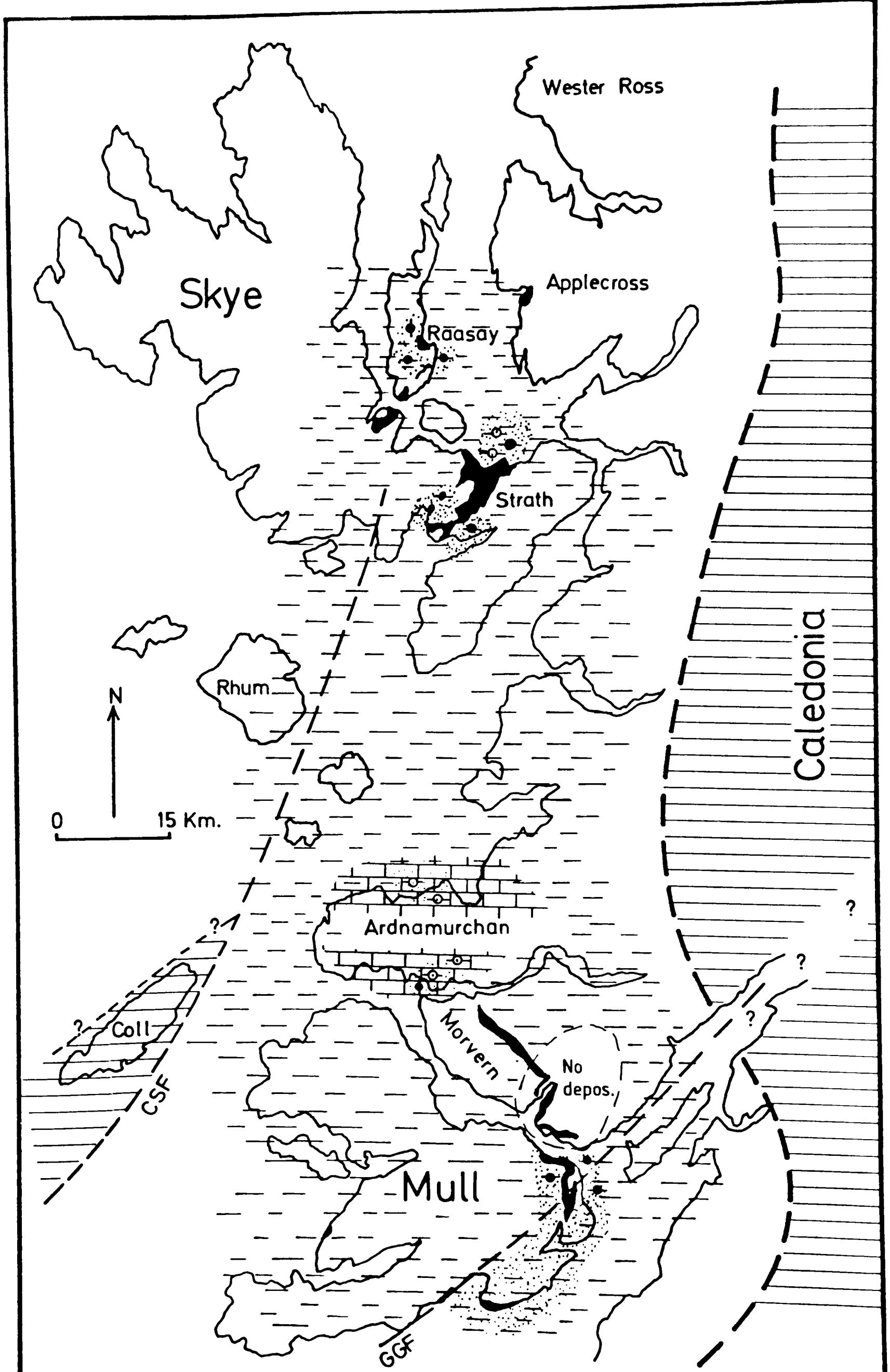


Fig. 12.6 Development of facies during sequence 5 (Semicost. Zone), in the studied area. For explanation of symb. see T.12.1

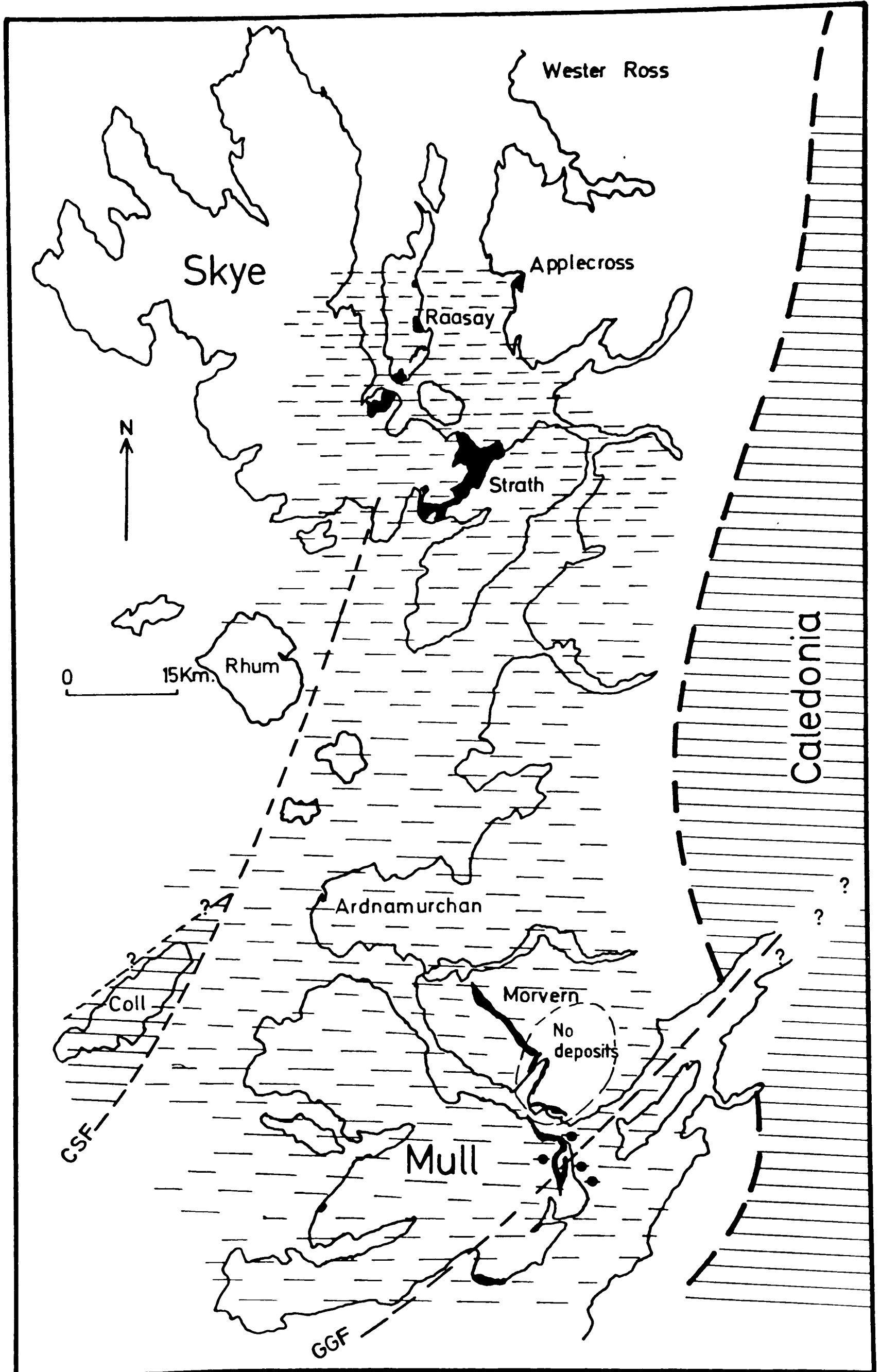


Fig. 12.7 Development of facies during sequence 6 (Semicost. Zone) in the studied area. Symbols explained in Table 12.1

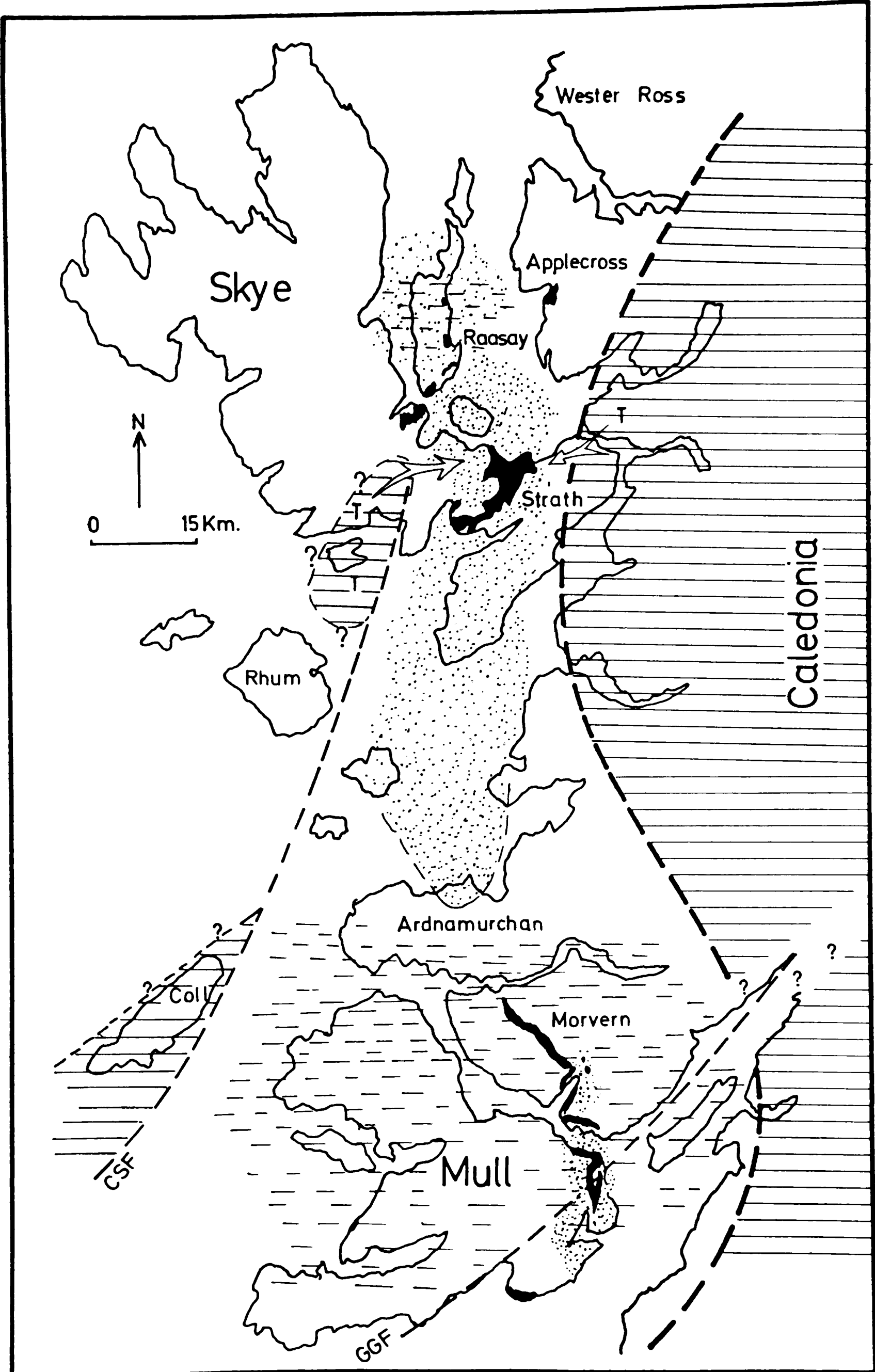


Fig. 12.8
Development of facies in the studied area during the Turner's Zone. The symbols are explained in Table 12.1

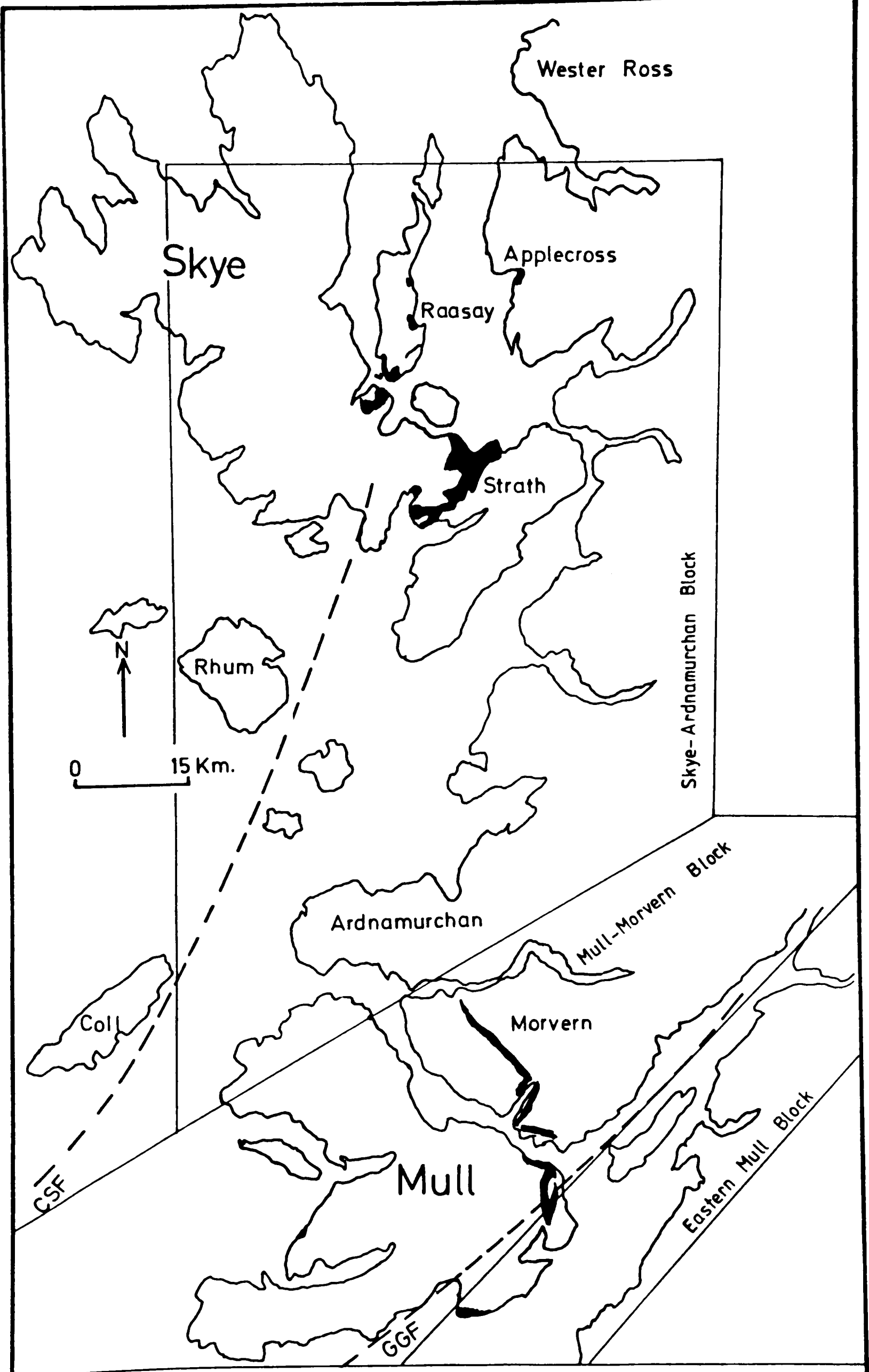


Fig. 12.9 Approximate geographic extent of the different "blocks" described in the text.

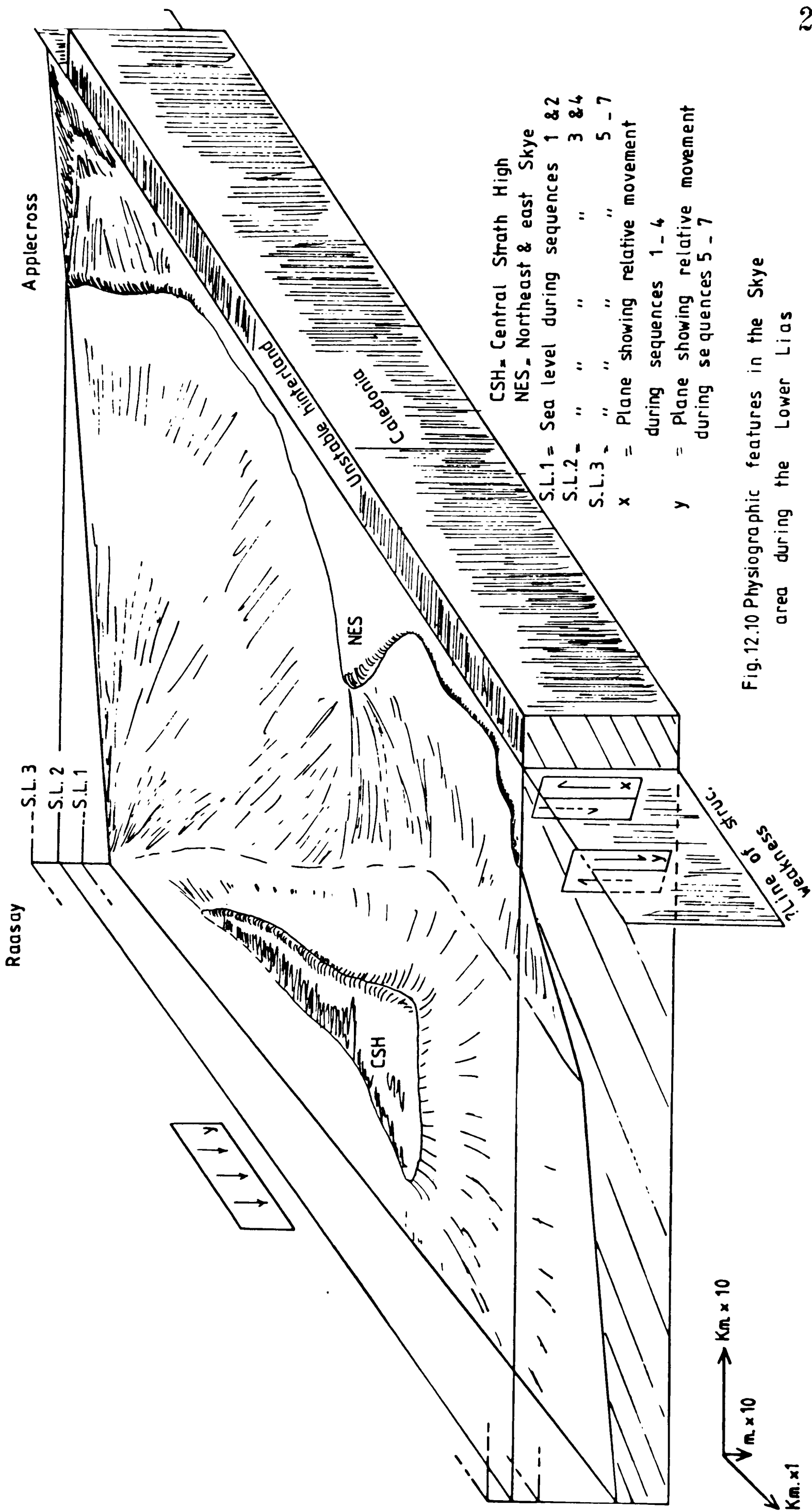


Fig.12.10 Physiographic features in the Skye area during the Lower Lias

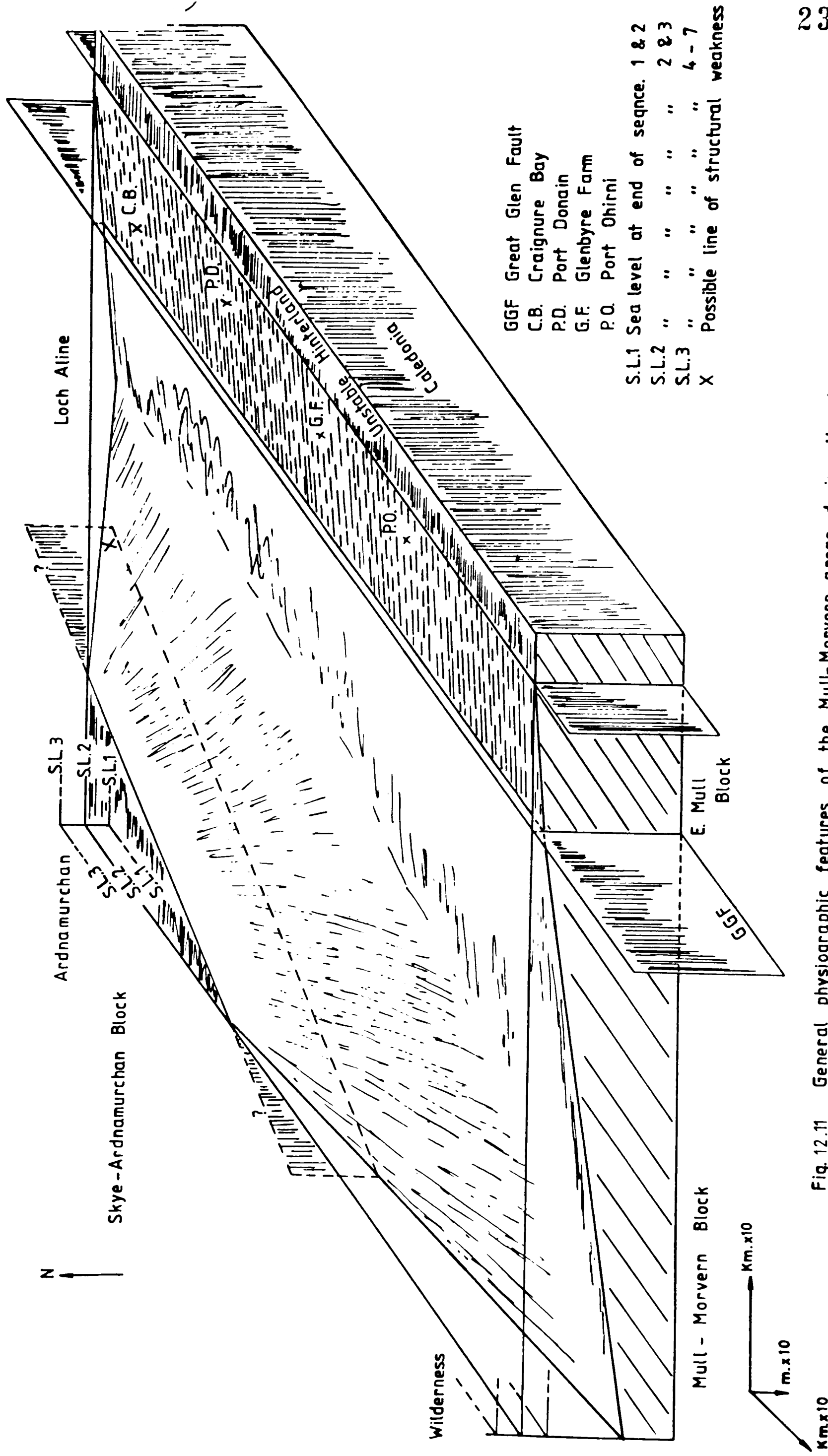


Fig. 12.11 General physiographic features of the Mull-Morvern areas during the Lower Lias.

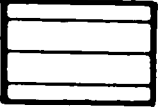
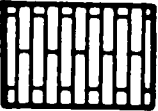
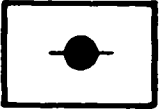
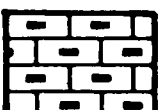
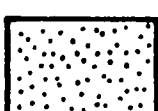
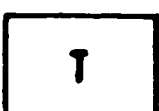
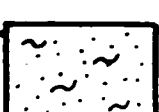
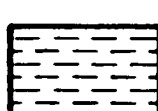
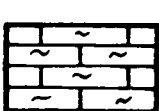
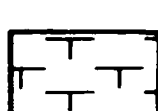
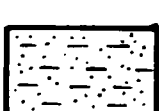
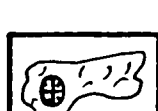
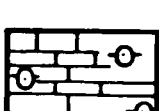
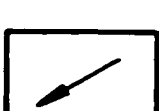
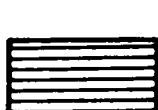
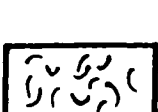
	Possible land areas.		Oolitic ironstone.
	Shallow-water limestones.		Ferruginous mudstone.
	Pebbly calc. sandstone.		Phosphatic nodules.
	Interbedded lsts. & sdy. shaly limestones.		? Aeolian silt.
	Calcareous sandst.		Torridonian sandstone.
	Micritic & "birds-eye" lsts.		Possible source of sed. not necessarily direct. of transport.
	Bioclastic & lithocl. lst.		Mixed, cont.-marine (nearshore) deposits.
	Marine dk. shales.		Calc. shales.
	Nodular lsts.		Pebbly sandstone.
	Lagoonal shales & lsts.		Ferruginous, calc. siltst. & mudstones.
	Oolites.		Ferruginous sandstone.
	Corals.		Calcareous oolitic ironstone.
	Oolitic shoals with inter-shoal channels.		Direction of transport.
	Back-barrier channel deposits.		Possible alluvial fan.
	Bioclastic sandst.		Fault.
	Algal mud-coated ooliths.		Great Glen Fault.
			Camasunary-Skerryvore Fault.

Table 12.1

Symbols used in facies and palaeogeographic maps.

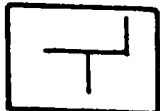
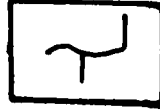
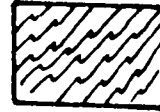
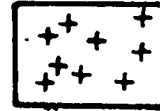
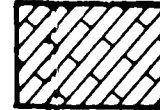
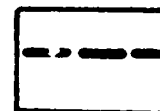
	Scour marks		Escape features
	Channel		<u>Kulindrichnus</u> <u>langi</u>
	Sharp contact		Mounds
	Burrowed contact		Gastropods
	Wavy contact		Liostrea
	Graded contact		
	Schists (Precambrian)		
	Quartzite (Cambrian)		
	Durness limestone		
	Torridonian sandstone		
	Permo/ Triassic congl.		
	Gap		
	Dykes (Tertiary)		

Table 2.3 (continued) Explanation of the different symbols used .

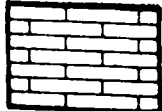
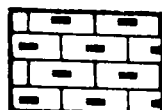
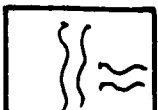
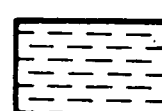
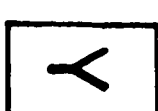
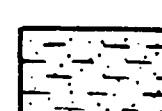
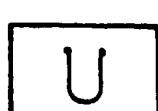
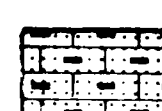
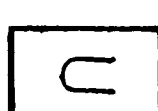
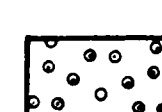
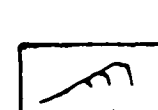
	Sandstone		Ostracods
	Limestone		Echinoderms
	Lst./Sh.		Bioturbation
	Congl.		Plant Fragments
	Shale		Coalif. wood & rootlets
	Pebbly sst.		<u>Thalassinoides</u>
	Silty sh.		<u>Diplocraterion</u>
	Silty calc. sh. & calc. sst.		<u>Rhizocorallium</u>
	Nodular Lst.		<u>Chondrites</u>
	Silty calc. sh.		Escape features & worm tubes
	Marlst./Lst.		Ferruginous beds
	Oolites		Phosphatic beds
	Bioclastic rocks		Festoon cross lam.
	<u>Pinna</u>		Tabular cross lam.
	<u>Gryphaea</u>		Trough cross lam.
	Brachiopods		Ripples
	Bivalves		Parallel lam.
	Corals		Ripple cross lam.

Table 2.3 Explanation of the different symbols used.

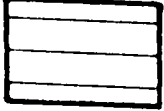
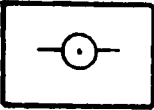
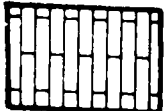
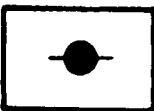
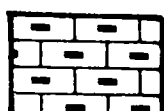
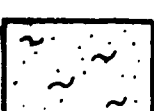
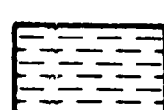
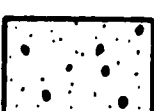
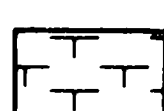
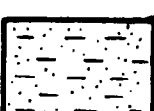
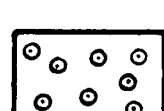
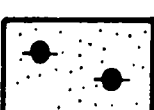
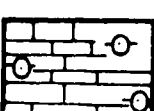
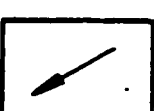
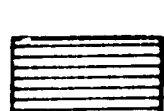
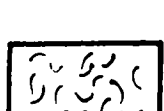
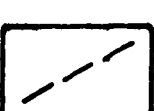
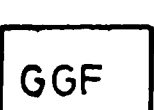
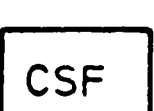
	Possible land areas.		Oolitic ironstone.
	Shallow-water limestones.		Ferruginous mudstone.
	Pebbly calc. sandstone.		Phosphatic nodules.
	Interbedded lsts. & sdy. shaly limestones.		? Aeolian silt.
	Calcareous sandst.		Torridonian sandstone.
	Micritic & "birds-eye" lsts.		Possible source of sed. not necessarily direct. of transport.
	Bioclastic & lithocl. lst.		Mixed, cont.-marine (nearshore) deposits.
	Marine dk. shales.		Calc. shales.
	Nodular lsts.		Pebbly sandstone.
	Lagoonal shales & lsts.		Ferruginous, calc. siltst. & mudstones.
	Oolites.		Ferruginous sandstone.
	Corals.		Calcareous oolitic ironstone.
	Oolitic shoals with inter-shoal channels.		Direction of transport.
	Back-barrier channel deposits.		Possible alluvial fan.
	Bioclastic sandst.		Fault.
	Algal mud-coated ooliths.		Great Glen Fault.
			Camasunary-Skerryvore Fault.

Table 12.1

Symbols used in facies and palaeogeographic maps.