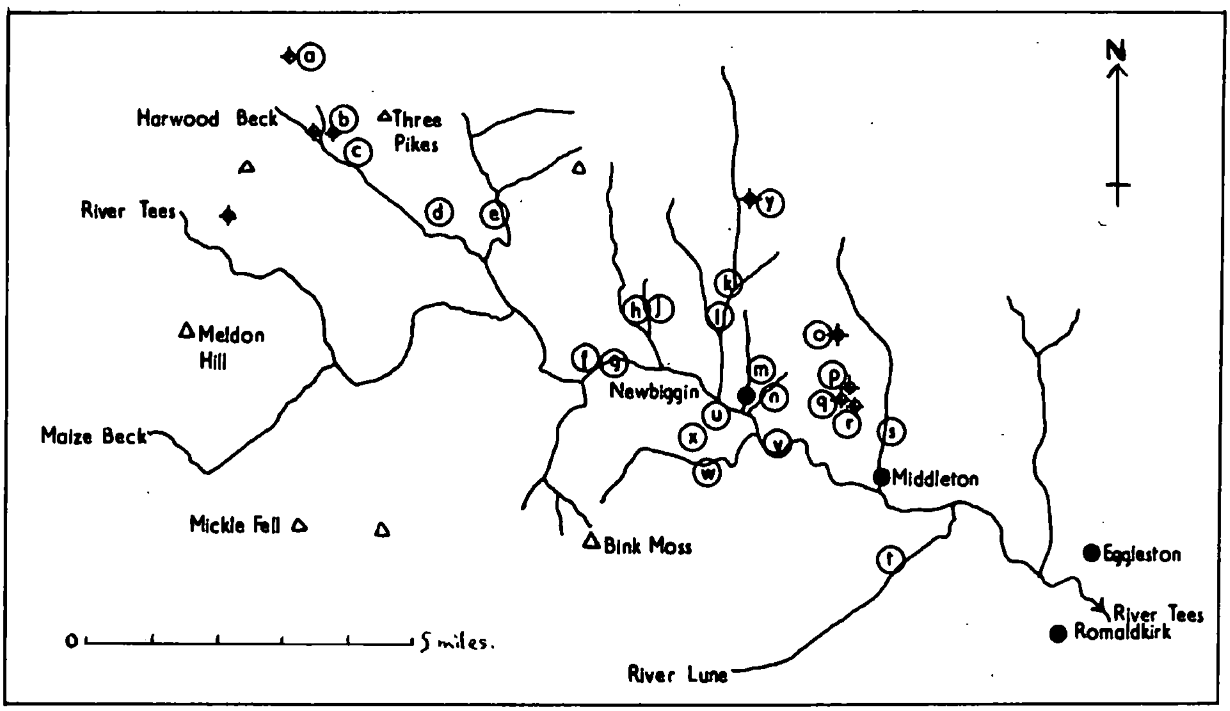
Mineralogy op yoredale series rocks in Upper Teesdale with special reference to clay minerals

Norman Henry Harbord

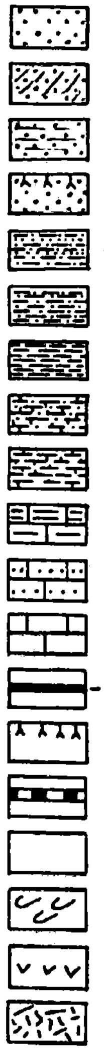
Sketch-map of Localities of Given Sections of Strata.



a. Ashgillhead Mine
b. Grasshill Shaft
c. Hawk Sike Hush
d. Birk Sike
e. Langdon Beck
f. Dine Holm
g. High Force
h. Ettersgill
J. Smithy Sike
k. Bleagill–Hell Cleugh
l. Bow Lees Beck
m. Newbiggin Beck
n. Brockers Gill
o. Coldberry – Lodgesike
p. Skears Vein F.
q. Skears Great Rise
r. Skears Vein D.
s. Hudeshope Beck
t. Lunedale Quarries
u. Scorberry Bridge
v. Tees
w. Rowton Beck
x. Eel Beck
y. Rylands Shaft

Fig. I.A.

Key.



- Sandstone
- False Bedded Sandstone
- Flaggy Sandstone
- Gannister
- Shale with Sandstone Bands
- Arenaceous Shale
- Shale
- Calcareous Arenaceous Shale
- Calcareous Shale
- Shaly Limestone
- Arenaceous Limestone
- Limestone
- C Coal
- Underclay
- Pyrite Bed
- Gap in Succession
- Large Brachiopods
- Coral Band
- Whin Sill
- N Nodular Shales
- F Fossiliferous Beds

Comparative Sections of Strata between the Tyne Bottom and Scar Limestones.

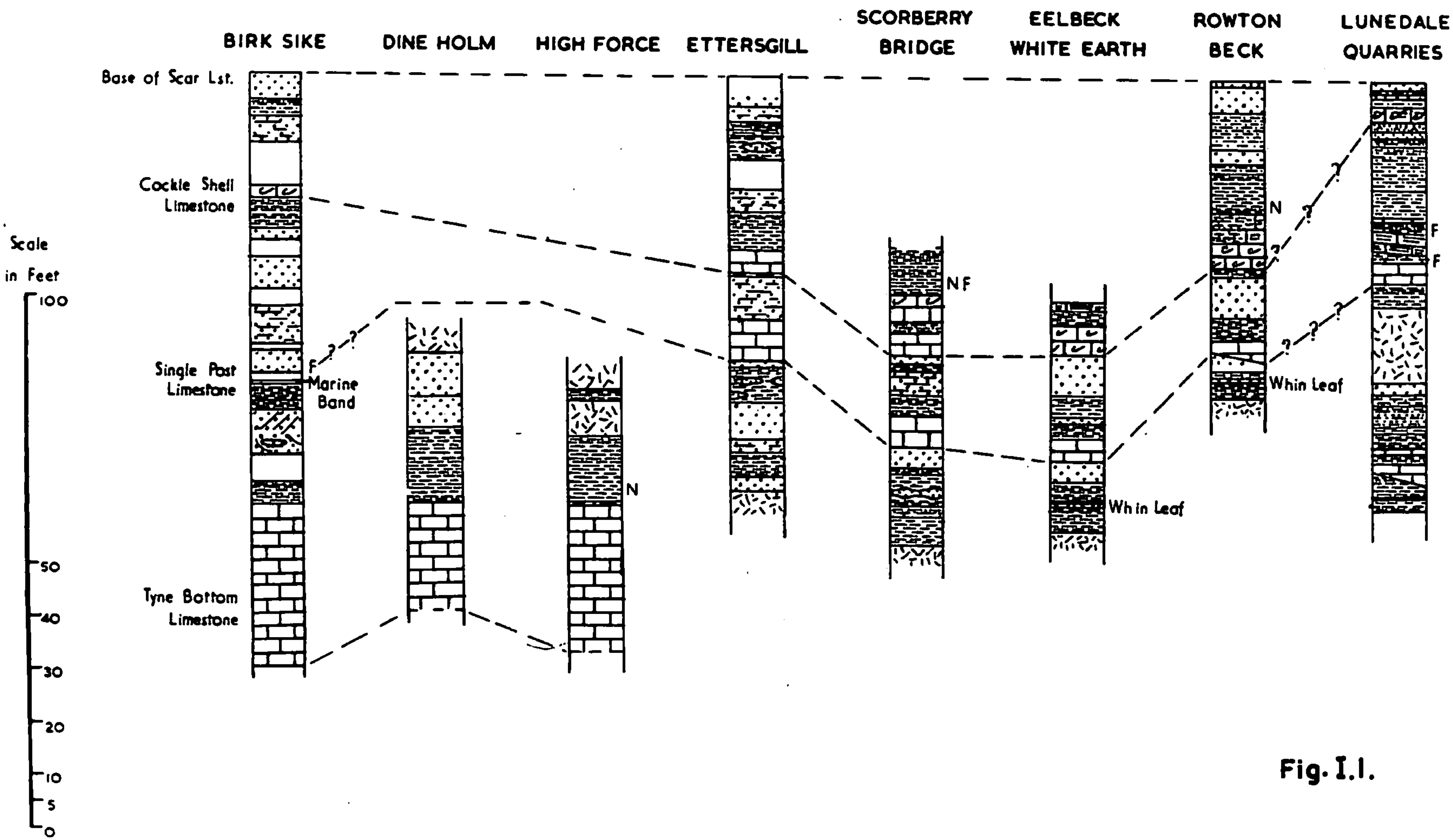


Fig. I.I.

Comparative Sections of Strata between the Scar and Three Yard Limestones.

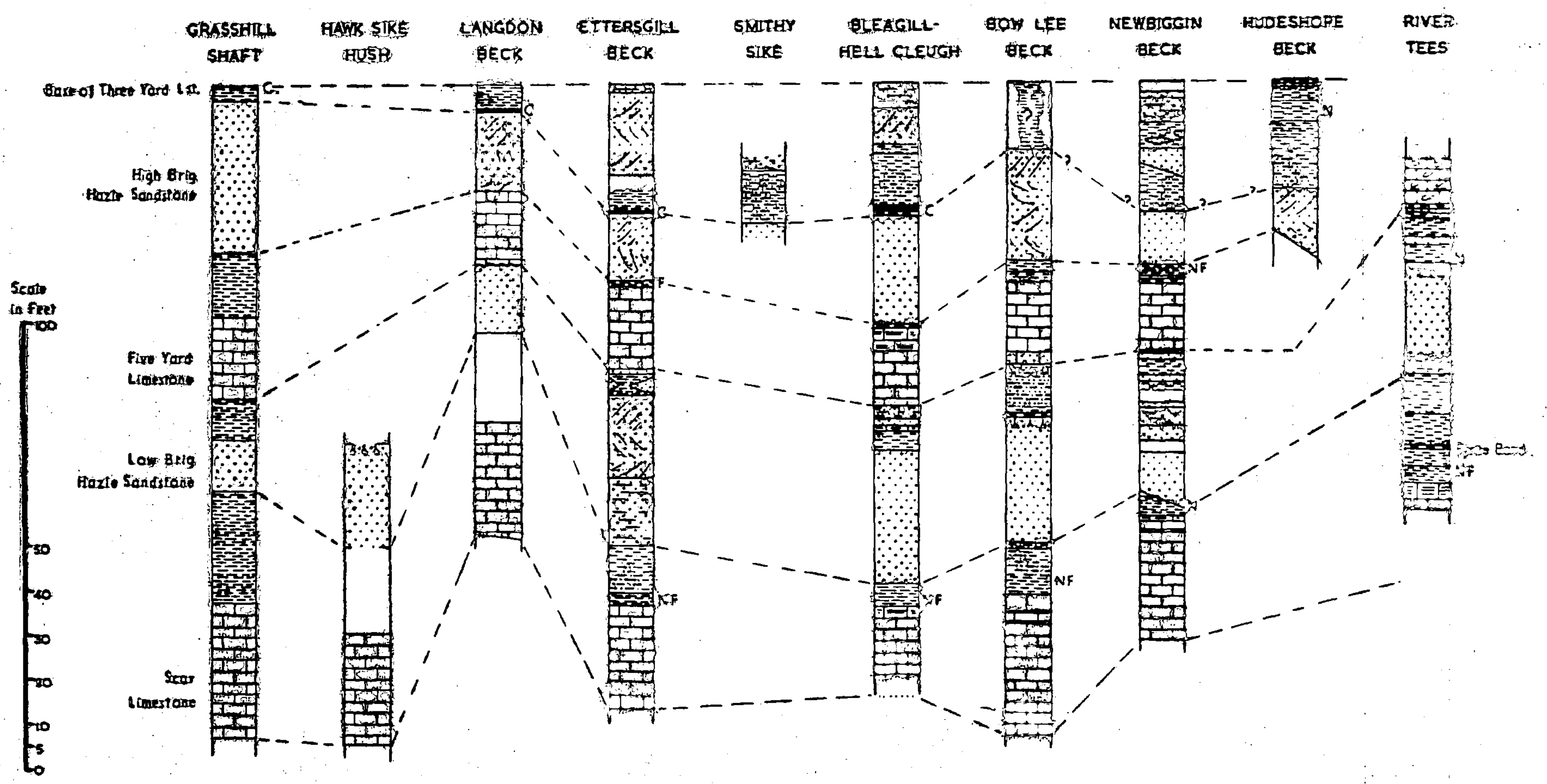


Fig.I.2.

Comparative Sections of Strata between the Three Yard and Great Limestones.

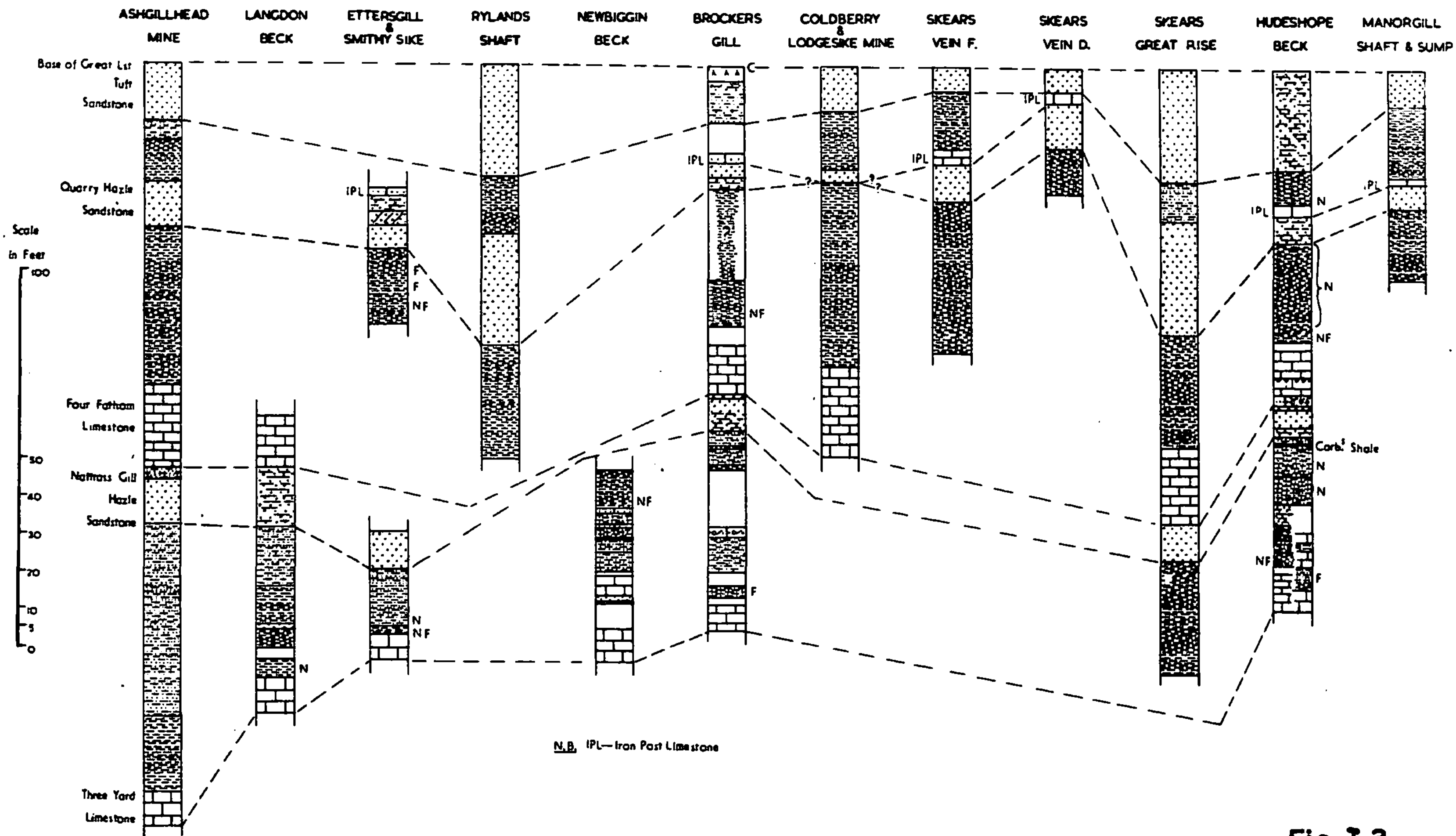
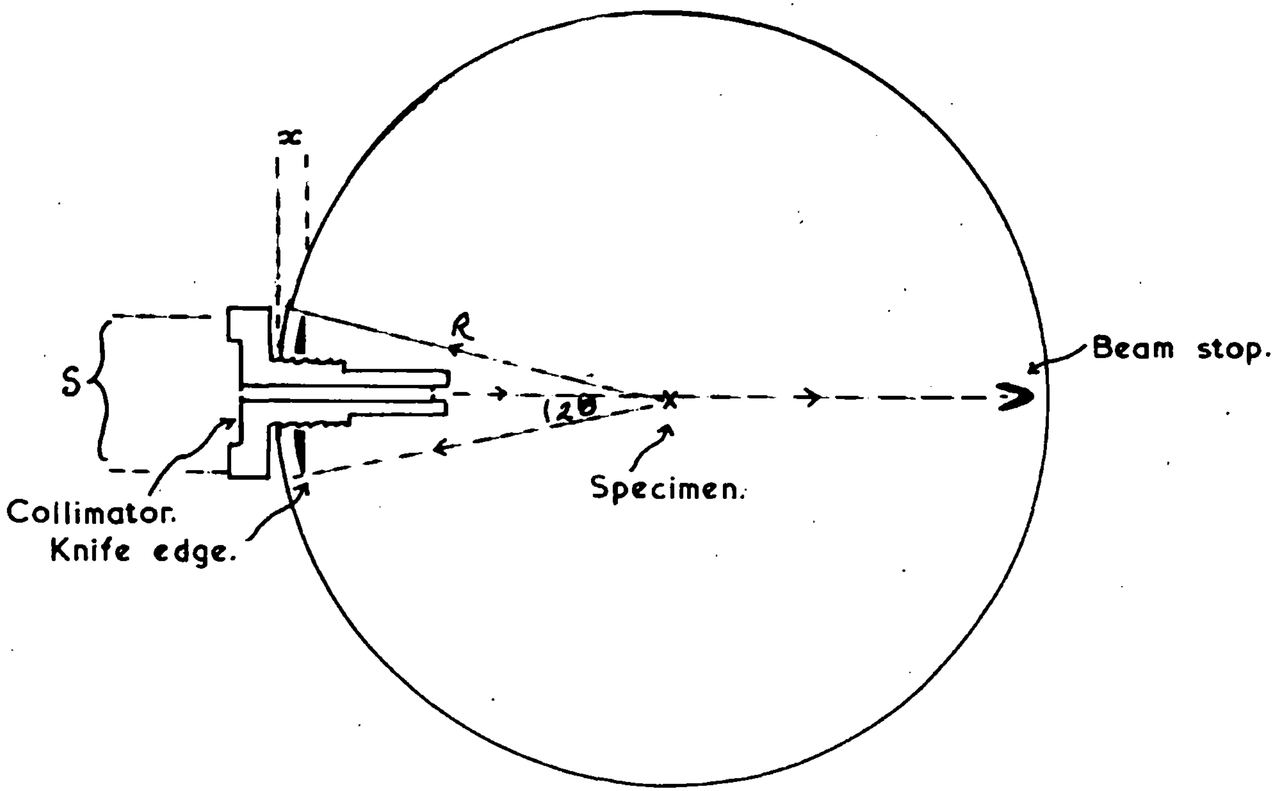


Fig. I.3.

Measurements used in determination of 9cm. camera constant.



$$\tan 2\theta = \frac{S/2}{R - x}$$

& x - 1·43 mm.
S - 19·36 mm.
R - 45·389 mm.

Camera constant $= \rho K = 90° - \theta.$
$= 84{\cdot}2°$

Fig. 2.1

X-RAY POWDER DATA FOR 1-LAYER MONOCLINIC POLYMORPHS

1. 1M Lepidolite d(Å)	I	*2. 1M Illite* d(Å)	I	*3. 1M "Hydromuscovite"* d(Å)	I	*4. 1Md Illite* d(Å)	I	*5. 1Md Illite* d(Å)	I
9.98	MS	10.1	S	10.1	S	10.1	S	10.0	VS
4.98	MS	4.98	M	4.98	W	4.98	W	5.0	M
4.53	M	4.50	S	4.48	S	4.48	S	4.46	VS
4.34	VW	4.35	VW	—		—		—	
4.12	VW	4.10	VW	4.09	VW	—		—	
3.86	VW	3.85	VW	3.87	VW	—		—	
3.62	S	3.62	MS	3.65	M	—		—	
3.33	VS	3.32	S	3.34	S	3.33	S	3.32	VS
3.07	S	3.08	MS	3.07	M	3.07	VW	2.97	VW
2.86	M	2.89	MW	2.88	VVW	2.85	VW	2.80	VW
2.68	W	2.67	W	2.67	MW	—		—	
2.58	S	2.57	VS	2.56	S	2.57	VS	2.55	VS
2.48	W	2.47	W	2.46	W	2.46	W d	2.44	W
2.39	MW	2.38	M	2.38	MW	2.38	W d	2.37	WM
2.26	W	2.25	MW	2.25	W	2.25	W d	2.23	W
—		—		—		—		2.17	
2.14	MW	2.14	M	2.13	MW	2.14	W d	2.14	M
1.99	MS	1.99	S	2.00	M d	1.99	W d	1.98	M
1.96	VVW	—		—		—		—	
1.72	VW	1.71	VW	—		—		—	
1.65	M d	1.65	M d	1.64	W d	1.65	W d	1.64	M
1.58	VW	1.58	VVW	—		—		—	
1.51	S	1.50	S	1.50	MS	1.50	S	1.49	VS
1.43	VW	—		—		—		—	
1.38	VW	1.38	VVW	—		—		—	
1.35	VW	—		—		—		—	
1.34	W	1.34	W d	1.34	W	1.34	W d	1.34	W
1.30	M	1.30	M	1.29	W	1.30	MW	1.29	M
1.25	VW	1.25	W	1.25	VW	1.25	W	1.24	W

Data for samples 1 through 4 obtained using filtered copper radiation and 114.59 mm. diameter camera. $CuK\alpha = 1.5418$ Å.

1. *1M* Lepidolite, Brown Derby pegmatite, Colorado.
2. *1M* Illite, St. Austell Clay, Cornwall.
3. *1M* "Hydromuscovite" from decomposed granite, Aberdeenshire.
4. *1Md* Illite, Fithian, Illinois.
5. *1Md* Illite, South Wales, described by Nagelschmidt and Hicks (1943). Spacings from original paper: CoK_α radiation.

Table 2.1. X-ray powder data for the illites (taken from Levinson, 1955).

	Illites						2M	
	3R Ballater < 0·4 μ		1 Md South Wales (5).		2M Gilead, Ill. (4).		Hydromuscovite Ogofau, Wales (7).	
Indices.	*d.*	*I.*	*d.*	*I.*	*d.*	*I.*	*d.*	*I.*
002	9·9	s	10·0	vs	9·98	s	9·98	s
004	4·9	m	5·0	m	4·97	w	5·02	s
110	4·45	vs	4·46	vs	4·47	s	4·51	m
111	4·28	w	—		—		—	
022	4·10	w	—		4·11	vw	—	
$11\bar{3}$	3·87	m	—		—		—	
023	3·64	mw	—		3·7	vw	3·62	s
$11\bar{4}$	—		—		3·4	vw	—	
006	3·35	vs	3·32	vs	3·31	m	3·34	vs b
114	—		—		3·2	vw	—	
025, $11\bar{5}$	3·09	mw d	2·97	vw	2·98	w	3·09	s
115	2·85	m d	2·80	vw	2·84	vw	2·89	s
$20\bar{2}$	2·56	vs	2·55	vs	2·56	s	2·59	vs
$13\bar{3}$, 202	2·45	mw	2·44	w	2·44	w	2·470	m
$20\bar{4}$, 133	2·39	m	2·37	mw	2·38	m	2·390	s
$22\bar{1}$	2·235	mw	2·23 }	w	2·24	m	2·27 }	w
$22\bar{3}$	—		2·17 }		2·18	w	2·18 }	
$20\bar{6}$, 043	2·14	m	2·14	m	2·11	w	2·135	s
0010	1·988	m	1·98	m	1·98	m	1·994	vs
206	1·940	w	—		—		—	
208	—		—		—		1·715	vw
$20\bar{10}$, 312	1·647	m d	1·64	m	1·65	w	1·648	s
060, $33\bar{1}$	1·497	s	1·49	vs	1·50	s	1·505	s
0014	—		—		—		1·416	vw
$33\bar{7}$	—		—		—		1·380	vw
335	1·342	mw d	1·34	w	1·34	vw	1·350 }	m
							1·336 }	
400	1·294	m	—		—		1·297	m
402	1·266	w	—		—		—	
0016	1·243	mw	1·24	w	1·24	w	1·245	w

The Ballater illite was photographed with Fe-$K\alpha$ radiation in a 9 cm. camera. *d*-spacings in Ångström units and intensities estimated visually. vs = very strong s = strong; ms = medium strong; m = medium; mw = medium weak; w = weak; vw = very weak; d = diffuse; b = broad.

Table 2.2. X-ray powder data for the illites (taken from MacKenzie, Walker and Hart, 1949).

"*d*" VALUES OF SOME KAOLIN MINERALS IN ANGSTROM UNITS

Brindley and Robinson	*I*	Ga. (soft)	*I*	Flint Mo.	*I*	Flint Ky.	*I*	*hkl*	Tenn. Ball Clay	*I*	Union Co. Kaolin	*I*	Fireclay Mo.	*I*	Grundy Co. Underclay	*I*	Dehy-drated Halloysite	*I*
7.15	10	7.18	VS	7.18	VS	7.18	VS	001	7.20	VS	7.20	VS	7.30	VS	7.30	VS	7.42	VS
4.453	4	4.50	S	4.49	M	4.50	M	020	4.55	S	4.48	S	4.49	S	4.49	S	4.47	VS
4.349	6	4.41	S	4.41	S	4.43	S	$1\bar{1}0$										
4.170	6	4.21	S	4.23	M	4.23	M	$11\bar{1}$										
4.120	3							$1\bar{1}\bar{1}$										
3.837	4	3.87	M	3.87	M	3.91	M	$02\bar{1}$	3.95	W								
3.734	2	3.76	W			3.76	W	021										
3.566	10	3.62	VS	3.61	VS	3.61	VS	002	3.59	VS	3.58	VS	3.58	VS	3.56	VS	3.63	VS
3.365	4	3.42	M	3.43	M	3.41	M	111										
3.138	2	3.13	W	3.13	W	3.15	W	$11\bar{2}$										
3.091	2							$11\bar{2}$	3.09	W								
2.748	2	2.76	W	2.75	W	2.76	W	022										
2.553	8	2.56	S	2.55	S	2.57	S	$20\bar{1}, 1\bar{3}0, 130$	2.56	S	2.55	S	2.57	M	2.56	M	2.56	M
2.521	4	2.52	M					$13\bar{1}, 1\bar{1}2$	2.52	S	2.49	S	2.50	M				
2.486	9	2.48	S	2.50	S	2.49	S	$1\bar{3}\bar{1}, 200, 112$									2.48	M
2.374	7	2.38	M	2.42	M	2.41	M	003	2.42	M								
2.331	10	2.36	VS	2.37	VS	2.36	S	$20\bar{2}, 1\bar{3}1$	2.36	S	2.35	S	2.35	M	2.37	M	2.35	M
2.284	9	2.32	S	2.31	S	2.31	M	$1\bar{1}\bar{3}, 13\bar{1}$	2.29	S	2.30	S						
2.243	1	2.26	W					$13\bar{2}, 040$										
2.182	3	2.20	W	2.21	M	2.22	W	$201, 1\bar{3}\bar{2}, 2\bar{2}0$	2.21	W	2.20	W	2.21	W				
2.127	2	2.13	W					$02\bar{3}, 041$							2.13	W		
2.057	1	2.08	W	2.01	S	2.05	M	$023, 2\bar{2}\bar{2}$										
1.985	7	1.99	S	1.96	W	1.96	W	$20\bar{3}, 1\bar{3}2$	1.97	S	1.99	S	2.00	W	2.00	W		
1.935	4	1.95	W					221, 132										
1.892	2	1.92	W	1.91	W	1.90	W	$113, 13\bar{3}$	1.92	W	1.90	W	1.90	W	1.90	W		
1.865	1							042										
1.836	4	1.86	M	1.86	M	1.85	M	$1\bar{3}\bar{3}, 202, 22\bar{3}$										
1.805	1							$11\bar{4}, 2\bar{2}\bar{3}$										
1.778	5	1.79	M	1.80	M	1.80	M	004	1.80	M	1.79	M						
1.704	1							$2\bar{2}2$										
1.682	2	1.68	W	1.69	W			$1\bar{5}0, 24\bar{1}, 31\bar{1}$										
1.659	8	1.66	S	1.67	S	1.67	S	$2\bar{4}0, 20\bar{4}, 1\bar{3}3$	1.66	S	1.67	S	1.68	M	1.67	W	1.67	W
1.616	6	1.62	M	1.62	M	1.63	M	$24\bar{2}, 133, 310$	1.63	M	1.62	M						
1.581	4	1.58	M	1.58	M	1.58	W	$15\bar{2}, 13\bar{4}$										
1.539	5	1.52	M	1.54	M	1.54	M	$241, 1\bar{1}4, 1\bar{3}\bar{4}$										
1.486	9	1.48	S	1.49	S	1.49	S	$060, 3\bar{3}\bar{1}, 33\bar{1}$	1.50	S	1.48	S	1.49	S	1.49	S	1.48	M

Table 2.3. X-ray powder data for the kandites (taken from Murray, 1954).

Powder diagrams of some chlorite minerals

Diabantite		Leuchtenbergite		Magnesian chamosite		Prochlorite		Bavalite		Chamosite	
d (kX)	I	d (kX)	I	d (kX)	I	d (kX)	I	d (kX)	I	d (kX)	I
15	10	13·1	6	14	9	13·6	4	13·7	5	14	3
7·15	9	6·97	9	7·1	10	6·90	8	6·92	10	6·93	10
4·80	3			4·73	3						
4·62	6	4·68	9	4·69	7	4·65	6	4·63	7	4·63	7
3·58	7	3·515	10	3·53	10	3·480	10	3·48	10	3·50	9
3·04	5										
2·87	1	2·824	5	2·83	1	2·797	5	2·796	4	2·779*	3
2·66	6			2·69	3					2·689	1
				2·61	2			2·619	1		
2·60	6			2·60	1						
2·53	6	2·523	8	2·52	1	2·546	6			2·507	7
2·47	6	2·431	5	2·46	5	2·442	4				
2·40	3	2·369	1	2·39	5	2·373	4	2·393	2	2·330	½
2·29	1	2·251	3	2·28	3	2·259	3	2·264	2		
2·145	1			2·14	1					2·134	3
				2·08	1						
2·02	1	1·998	8	2·01	5	1·996	8	2·002	7		
1·90	1	1·880	3	1·89	3	1·873	4	1·886	2		
		1·818	3	1·83	1	1·814	3				
1·74	5			1·72	2					1·767	2
1·70	5	1·688	2	1·67	2	1·700	2				
		1·655	2	1·63	1	1·653	2	1·658	2		
		1·563	7	1·573	4	1·558	7				
1·545	7	1·531	9	1·552	7	1·539	7	1·558	6	1·556	5
1·518	3	1·499	3	1·517	5	1·505	4	1·517	2	1·524	2
		1·455	2	1·479	1	1·464	½			1·473	1
1·427	5	1·420	1	1·424	5	1·407	4			1·425	1
		1·394	8	1·395	5	1·384	8	1·391	4		
				1·361	1						
1·331	3			1·333	1	1·324	2				
1·303	1	1·315	3	1·301	1	1·295	2				

Notes.

Diabantite, Mag. chamosite—Bannister and Whittard (1945). Unfiltered FeK radiation. Camera radius 30 mm.

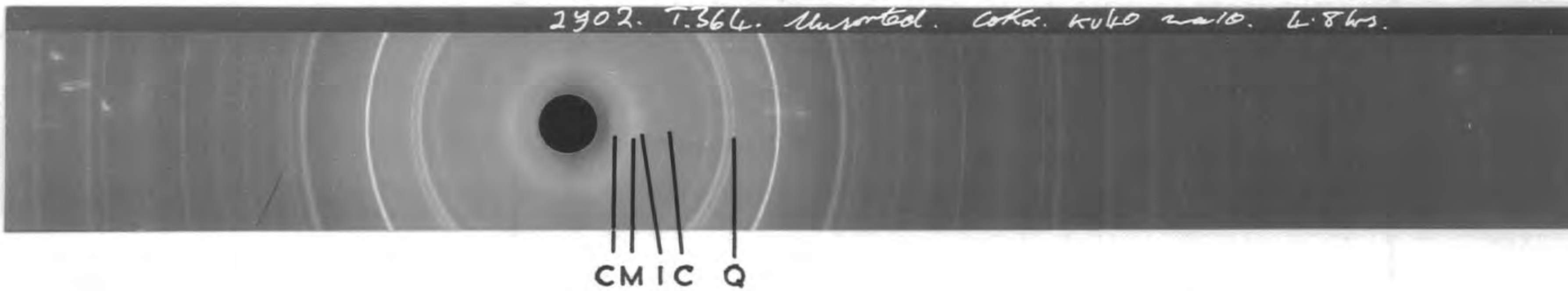
Leuchtenbergite. Prochlorite—McMurchy (1934). Unfiltered FeK radiation. Camera radius 57·3 mm.

Bavalite and Chamosite—v. Engelhardt (1942). Filtered FeKα radiation. Camera radius 28·75 mm.

* A line possibly due to siderite.

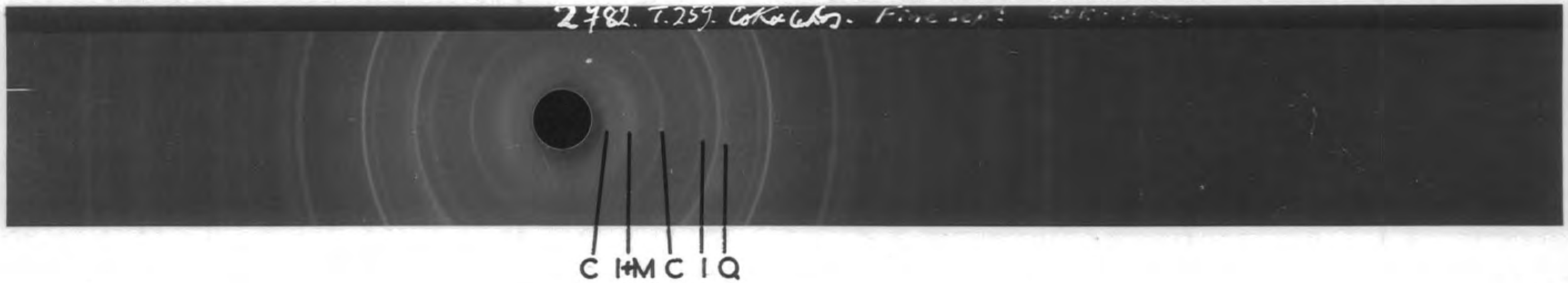
Table 2.4. X-ray powder data for some chlorites (taken from Brindley and Robinson, 1951).

Figure 2.2. X-ray powder photographs of some representative Teesdale argillaceous rocks. (Principal lines marked thus: illite (I), chlorite (C), mixed-layer mineral (M) and quartz (Q)).

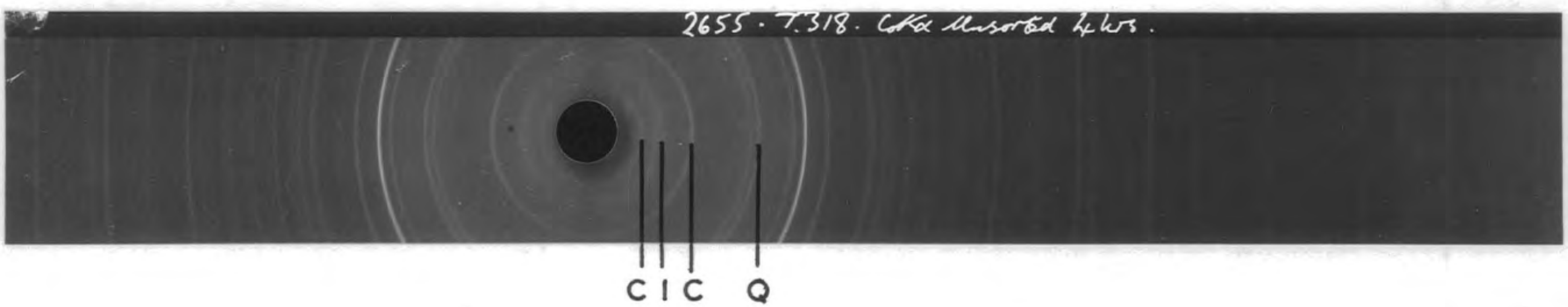


Underclay, T.364., containing illite, chlorite, mixed-layer mineral and quartz.

Figure 2.2. continued.

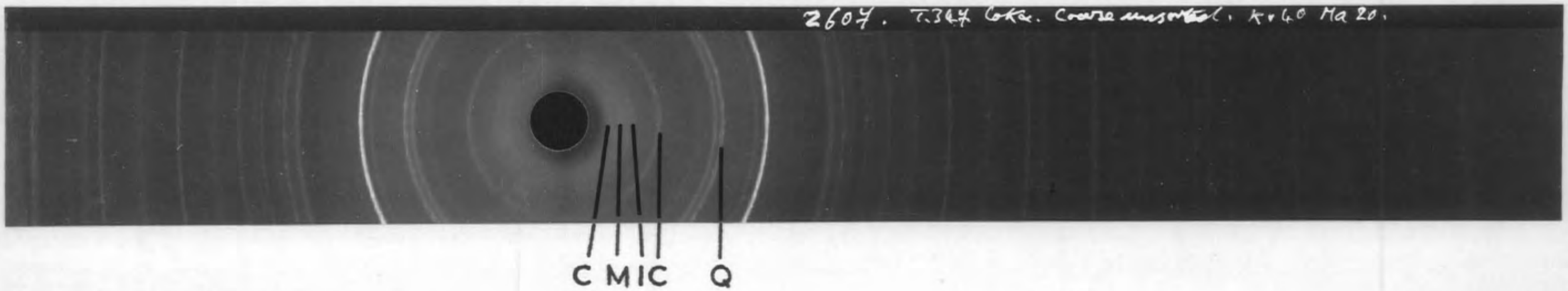


Underclay, T.259, containing illite, chlorite, mixed-layer mineral and quartz.

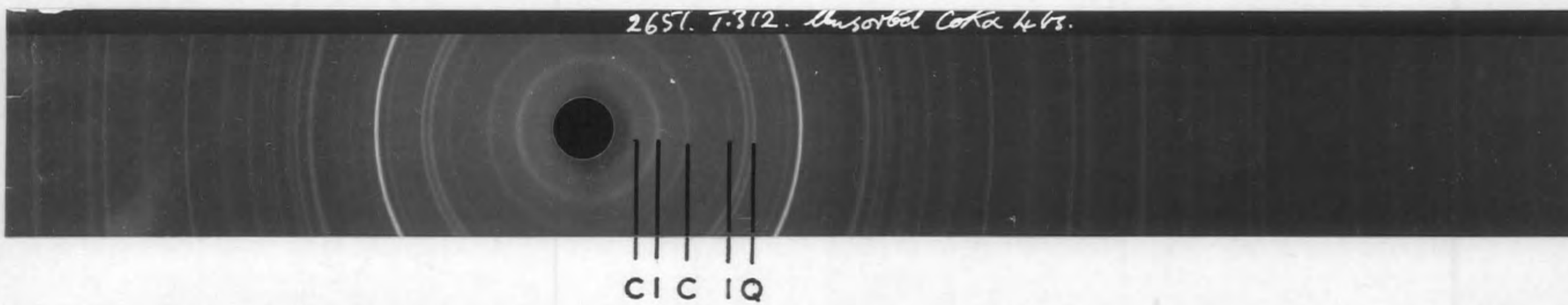


Type 3. shale, T.318, containing illite, chlorite and quartz.

Figure 2.2 continued.

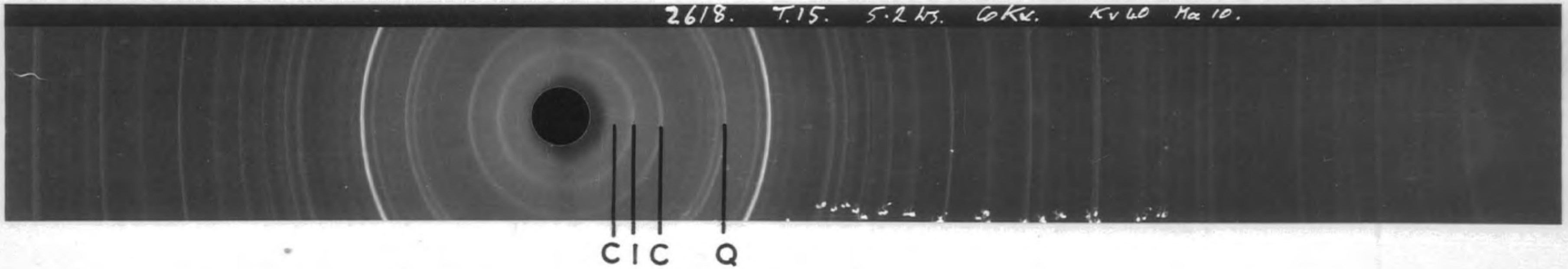


Type 3 shale, T.347., containing illite, chlorite, mixed-layer mineral and quartz.

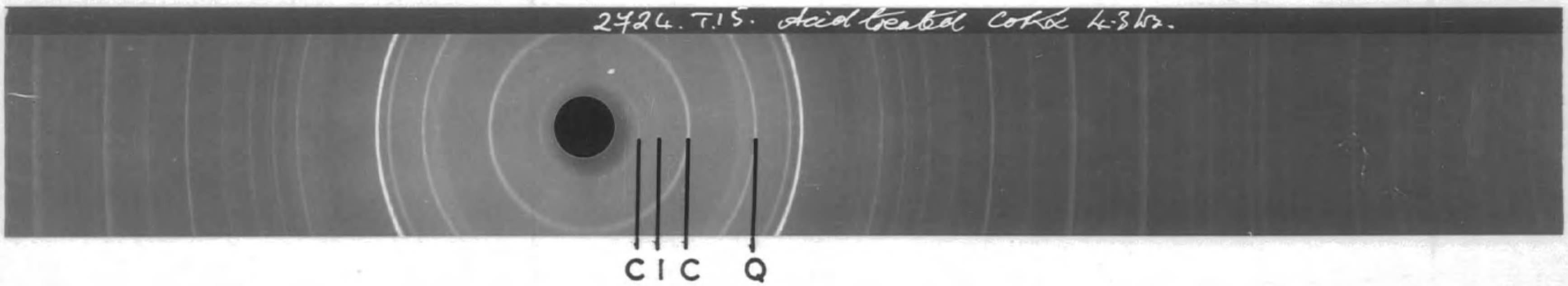


Type 3 shale, T.312., containing illite, chlorite and quartz.

Figure 2.2 continued.



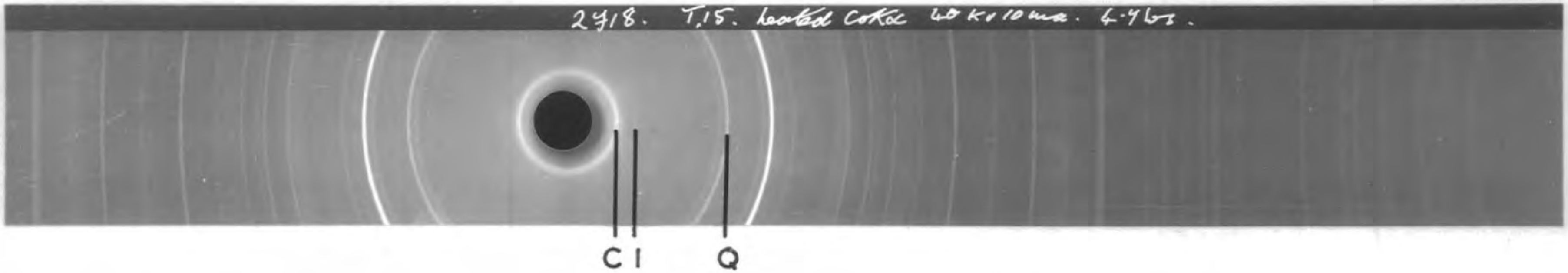
(a)



(b)

(continued on next page)

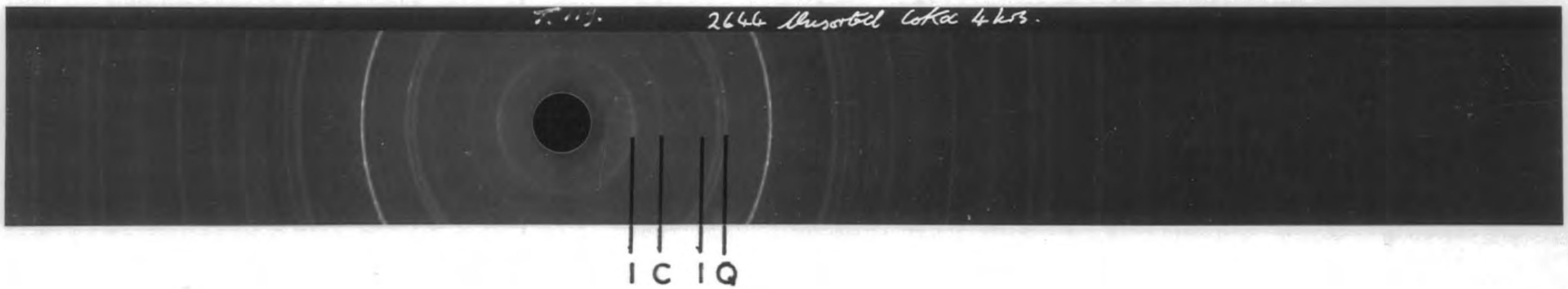
Figure 2.2 continued.



(c)

Type 4 shale, T.15., untreated (a) and after acid (b) and heat treatment (c), showing the effect on the chlorite lines. Shale contains illite, chlorite and quartz.

Figure 2.2 continued.



Type 5 shale, T.119., containing illite, chlorite and quartz.

D.T.A. Curves of Some Representative Shales and Underclays of the Middle Limestone Group.

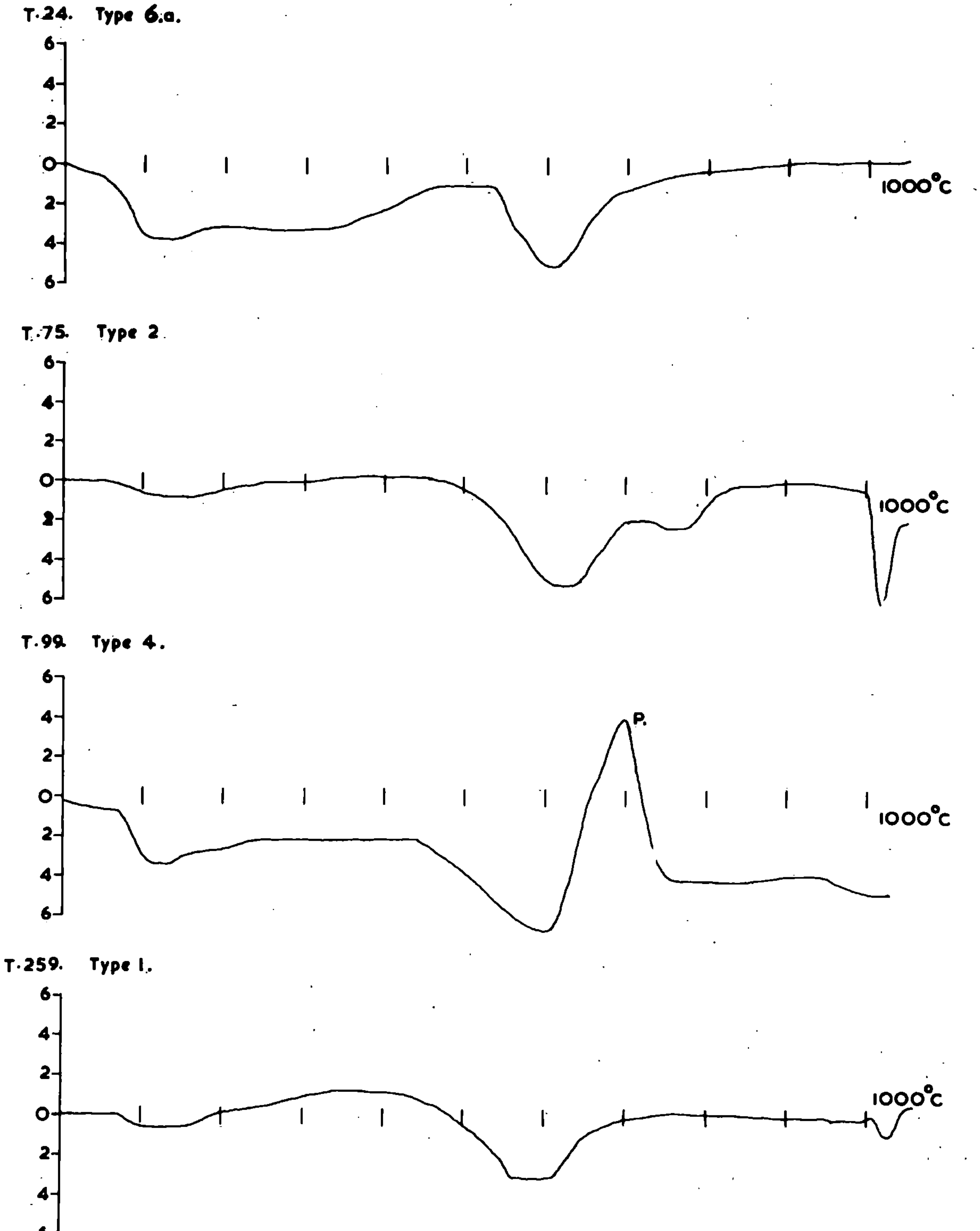


Fig. 2.3

D.T.A. Curves of the Underclay T. 364. below the Four Fathom, Limestone Harter Fell.

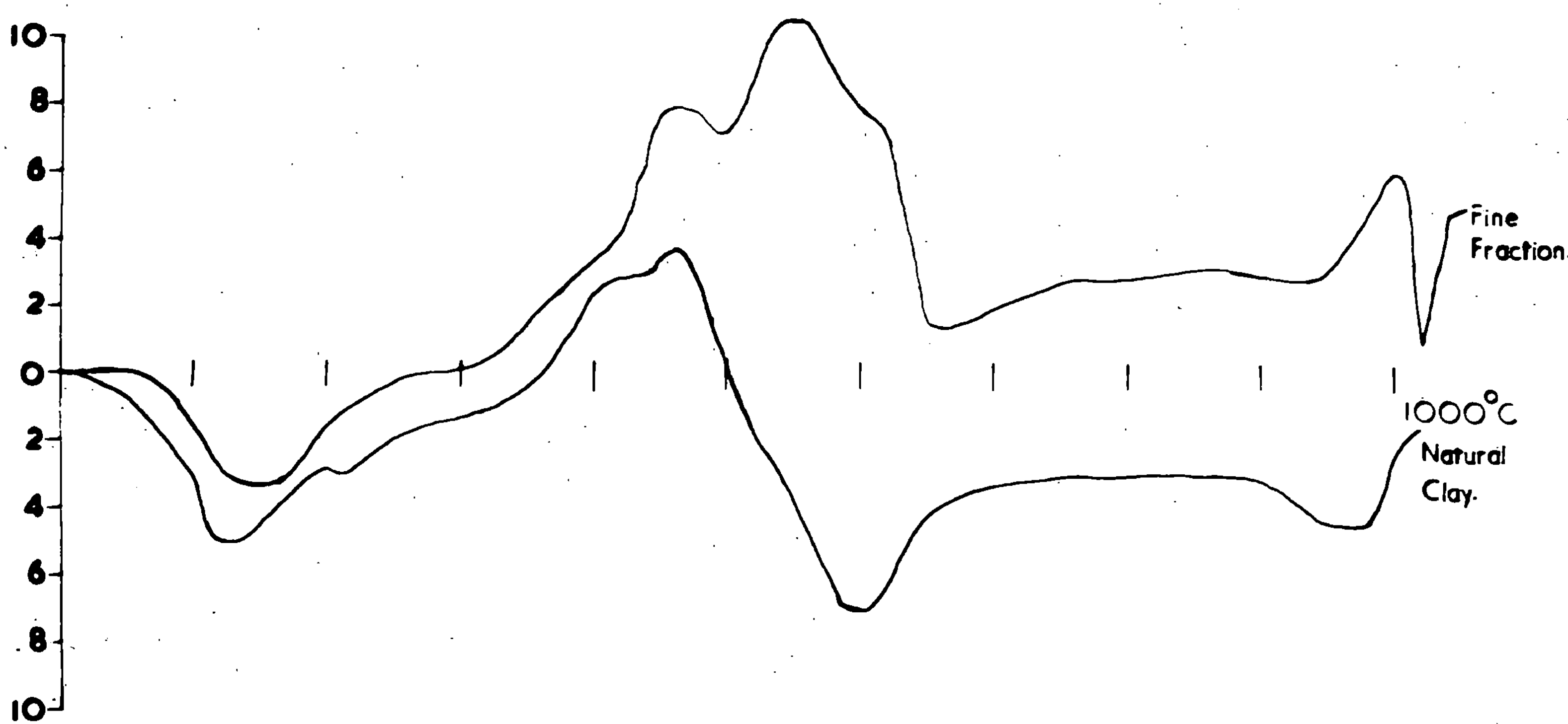
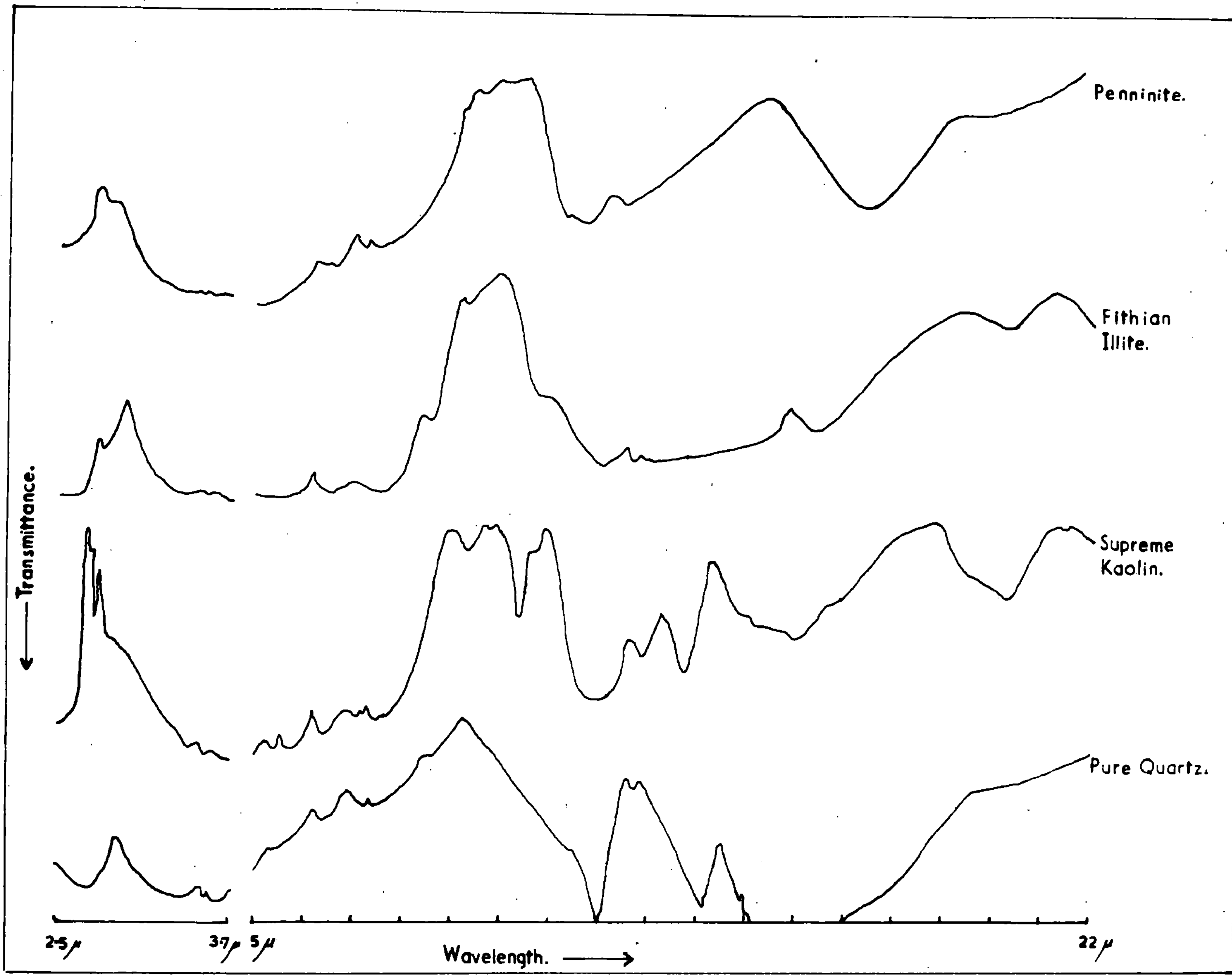


Fig. 2.4

Fig. 2.5 The Infra-red Absorption Spectra of Some Pure Reference Minerals.



Graph of Peak Height Differences in Infra-red Absorption Spectra of Illite-Kaolinite Mixtures.

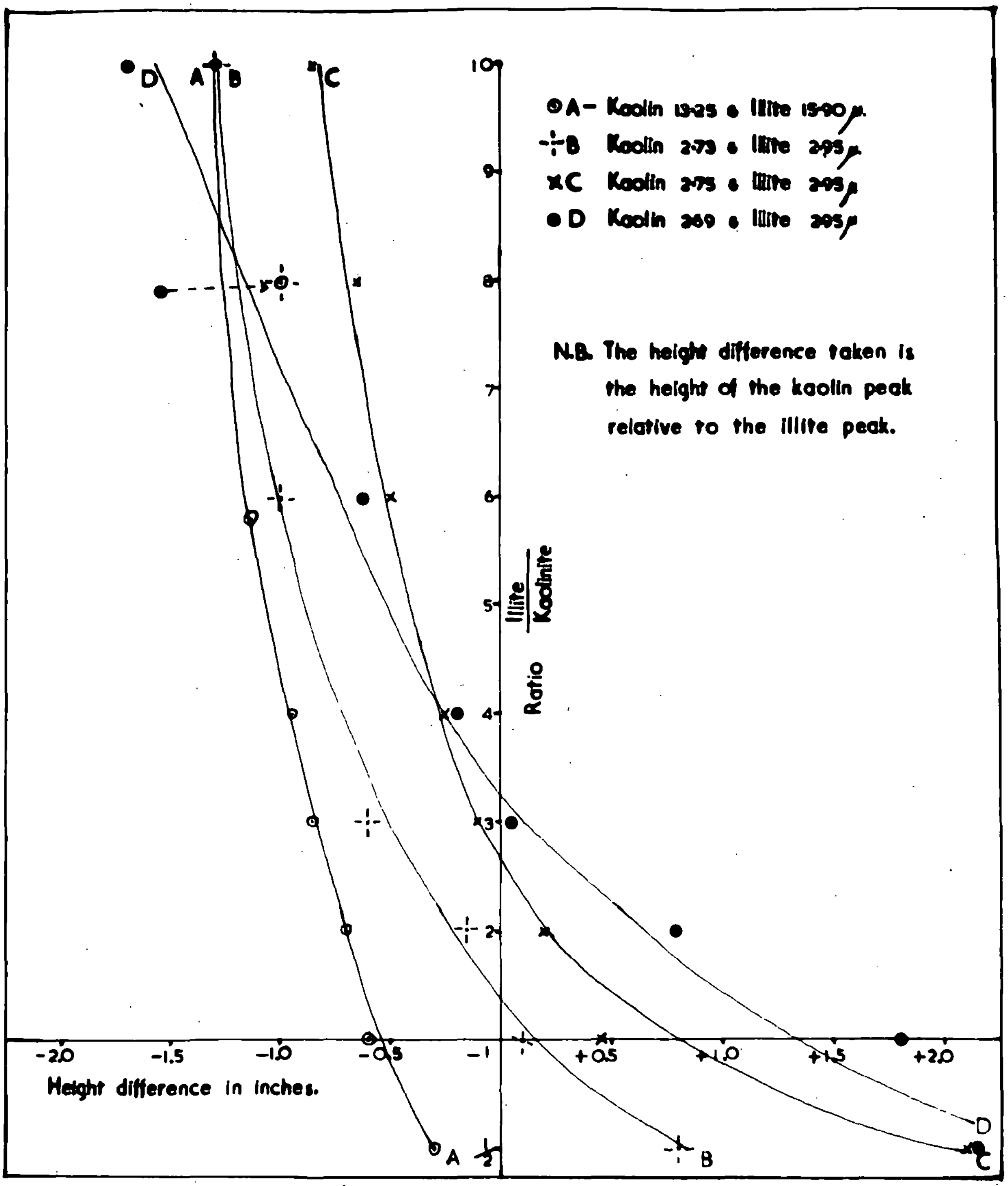


Fig. 2.6

Fig. 2.7 The Infra-red Absorption Spectra of Some Illite-kaolinite Mixtures and Teesdale Clay Minerals.

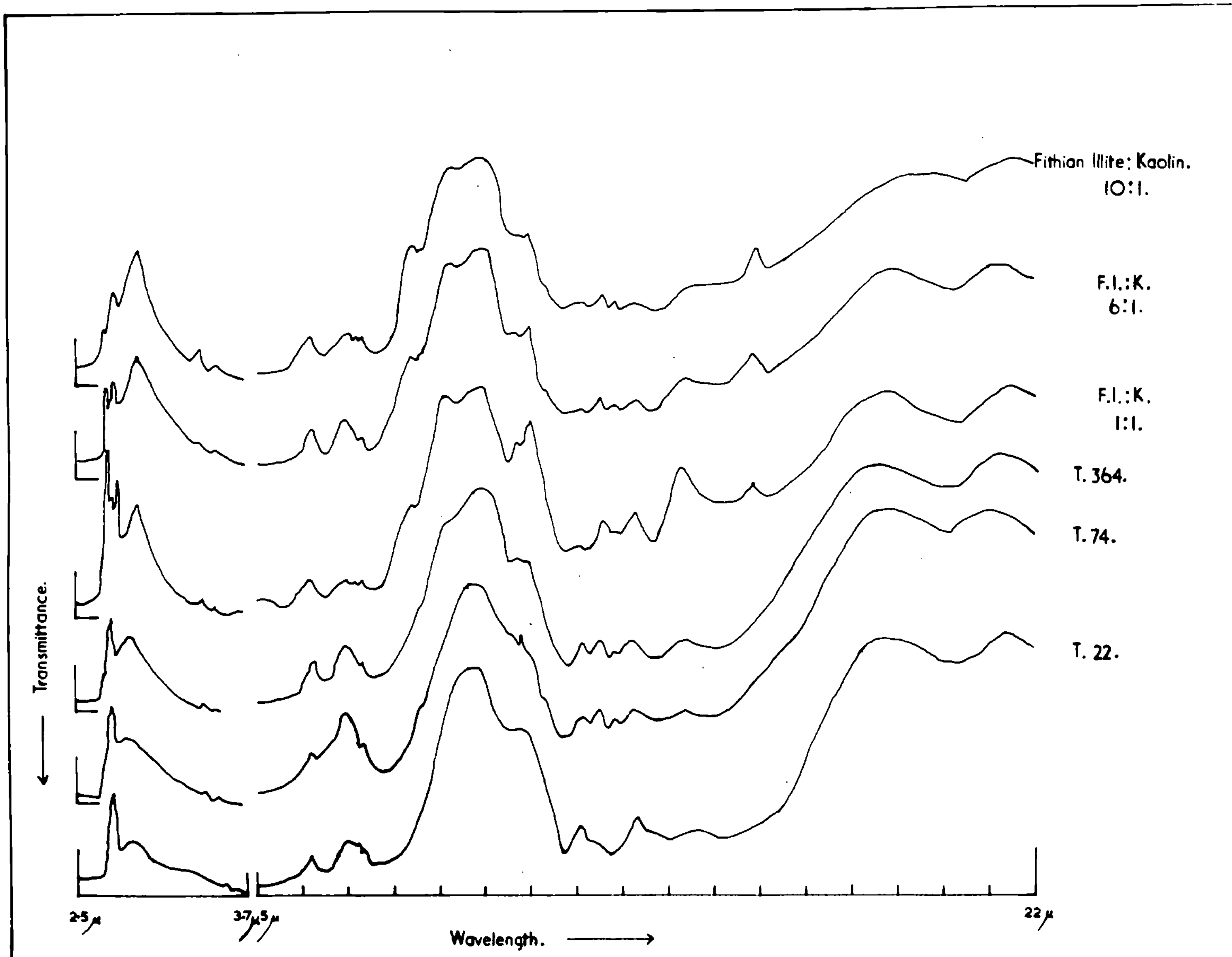


TABLE 3.1. TABLE OF CHARACTERS USED IN THE FIELD CLASSIFICATION OF THE ARGILLACEOUS ROCKS

Type	1	2	3	4	5	6a
Effervesce with acid.	No	Generally positive.	Rarely positive.	Very rare.	Very rare.	No
Mica.	Variable	Absent	Generally fine.	Fine to medium.	Fine to coarse.	Medium to very coarse.
Fossils.	Plant Rootlets.	Generally abundant, bryozoa, crinoids, brachiopods.	Absent to abundant, generally brachiopods.	Rare, tracks and trails.	Absent. Occasional plant fragments.	Absent.
Bedding.	Very poor to absent.	Good	Good	Good	Good	Good
Fissility.	Absent.	Poor to fair.	Fair to very good.	Good to very poor.	Good to very poor.	Generally friable.
Nodules.	No.	Rare	Pyrite common.	Pyrite common	Pyrite or ironstone, rare.	No
Quartz.	Variable.	No	Generally little.	Abundant by feel.	Abundant.	Variable, generally absent.
Occurrence.	Under coals or limestones.	In and immediately above limestones. Occasionally below.	Above Type 2, above limestones.	Above Type 3, below sandstones.	Above main sandstones or above Type 4.	In massive clean sandstones.

TABLE 3.2. FIELD AND LABORATORY DATA OF THE TYPE 1 ARGILLACEOUS ROCKS

No.	Stratigraphical Horizon	Grid Ref.	Presence $CaCO_3$	Visible Mica	Fossils	Bedding	Nodules	Quartz			X-ray Data				Remarks
								Field Est'n.	Micro Est'n	Grain size in mm.	Illite	Chlorite	Mixed-Layer	Quartz	
38a	Below 5 Yd Lst.	910287	Yes	V. Fine	Rootlets	None	Yes	V.A.	N.D.	N.D.	x	x		x	
37	Below 5 Yd Lst.	910287	No	None	Coal	Shaly	None	N.A.	N.D.	N.D.	x	x	x	x	Coal Band
200	Below 3 Yd Lst.	885304	No	None	Carbonaceous	V.Poor	None	V.A.	N.D.	N.D.	x		x	x	
259	Below 3 Yd Lst.	915283	No	Med-Coarse	Rootlets	V.Poor	None	V.A.	85%	0.025-0.2	x	x	x	x	
322	Below F.F. Lst.	948270	No	Fine	Rootlets	None	None	V.A.	N.D.	N.D.			x	x	
323	Below F.F. Lst.	948270	No	Fine	Very Carbonaceous	None	None	A.	N.D.	N.D.	x		x	x	
364	Below F.F. Lst.	929237	No	None	Rootlets	None	None	A.	N.D.	N.D.	x	x	x	x	
385	Below Gt. Lst.	924273	No	V.Coarse	None	Good	None	V.A.	N.D.	N.D.	x		x	x	
386	Below F.F. Lst.	924273	No.	Fine	Carbonaceous	Poor	None	A little	N.D.	N.D.			x	x	

Abbreviations:
V.A. = Very abundant
N.A. = Not Apparent
A. = Abundant
N.D. = Not Determined

TABLE 3.5. FIELD AND LABORATORY DATA OF THE TYPE 4 ARGILLACEOUS ROCKS

No.	Stratigraphical Horizon	Grid Ref.	Presence $CaCO_3$	Visible Mica	Fossils	Bedding	Fissility	Nodules	Quartz			X-ray Data				Remarks
									Field Est'n	Micro Est'n	Grain Size in mm.	Illite	Chlorite	Mixed-layer	Quartz	
15	Nodule in 16	907285	Yes	Very Fine	None	-	-	Nodule	V.A.	75%	<0.05	x	x		x	
16	Above Scar Lst.	907285	No	Very Fine	Algae?	Good	V.F.	Pyrite	V.A.	20%+	<0.05	x	x		x	
17	Above Scar Lst.	907285	No	Fine-Med	None	Good	V.F.	Pyrite	Silty bands	75-80%	0.025-0.125	x	x		x	
87	Above 3 Yd Lst.	858317	No	Fine	None	Poor	N.F.	Pyrite	A.	c.30%	<0.05	x	x	x	x	
94	Above C.S. Lst.	892289	No	V.V.Fine	None	Good	V.F.	Pyrite	N.A.	1-2%	<0.025	x	x		x	
95	Above C.S. Lst.	892289	Yes	V.Fine-Fine	None	Good	P.F.	Pyrite	A.	40-50%	0.025-0.075	x	x		x	Calcareous Siltstone.
96	Above C.S. Lst.	892299	Yes	Medium	None	Good	N.F.	Pyrite	A.	95%+	0.05-0.15	x			x	Calcareous Siltstone.
99	Above C.S. Lst.	892292	No	V.V.Fine	None	Good	V.F.	Pyrite	N.A.	<1%	<0.025	x	x		x	
121	Above Scar Lst.	892293	No	V.Fine	None	Good	P.F.	None	Little Pres.	c.25%	<0.05	x	x		x	Very carbonaceous
123	Above Scar Lst.	892294	No	Fine-Med	None	Good	Fissile	None	V.A.	65%	<0.05	x			x	Base of Low Brig Hazle-Coal Frag's.
127	Above 5 Yd Lst.	892296	No	Very Fine	None	Good	Fissile	None	V.A.	95%	0.1-0.25	x	x		x	
129	Above 3 Yd Lst.	888302	No	Very Fine	None	Good	V.F.	Pyrite	A.	c.25%	<0.075	?	x		x	Very carbonaceous.
135	Above Scar Lst.	884297	No	None	Pit and Mound.	Good	Fissile	None	N.A.	<5%	<0.075	x	x		x	
179	?	848335	No	Med-Coarse	None	Good	N.F.	None	V.A.	c.90%	0.075-0.2	x	x	x	x	Siltstone band in 180.
193	Above F.F. Lst.	883310	No	Fine	Few Brachs.	Good	Fissile	None	V.A.	N.D.	<0.025	x	x	x	x	
194	Above F.F. Lst.	883310	No	Fine	Plant fragments	Poor	N.F.	None	A.	N.D.	N.D.	x	x		x	
195	Above F.F. Lst.	883310	No	Very Fine	Micro-fossils	Good	Fissile	Iron-stone	N.A.	2-3%	<0.01	?	x		x	
196	Above F.F. Lst.	883310	No	V.V.Fine	Micro-fossils	Good	Fissile-friable	Pyrite	N.A.	N.D.	N.D.	x	x	x	x	
289	Above F.F. Lst.	896255	No	Very Fine	Micro-fossils	Good	V.F.	Septaria	N.A.	None	None	x	x	x	x	
324	Above F.F. Lst.	948272	No	V.V.Fine	Micro-fossils	Good	V.F.	Iron-stone	N.A.	N.D.	N.D.	x	x	x	x	

Abbreviations:
- V.A. = Very Abundant.
- N.D. = Not Determined.
- A. = Abundant.
- N.A. = Not Apparent.
- V.F. = Very Fissile.
- N.F. = Non-Fissile.
- P.F. = Poor Fissility.

TABLE 3.6. FIELD AND LABORATORY DATA FOR THE TYPE 5 ARGILLACEOUS ROCKS.

No.	Stratigraphical Horizon	Grid Ref.	Presence $CaCO_3$	Visible Mica	Fossils	Bedding	Fissility	Nodules	Field Est'n of Quartz	Quartz Micro-Deter'n	Quartz Grain Size in mm.	X-ray Data: Illite	X-ray Data: Chlorite	X-ray Data: Mixed-layer	X-ray Data: Quartz	Remarks
11	Below Scar Lst.	907285	No	Very Fine	None	Good-rippled	Fissile	None	Very Abundant	90%+	0.025-0.1	x	x		x	
12	Below Scar Lst.	"	"	" "	"	" "	"	"	" "	90%+	0.025-0.1	x	x		x	
13	Below Scar Lst.	"	"	" "	"		"	"	" "	90%+	0.025-0.1	x			x	Microstructures.
29	Below 5 Yd Lst.	907287	"	Very Fine-Coarse	"	Good	V. Fissile	"	Not Apparent	c.20%+	0.05-0.3	x	x		x	Quartz concentrated in siltstone bands.
35	Below 5 Yd Lst.	910287	"	Medium	"	"	Fissile	"	Very Abundant	90%+	-	x	x		x	Very coarse siltstone-fine sandstone.
36	Below 5 Yd Lst.	"	"	Fine-Coarse	"	"	"	"	" "	70%	<0.05	x	x		x	High carbon content.
47	Below 5 Yd Lst.	908292	"	Fine-Medium	"	Good-rippled	Fissile	"	" "	90%	<0.05	x	x		x	
55	Below 5 Yd Lst.	910295	"	V.Fine-Medium	"	" "	"	"	" "	90%	0.05-0.125	x	x		x	
60	Below 3 Yd Lst.	910298	"	Coarse	"	Good	Friable	"	Little	N.D.	N.D.	x		x		
62	In top L.B.H.	"	"	Fine	"	Poor	Non-Fissile	Small Pyrite	"	N.D.	N.D.	x	x		x	
78	Below C.S. Lst.	911276	"	Fine-Medium	"	Good	Friable	None	Abundant	80%	0.05-0.2	x			x	
81	Below C.S. Lst.	910274	"	None	"	"	Fissile	"	Not Apparent	c.1%	<0.05	x	x		x	
84	Below C.S. Lst.	910274	"	"	"	"	Poor	"	" "	<1%	<0.025	x	x		x	
86	Below S.P. Lst.	909275	"	"	"	"	Non-Fissile	"	" "	c.2%	<0.25	x	x		x	
118	Above S.P. Lst.	892287	"	"	"	"	" "	"	" "	<1%	<0.125	x	x		x	
119	Above S.P. Lst.	892287	"	"	"	"	" "	"	" "	10%	<0.125	x	x		x	
132	Below 5 Yd Lst.	885302	"	V.Fine-Medium	"	Good	Very "	"	Little	5-10%	<0.025	x	x	x	x	
133	Below 5 Yd Lst.	884302	"	V.Fine	Plant frags.	"	Fissile	"	Not Apparent	N.D.	N.D.	x	x	x	x	
134	Below S.P. Lst.	884297	"	V.Fine	None	"	"	"	" "	<2%	<0.05	x	x		x	
143	Below Scar Lst.	889292	Yes	V.Fine-Fine	"	Good-rippled	"	"	Very Abundant	90%+	<0.1	x			x	
192	Below Scar Lst.	857308	No	V.Very Fine	"	Good	"	"	Not Apparent	2-3%	0.025	x	x		x	
204	Below 5 Yd Lst.	885302	"	V.Fine	Some plants	Good	V.Fissile	"	" "	N.D.	N.D.	x	x		x	
208	Above T.B. Lst.	829334	"	V.Very Fine	None	"	Fissile	"	" "	N.D.	N.D.	x	x	x	x	
209	Above T.B. Lst.	829334	"	Fine	"	Very good	V.Fissile	"	Very Abundant	90%	0.025-0.075	x	x		x	
211	Above T.B. Lst.	829334	"	V.Fine	"	Good	V.V.Fissile	"	Not Apparent	N.D.	N.D.	x			x	
212	Above T.B. Lst.	829334	"	V.Fine	"	"	Friable	"	Little	N.D.	N.D.	x	x	x	x	
215	Above T.B. Lst.	830335	"	Medium	"	"	V.Fissile	"	Abundant	2-3%	0.015-0.125	x	x			
223	Above T.B. Lst.	830335	"	V.Fine-Fine	"	"	Non-Fissile	"	Very Abundant	90%	0.025-0.05	x	x	x		
234	?	797256	"	Very Fine	?	"	Fissile	"	Not Apparent	N.D.	N.D.	x	x	x	x	
247	?	915277	Yes	Fine-Medium	None	Good-rippled	"	"	Very Abundant	85%	0.025-0.2	x	x		x	
255	Below 3 Yd Lst.	915280	No	Very Fine	"	Good	"	"	" "	N.D.	N.D.	x	x		x	
256	Below 3 Yd Lst.	915280	"	V.Very Fine	Plant frags	Good	"	"	Not Apparent	N.D.	N.D.	x	x	x	x	
258	Below 3 Yd Lst.	915283	"	Very Fine		"	Non-Fissile	"	Little	N.D.	N.D.	x	x	x	x	
260	Below 3 Yd Lst.	915283	"	" "	None	"	Very "	"	Very Abundant	N.D.	N.D.	x	x	x		
263	Above 3 Yd Lst.	915286	Yes	V.Fine-Fine	"	"	Non-Fissile	"	" "	30%	0.015-0.125	x	x	x	x	
267	Above 3 Yd Lst.	915288	No	V.Fine-Fine	"	"	" "	"	" "	85%	0.025-0.05	x	x	x	x	
288	Below I.P. Lst.	896255	"	Very Fine	?	"	V.Fissile	"	Little	N.D.	N.D.	x	x	x	x	
294	Below F.F. Lst.	767291	"	Fine	None	Poor	Non-Fissile	"	Very Abundant	c.30%	0.015-0.05		x		x	Siltstone with abundant coal fragments.
302	Above 3 Yd Lst.	775283	"	Fine-Medium	"	Good	Poor	"	" "	90%	0.05-0.2	x			x	
309	Basal L.B.H.	884302	"	" "	"	"	Fissile	"	" "	<1%	<0.025	x	x		x	
310	Below C.S. Lst.	883299	"	Very Fine	"	"		"	Not Apparent	85%	0.015-0.05	x	x		x	
314	Above 3 Yd Lst.	947260	Yes	Fine-Medium	"	"	Very Poor	"	Very Abundant	N.D.	N.D.	x	x	x	x	
321	Above 3 Yd Lst.	848269	No	Fine-V.Coarse		"	V.Fissile	"	" "	N.D.	N.D.	x	x		x	
327	Below 5 Yd Lst.	940255	No	V.Fine-Fine	Carbs. Mark'gs	"	Poor	Pyrite	Little	N.D.	N.D.	x	x	x	x	
349	Below 3 Yd Lst.	922273	"	V.Fine-Fine	None	"	V.Fissile	"	Little	N.D.	N.D.	x	x	x	x	
350	Below 3 Yd Lst.	922273	"	V.Very Fine	"	"	V.V.Fissile	"	Not Apparent	N.D.	N.D.	x	x	x	x	With coal lenses.
368	Below 3 Yd Lst.	910298	"	Fine-Medium	"	"	Fissile	Small pyrite	Abundant	N.D.	N.D.	x	x	x	x	
371	Below 3 Yd Lst.	948271	Yes	V.Fine	"	"	"	Ironstone	Not Apparent	N.D.	N.D.	x	x		x	

N.D. = Not Determined.

TABLE 3.7. FIELD AND LABORATORY DATA OF THE TYPES 6a AND 6b ARGILLACEOUS ROCKS

No.	Stratigraphical Horizon	Grid. Ref.	Presence $CaCO_3$	Visible Mica	Fossils	Bedding	Fissility	Nodules	Quartz			X-ray Data				Remarks
									Field Est'n	Micro Est'n	Grain size in mm.	Illite	Chlorite	Mixed-layer	Quartz	
9	In Low Brig Hazle	907285	No	Medium	None	Good	Friable	None	N.A.	None	None	x				
22	In Low Brig Hazle	907285	No	Med-Coarse	None	Good	Friable	None	N.A.	None	None	x				
23	In Low Brig Hazle	907285	No	Med-Coarse	None	Good	N.F.	None	V.A.	<90%	c.0.2	x	x			Type 6a
24	In Low Brig Hazle	907285	No	Fine-Coarse	None	Good	V.F.	None	N.A.	V.V.Little	<0.001	x				
26	In Low Brig Hazle	907285	No	Very Coarse	None	Good	Friable	None	N.A.	V.V.Little	<0.001	x	x			
30	Gall in L.B.H.	907287	No	Fine-Coarse	None	N.D.	Fissile	None	A little	N.D.	N.D.	x	x		x	
92	Gall in Sst.	892287	No	Fine	None	N.D.	N.D.	None	N.A.	N.D.	N.D.		x		x	Type 6b
160	Gall in L.B.H.	858314	No	None	None	N.D.	N.D.	None	N.A.	N.D.	N.D.	x	x		x	
165	Gall in Quarry H.	860327	No	Fine	None	N.D.	N.D.	None	N.A.	N.D.	N.D.	x			x	

Abbreviations: N.A. = Not Apparent
V.A. = Very Abundant
N.F. = Non-fissile
V.F. = Very Fissile

TABLE 3.8. TABLE OF SAMPLES CONTAINING VARIOUS CLAY MINERALS

Type	1	2	3	4	5	6a	6b
Illite	0	9	3	2	5	3	1
Chlorite	0	1	1	2	0	0	1
Illite plus chlorite	1[x]	16	23	10	24	2	2
Mixed-layer minerals	2	0	0	0	1	0	0
Illite plus mixed-layer	3	0	0	0	1	0	0
Illite plus chlorite plus mixed-layer	3	0	5	6	17	0	0
Total number of samples	9	26	32	20	48	5	4

[x]with calcium carbonate.

TABLE 3.9. TABLE OF THE PERCENTAGES OF THE SAMPLES OF EACH SHALE TYPE CONTAINING THE VARIOUS MINERALOGIES

Type	1	2	3.6a	4	5
Illite	0	34.6%	16.2%	10%	10.4%
Chlorite	0	3.9%	2.7%	10%	0
Illite plus chlorite	0[x]	61.5%	67.6%	50%	50%
Mixed-layer	25%	0	0	0	2.1%
Illite plus mixed-layer	37.5%	0	0	0	2.1%
Illite plus chlorite plus mixed-layer	37.5%	0	13.5%	30%	35.4%

[x] This sample was not taken into account in this table as the underclay contained calcium carbonate (see Table 3.8.).

Graph of the Percentage of Samples Containing Particular Clay Minerals Against the Shale Types.

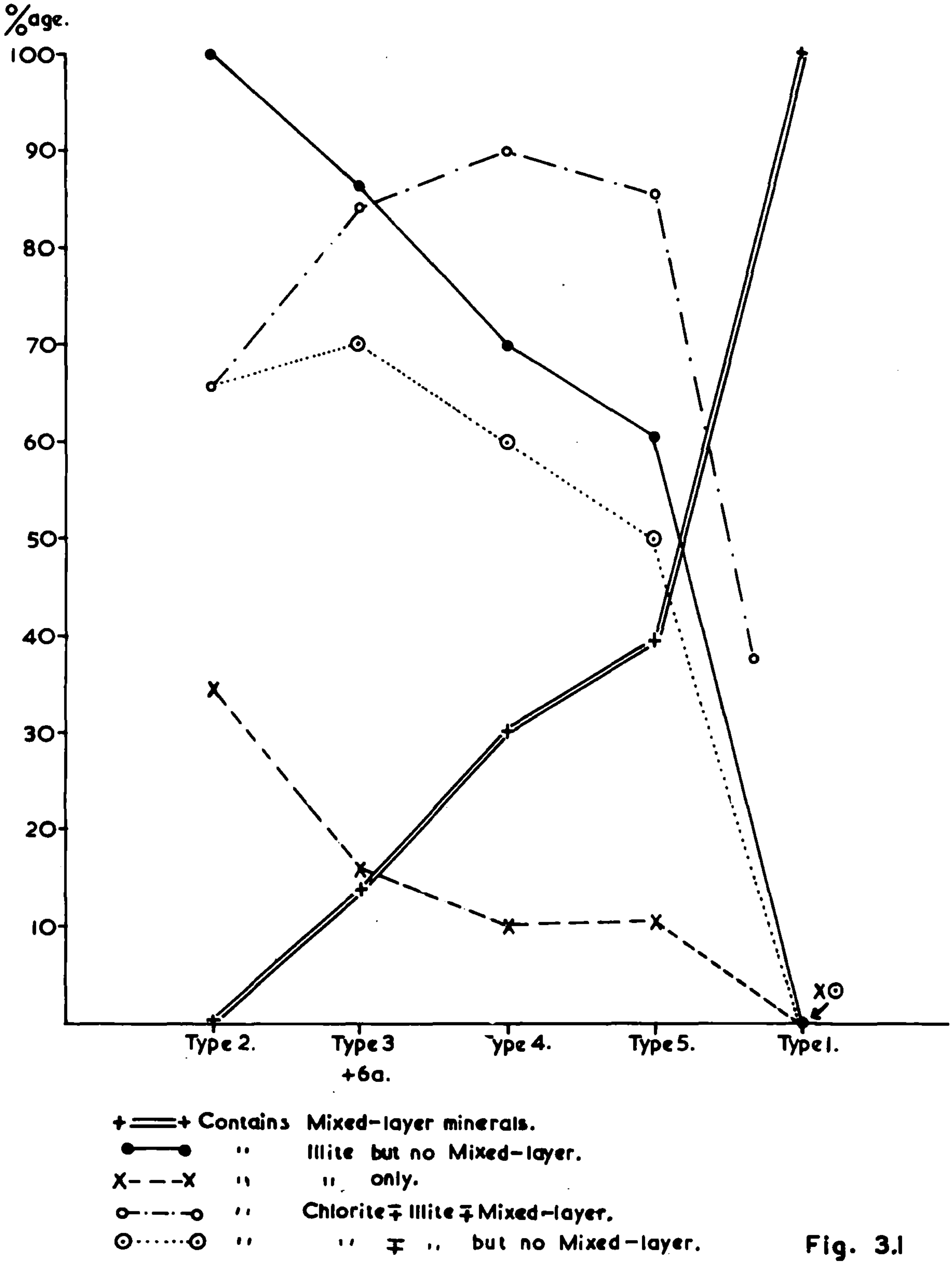


Fig. 3.1

TABLE 3.10. X-RAY POWDER DATA FOR THE ILLITIC TYPE 6a SHALE, T.22

d(Å)	Intensity
10.24	v.s.
4.96	m.
4.46	v.s.
3.86	v.v.w.
3.69	v.w.
3.49	v.w.
3.32	s.
3.18	v.v.w.
3.00	v.v.w.
2.822	v.w.b.
2.558	v.s.b.
2.447	m.
2.367	m.
2.222	v.v.w.b.
2.092	w-m
1.982	m.vb.
1.887	v.v.w.
1.833	v.v.w.
1.694	v.w.
1.644	v.w.b.
1.496	m-s.
1.373	v.v.w.
1.343	v.v.w, v.b.
1.289	w.

Lines correspond to 1Md illite with some ?2M? mica.

Camera: 9cm. Radiation: CuKα, Exposure: 3 hours.

Intensities estimated visually.

Abbreviations: v - very; w - weak; m - medium;
s - strong; b - broad.

TABLE 3.11. X-RAY POWDER DATA FOR THE CHLORITIC TYPE 5 SHALE, T.130.

d (Å)	Intensity
14.00	v.v.w.
7.05	s.
4.65	v.v.w.
4.46	v.v.w.
x4.25	m.w.
3.53	m.
x3.39	v.s.
2.67	v.v.w.
2.506	v.v.w.
x2.450	v.w.
x2.275	v.w.
x2.235	v.v.w.
x2.122	v.w.
x1.976	v.v.w.
x1.816	w.
x1.669	v.v.w.
1.551	v.w.
x1.539	v.w.
1.517	v.w.
x1.452	v.v.w.
1.381	v.v.w.
x1.371	v.w.

Lines correspond to iron-rich chlorite with quartz (x).

Camera: 11.4 cm. Radiation: CoKα. Exposure: 4 hours.

Intensities estimated visually.

Abbreviations: v - very, w - weak, m - medium,
s - strong.

TABLE 3.12. X-RAY POWDER DATA FOR THE TYPE 4 SHALE, T.15, CONTAINING ILLITE AND CHLORITE

Powdered, natural shale.		Shale heated at 600°C for 3 hours.		Shale boiled in 1:10 HCl for 1 hour.	
d (Å)	Intensity	(Å)	Intensity	(Å)	Intensity
14.44	w.	13.82	s.	14.19	v.w.
10.03	m.	10.10	v.v.w.	9.98	v.v.w.
7.10	m.			7.07	s.
4.98	w.				
4.66	v.w.			4.66	v.w, d.
4.47	m.	4.48	v.w.	4.44	v.v.w,d.
x4.27	m.s.	x4.25	m.	x4.28	m.s.
4.04	v.v.w.				
3.87	v.v.w.				
3.67	v.v.w.				
3.59	v.w.	3.49	v.w.	3.53	m.
x3.35	v.s.	x3.34	v.s.	x3.35	v.s.
3.20	w.				
3.00	v.v.w.	3.03	v.w.		
2.99	v.v.w.	?			
2.87	v.v.w.				
2.80	v.v.w.	?			
2.67	v.v.w.	2.70	v.v.w.	2.66	v.v.w.
2.57	m.b.	?		2.60	v.v.w.
				2.551	v.v.w.
				2.500	v.v.w.
x2.454	m.	x2.449	w.	x2.452	w.
2.391	v.w.b.				
x2.280	w.	x2.277	w.	x2.275	w.
x2.236	v.w.	x2.234	v.w.	x2.233	v.w.
x2.128	w.	x2.125	w.	x2.123	w.
x1.983	w.d.	x1.974	v.w.	x1.978	v.w.
x1.820	s.	x1.815	m.	x1.815	m.
x1.673	w.m.	x1.668	v.w.	x1.670	v.w.
1.662	v.w.	1.655	v.w.	1.657	v.v.w.
				1.550	v.v.w.
x1.544	m.s.	x1.540	m.	x1.540	w.
1.503	w.			1.514	v.v.w.
x1.455	v.w.	x1.451	v.w.d.	x1.449	v.v.w.
				1.415	v.v.w.,v.d.
1.386	w.	1.381	v.w.	1.381	v.w.
x1.376	m.	x1.372	w.	x1.372	w.

Lines correspond to illite and iron-rich chlorite plus quartz(x).

Camera: 11.4 cm. Radiation: CoKα. Exposures: 5 hours.

Intensities estimated visually.

Abbreviations: v - very, w - weak, m - medium, s - strong,
d - diffuse, b - broad.

N.B. Loss of 7Å Line and increased intensity of 14Å Line in heated sample and reduced intensity of 14Å Line in acid treated sample.

TABLE 3.13. X-RAY POWDER DATA FOR THE UNDERCLAY, T.386, CONTAINING MIXED-LAYER CLAY MINERAL.

d (Å)	Intensity
11.14	w.v.b.
4.99	v.w.
4.47	m.
x4.25	m.w.
?	
3.70	v.v.w.
3.50	v.v.w.
x3.34	s.
3.22	v.v.w.
2.560	m.
x2.453	w.
2.383	v.w.
x2.273	w.
x2.232	w.
x2.125	w.
x1.977	w.d.
1.885	v.v.w.
x1.816	m.w.
1.691	v.w.
x1.667	w.d.
?	
x1.539	w.m.
1.510	m.
x1.451	v.v.w.
x1.372	m.b.
x1.290	w.b.

Lines correspond to degraded illite mixed-layer mineral and quartz (x).

Camera: 9 cm. Radiation: CuKα. Exposure: 4 hours.

Intensities estimated visually.

Abbreviations: v - very, w - weak, m - medium, s - strong, b - broad, d - diffuse.

TABLE 3.14. X-RAY POWDER DATA FOR UNDERCLAY, T.323, CONTAINING ILLITE AND MIXED-LAYER CLAY.

d (Å)	Intensity
10.91	s, v.b.
4.95	m.w.
4.47	s.
x4.26	m.
3.69	v.v.w.
3.49	v.w.
x3.34	v.s.
2.832	v.v.w.
2.693	v.w.
2.563	s.
x2.458	w.
2.368	w.
2.272	v.w.
x2.226	v.w.
x2.125	w.
x1.985	w.b.
x1.812	w.m.
1.692	v.w.
x1.663	v.w.
1.632	w.
x1.537	w.m.
1.494	m.s.
x1.450	m.s.
1.385	w.

Lines correspond to illite with mixed-layer component and quartz (x).

Camera: 9 cm. Radiation: CuKα. Exposure: 3 hours.

Intensities estimated visually.

Abbreviations: v - very, w - weak, m - medium, s - strong, b - broad.

TABLE 3.15. X-RAY POWDER DATA FOR THE UNDERCLAY, T.364, CONTAINING ILLITE, CHLORITE AND MIXED-LAYER COMPONENTS

d (Å)	Intensity	
c14.78	v.w.	
z11.36	w.	diffuse area.
10.12	v.w.	diffuse area.
c 7.13	v.w.	
5.00	w.	
4.46	s.	
x 4.25	m.	
3.72	v.v.w.	
c 3.51	v.w.	
x 3.34	v.s.	
3.23	v.v.w.	
3.00	v.v.w.	
2.570	m.b.	
x 2.455	w.	
2.377	v.w.d.	
x 2.278	v.w.	
x 2.235	v.w.	
x 2.128	w.	
x 1.976	v.w.d.	
x 1.816	w.	
1.693	v.v.w.d.	
x 1.667	v.v.w.v.d.	
x 1.541	w.	
1.498	m.	
x 1.452	v.v.w.	
1.381	v.w.	
x 1.373	w.	

Lines correspond to illite plus chlorite (c) plus mixed-layer clay (z) and quartz (x).

Camera: 11.4 cm. Radiation: CuKα. Exposure: 5½ hours.

Intensities estimated visually.

Abbreviations: v - very, w - weak, m - medium, s - strong, b - broad, d - diffuse.

TABLE 3.16. CORRECTED VALUES OF THE FLUORINE ANALYSES AFTER ALLOWING FOR THE PRESENCE OF QUARTZ

No.	% Quartz	% Fluorine	Corr. factor.	Corr. % Fluorine
T. 2	1	0.217	-----	0.217
17*	75	0.093	x4	0.372
22	0	0.190	-----	0.190
31	1	0.142	-----	0.142
129	25	0.085	x1.33	0.113
133	25	0.148	x1.33	0.197
346	30	0.107	x1.4	0.153
350	30	0.094	x1.4	0.134
352	25	0.090	x1.33	0.120
364	20	0.131	x1.25	0.164
371	20	0.108	x1.25	0.135
386	25	0.150	x1.33	0.200

* This result appears to be too high and this may be due to errors in the estimation of the quartz percentage.

TABLE 3.17. FLUORINE ANALYSES IN RELATION TO CLAY MINERALOGY

Type	No.	% Fluorine		Clay Mineralogy
2 and 6a	T. 2	0.217	Average 0.183	Illite
	22	0.190		"
	31	0.142		"
3	346	0.153	0.136	Illite, chlorite and mixed-layer.
	352	0.120		Illite and chlorite.
4	129	0.113		Chlorite.
	(Corrected value for T.17 not included as this seems very high).			
5	371	0.135	0.134	Illite and chlorite.
	350	0.134		Illite, chlorite and mixed-layer.
1	386	0.200	0.182	Mixed-layer
	364	0.164		Illite, chlorite and mixed-layer.

TABLE 4.1. TABULAR CLASSIFICATION OF THE DIFFERENT SANDSTONE TYPES

Type	1	2	3	4	5	6
Effervesce with acid	Very rare	Occasionally	No	Yes	No	Occasionally
Pyrite	Very rare	Common	None	Common	None	Occasionally
Mica %age	Low	Medium	Variable	Variable	Low	Variable
Clay %age	Low	Medium	High	Variable	High	High
Organic structures	None	Pit and mound	None	Occasional fossils	None	None
Bedding	Massive, false bedded, occasionally rippled.	Flaggy, often rippled.	Poor or absent	Flaggy to massive	Massive, false bedded	Massive
Grain Size	Fine	Fine	Fine	Fine	Fine to coarse	Fine to coarse conglomeratic
Occurrence	Main sand-stone in cyclothem	Base main sandstones	At or near top of cyclothems	Base of or lateral to lime-stones	Main sand-stone in cyclothem	Base main sandstone-washout base

ABBREVIATIONS USED IN THE TABLES OF THE SANDSTONES.

H.B.H.	=	High Brig Hazle
L.B.H.	=	Low Brig Hazle
N.G.H.	=	Nattrass Gill Hazle
Q.H.	=	Quarry Hazle
I.P. Lst.	=	Iron Post Limestone
F.F. Lst.	=	Four Fathom Limestone
3 Yd Lst.	=	Three Yard Limestone
5 Yd Lst.	=	Five Yard Limestone
C.S. Lst.	=	Cockle Shell Limestone
S.P. Lst.	=	Single Post Limestone
T.B. Lst.	=	Tyne Bottom Limestone

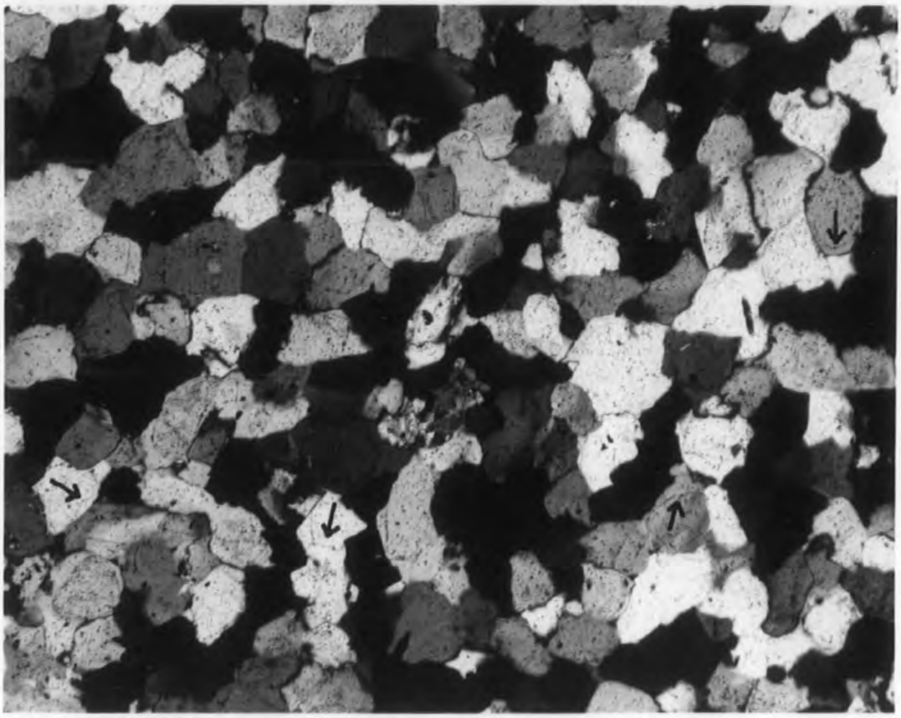


Fig. 4.1. Type 1 sandstone, T.20, illustrating the highly quartzose nature. Note secondary overgrowths (arrowed).

Polarised transmitted light X 40

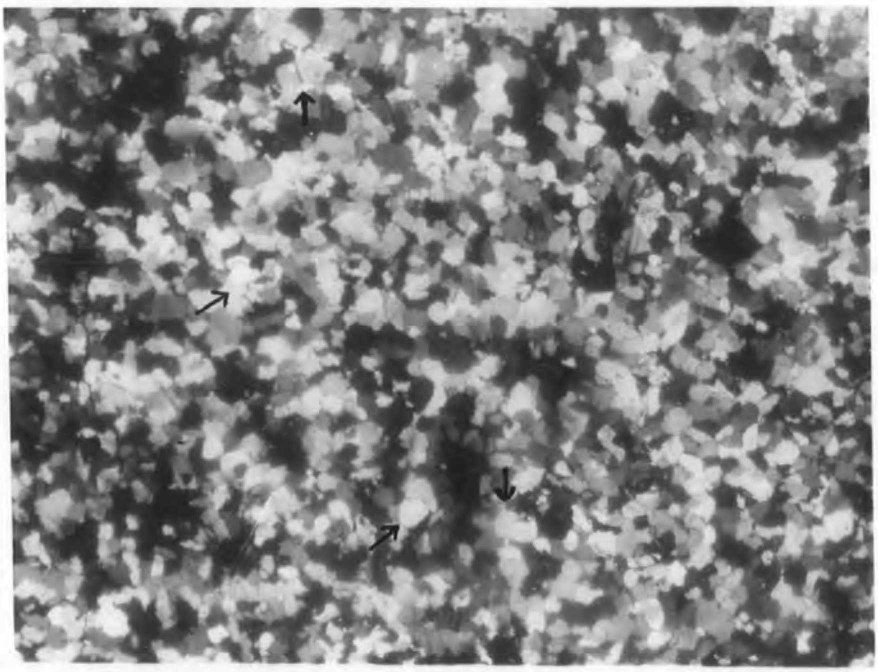


Fig. 4.2. Sandstone illustrated in Figure 4.1, showing euhedral quartz boundaries. (arrowed).

Polarised transmitted light X 10

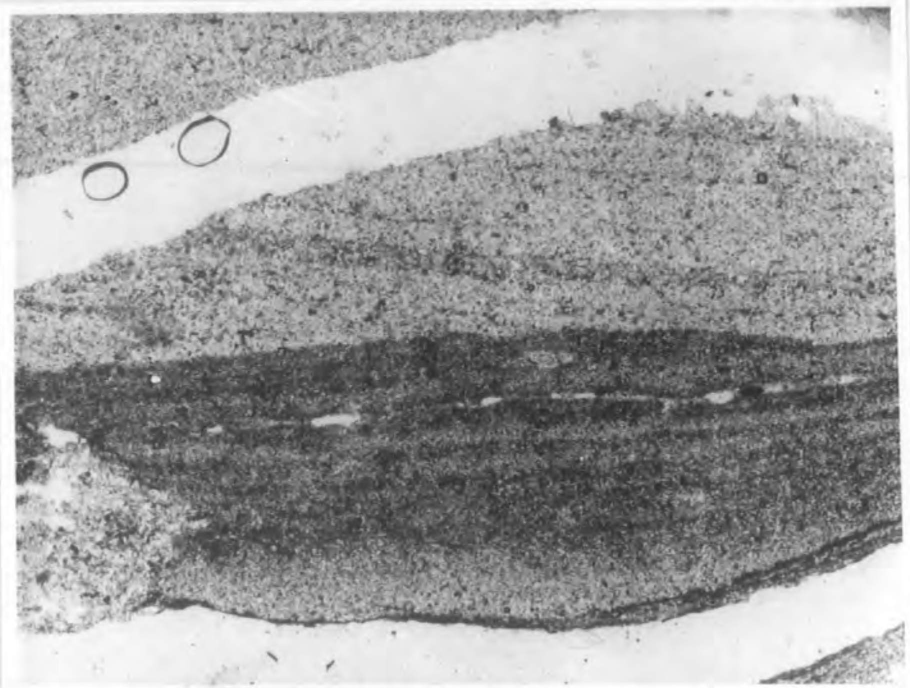


Fig. 4.3. Type 2 sandstone , T.143, showing ripple bedding and shaly band.
Ordinary transmitted light X 10

Fig. 4.4. Type 2 sandstone, T.248, showing argillaceous matrix and pyrite, P.
Ordinary transmitted light X 10

4.2. FIELD AND LABORATORY DATA FOR THE TYPE 1 SANDSTONES

Grid Ref.	Horizon	Bedding	Fissility	Ripple Marks	Clay %age	$CaCO_3$ %age	Mica %age	Mica Size in mm.	Quartz Size in mm.	Quartz Angularity	Cement	Heavy Minerals: Zircon	Tourmaline	Rutile	Leucoxene	Magnetite Ilmenite	Pyrite	Comments
907285	Lower Half L.B.H.	Massive	N-F	N-R	<1	<1	<1	<1.5	0.125-0.25	Subangular-subrounded	Quartz	+	+	-	-	-	Absent	Occasional Limestone pebbles.
907285	Upper Half L.B.H.	Massive,False Bedded	"	"	<1	0	<1	<2	0.1-0.25	"	"	-	-	-	-	-	?	Limonitic spots ?after pyrite?
909289	H.B.H.	Massive,False Bedded	"	"	1-2	0	<1	<0.25	0.075-0.375	Subangular-rounded	"	-	-	-	-	-	Absent	
909293	L.B.H.	Massive	"	"	<1	0	c.5	<0.3	0.05-0.25	Subangular-subrounded	"	-	+	-	-	-	Absent	Clay galls and pellets in places.
909293	L.B.H.	Massive	"	"	c.3	0	<1	<1	0.175-0.3	"	"	-	+	-	+	?	?	Limonitic spots ?after pyrite?
910295	Sst below 5 Yd Lst	Massive	"	"	c.5	0	<<1	<0.25	0.075-0.2	"	"	-	+	-	-	+	1-2%	Pyrite mostly limonitised.
910295	H.B.H.	Massive	"	"	5-7	0	2-3	<1.5	0.125-0.5	Subrounded-rounded	"	-	+	-	-	-	?	Limonitic clay aggregates ?after pyrite?
908293	?L.B.H. or H.B.H.?	Massive	"	"	<1	<1	1	<2	0.075-0.325	Subangular-subrounded	"	+	-	-	-	+	Little	Limonitic clay ?after pyrite? Shale galls.
881285	Sst above T.B. Lst	Massive	"	"	<1-2	0	0	-	0.025-0.125	Recrystallised	"	-	-	-	-	?	Absent	Graded bedded. Contains <1% oligoclase.
883285	" " " "	Massive	"	"	3-4	0	Negligible	V.Fine	0.5-0.125	"	"	-	-	+	-	-	Absent	Limonitic spots. Very little plagioclase.
869281	" " " "	Massive	"	"	<1	0	0	-	0.175-0.5	Partially "	"	+	-	-	-	-	"	Limonitic spots. 2.5% Plagioclase.
871295	" " " "	?	?	?	<3	0	0	-	0.025-0.5	Subangular-rounded	"	-	-	-	-	-	<1%	Badly weathered, much limonite.
892295	L.B.H.	Massive	N-F	N-R	<1	0	<1	0.5	0.1-0.3	"	"	-	+	-	-	+	Absent	Limonitic areas <1%.
892296	H.B.H.	Massive	"	"	0	0	Negligible	<0.25	0.1-0.375	"	"	-	+	-	-	-	"	
886296	Sst above T.B. Lst	Massive	"	"	<1	0	0	-	0.125-0.25	"	"	+	-	-	-	-	"	Cut by quartz-siderite veinlets.
856314	Copper Hazle	Massive,False Bedded	"	"	<5	?	<1	0.5	0.125-0.25	"	"	-	-	-	-	-	"	About 1% scattered limonite.
858314	L.B.H.	Massive	"	"	3-5	0	<<1	Fine	0.125-0.225	"	"	+	+	-	-	-	"	
858314	"	Massive	"	"	1	3	<1	1.5	0.15-0.275	Subangular-rounded	Quartz + Calcite	+	-	-	-	-	"	
853311	Quartzite Assoc. with S.P. Lst.	Massive	"	"	c.2	0	0	-	0.125-0.375	"	Quartz	+	+	-	-	-	7%	Pyrite replacing quartz, assoc. with small faults and veins. (Forms 75-80% in places).
886304	Upper Half H.B.H.	Massive,False Bedded	"	"	<1	0	<1	<2	0.125-0.375	Subangular-subrounded	"	-	-	-	-	+	Absent	
886303	Lower Half H.B.H.	Massive	"	"	2-3	0	<1	<1	0.125-0.375	Subangular-rounded	"	-	+	-	-	-	"	Limonite about 1%.
904304	N.G.H.	Massive	"	"	<3	0	<1	<2	0.1-0.5	Subangular-subrounded	"	-	-	-	-	+	"	Limonite <1%.
815349	Bottom L.B.H.	Massive	"	"	c.5	0	<1	0.5	0.15-0.75	"	"	+	-	-	-	+	?	2% Limonite ?after pyrite?
815349	Middle L.B.H.	Massive,False Bedded	"	"	1-2	0	<1	<2.0	0.15-0.375	"	"	-	-	-	-	+	Absent	
815349	Top L.B.H.	Massive	"	"	1-2	0	<1	<1.5	0.175-0.5	"	"	+	-	-	-	-	"	<1% Badly altered Feldspar. Rootlets in T.of B*
801349	Above C.S. Lst.	Massive	"	"	c.5	0	<1	<0.25	0.125-0.375	Subangular	"	+	-	+	-	-	"	
809258	L.B.H.	Massive	"	"	0	0	<1	<2.0	0.1-0.55	Subangular-subrounded	"	+	+	+	-	-	"	
820254	L.B.H.	Massive	"	"	c.5	0	1-2	<2.0	0.1-0.5	Subangular-angular	"	+	+	-	-	-	?	Limonitic spots.
839264	L.B.H.	Massive	"	"	<1	0	0	-	0.125-0.25	Subangular-subrounded	"	+	+	-	-	+	Absent	Few Limonitic spots.
839255	N.G.H. or Q.H.	Massive	"	"	<1	0	<1	<0.25	0.1-0.25		"	+	+	-	-	-	"	Little Limonite.
841255	N.G.H. or Q.H.	Massive	"	"	<1	0	<1	<0.4	0.075-0.2	Subangular-angular	"	-	+	-	-	+	Absent	Limonitic spots.
847255	H.B.H.	Massive	"	"	1-2	0	<1	V.Fine	0.075-0.25	"	"	+	+	+	-	+	?	Limonitic spots.
869266	Copper Hazle	Massive	"	"	1-2	0	<1	<1	0.1-0.3	Subangular-subrounded	"	-	+	+	-	-	Present	Limonite after pyrite.
815276	Copper Hazle	Massive	"	"	2-3	0	<1	<1	0.2-0.5	"	"	+	-	-	-	-	Absent	1% Limonite.
835333	L.B.H.	Massive	"	"	0	0	<1	<1	0.125-0.3	Angular-subrounded	"	+	+	-	-	+	"	
916298	Tuft	Massive	"	"	<1	0	<1	<0.25	0.05-0.25	Subangular-rounded	"	-	-	-	-	-	"	
872261	Sst above 3 Yd Lst	Massive	"	"	3-5	0	1-2	<1.5	0.05-0.375	Angular-subrounded	"	+	+	+	-	+	"	
872266	H.B.H.	Massive	"	"	c.1	0	<<1	<0.25	0.1-0.275	Subangular-rounded	"	+	+	+	-	+	"	
882270	L.B.H.	Massive	"	"	<1	0	<1	?	0.1-0.275	Subangular-angular	"	-	-	-	-	-	"	
879262	Sst above F.F. Lst	Massive	"	"	1-2	0	<<1	<0.25	0.125-0.375	Angular-subrounded	"	-	+	-	-	-	"	
896267	L.B.H.	Massive	"	"	1-2	0	<<1	<0.75	0.1-0.875	Subangular-subrounded	"	+	-	+	-	+	"	
893276	Sst below Scar Lst	Massive	"	"	<<1	0	<<1	<0.75	0.125-0.375	"	"	-	+	-	-	-	"	
902259	H.B.H.	Massive	"	"	<1	0	<1	<1.0	0.15-0.625		"	-	-	-	+	-	"	
905254	H.B.H.	Massive	"	"	<1	0	0	-	0.15-0.55	Subangular-rounded	"	-	-	-	-	-	"	
762287	N.G.H.	Massive	"	"	Neg.	0	1	<2.0	0.1-0.375	Angular-subangular	"	+	-	+	-	-	Present	
772276	L.B.H.	Massive	"	"	0	0	<<1	<2.0	0.15-0.325	Subangular-subrounded	"	?	+	-	-	-	Absent	
776277	L.B.H.	Massive	"	"	0	0	<1	<2.0	0.2-0.5	Angular-subangular	"	-	-	-	-	-	"	
797287	?L.B.H.?	Massive	"	"	<1	0	<1	<0.2	0.1-0.375	Subrounded-subangular	"	+	-	-	-	+	"	
763277	L.B.H.	Massive	"	"	<1	0	<1	<2.0	0.125-0.25		"	-	+	-	-	-	"	
937255	L.B.H.	Massive	"	"	c.1	2-3	<<1	<0.75	0.05-0.25	Angular-subangular	"	+	+	-	-	-	Present	
909238	?H.B.H.?	Massive	"	"	<1	0	0	-	0.075-0.25	Subangular-subrounded	"	-	+	-	-	-	Absent	
917245	?H.B.H.?	Massive	"	"	c.1	0	1-2	<2.0	0.1-0.45	Angular-subangular	"	+	-	-	-	-	"	Little Limonite.
918245	?H.B.H.?	Massive	"	"	Neg.	0	<1	<1.0	0.125-0.5	Subrounded-subangular	"	-	+	-	-	-	"	
838336	H.B.H.	Massive	"	"	<1	0	<1	<2.0	0.1-0.3	"	"	+	-	-	-	-	"	1% Limonite.
804249	?Tuft?	Massive	"	"	3-5	0	Neg.	<2.0+	0.175-0.925	Rounded-subangular	"	+	-	-	-	-	?	Cubes of limonite after ?pyrite?
957248	H.B.H.	Massive	"	"	<1	1-2	<1	<1.5	0.15-0.5	"	"	-	+	-	-	-	Absent	Clay mineral kaolinite. Limonitic spots.
892287	Sst above S.P. Lst	Massive	"	"	<2	0	<1	<1.6	0.025-0.2	Subangular-subrounded	"	-	-	-	-	-	Little	) Not strictly Type 1
892287	Sst above S.P. Lst	Massive	"	"	N.D.	0	<1	N.D.	0.05-0.3	Angular-subrounded	Clay and quartz	-	-	-	-	-	Absent	) Sandstones.
860327	Sst above F.F. Lst	Massive,False bedded	"	R	<3	0	<1	<0.5	<0.15	Subangular	Quartz	+	+	+	-	+	"	

Abbreviations: N-F = Non-Fissile
N-R = Non-Rippled
R = Rippled.
Neg.= Negligible.

* = Top of Bed.

4.3. FIELD AND LABORATORY DATA FOR THE TYPE 2 SANDSTONES.

Grid Ref.	Horizon	Bedding	Fissility	Ripple Marks	Clay %age	$CaCO_3$ %age	Mica %age	Mica Size	Quartz Size	Quartz Angularity	Cement	Heavy Minerals: Zircon	Tourmaline	Rutile	Leucoxene	Magnetite & Ilmenite	Pyrite	Comments
07285	Siltst. below Scar Lst	Non-Massive	Fissile	Rippled	<15	0	<1	<2.0	0.025-0.125	Subangular-Angular	Clay	–	–	–	–	?	–	Graded bedding.
07285	" " " "	" "	"	"	<10	0	<1	<1.0	0.025-0.075	Angular-subrounded	"	–	–	–	–	–	–	c.2% carbonaceous fragments.
07285	Base L.B.H.	" "	N.F.	Non-Rippled	Variable <c.10	<20	<1	<0.2	0.05-0.2	Subangular	Calcite	–	–	–	–	–	A.	Very variable, up to 50% pyrite in places. Carbonaceous material, common. Pit and mound structures.
07285	" "	" "	N.F.	Rippled	3-5	1-2	2-7	<1.0	0.05-0.25	Subangular	Calcite + Quartz	–	–	–	–	–	"	
08292	Sst. below Scar Lst	" "	Fissile	Non-Rippled	5	0	<1	<0.25	0.03-0.1	"	Clay and Quartz	–	–	–	–	–	Absent	
08292	Siltst. above L.B.H.	" "	N.F.	Rippled	N.D.	0	N.D.	<0.25	<0.05	Angular	Clay	–	–	–	–	–	"	
08292	" " "	" "	Fissile	Non-Rippled	V.Var.	0	<1	<1.5	0.05-0.25	Subrounded-subangular	Quartz	–	+	–	–	–	A.	
08292	Sst. above L.B.H.	" "	Fissile	?Rippled?	"	0	<1	<0.5	0.05-0.2	Subangular	"	–	–	–	–	–	Absent	Limonite after ?pyrite?
07285	Sst. below Scar Lst.	" "	N.F.	Non-Rippled	3-5	1	1-2	<2.0	0.05-0.2	Subangular-subrounded	"	–	–	–	–	?	Present	Little feldspar present.
10274	Sst. below C.S. Lst.	Massive	N.F.	" "	<5	<1	<1	<2.0	0.05-0.225	Subangular	Clay + Quartz	–	–	–	–	?	Absent	Graded,bedded.
10274	" " " "	Non-Massive	Fissile	Rippled	<50	0	<1	<0.25	0.001-0.125	Subangular	Clay	–	–	–	–	–	"	Carbonaceous matter abundant.
39318	Sst. below F.F. Lst.	" "	"	"	1-2	0	2	<1.0	0.05-0.375	"	Quartz	–	+	–	–	+	"	
09275	Sst. above T.B. Lst.	Massive	N.F.	Non-Rippled	25	0	0	–	0.025-0.125	"	Clay and Quartz	–	–	–	–	–	Little	Metamorphosed rock.
09275	" " " "	"	N.F.	" "	10	0	0	–	0.025-0.05	Angular-subangular	Clay and Quartz	–	–	–	–	–	Absent	Metamorphosed rock.
93290	Sst. above C.S. Lst.	Non-Massive	Fissile	" "	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	ND	ND	ND	ND	ND	V.A.	
92293	L.B.H.	Flaggy	"	" "	<1	0	5-7	<1.5	0.05-0.2	Subangular-subrounded	Quartz	+	+	–	–	–	Present	Pit and Mound structures.
92294	Upper half L.B.H.	"	"	Rippled	<10	0	25	<1.0	<0.1	Angular	Clay	+	+	+	–	–	Absent	Carbonaceous material common.
92296	Sst. below H.B.H.	Non-Massive	"	"	5-10	0	5-7	<2.0	0.025-0.2	Angular-subrounded	Quartz	+	–	–	–	?	Present	Graded, bedded.
84302	Sst. base L.B.H.	" "	"	Non-Rippled	N.D.	0	N.D.	<0.25	<0.05	Angular	N.D.	ND	ND	ND	ND	ND	Absent	
89292	Sst. below Scar Lst.	Flaggy	N.F.	Rippled	20	0	<1	<0.5	0.025-0.075	Subangular	Quartz and Clay	–	–	–	–	–	Present	Calcite-pyrite veinlets.
60317	Sst. above 3 Yd Lst.	Non-Massive	Fissile	Non-Rippled	20	0	<3	<0.25	0.01-0.175	Angular	Clay	–	–	–	–	–	Absent	
47320	?	Flaggy	"	" "	2	0	2-4	<1.0	0.1-0.25	Angular-Subangular	Quartz	–	–	–	–	–	Absent	
48335	?	"	"	" "	c.5	0	c.2	<2.0	0.025-0.2	Angular	Quartz and Clay	–	–	–	–	–	Absent	
48335	Above 179	Non-Massive	"	" "	<20	0	<5	<0.5	0.03-0.15	Angular-subangular	Clay	–	+	–	–	–	Present	
48335	Above 180	Flaggy	"	" "	<4	0	<1	<1.0	0.05-0.375	Angular-few rounded	Quartz	+	?	–	–	+	Absent	
84305	Sst. above 3 Yd Lst.	Flaggy	N.F.	Non-Rippled	V.Var.	0	5-10	<1.0	0.03-0.25	Angular	Clay and Quartz	–	+	–	–	–	V.A.	Pyrite forms up to 75% of rock.
29334	Sst. below S.P. Lst.	Non-Massive	Fissile	" "	<5	0	<20	<0.3	0.035-0.125	Subangular	Clay and Quartz	–	–	–	–	–	Absent	
30335	Sst. above S.P. Lst.	" "	"	" "	<30	0	<20	<0.5	0.025-0.125	Angular	Clay	+	+	–	–	–	Absent	Spheroidal aggregates chlorite, common.
30335	Copper Hazle	Flaggy	"	" "	2-3	0	<1	<1.5	0.1-0.25	Subangular-rounded	Quartz	+	–	–	–	+	Absent	
12345	Silst. below S.P. Lst.	Non-Massive	"	" "	5-10	0	5-10	<0.25	<0.05	Angular-subangular	Clay	–	–	–	–	–	Absent	
07285	Base L.B.H.	Flaggy	N.F.	" "	<1	<1	3-5	<2.5	0.05-0.25	"	Quartz	+	+	+	–	–	Absent	Pit and mound structures.
69267	Sst. below Scar Lst.	"	N.F.	" "	<2	0	<1	<2	0.05-0.375	"	"	+	+	+	–	–	Absent	1% albite-andesine.
14279	L.B.H.	"	N.F.	Rippled	2-3	0	<1	<0.25	0.025-0.125	"	Clay and Quartz	–	–	–	–	–	Absent	
15283	Sst. below 3 Yd Lst.	"	N.F.	"	2-3	0	c.5	<1.0	0.025-0.3	"	Quartz	+	–	–	–	–	?	Limonite cubes after pyrite.
15288	Silst. above 3 Yd Lst.	Massive	N.F.	Non-Rippled	15	0	1-2	<0.25	0.025-0.075	Subangular-subrounded	Clay	+	+	–	–	–	Absent	
05262	Sst. below S.P. Lst.	Flaggy	N.F.	" "	N.D.	0	Negligible	–	0.05-0.2	Subangular	"	+	–	–	–	–	"	
57291	Silst. below F.F. Lst.	Massive	Friable	" "	N.D.	0	<1	<0.2	0.01-0.1	Angular	"	–	–	–	–	–	"	
75283	Sst. below N.G.H.	Non-Massive	Fissile	" "	10	0	<1	<0.5	0.025-0.125	"	"	–	–	–	–	–	Little	
"	" " "	Flaggy	Fissile	Rippled	2-3	0	1-2	<0.25	0.05-0.325	Angular-subrounded	Quartz	+	–	–	–	–	Little	
73285	?Tuft?	Non-Massive	"	Non-Rippled	N.D.	0	N.D.	<0.25	<0.2	Subangular	"	–	–	–	–	–	Absent	
33299	Silst. below Scar Lst.	Flaggy	N.F.	" "	10	0	<1	<0.5	0.01-0.05	Angular-subangular	Quartz and clay	–	–	–	–	–	Little	Shell fragments in shaly partings.
84302	Base L.B.H.	Flaggy	Fissile	" "	7-10	0	1-2	<2.0	0.075-0.2	Subangular	Quartz	+	–	–	–	–	A.	
46258	Top H.B.H.	"	N.F.	" "	<1	0	<1	<0.25	0.03-0.225	Angular & subangular	"	+	+	–	–	–	Absent	
40255	Sst. above L.B.H.	Non-Massive	N.F.	Rippled	25	0	<1	<0.75	0.025-0.1	Angular	Clay	–	–	–	–	–	"	
43258	L.B.H.	Flaggy	Fissile	Rippled	5	0	5-7	<0.75	0.025-0.125	"	"	+	+	–	–	–	"	
40255	Top L.B.H.	"	N.F.	Non-Rippled	<1	0	c.2	<1.5	0.05-0.125	Subrounded-subangular	Clay and Quartz	+	–	–	–	–	A.	
23273	Sst. below I.P. Lst.	"	Fissile	Rippled	<25	0	<5	<2.0	<0.125	Angular-subangular	Clay	+	+	–	–	–	Absent	Limonite Abundant.
62243	?	"	"	"	<25	0	N.D.	<3.0	0.025-0.325	"	Clay	+	–	+	–	–	Absent	
63238	Sst. above T.B. Lst.	"	N.F.	"	<1	0	1-2	<0.25	0.075-0.25	"	Quartz	–	?	?	–	?	Absent	
84236	" " " "	"	N.F.	"	10-20	0	0	–	0.05-0.1	Angular	"	+	–	?	–	–	Absent	
84236	" " " "	"	"	"	<60	0	Negligible	<0.25	0.03-0.1	"	Clay	+	–	–	–	–	Absent	

A = Abundant
N D = Not Determined.
V.A.= Very Abundant.

TABLE 3.4. FIELD AND LABORATORY DATA ON THE TYPE 3 ARGILLACEOUS ROCKS

No.	Stratigraphical Horizon	Grid Ref.	Presence $CaCO_3$	Visible Mica	Fossils	Bedding	Fissility	Nodules	Quartz			X-ray Data				Remarks
									Field Est'n.	Micro Est'n.	Grain size in mm.	Illite	Chlorite	Mixed-layer	Quartz	
80	Above C.S. Lst.	910273	No	V.Fine	Brachs.	Good	V.F.	Pyrite	N.A.	2-3%	<0.025	x	x		x	
91	Above S.P. Lst.	892287	No	None	None	Good	Fissile	None	Little	10-30%	<0.1	x	x		x	
100	Above C.S. Lst.	892292	No	None	None	Good	Non-F.	Pyrite	N.A.	c.5%	<0.025	x	x		x	
130	Above 3 Yd Lst.	888302	No	V.Fine	Brachs.	Good	V.F.	Pyrite	Little	N.D.	N.D.		x		x	
140	Above S.P. Lst.	890291	No	None	None	Poor	N-F.	None	N.A.	3-5%	<0.05	x			x	
145	Below C.S. Lst.	887293	No	V.Fine	Brachs.	Good	Fissile	None	N.A.	N.D.	N.D.	x	x		x	
171	Above 3 Yd Lst.	859316	No	V.V.Fine	Brachs.	Good	Fissile	Pyrite	Little	N.D.	N.D.	x	x		x	
174	Above C.S. Lst.	853315	No	V.Fine	None	Good	Fissile	None	N.A.	<30%	<0.05	x	x		x	
197	Above 3 Yd Lst.	884305	No	V.Fine-Fine	Brachs.	Good	Fissile	Non-Pyritous	Little	N.D.	N.D.	x	x		x	
198	Above 3 Yd Lst.	884305	No	Fine-Medium	None	Good	V.F.	None	V.A.	c50%	0.01-0.15	x	x		x	Very abundant coal fragments
205	Above Scar Lst.	908293	No	V.V.Fine	Brachs.	Good	Fissile	None	A.	N.D.	N.D.	x	x		x	
206	Above Scar Lst.	908293	No	V.V.Fine	Brachs.	Good	Fissile	Pyrite	N.A.	N.D.	N.D.	x	x		x	
266	Above 3 Yd Lst.	915286	No	V.Fine-Med.	Brachs.	Good	Fissile	Pyrite	N.A.	<<1%	0.015-0.5	x	x	x	x	
284	In C.S.Lst.	904262	No	V.V.Fine	None	Good	Fissile	None	N.A.	N.D.	N.D.	x	x		x	
306	Below Scar Lst.	883299	No	Fine	Brachs.	Good	V.F.	None	N.A.	N.D.	N.D.	x	x		x	
307	Below Scar Lst.	883299	No	Fine	Brachs.	Good	N.F.	None	V.A.	95%	0.015-0.025	x	x		x	
308	Below Scar Lst.	883299	No	V.Fine	None	Good	V.F.	None	N.A.	N.D.	N.D.	x	x		x	
312	Above Scar Lst.	907285	No	V.Fine	Brachs.	Good	V.F.	Pyrite	Little	5%	<0.05	x	x		x	
318	Above 3 Yd Lst.	947260	Yes	Fine	Brachs.	-	-	Pyrite	N.A.	<<1%	<0.03	x	x		x	
319	Above 3 Yd Lst.	947260	Little	Fine-Med	Brachs.	Good	Fissile	Pyrite	Little	N.D.	N.D.	x	x		x	
331	Above Scar Lst.	927266	No	V.Fine-Fine	Brachs.	Good	Fissile	None	Little	N.D.	N.D.	x	x		x	
332	Above Scar Lst.	927266	No	Fine-Med	Brachs.	Good	V.F.	Pyrite	A.	N.D.	N.D.	x	x		x	
346	Above 5 Yd Lst.	965251	Yes	V.Fine	Brachs.	Good	Fissile	Pyrite	A.	N.D.	N.D.	x	x	x	x	
347	Above 5 Yd Lst.	965251	No	V.Fine	Brachs.	-	-	Pyrite	Little	N.D.	N.D.	x	x	x	x	
352	Above 3 Yd Lst.	922273	No	Fine-Med	Brachs.	Good	Fissile	None	A.	N.D.	N.D.	x	x		x	
353	Above F.F. Lst.	923273	Little	V.V.Fine	Brachs.	Good	N.F.	None	N.A.	N.D.	N.D.	x			x	
360A	Above S.P. Lst.	953238	No	Fine	Brachs.	Good	V.F.	None	Little	N.D.	N.D.	x	x		x	Siltstone bands up to 95% quartz. Size 0.025-0.05 mm.
365	Above C.S. Lst.	889292	No	V.Fine	Brachs.	Good	Fissile	Pyrite	N.A.	c.10%	0.015-0.025	x	x		x	
367	Above 3 Yd Lst.	884305	No	Fine-Med	Brachs.	Good	Fissile	Pyrite	Little	c.60%	0.025-0.125	x	x	x	x	
369	Above C.S. Lst.	910273	No	V.Fine	Brachs.	Good	V.F.	Pyrite	N.A.	N.D.	N.D.	x	x		x	
370	Above Scar Lst.	909293	No	V.Fine	Brachs.	Good	Fissile	Pyrite	Little	N.D.	N.D.	x	x		x	
374	Above F.F. Lst.	948272	No	V.V.Fine	Brachs.	Good	Fissile	None	N.A.	N.D.	N.D.	x	x	x	x	

Abbreviations:
N.A. = Not Apparent.
N.D. = Not determined.
V.F. = Very Fissile.
N-F. = Non-Fissile.
V.A. = Very Abundant.
A. = Abundant.

ND LABORATORY DATA FOR THE TYPE 3 SANDSTONES.

Horizon	Bedding	Fissility	Ripple Marks	Clay %age	$CaCO_3$ %age	Mica %age	Mica Size	Quartz Size	Quartz Angularity	Cement	Heavy Minerals					Pyrite	Comments
											Zircon	Tourmaline	Rutile	Leucoxene	Magnetite & Ilmenite		
below 3 Yd Lst.	Massive	Non-Fissile	Non-Rippled	40	0	<1	<0.5	0.01-0.25	Angular-Subangular	Clay	-	-	-	-	-	Absent	Stigmarian Rootlets.

D LABORATORY DATA FOR THE TYPE 4 SANDSTONES.

Horizon	Bedding	Fissility	Ripple Marks	Clay %age	$CaCO_3$ %age	Mica %age	Mica Size	Quartz Size	Quartz Angularity	Cement	Heavy Minerals					Pyrite	Comments
											Zircon	Tourmaline	Rutile	Leucoxene	Magnetite & Ilmenite		
er Hazle	Massive	N.F.	Rippled	0	5	<1	<0.2	0.025-0.2	Subangular	Calcite + Quartz	-	-	-	-	-	Pres.	
"	"	"	"	2.5	0	<1	<2.0	0.075-0.2	"	Clay + Quartz	-	+	-	-	?	Absent	Graded bedded.
st.below Scar Lst	"	"	"	0	2	<1.5	<0.25	0.05-0.15	Angular-Subangular	Calcite + Quartz	-	-	-	-	-	Little	
base of 5 Yd Lst	"	"	Non-Rippled	<<1	10	<1	<1.0	0.075-0.2	Angular-subrounded	Calcite	-	-	-	-	-	"	Shell Fragments.
below 5 Yd Lst.	"	"	" "	1-2	1	<1	<0.5	0.1-0.2	Subangular-subrounded	Quartz	-	+	-	-	+	Absent	Clay galls.
below Scar Lst	"	"	" "	<1	3-5	0	-	0.1-0.375	" "	Calcite	-	-	-	-	-	"	
above C.S. Lst	"	"	" "	2-5	3-5	<3	0.3	0.05-0.125	Subangular	Calcite + Quartz	+	+	-	-	-	?	Limonite ?after pyrite? 1% Oligoclase.
valent C.S. Lst	"	"	" "	<1	40	1-2	<0.5	0.075-0.2	Angular-Subrounded	Calcite	+	-	-	-	+	A.	1% Oligoclase.
below Scar Lst	"	Fissile	" "	<30	<1	4-6	<1.0	0.025-0.2	Angular-Subangular	Clay	-	-	-	-	-	Absent	
above L.B.H.	Flaggy	N.F.	Rippled	<2	30	<1	<0.5	0.05-0.25	" "	Calcite	+	+	+	-	-	Pres.	
above 3 Yd Lst.	Massive	N.F.	Non-Rippled	N.D.	N.D.	N.D.	<0.75	0.025-0.125	Angular	Clay + Calcite	+	-	-	-	-	Absent	Calcite,clay & mica,mixed. Ankerite pres.?
" " "	"	"	" "	N.D.	45	N.D.	<0.5	0.025-0.125	"	" "	+	+	-	-	-	Absent	?Ankerite?
" " "	Non-Massive	Fissile	Rippled	N.D.	N.D.	N.D.	<0.75	0.025-0.5	"	" "	-	-	-	-	-	Little	?Ankerite?

D LABORATORY DATA FOR THE TYPE 5 SANDSTONES.

Horizon	Bedding	Fissility	Ripple Marks	Clay %age	$CaCO_3$ %age	Mica %age	Mica Size	Quartz Size	Quartz Angularity	Cement	Heavy Minerals					Pyrite	Comments
											Zircon	Tourmaline	Rutile	Leucoxene	Magnetite & Ilmenite.		
bove H.B.H.	Massive to Flaggy.	N.F.	Non-Rippled	7	0	<1	<2.0	0.05-0.5	Subangular-subrounded	Clay + Quartz	+	-	+	-	+	Absent	
uft?	Massive	"	" "	15	0	3-5	N.D.	0.25-1.25	" "	Quartz	-	-	-	-	-	"	Clay kaolinite with remnant plagioclase.
?	"	"	" "	<10	0	<1	<0.75	0.1-0.5	Subangular-rounded	"	+	-	+	-	-	A.	Clay galls. Pyrite abundant.
below S.P. Lst	"	"	" "	8	0	<1	<1.0	0.125-0.4	Subangular	"	-	-	-	-	-	Absent	
H.	"	"	" "	3-5	0	<1	<2.0	0.15-1.375	Subangular-subrounded	"	+	-	-	-	-	"	Clay kaolinite.
H.	"	"	" "	10	0	<1	<0.5	0.125-1.5	Angular	"	+	-	-	-	-	"	" "
H.	"	"	" "	20	0	1-2	<0.75	0.125-1.5	"	"	+	-	-	-	-	"	" "
H.	"	"	" "	<6	0	1-2	<2.0	0.125-0.925	Subrounded	"	-	-	-	-	-	"	" ", little feldspar.

D LABORATORY DATA FOR THE TYPE 6 SANDSTONES.

Horizon	Bedding	Fissility	Ripple Marks	Clay %age	$CaCO_3$ %age	Mica %age	Mica Size	Quartz Size	Quartz Angularity	Cement	Heavy Minerals					Pyrite	Comments
											Zircon	Tourmaline	Rutile	Leucoxene	Magnetite & Ilmenite.		
H.B.H.	Massive	N.F.	Non-Rippled	25	<1	0	-	0.05-1.75	Angular	Quartz	-	-	-	-	-	A.	Clay galls 50% rock.
"	"	"	" "	<15	0	<1	<1.5	0.1-0.75	Subangular-subrounded	"	+	+	-	-	-	"	Clay ironstone pellets.
"	"	"	" "	15-20	0	0	-	0.1-1.125	Subangular-rounded	"	+	-	-	-	-	Absent	Clay galls and carbonaceous fragments.

Abbreviations: N.F. = Non-Fissile
A. = Abundant.
Pres.= Present.

TABLE 3.3. FIELD AND LABORATORY DATA OF THE TYPE 2 ARGILLACEOUS ROCKS

No.	Stratigraphical Horizon	Grid. Ref.	Presence $CaCO_3$	Visible Mica	Fossils	Bedding	Fissility	Nodules	Quartz			X-ray Data				Remarks
									Field Est'n.	Micro Est'n.	Grain size in mm.	Illite	Chlorite	Mixed-layer	Quartz	
1	In Scar Lst.	907285	Yes	None	Brachs.	Good	P.F.	None	N.A.	None	None	x			x	
2	In Scar Lst.	907285	Yes	None	Brachs.	Good	P.F.	None	N.A.	<1%	<0.05	x			x	
3	In Scar Lst.	907285	Yes	None	Crinoids	Good	P.F.	None	N.A.	N.D.	N.D.	x	x		x	
5	In Scar Lst.	907285	Yes	None	None	Good	P.F.	None	N.A.	None	None	x	x			
14	Top of Scar Lst.	907285	Yes	None	Brachs.	Good	P.F.	None	N.A.	None	None	x	x		x	
31	In 5 Yd Lst.	907287	Yes	None	Brachs.	Good	Fissile	None	N.A.	None	None	x			x	
51	In Scar Lst.	908292	Yes	None	Brachs.	Massive	Massive	None	N.A.	None	None		x			
52	In Scar Lst.	908292	Yes	None	Brachs.	Good	P.F.	None	N.A.	None	None	x	x		x	
74	In Lst.	908282	No	None	None	Good	Fissile	None	N.A.	<5%	<0.05	x				
75	Below Lst.	908282	No	None	None	Good	Non-Fissile	None	N.A.	5-7%	0.001-0.125	x	x		x	
76	Below Lst.	908282	No	None	None	Good	Fissile	None	N.A.	<3%	<0.05	x	x		x	
93	Above C.S.Lst.	892299	No	None	None	Good	Very Fissile	Pyrite	N.A.	None	None	x			x	
102	Above T.B.Lst.	883286	No	None	None	Good	Fissile	Pyrite	N.A.	None	None	x	?		x	
105	Above T.B. Lst.	885286	No	None	None	Good	P.F.	None	N.A.	None	None	x	x		x	
111	Above T.B. Lst.	869281	No	None	None	Good	Fissile	Pyrite	N.A.	<1%	0.025	x	x		x	
117	Above S.P. Lst.	893286	No	None	None	Good	Fissile	None	N.A.	3-5%	<0.1	x	x		x	
131	Above 5 Yd Lst.	886303	Yes	None	Brachs.	Good	Friable	None	N.A.	None	None	x			x	
141	In C.S. Lst.	889292	No	None	None	Good	Non-Fissile	None	N.A.	1-3%	0.025	x			x	
142a	Above C.S.Lst.	889292	No	None	Brachs.	Good	Fissile	Pyrite	N.A.	<1%	0.025	x	x		x	
161	Above 5 Yd Lst.	858314	Yes	None	Brachs.	Good	Non-Fissile	None	N.A.	None	None	x			x	
162	Above 5 Yd Lst.	858314	Yes	None	Brachs.	Good	Non-Fissile	None	N.A.	None	None	x			x	
203	Above 5 Yd Lst.	886303	Yes	None	Brachs.	Good	Non-Fissile	None	N.A.	None	None	x			x	
252	Above 5 Yd Lst.	915281	No	None	Brachs.	Good	Fissile	Pyrite	N.A.	None	None	x	x		x	
253	Above 5 Yd Lst.	915281	Yes	None	Brachs.	Good	Fissile	None	N.A.	<1%	<0.015	x	x		x	
265	Above 3 Yd Lst.	915286	Yes	V.Fine-Fine	Bryozoa	Good	Fissile	None	N.A.	<1%	<0.05	x			x	
281	Above S.P. Lst.	905262	No	None	None	Good	Fissile	None	N.A.	<5%	<0.025	x	x		x	

Abbreviations:
P.F. = Poor fissility.
N.A. = Not Apparent
N.D. = Not Determined.
V. = Very.

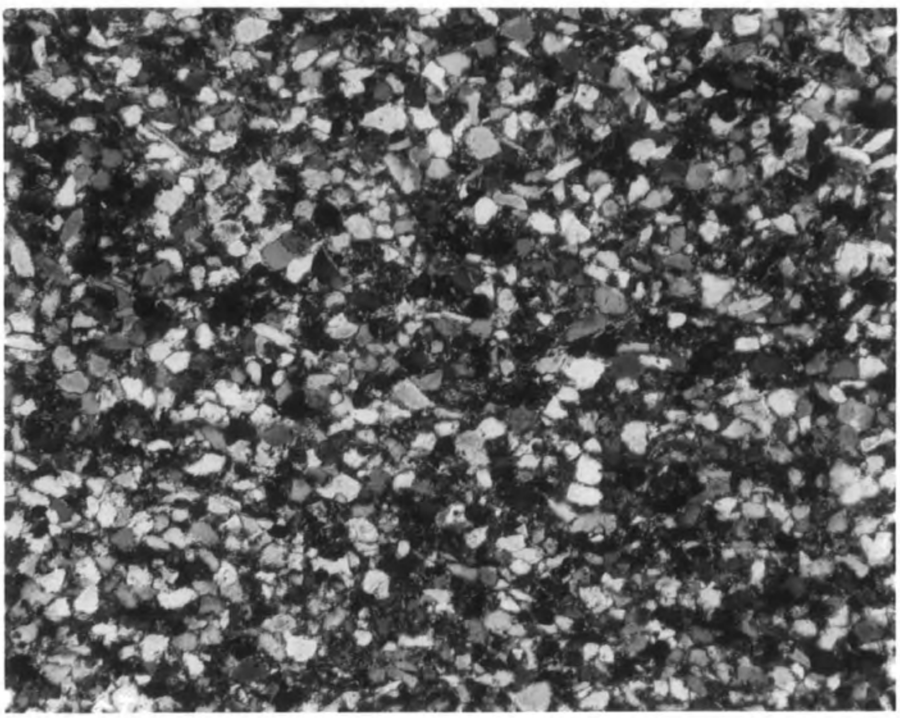


Figure 4.4a. Type 2 sandstone, T.248., showing argillaceous matrix.

Polarised transmitted light X40

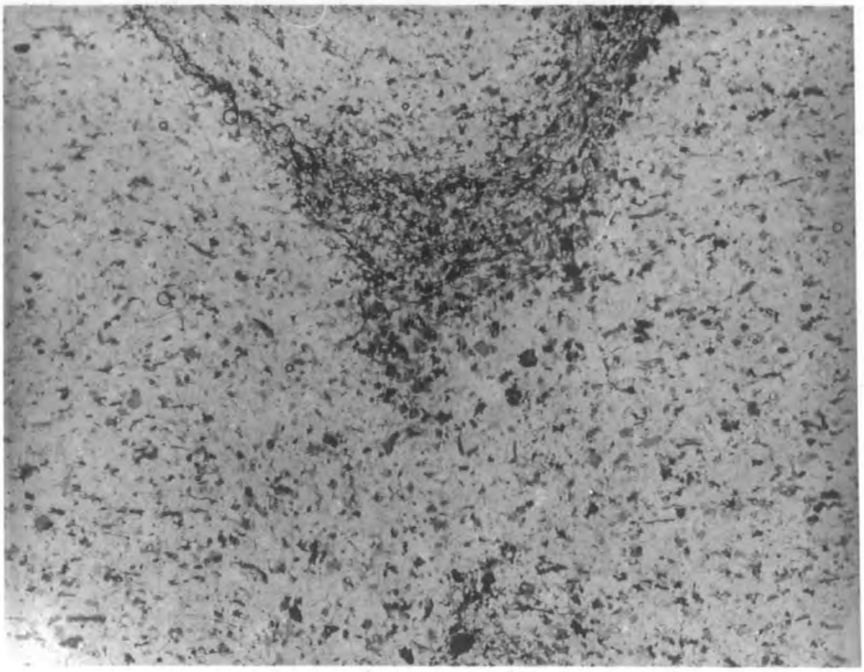


Fig. 4.5. Section through top of pit and mound structure in Type 2 sandstone, T.19, showing concentration of mica (dark grey).

Ordinary transmitted light X 6.5.

Fig. 4.6. Type 2 sandstone, T.362, showing unidentified structure of sand in mica shaly layer.

Ordinary transmitted light X 10.

TABLE 4.8. X-RAY POWDER DATA FOR IRON-RICH CHLORITE IN CLAY SPHEROIDS FROM TYPE 2 SANDSTONE T.215

Spacing in Å	Intensity, estimated visually.
14.12	weak.
7.09	strong.
4.34	very very weak, very broad.
3.51	medium.
3.34	medium.
?	
2.653	very weak.
2.551	very weak.
2.415	very weak, very broad.
?	
1.990	very very weak.
1.809	very very weak.
1,543	weak.
?	
1.419	very very weak.

Camera diameter: 9 cm.

Radiation: CuKα.

Exposure: 3 hours.

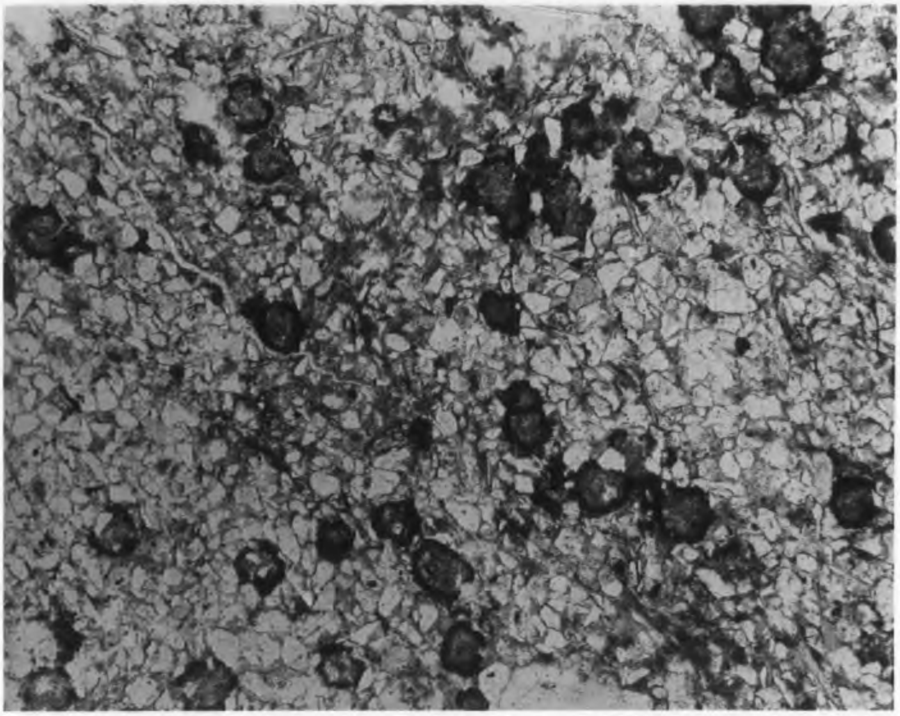


Fig. 4.7. Type 3 sandstone, T.259, showing spheroidal chlorite with iron stained rims in argillaceous matrix. Colourless material, quartz.

Ordinary transmitted light X 40

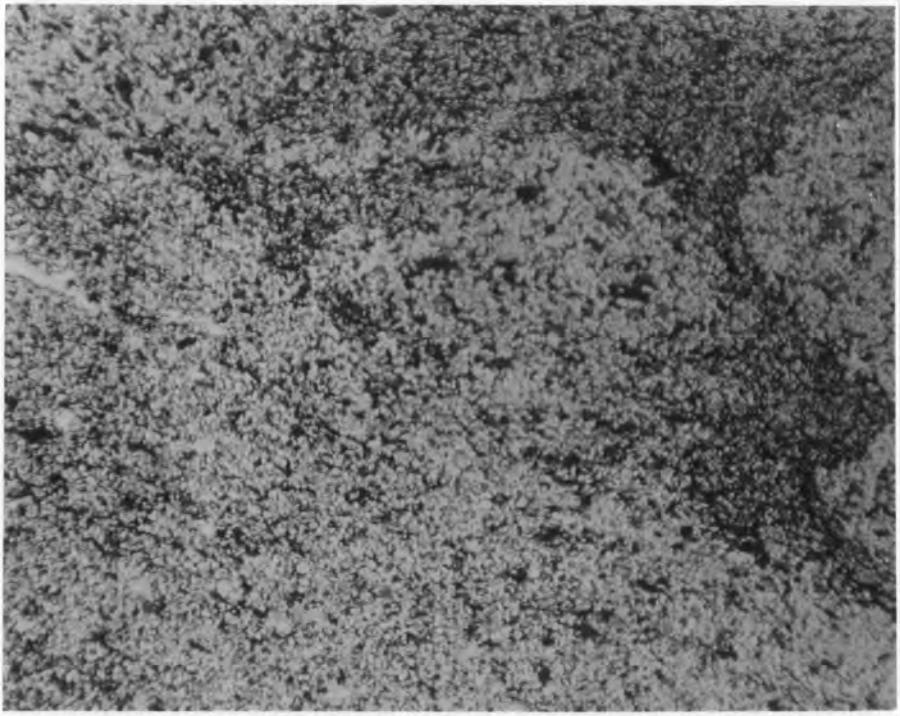


Fig. 4.8. Type 4 sandstone, T.247, showing abundant fine brown mica.

Ordinary transmitted light X 10

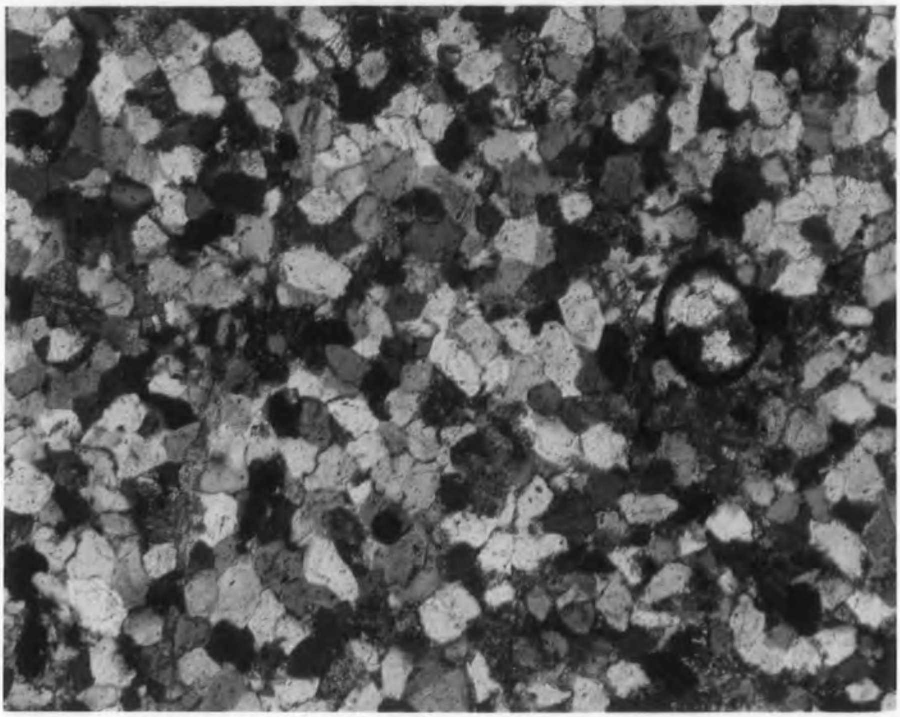


Fig. 4.9. Type 4 sandstone, T.27, showing sand grains embedded in fine-grained calcite matrix.

Polarised transmitted light X 40

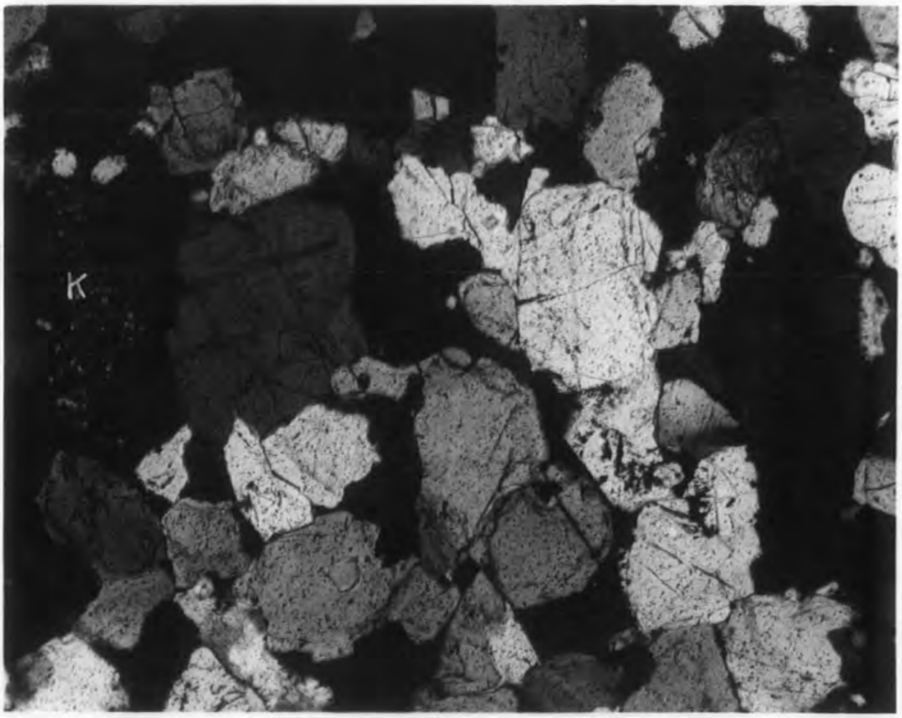


Fig. 4.10. Type 5 sandstone, T.292, showing kaolin (K), interstitial to ill-sorted quartz grains.

Polarised transmitted light X 40

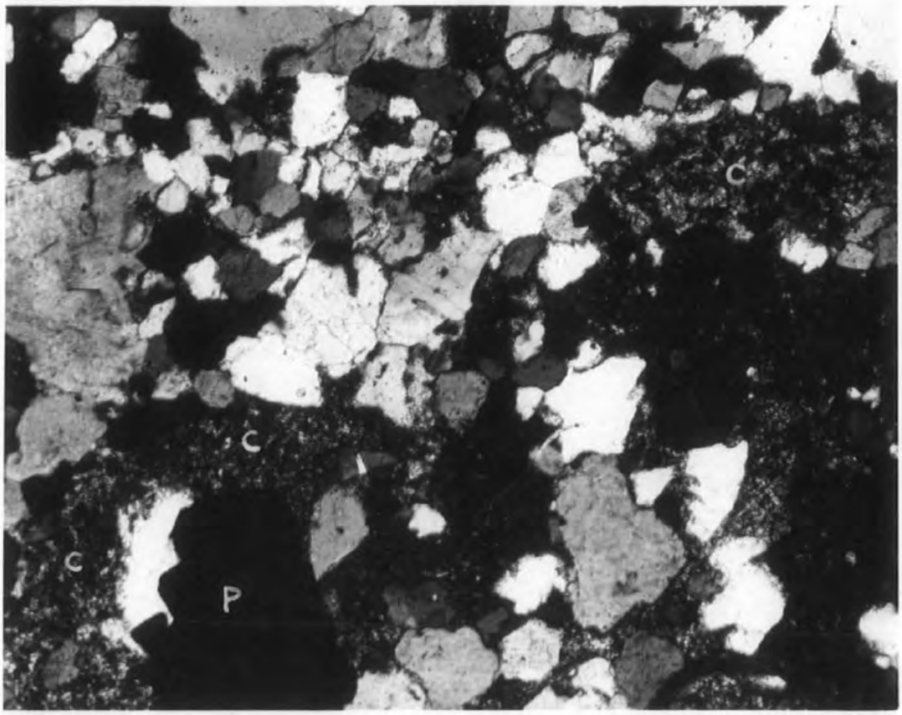
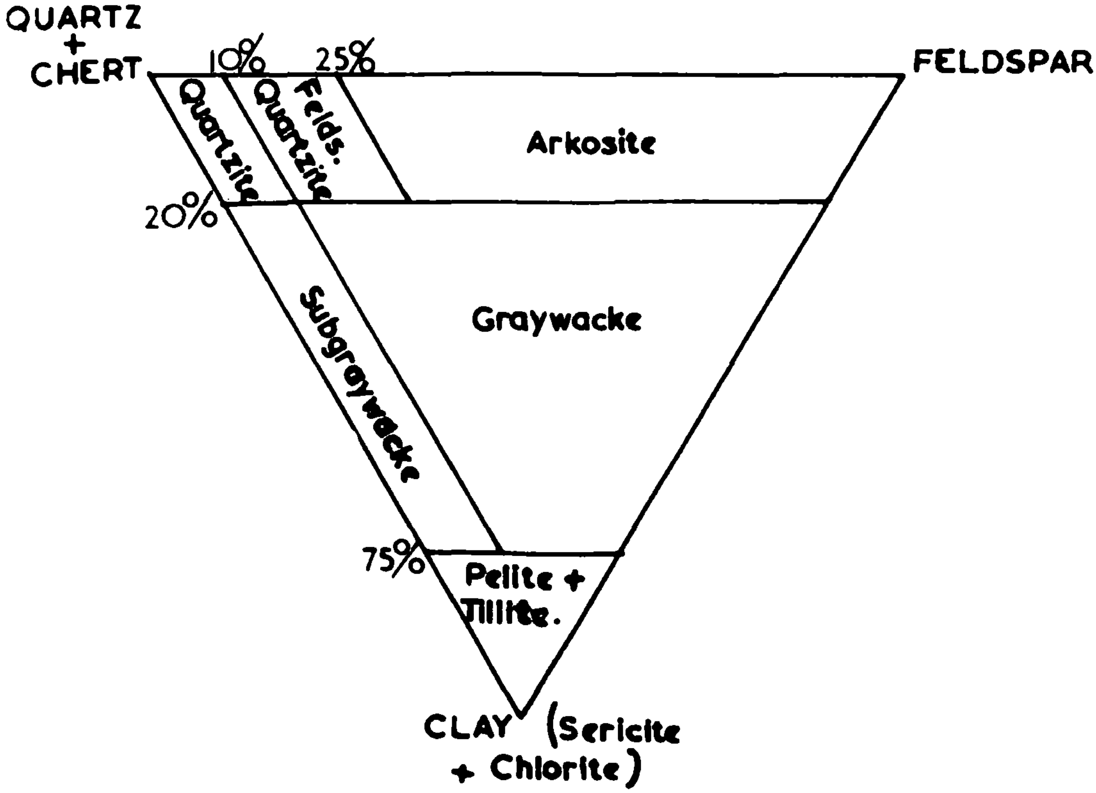


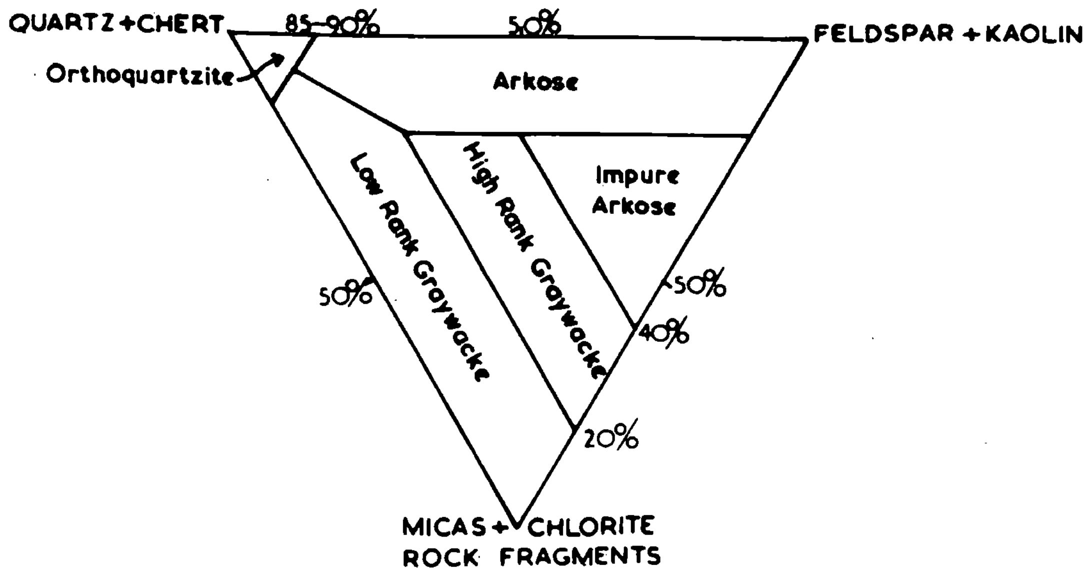
Fig. 4.11. Type 6 sandstone, T.249, showing aggregates of interstitial chlorite (C) amongst poorly sorted sand grains. Note pyrite (P) with euhedral boundaries.

Polarised transmitted light X 40

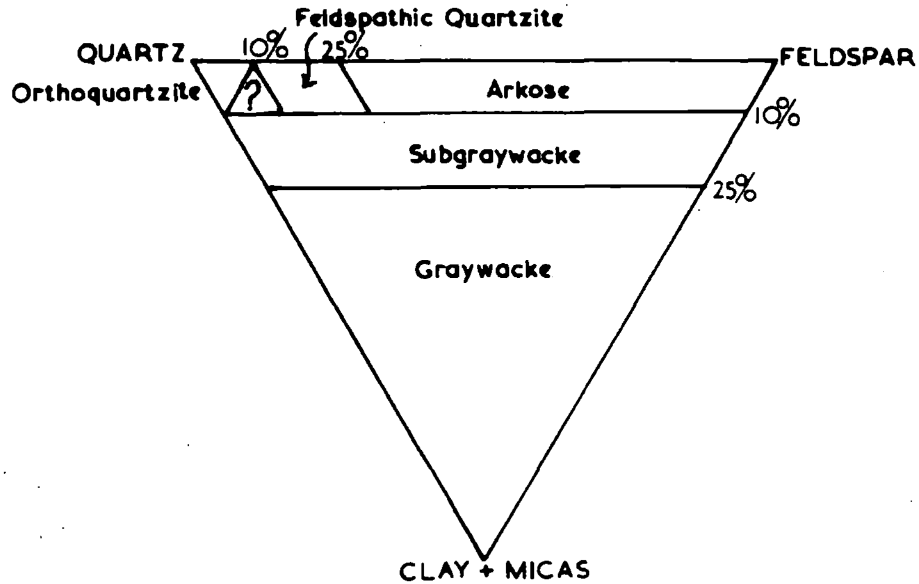
II.1. CLASSIFICATION OF THE SANDSTONES—PETTIJOHN 1948.



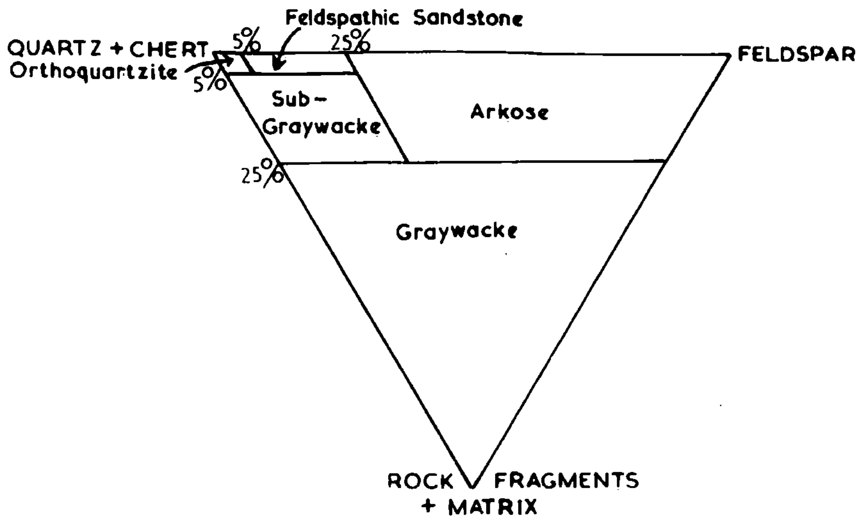
II.2. CLASSIFICATION OF THE SANDSTONES—KRYNINE 1948.



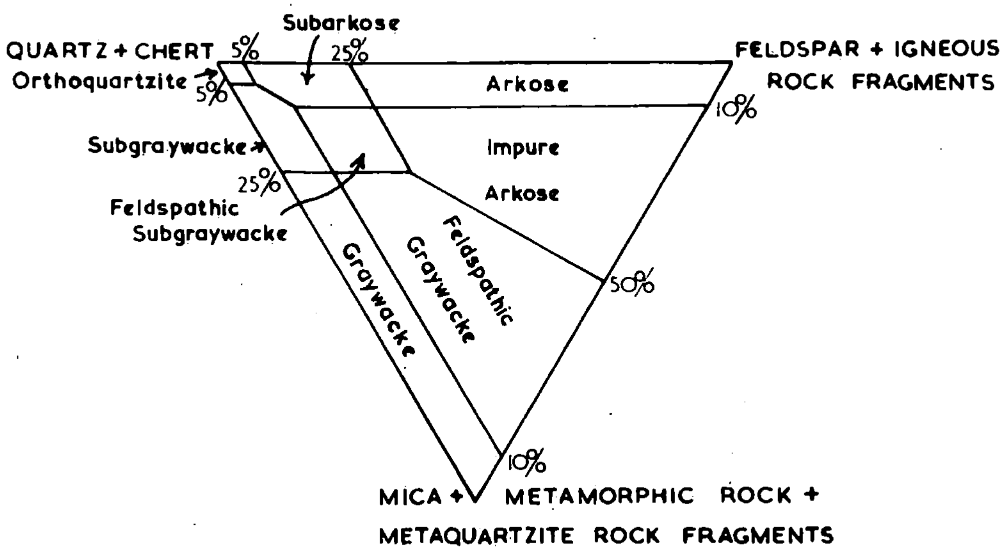
II.3. CLASSIFICATION OF THE SANDSTONES—AFTER TALLMAN 1949.



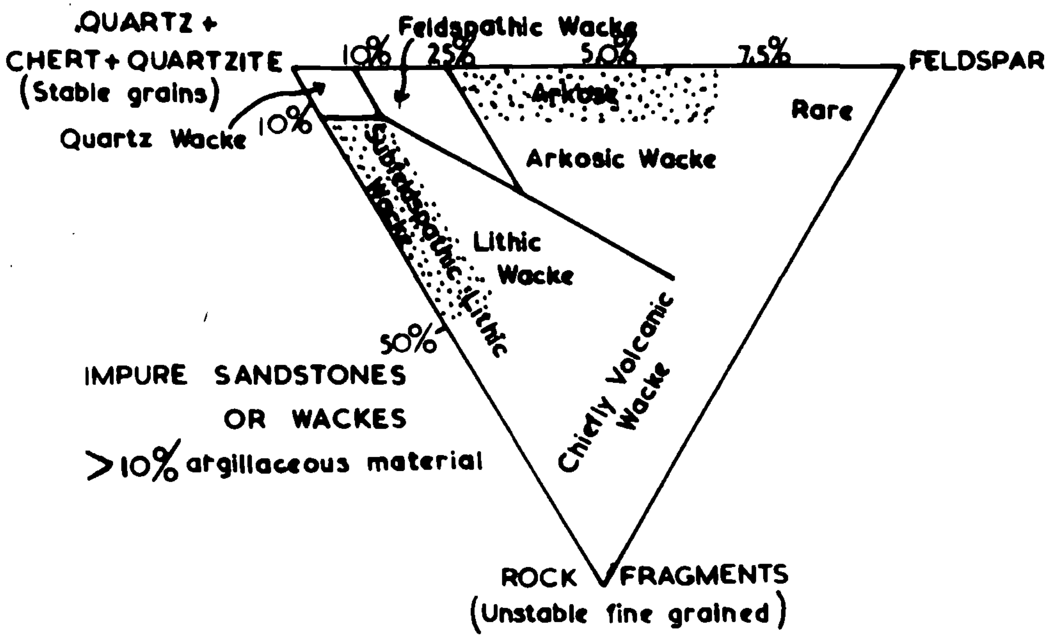
II.4. CLASSIFICATION OF THE SANDSTONES—DAPPLES et al. 1953.

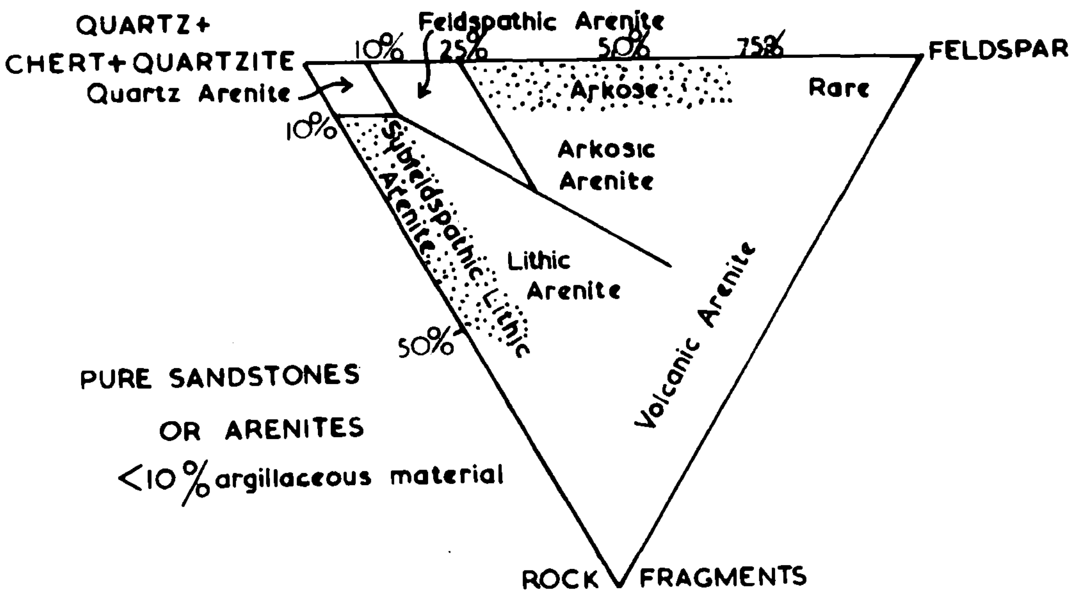


II. 5. CLASSIFICATION OF THE SANDSTONES—FOLK 1954.

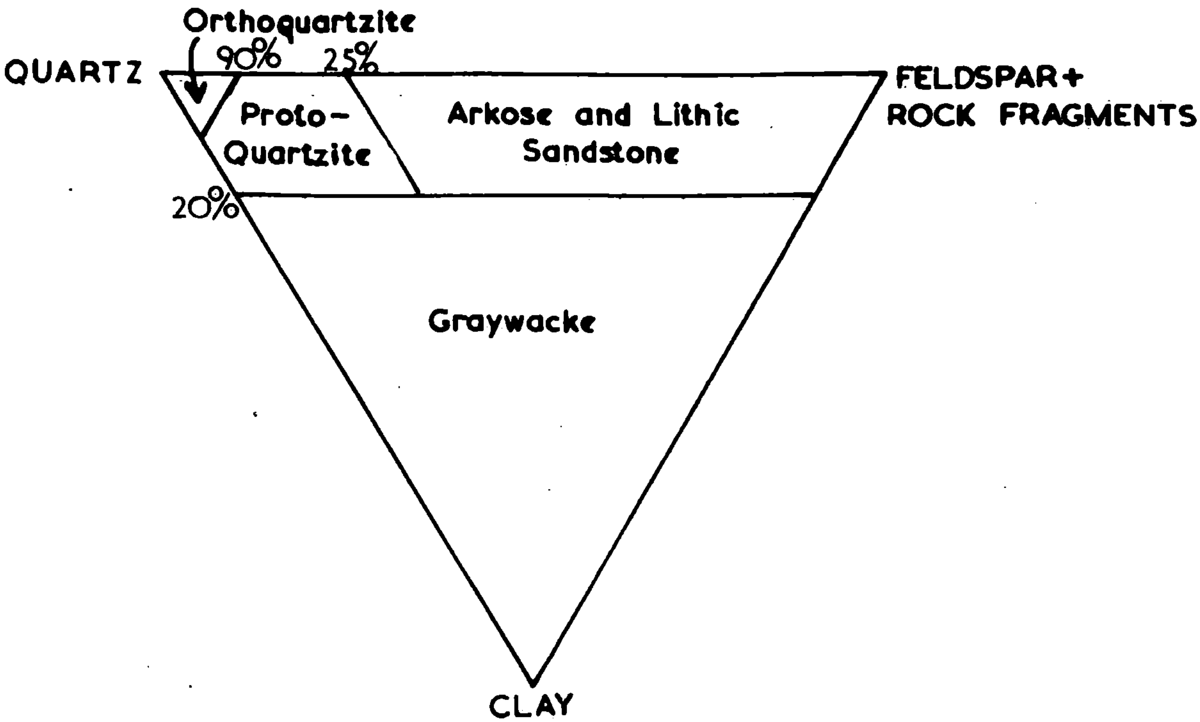


II.6,7. CLASSIFICATION OF THE SANDSTONES—WILLIAMS et al. 1954.



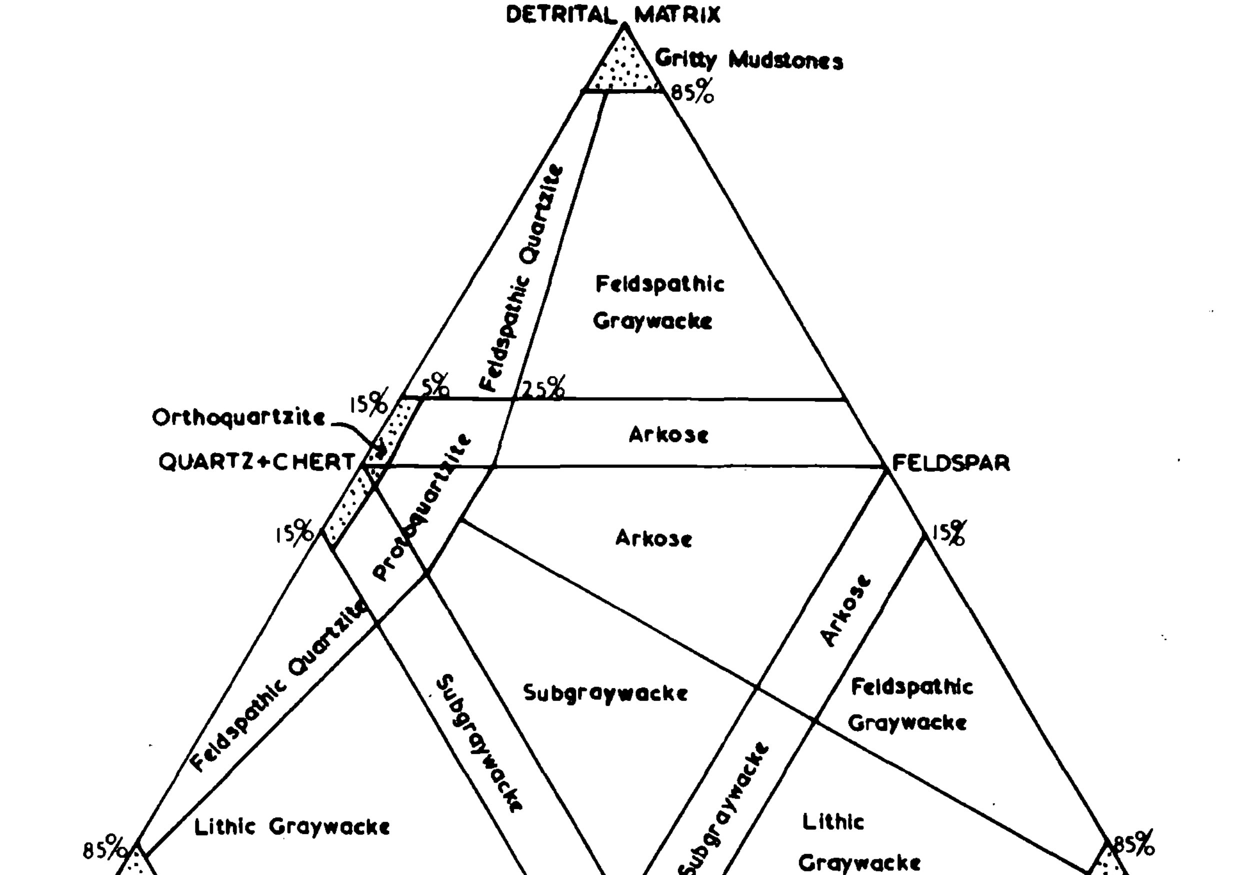


II.8. CLASSIFICATION OF THE SANDSTONES—BOKMAN 1955.

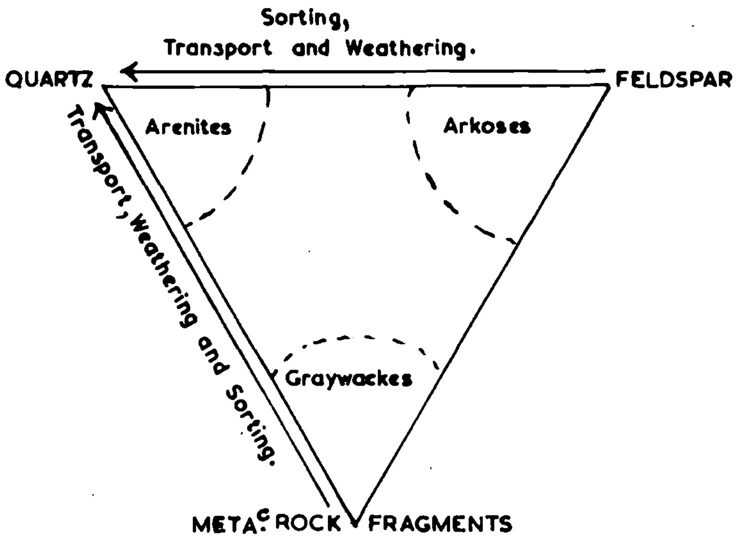


II.9. CLASSIFICATION OF THE SANDSTONES — AFTER PETTIJOHN, 1957.

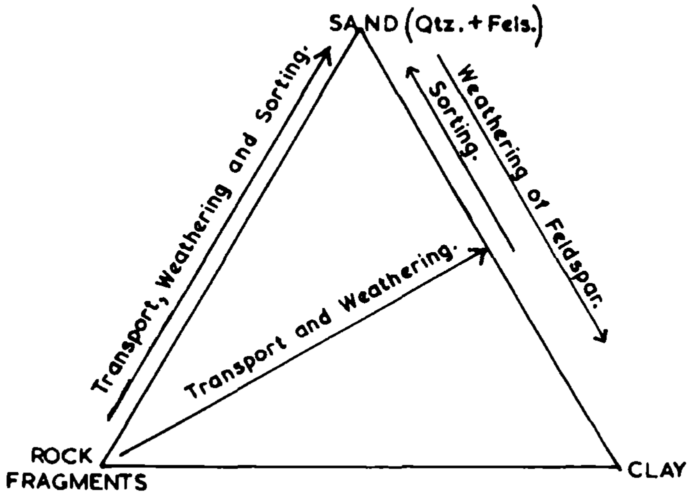
"EXPLODED" VIEW OF THE TETRAHEDRON.



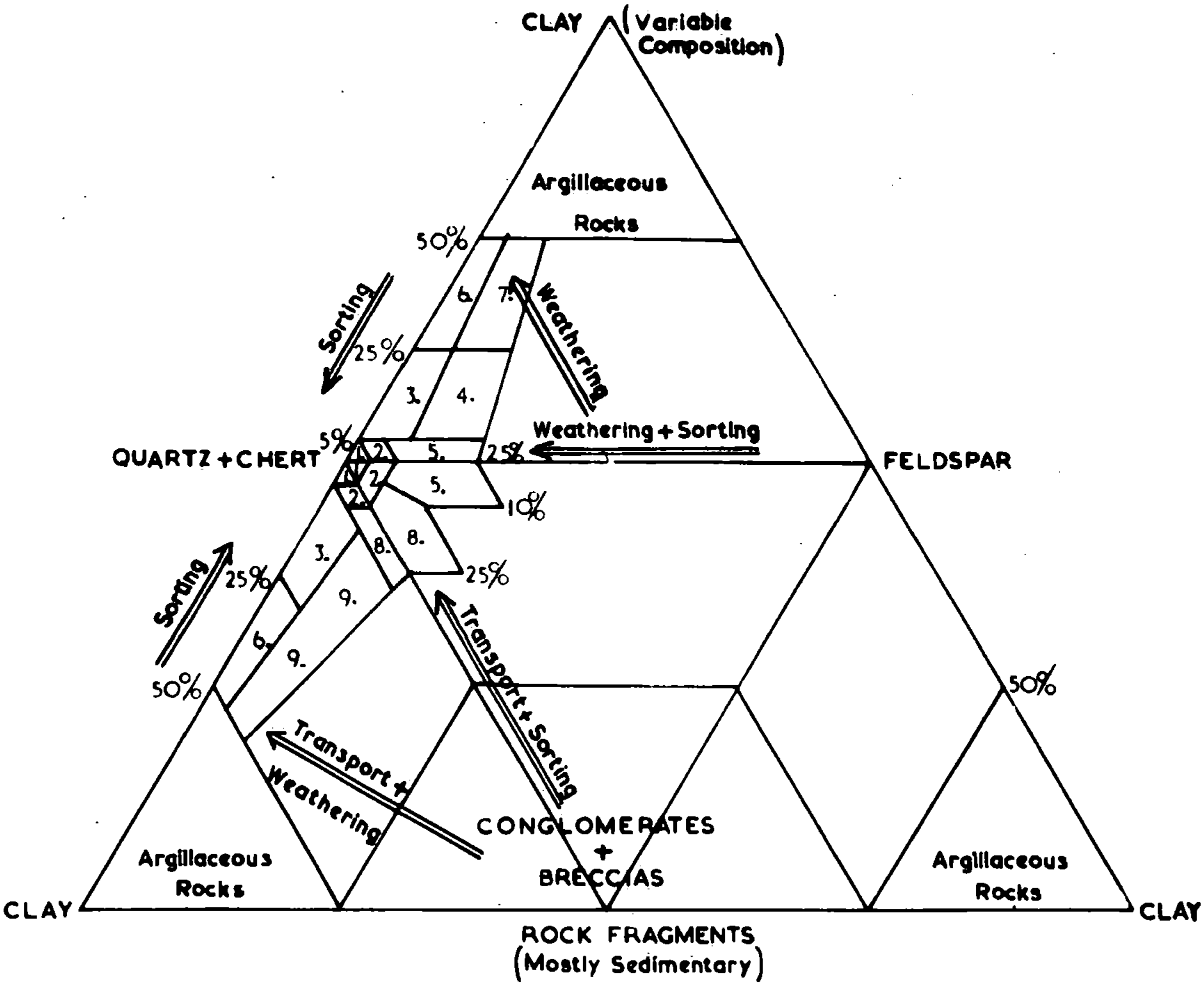
II. 10. ENVIRONMENTS OF SANDSTONES AND TRENDS.



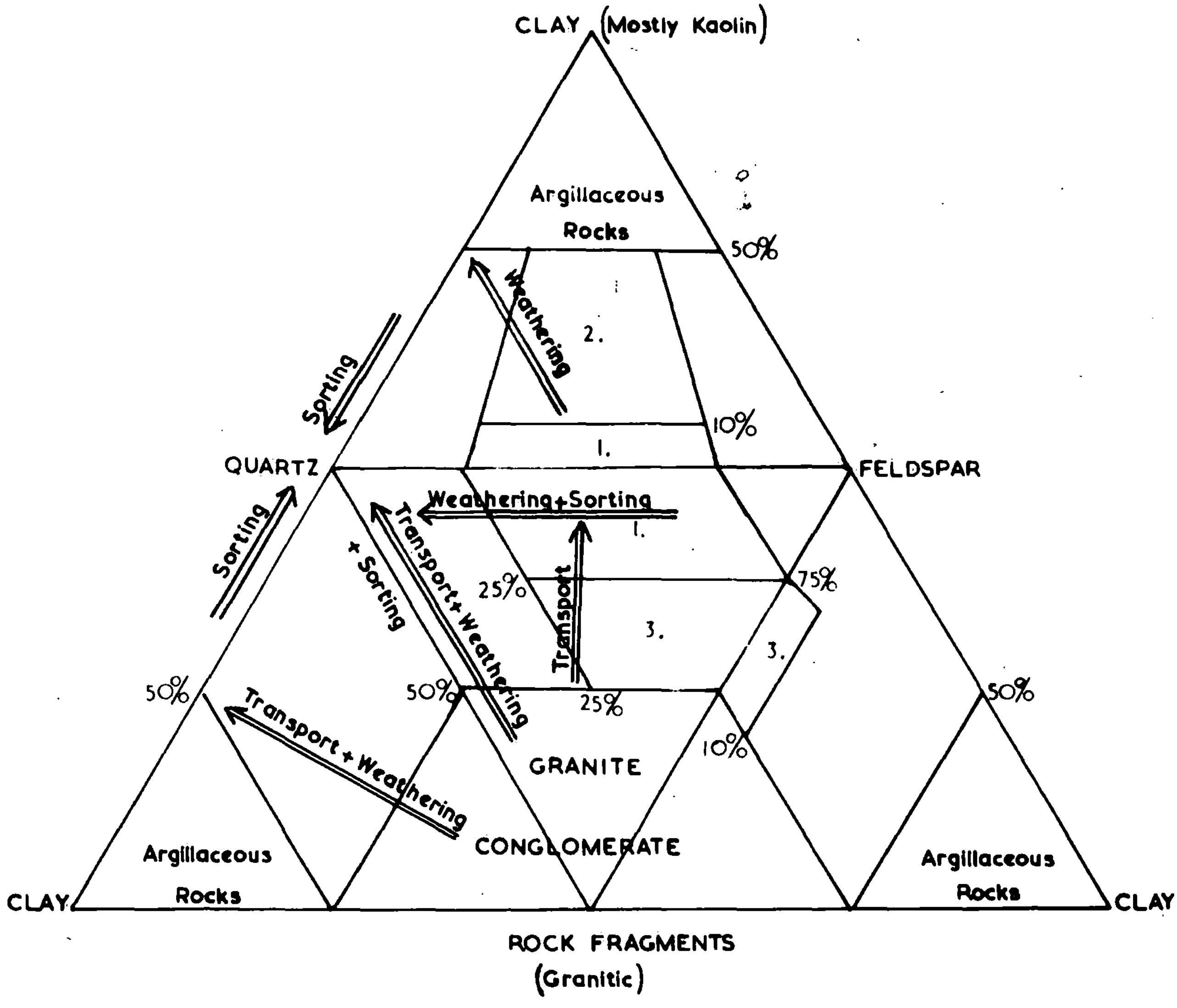
II. 11. TRENDS IN THE CONSTITUENTS OF THE SANDSTONES.



II. 12. THE NON-TECTONIC OR ORTHOQUARTZITE SERIES—"EXPLODED" VIEW OF THE TETRAHEDRON.



II.13. THE LATE TECTONIC OR ARKOSE SERIES — "EXPLODED" VIEW OF THE TETRAHEDRON.



II.14. THE EARLY TECTONIC OR GRAYWACKE SERIES — "EXPLODED" VIEW OF THE TETRAHEDRON.

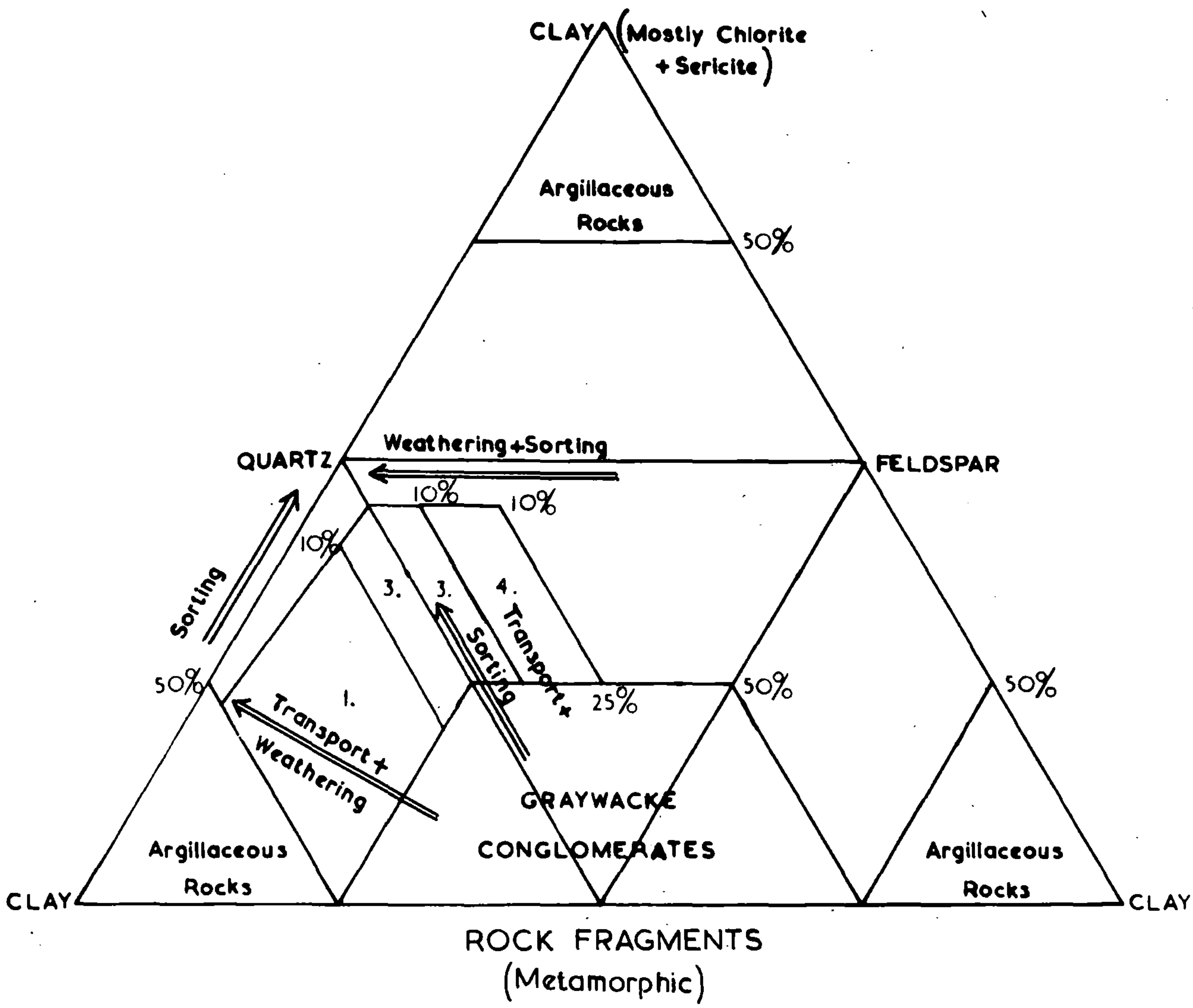


TABLE 6.1. THE CLASSIFICATION OF THE LIMESTONES ON FIELD CHARACTERS

Type	Colour	Crinoids	Coarseness	Quartz	Shaliness	Remarks
1.	Pale grey to brown.	Abundant fragments.	Coarse	Not Apparent.	Non-shaly	
2.	Pale grey.	"	"	Apparent.	" "	Sometimes grade into sandstones.
3.	Dark grey	Present	Fine	Not Apparent	" "	
4.	" "	Abundant	Coarse	"	" "	Rare.
5.	" "	Present	Fine	"	Shaly	Grade into calcareous shales.
6.	Medium grey.	Absent or present.	Coarse	Apparent	Shaly to non-shaly.	

<table>
<tr><td colspan="5" rowspan="4"></td><td colspan="6">Limestones, Partly Dolomitized Limestones, and Primary Dolomites (see Notes 1 to 6)</td><td colspan="3">Replacement Dolomites[7] (V)</td></tr>
<tr><td colspan="2">>10% Allochems Allochemical Rocks (I and II)</td><td colspan="3"><10% Allochems Microcrystalline Rocks (III)</td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>Sparry Calcite Cement > Microcrystalline Ooze Matrix</td><td>Microcrystalline Ooze Matrix > Sparry Calcite Cement</td><td colspan="2" rowspan="2">1–10% Allochems</td><td rowspan="2"><1% Allochems</td><td rowspan="2">Undisturbed Bioherm Rocks (IV)</td><td colspan="2" rowspan="2">Allochem Ghosts</td><td rowspan="2">No Allochem Ghosts</td></tr>
<tr><td>Sparry Allochemical Rocks (I)</td><td>Microcrystalline Alochemical Rocks (II)</td></tr>
<tr><td rowspan="5">Volumetric Allochem Composition</td><td colspan="4">>25% Intraclasts (i)</td><td>Intrasparrudite (Ii:Lr)
Intrasparite (Ii:La)</td><td>Intramicrudite* (IIi:Lr)
Intramicrite* (IIi:La)</td><td rowspan="5">Most Abundant Allochem</td><td>Intraclasts: Intraclast-bearing Micrite* (IIIi:Lr or La)</td><td rowspan="5">Micrite (IIIm:L); if disturbed, Dismicrite (IIImX:L); if primary dolomite, Dolomicrite (IIIm:D)</td><td rowspan="5">Biolithite (IV:L)</td><td rowspan="5">Evident Allochem</td><td>Finely Crystalline Intraclastic Dolomite (Vi:D3) etc.</td><td>Medium Crystalline Dolomite (V:D4)</td></tr>
<tr><td rowspan="4"><25% Intraclasts</td><td colspan="3">>25% Oölites (o)</td><td>Oösparrudite (Io:Lr)
Oösparite (Io:La)</td><td>Oömicrudite* (IIo:Lr)
Oömicrite* (IIo:La)</td><td>Oölites: Oölite-bearing Micrite* (IIIo:Lr or La)</td><td>Coarsely Crystalline Oölitic Dolomite (Vo:D5) etc.</td><td>Finely Crystalline Dolomite (V:D3)</td></tr>
<tr><td rowspan="3"><25% Oölites</td><td rowspan="3">Volume Ratio of Fossils to Pellets</td><td>>3:1 (b)</td><td>Biosparrudite (Ib:Lr)
Biosparite (Ib:La)</td><td>Biomicrudite (IIb:Lr)
Biomicrite (IIb:La)</td><td>Fossils: Fossiliferous Micrite (IIIb: Lr, La, or Ll)</td><td>Aphanocrystalline Biogenic Dolomite (Vb:Dl) etc.</td><td></td></tr>
<tr><td>3:1–1:3 (bp)</td><td>Biopelsparite (Ibp:La)</td><td>Biopelmicrite (IIbp:La)</td><td>Pellets: Pelletiferous Micrite (IIIp:La)</td><td>Very Finely Crystalline Pellet Dolomite (Vp:D2) etc.</td><td>etc.</td></tr>
<tr><td><1:3 (p)</td><td>Pelsparite (Ip:La)</td><td>Pelmicrite (IIp:La)</td><td></td><td></td><td></td></tr>
</table>

Table 6.2. Laboratory classification of the limestones, (from Folk, 1959).

Boundary	Transported Constituents	Authigenic Constituents	Boundary
	Very coarse calcirudite	Extremely coarsely crystalline	
64 mm	Coarse calcirudite		
16 mm	Medium calcirudite		
4 mm	Fine calcirudite	Very coarsely crystalline	4 mm
1 mm	Coarse calcarenite	Coarsely crystalline	1 mm
0.5 mm	Medium calcarenite		
0.25 mm	Fine calcarenite	Medium crystalline	0.25 mm
0.125 mm	Very fine calcarenite		
0.062 mm	Coarse calcilutite	Finely crystalline	0.062 mm
0.031 mm	Medium calcilutite		
0.016 mm	Fine calcilutite	Very finely crystalline	0.016 mm
0.008 mm	Very fine calcilutite		
0.004 mm		Aphanocrystalline	0.004 mm

Table 6.3. Grain Size Scale for Carbonate Rocks, (from Folk, 1959).

TABLE 6.4. LABORATORY DATA FOR THE TYPE 1 LIMESTONE

No.	Horizon	Grid Ref.	Sparry Calcite %	Sparry Calcite Size in mm.	Ooze %	Ooze Size in	Quartz %	Pyrite %	Dolomite %	Fossils and Comments
T. 4	Scar Limestone	907285	100	0.005-1.5	0	-	0	0	0	Crinoid Ossicles.
T. 32	3 Yd Limestone	909289	100	<Silt.	0	-	0	0	0	Crinoid Ossicles, Forams.
T. 33	3 Yd Limestone	909289	100	0.05-0.25	0	-	0	?	0	Crinoid Ossicles.
T. 85	Single Post Lst.	909274	100	0.2-1.0	0	-	0	<1	0	Marmorised.
T.153	Single Post Lst.	884298	100	0.2-1.0	0	-	0	<1	0	Marmorised.
T.159	Scar Limestone	856314	100	0.006-0.15	0	-	0	0	0	Chalcedony in some brachiopod fragments. Crinoid Ossicles.
T.188	Single Post Lst.	801321	95-100	<0.75	0-5	1-2	0	0	Variable	Crinoid Ossicles and Forams.
T.222	Single Post Lst.	812346	90-100	<0.75	0-10	<5	0	0	0	Corals, Forams and bryozoa.
T.243	Scar Limestone	868265	100	<0.3	0	-	0	0	<50	Recrystallised.
T.271	Scar Limestone	884275	90-100	<0.1	0-10	3.5-5	0	0	c.5	Crinoid Ossicles, Corals, Forams, and brachiopod debris.
T.280	Single Post Lst.	905263	100	1.0+	0	-	0	Variable	0	Highly metamorphosed.
T.334	Scar Limestone	755280	100	<0.5	0	-	0	0	0	Corals, brachiopods, algae and Forams. Chalcedony in some corals.
T.342	3 Yd Limestone	765281	100	<0.1	0	-	0	0	3-5	Crinoid Ossicles, brachiopods, forams and bryozoa.
T.356	?Four Fathom Lst.	961249	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Dibunophyllum band.
T.373	Four Fathom Lst.	948272	100	0.05-0.75	0	-	0	0	60-75	Coral band. 3-5% chalcedony.
T.383	Cockle Shell Lst.	939245	100	<0.5	0	-	0	0	0	Coral bands.

TABLE 6.5. LABORATORY DATA FOR THE TYPE 2 LIMESTONES

No.	Horizon	Grid Ref.	Sparry Calcite %	Sparry Calcite Size in mm.	Ooze %	Ooze Size in	Quartz %	Pyrite %	Dolomite %	Fossils and Comments
T. 6a	Base Scar Lst.	907285	100	<0.025	0	-	25-30	<1	0	Crinoid ossicles.
T. 6b	" " "	"	100	<0.375	0	-	50	<1	0	" "
T.73	Cockle Shell ?Lst	"	100	?	0	-	30-40	<1	0	Recrystallised
T.77a	Cockle Shell Lst.	911276	100	Variable	0	-	95	0	0	Very arenaceous specimen.- calcareous sandstone.
T.77b	" " "	"	100	"	0	-	60-70	0	0	Crinoidal calcareous sandstone specimen.
T.139	" " "	891290	100	<0.007	0	-	c.30	<1	Little	Some mica. Badly altered.
T.158	Base Scar Lst.	856314	100	Variable	0	-	c.50	<1	0	Crinoid ossicles and brachiopods.
T.210	Calc. Lens in Sst	829334	Variable	Variable	Variable	V.Fine	5	c.1	Chalybite	Chalybite calcite lens in sandstone below Single Post Limestone.
T.381	Cockle Shell Lst	928245	100	0.15-0.2	0	-	c.5	<1	0	Recrystallised, no Fossils.
T.382	" " "	939245	100	0.15-0.2	0	-	2-3	<1	0	Recrystallised, no Fossils.

TABLE 6.6. LABORATORY DATA FOR THE TYPE 3 LIMESTONES

No.	Horizon	Grid Ref.	Sparry Calcite %	Sparry Calcite Size in mm.	Ooze %	Ooze Size in	Quartz %	Pyrite %	Dolomite %	Fossils and Comments
T. 28	5 Yd Limestone	907287	100	<0.006	0	-	0	<1	0	V. fossiliferous. Forams numerous.
T. 46	5 Yd Limestone	908292	100	<0.004	0	-	0	<2	0	V. fossiliferous. Forams numerous.
T. 51	Scar Limestone	908292	100	0.004-0.1	0	-	0	<1	0	10% crinoid fragments. Forams numerous.
T. 57	5 Yd Limestone	910295	100	<0.008	0	-	0	<1	0	High percentage forams.
T.106	Tyne Bottom Lst.	865290	Variable	<0.25	Variable	2-4	0	<1	0	Crinoid ossicles, brachiopods and forams.
T.237	?	827257	100	c.0.015	0	-	0	0	0	Forams abundant.
T.262	Lst.above 3 Yd Lst	915286	Variable	0.010-0.015	Variable	1-4	0	<1	0	Forams abundant.
T.274	?Four Fathom? Lst	882261	100	Variable	0	-	0	0	1	Forams and bryozoa abundant.
T.287	Iron Post Lst	896255	Variable	?	Variable	<3	0	<1	0	V.fossiliferous, forams abundant.
T.355	5 Yd Limestone	927270	100	<0.008	0	-	0	<1	0	Corals and forams.
T.361	Lst. below Cockle Shell Lst.	953238	0	-	100	<4	0	c.2	0	Algae common.
T.377	Iron Post Lst.	860322	Variable	Variable	Variable	Variable	<1	<1	0	Forams very abundant.

TABLE 6.7. LABORATORY DATA FOR THE TYPE 4 LIMESTONE

No.	Horizon	Grid Ref.	Sparry Calcite %	Sparry Calcite Size in mm	Ooze %	Ooze Size in	Quartz %	Pyrite %	Dolomite %	Fossils and Comments
T.229	Cockle Shell Lst.	801348	Variable	Variable	Variable	<0.004	c.7	0	0	Highly fossiliferous.

TABLE 6.8. LABORATORY DATA FOR THE TYPE 5 LIMESTONES

No.	Horizon	Grid Ref.	Sparry Calcite %	Sparry Calcite Size in mm	Ooze %	Ooze Size in	Quartz %	Pyrite %	Dolomite %	Fossils and Comments
T. 14	Top Scar Limestone	907285	?	?	?	?	0	Variable High	0	Calcite recrystallised - high percentage clay. Algae common.
T. 31	Shaly band in 5 Yd Limestone.	907287	0	-	100	N.D.	0	1-2	0	Bryozoa, forams and brachs.
T.121x	Calcite mudstone below Low Brig H.	892293	100	N.D.	0	-	0	0	0	Occasional bryozoa and shell frags. Very argillaceous.
T.131	Lst. below High Brig Hazle.	886303	0	-	100	N.D.	0	1-2	0	Forams, crinoid ossicles, shell fragments.
T.162	Shaly band in 5 Yd Limestone.	858314	0	0	100	N.D.	0	2	0	60-75% Fossil frags, bryozoa and forams with shell frags.
T.164	Nodule above ?Four Fathom? Limestone.	859326	0	0	100	N.D.	0	<1	0	Crinoid ossicles and shell fragments.
T.253	Shaly band above 5 Yd Limestone.	815281	N.D.	N.D.	N.D.	N.D.	Little	0	0	Crinoid ossicles and shell fragments.
T.273	Fossil band in 5 Yd Limestone.	876268	100	Fine	0	-	0	<1	0	Numerous shells and corals.
T.284	Shaly Lst. above Cockle Shell Lst.	904262	100	<0.75	0	-	0	c.1	0	Forams, crinoid ossicles and shell fragments.

N.B. Due to clay content masking grain relationships, determinations of grain sizes difficult.

TABLE 6.9. LABORATORY DATA FOR THE TYPE 6 LIMESTONES

No.	Horizon	Grid Ref.	Sparry Calcite %	Sparry Calcite Size in mm.	Ooze %	Ooze Size in	Quartz %	Pyrite %	Dolomite %	Fossils and Comments
T. 95	Lst. above Cockle Shell Limestone.	892289	100	Variable	0	-	40-50	1-2	0	No fossils. Mica <1%.
T.138	" " "	891289	100	Variable	0	-	25	10-30	0	
T.144	" " "	889292	100	<0.3	0	-	Variable	<50	0	Recrystallised. <1% mica.
T.263	Lst.above 3 Yd Lst	915286	100	<0.1	0	-	c.30	<1	0	c.5% mica. Few crinoid ossicles
T.264	" " "	"	100	<0.1	0	-	c.30	<1	0	1-2% Mica.Brachiopod frags.
T.315	" " "	947260	100	Variable	0	-	c.30	<1	?	1% Mica. Bryozoa.
T.372	Lst. below 3 Yd Limestone.	948271	100	Variable	0	-	c.3	c.3	0	50% Fossils in rock. Very little mica.

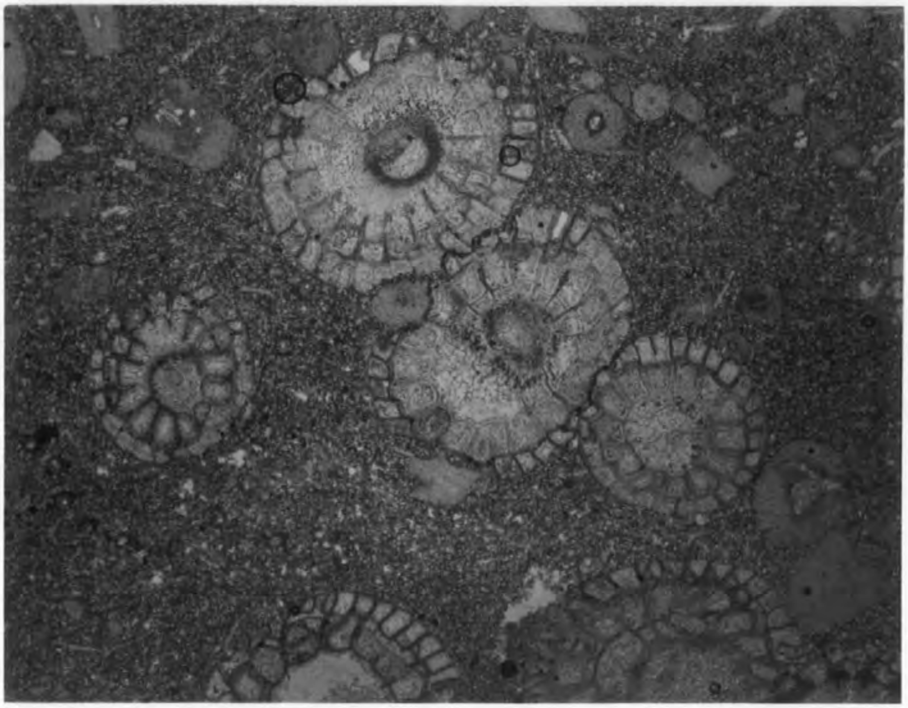


Fig. 6.1a. Type 1 limestone, T.373, showing rolled clisiophyllid corals with crinoid ossicles in a calcite-dolomite matrix.

Ordinary transmitted light X 10

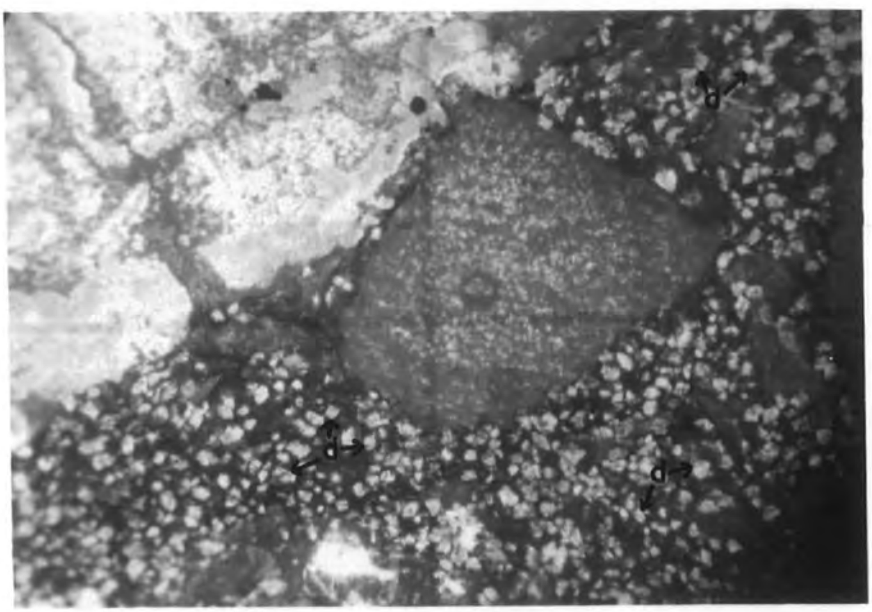


Fig. 6.1b. Limestone, T.373, (Fig.6.1a), stained to show small dolomite rhombs (d) in matrix of calcite.

Ordinary transmitted light X 40

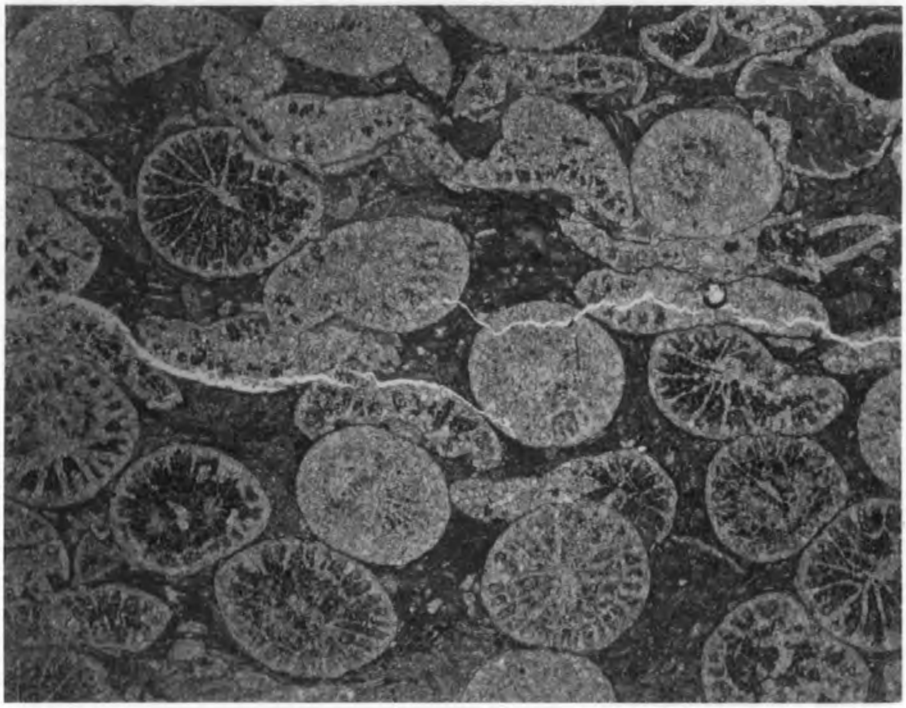


Fig. 6.2. Type 1 limestone, T.383, showing coral, Lithostrotion junceum, in unrecrystallised matrix.

Ordinary transmitted light X 10

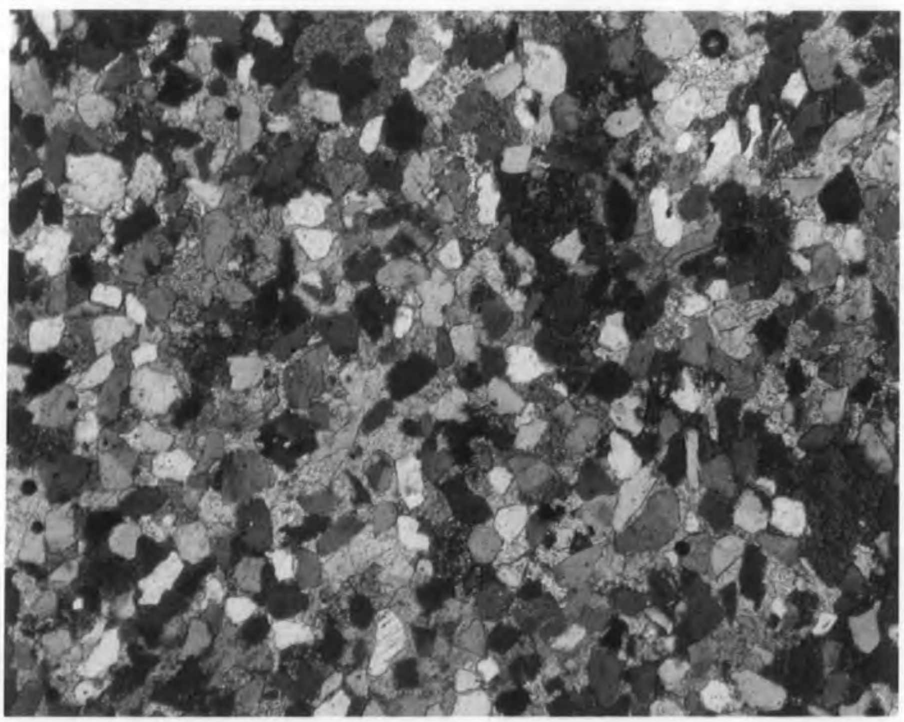


Fig. 6.3. Type 2 limestone, T.77b, showing quartz grains in calcite matrix.

Polarised transmitted light X 40

TABLE 6.10. X-RAY DATA ON THE CARBONATE IN THE TYPE 2 LIMESTONE, T.210

dÅ	Intensity, estimated visually
7.05	Weak.
3.56 x	Weak.
3.33	Weak.
3.01 +	Medium.
2.784 x	Strong.
2.479 +	Very, very weak.
2.335 x	Very weak.
2.265 +	Very, very weak.
2.210 x	Weak.
2.079 +	Very, very weak.
1.956 x	Very weak.
1.902	Very, very weak.
1.860 +	Very, very weak.
1.790 x	Very, very weak.
1.726 x	Medium-strong.
1.547	Very, very weak.
1.506 x	Very, very weak.
1.424 + x	Very, very weak.
?	
1.352 + x	Very weak.
1.196 x	Very, very weak.
1.078 x	Very, very weak.

Camera: 9 cm Unicam., Radiation: CuKα.
Exposure: 3 hours.

N.B. Extraneous lines due to clay minerals.

+ = Calcite.   x = Chalybite lines.

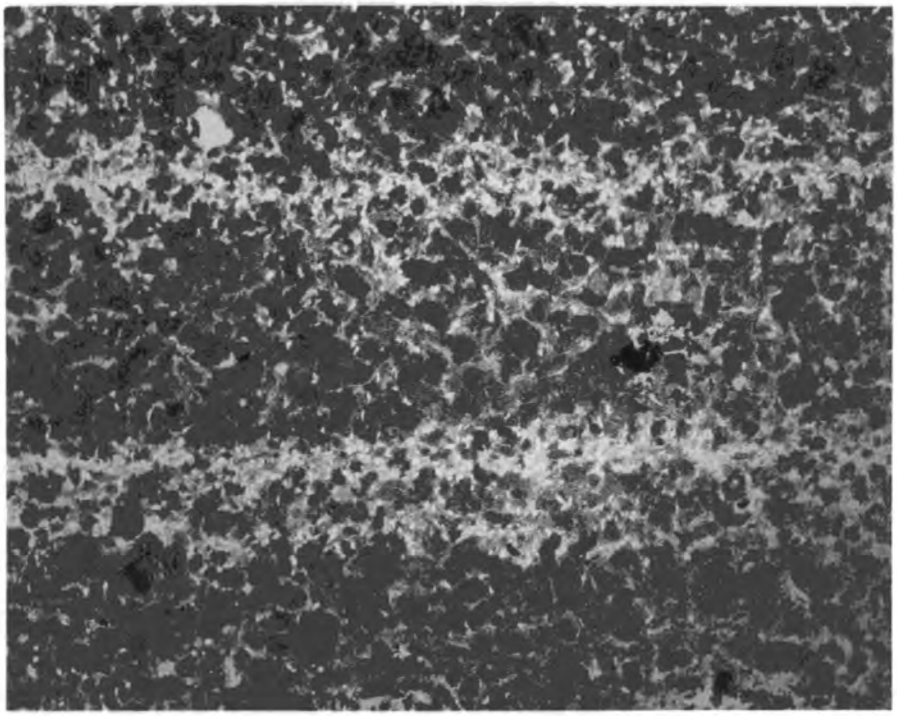


Fig. 6.4. Type 2 limestone, T. 210, showing quartz grains (colourless) in matrix of chalybite (dark grey) and fine calcite (light grey).

Ordinary transmitted light X 10

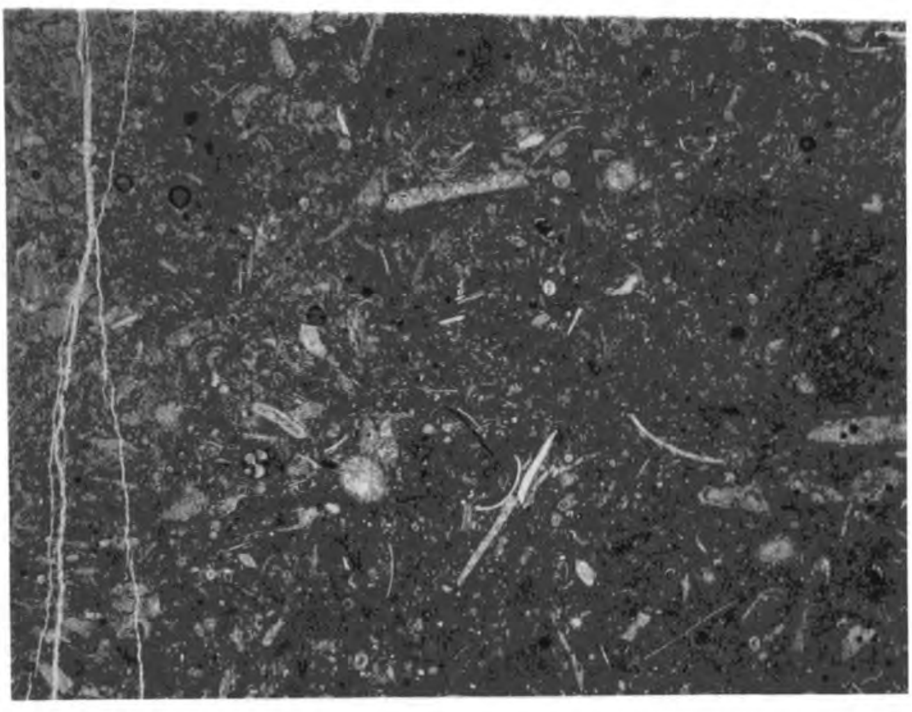


Fig. 6.5. Type 3 limestone, T.57, showing fine-grained nature with abundant micro-fossils and fossil fragments.

Ordinary transmitted light X 10

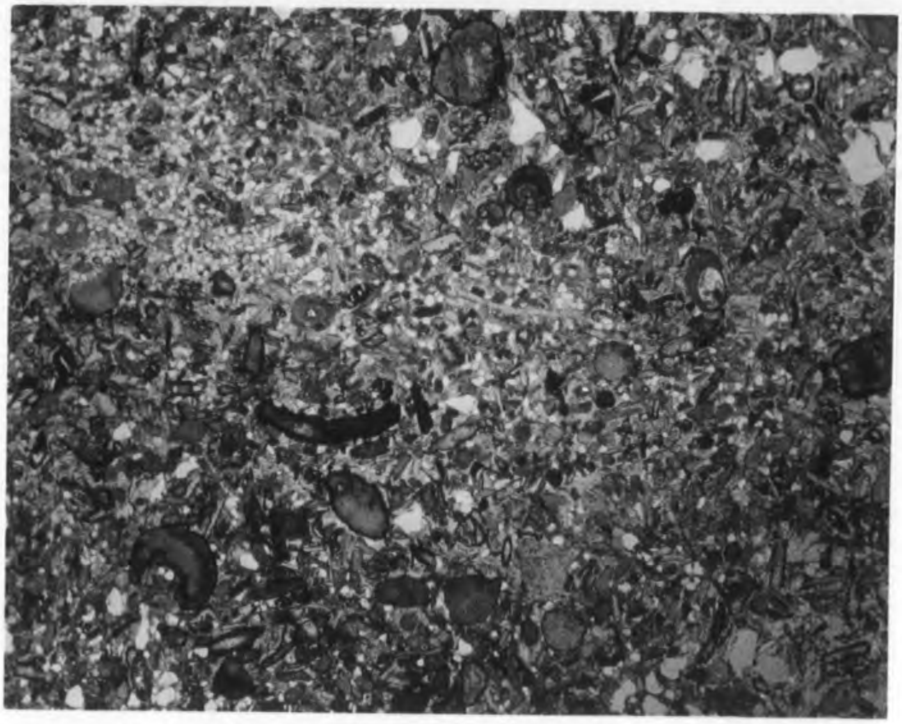


Fig. 6.6. Type 4 limestone, T.229, showing abundant fauna and silt size quartz grains (colourless).
Ordinary transmitted light X 10

Fig. 6.7. Type 5 limestone, T.121x, showing argillaceous matrix (grey) with recrystallised calcite layers (white).
Ordinary transmitted light X 10

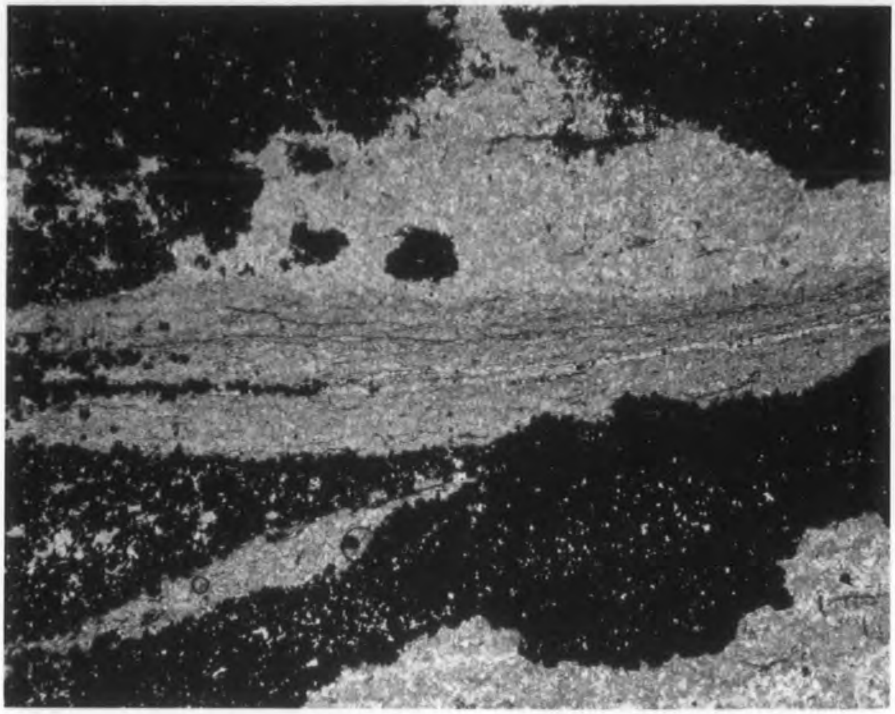


Fig. 6.8. Type 6 limestone, T.144, showing pyrite (black) in shaly and silty (quartz) calcite matrix.

Ordinary transmitted light X 10

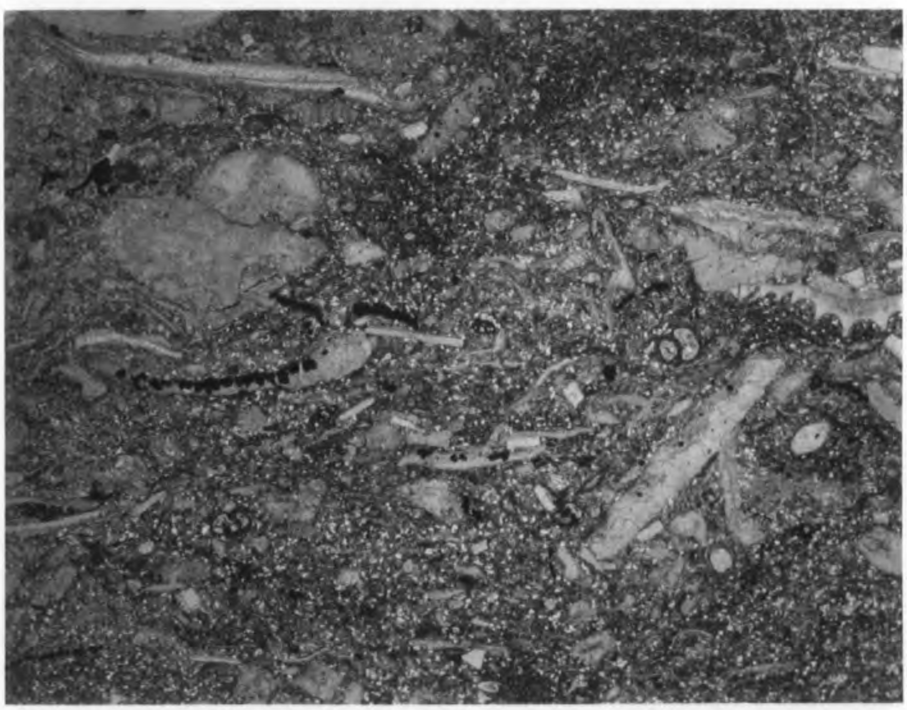


Fig. 6.9. Type 6 limestone, T.372, showing quartz grains (white) in shelly argillaceous calcite matrix. Note euhedral pyrite (black) replacing shell fragments.

Ordinary transmitted light X 10

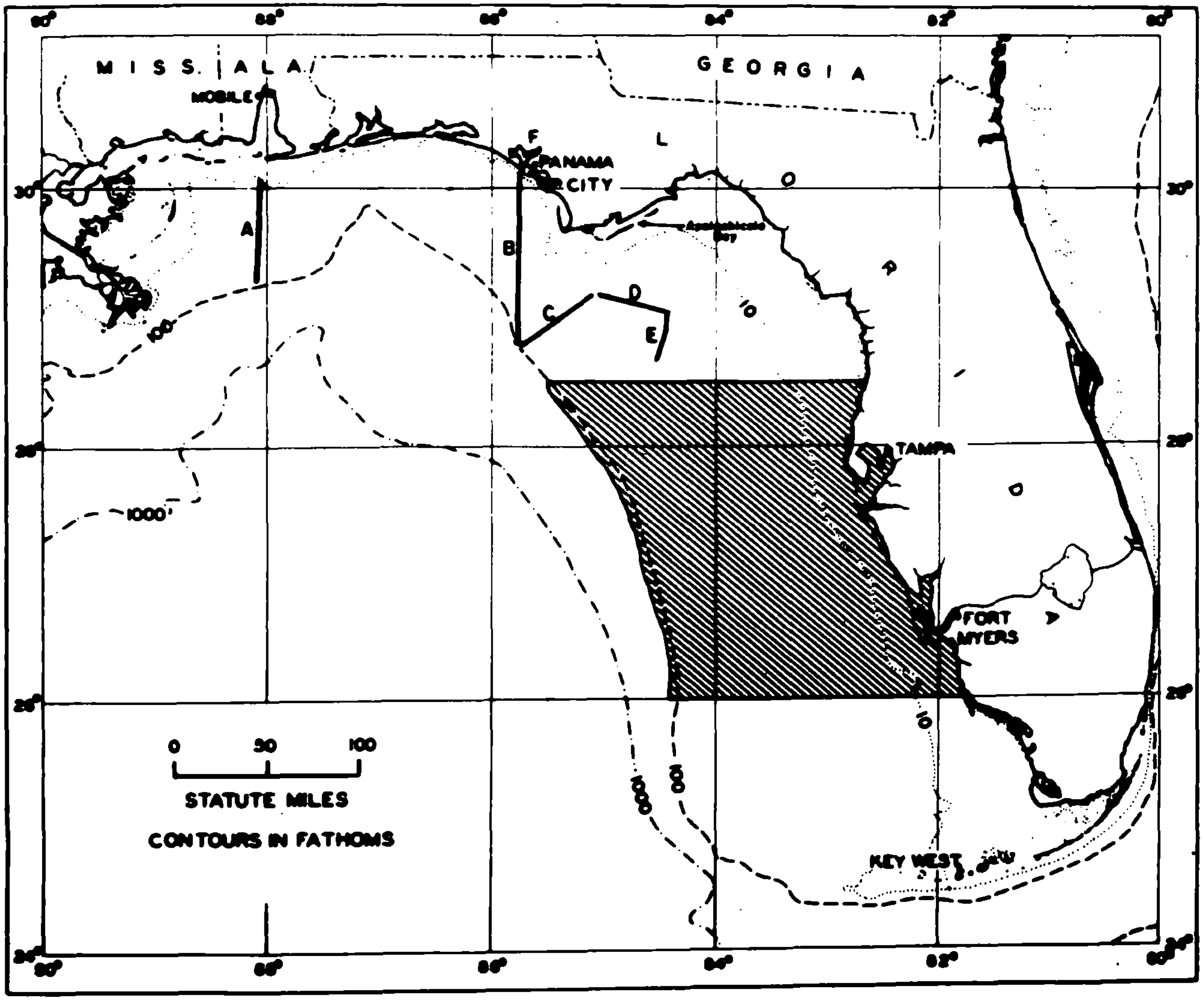


Fig. 8.1 Location map showing areas of sampling. Sampling traverses off northern Florida and Alabama are shown by heavy solid lines. Samples off west coast of central Florida were obtained from all parts of the area (cross-hatched) between shore and the 100-fathom contour.

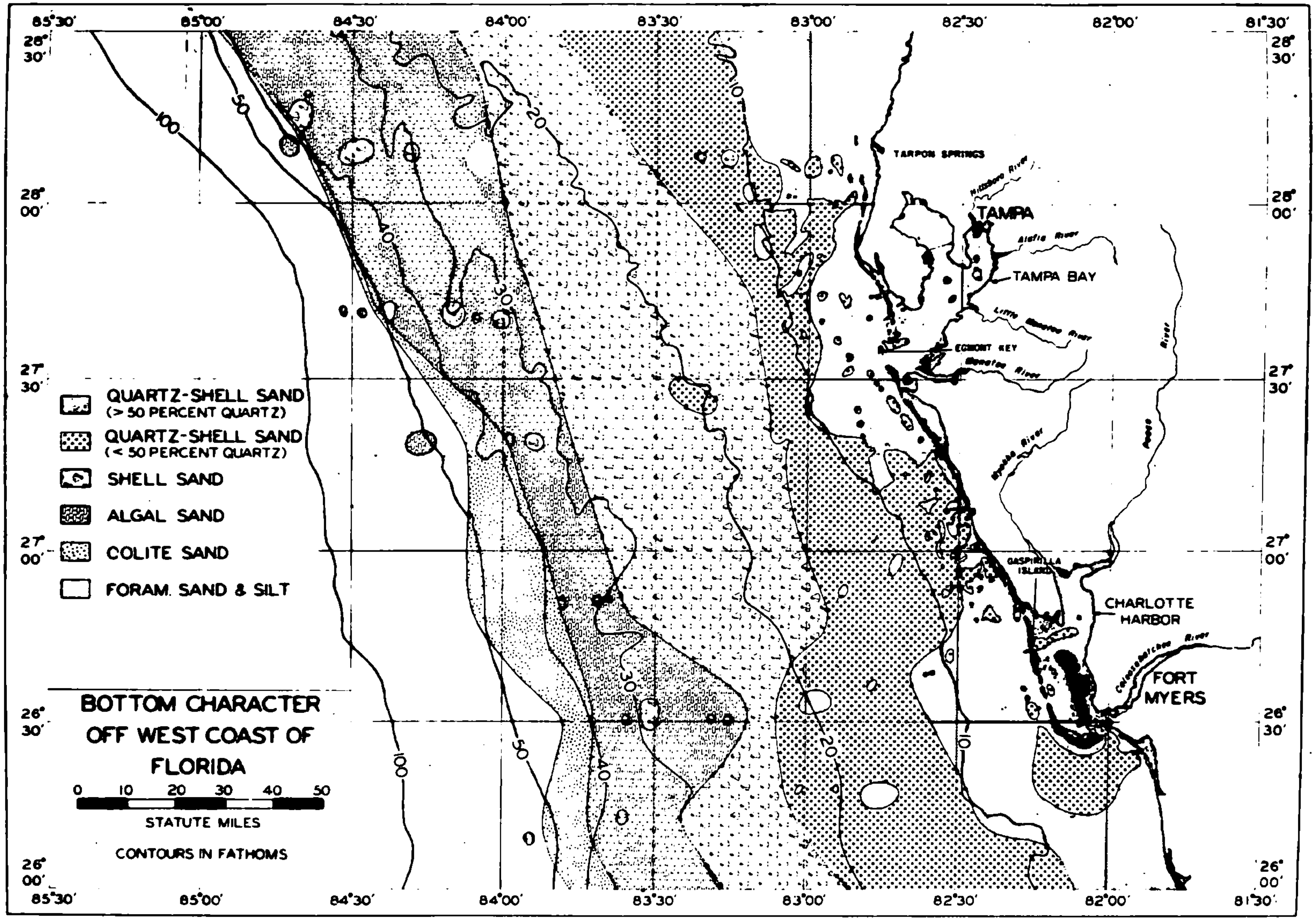

BOTTOM CHARACTER OFF WEST COAST OF FLORIDA
QUARTZ-SHELL SAND (> 50 PERCENT QUARTZ)
QUARTZ-SHELL SAND (< 50 PERCENT QUARTZ)
SHELL SAND
ALGAL SAND
OOLITE SAND
FORAM. SAND & SILT
0 10 20 30 40 50
STATUTE MILES
CONTOURS IN FATHOMS
TAMPA
TAMPA BAY
TARPON SPRINGS
EGMONT KEY
GASPARILLA ISLAND
CHARLOTTE HARBOR
FORT MYERS
85°30'
85°00'
84°30'
84°00'
83°30'
83°00'
82°30'
82°00'
81°30'
28° 30'
28° 00'
27° 30'
27° 00'
26° 30'
26° 00'
100
50
40
30
20
10

Fig. 8.2

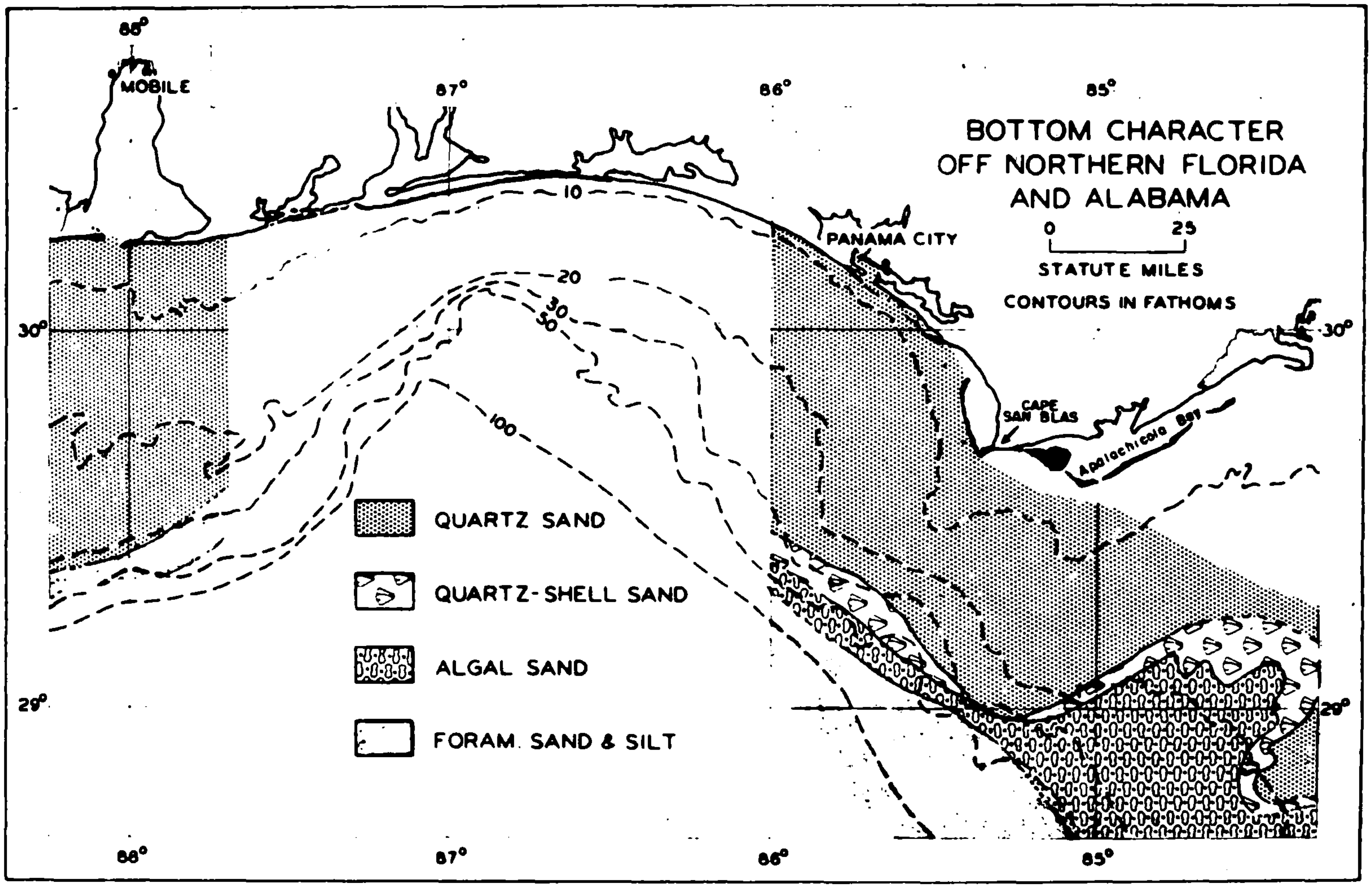

BOTTOM CHARACTER
OFF NORTHERN FLORIDA
AND ALABAMA
0
25
STATUTE MILES
CONTOURS IN FATHOMS
MOBILE
PANAMA CITY
CAPE SAN BLAS
Apalachicola Bay
88°
87°
86°
85°
30°
29°
10
20
30
50
100
QUARTZ SAND
QUARTZ-SHELL SAND
ALGAL SAND
FORAM. SAND & SILT

Fig. 8.3

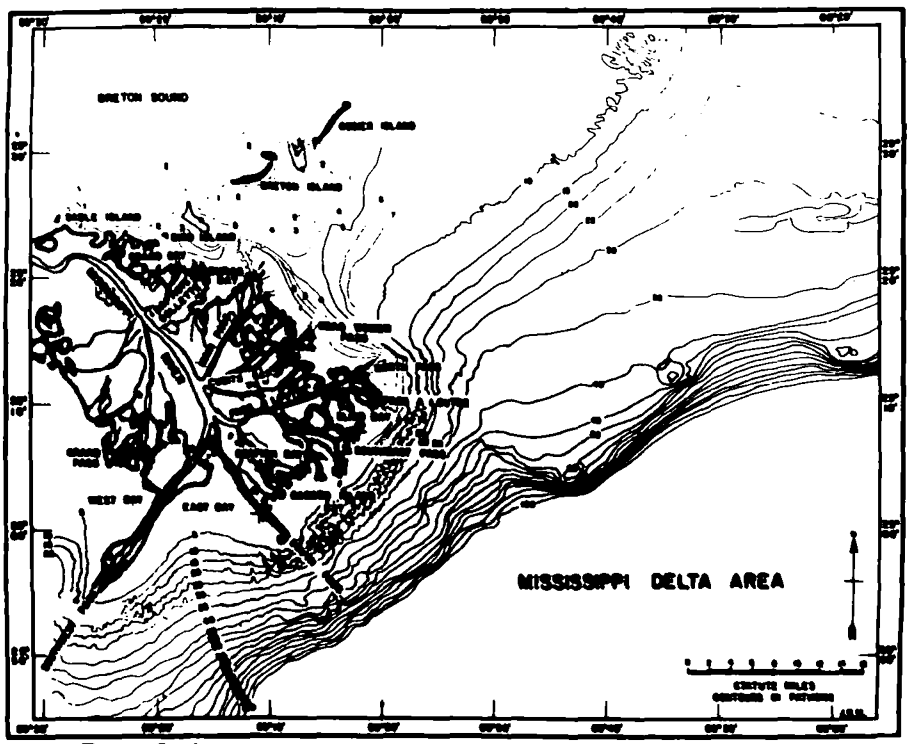


Fig. 8.4—Topography of sea floor marginal to Mississippi Delta. One-fathom contour intervals in part of area, and 5 fathoms elsewhere. All place names are included.

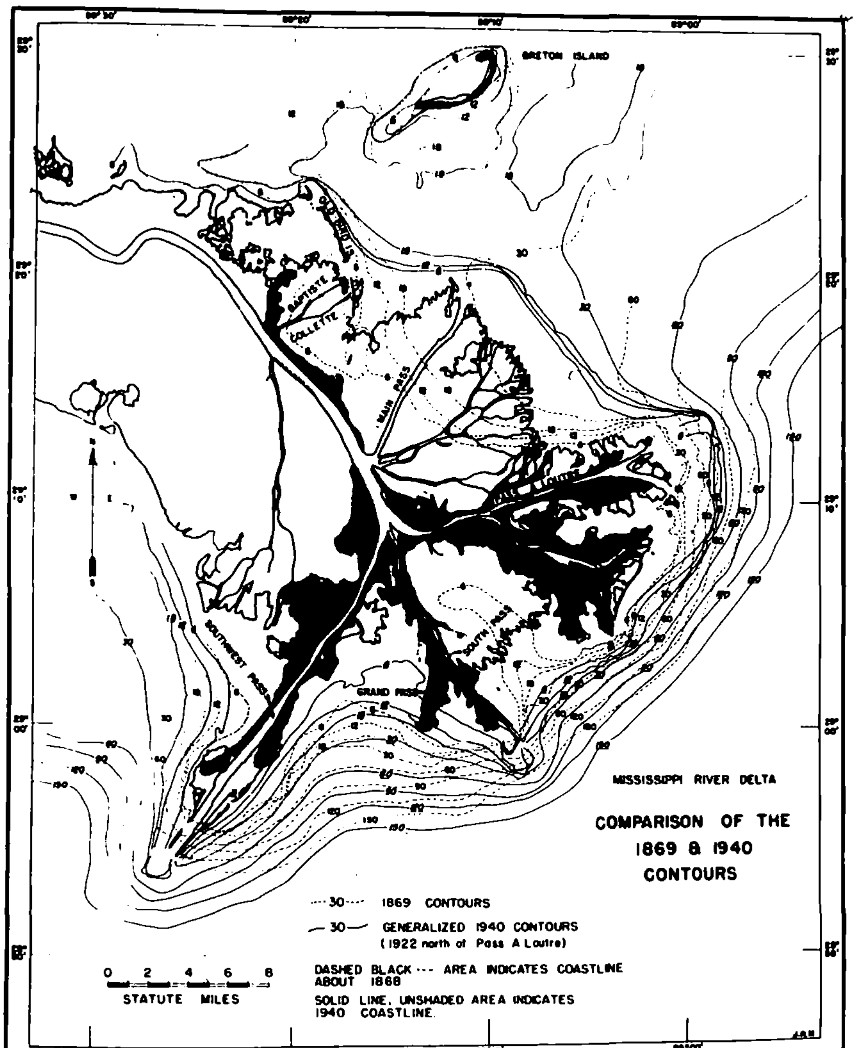


Fig. 8.5 Showing growth of Mississippi Delta since 1869 and depth changes. Because the 1869 soundings are not sufficiently detailed to show gullies, the 1940 contours were generalized on slope whereas true contours are indicated in Fig. 1 and Fig. 3.

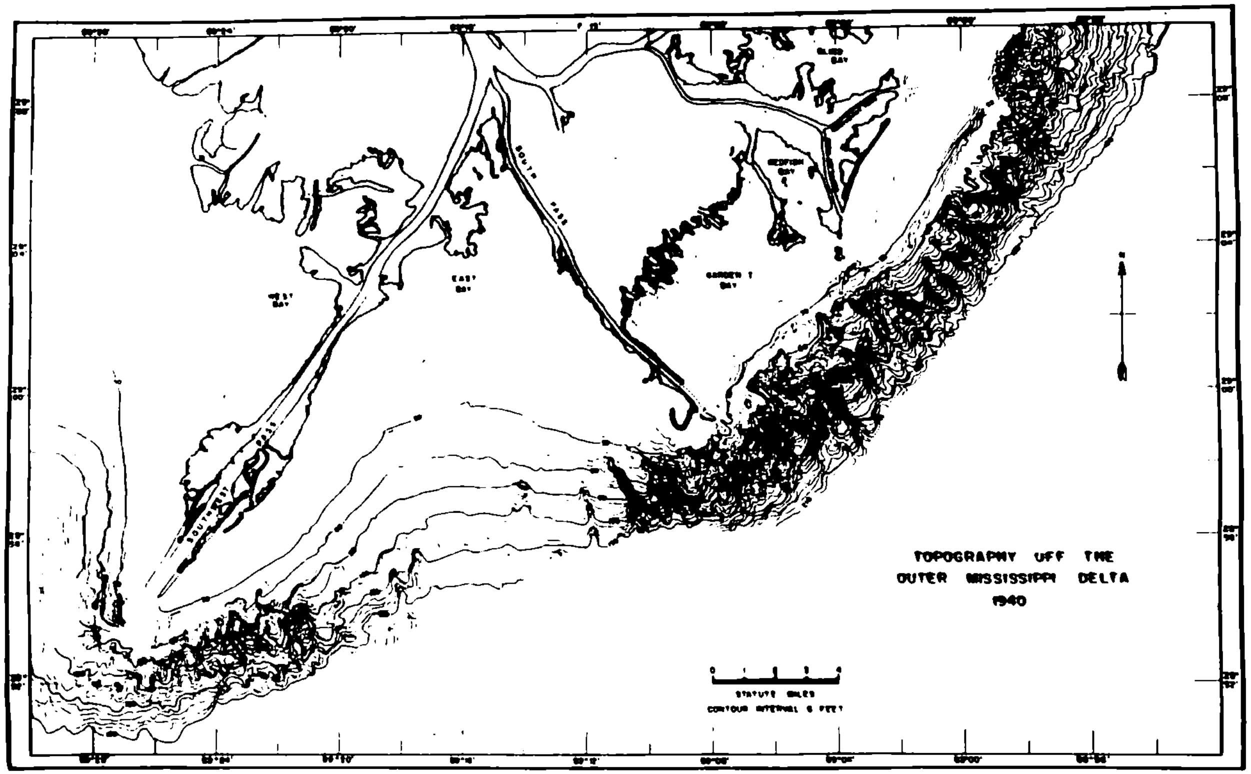


Fig. 8.6 Submarine gullies along foreset slope of advancing Mississippi Delta. Relation of gullies to distributaries is indicated.

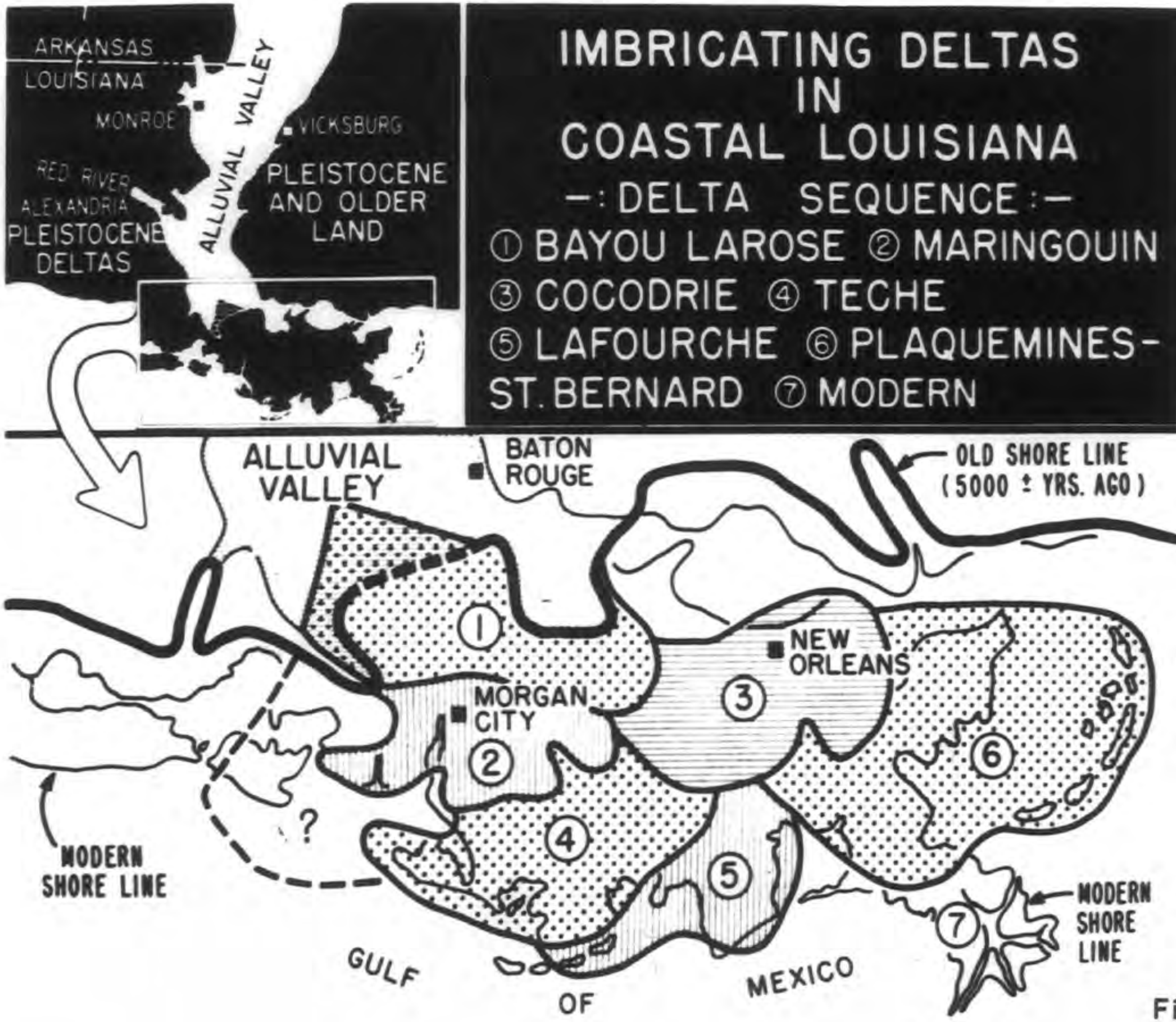

IMBRICATING DELTAS IN COASTAL LOUISIANA
—: DELTA SEQUENCE :—
① BAYOU LAROSE ② MARINGOUIN
③ COCODRIE ④ TECHE
⑤ LAFOURCHE ⑥ PLAQUEMINES-ST. BERNARD ⑦ MODERN
ARKANSAS
LOUISIANA
MONROE
VICKSBURG
ALLUVIAL VALLEY
RED RIVER
ALEXANDRIA
PLEISTOCENE DELTAS
PLEISTOCENE AND OLDER LAND
ALLUVIAL VALLEY
BATON ROUGE
OLD SHORE LINE (5000 ± YRS. AGO)
NEW ORLEANS
MORGAN CITY
MODERN SHORE LINE
MODERN SHORE LINE
GULF OF MEXICO
?

Fig. 8.7

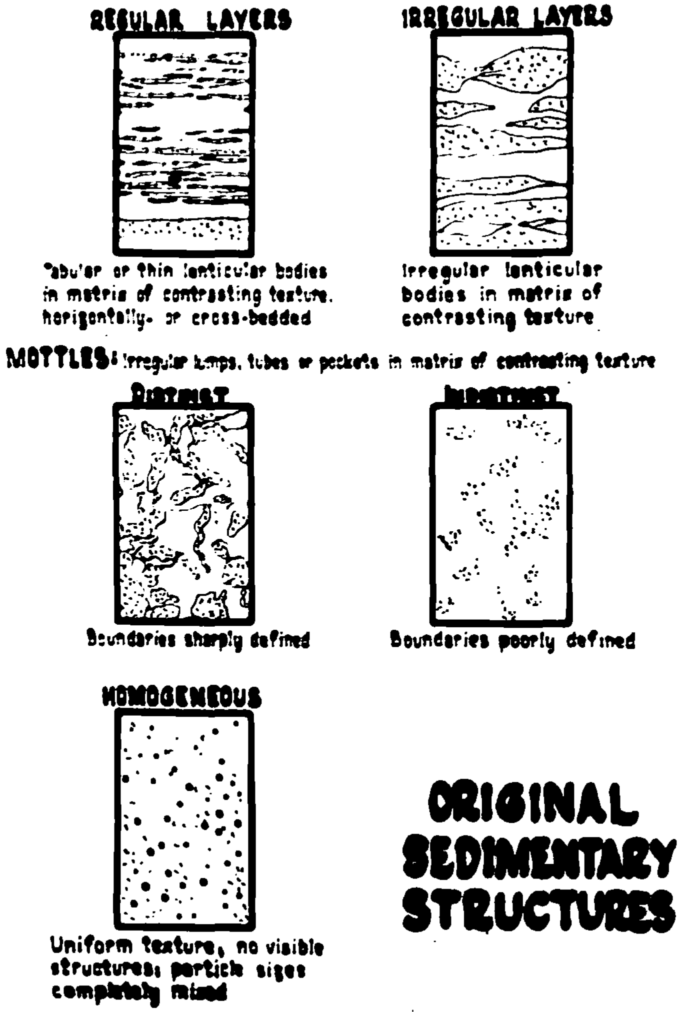


Fig. 8.8 Basic types of minor internal structures.

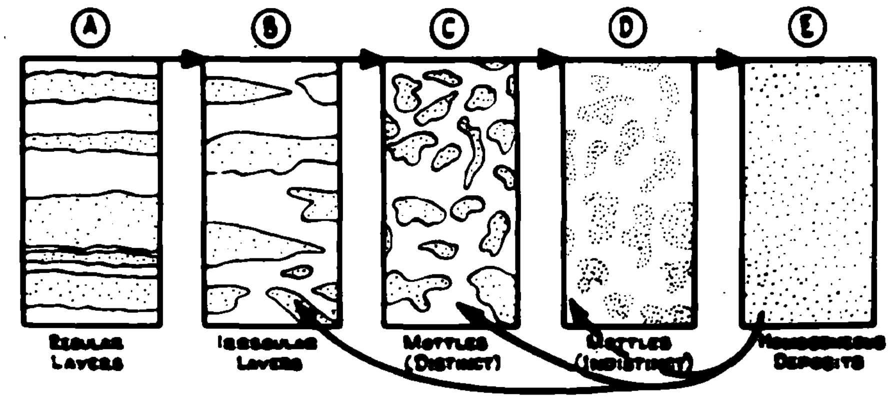


Fig. 8.9—Progressive alteration of sediments by burrowing organisms. Sequences of minor internal structures formed by continuing action of burrowing animals. Top arrows indicate sequence formed by destruction of primary and secondary structures. Bottom arrows show how mottles or irregular layers may be created from homogeneous deposits.

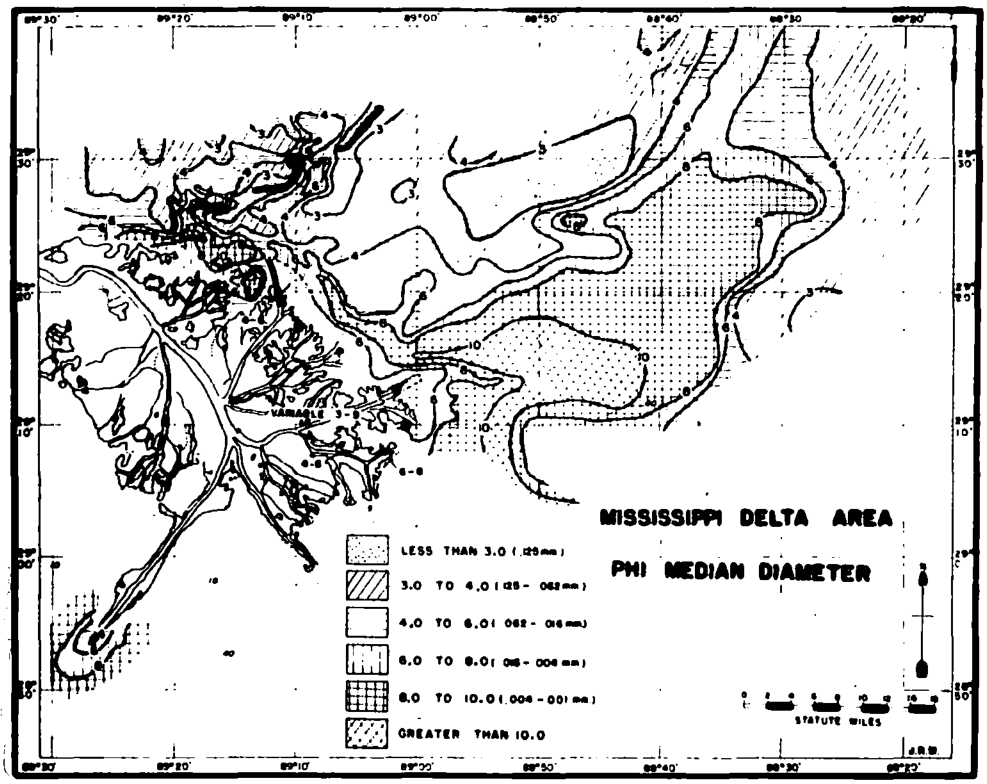


Fig. 8.10–Variation in median diameter of sediments shown by isopleths. Relation of isopleths to distributary mouths is clearly indicated.

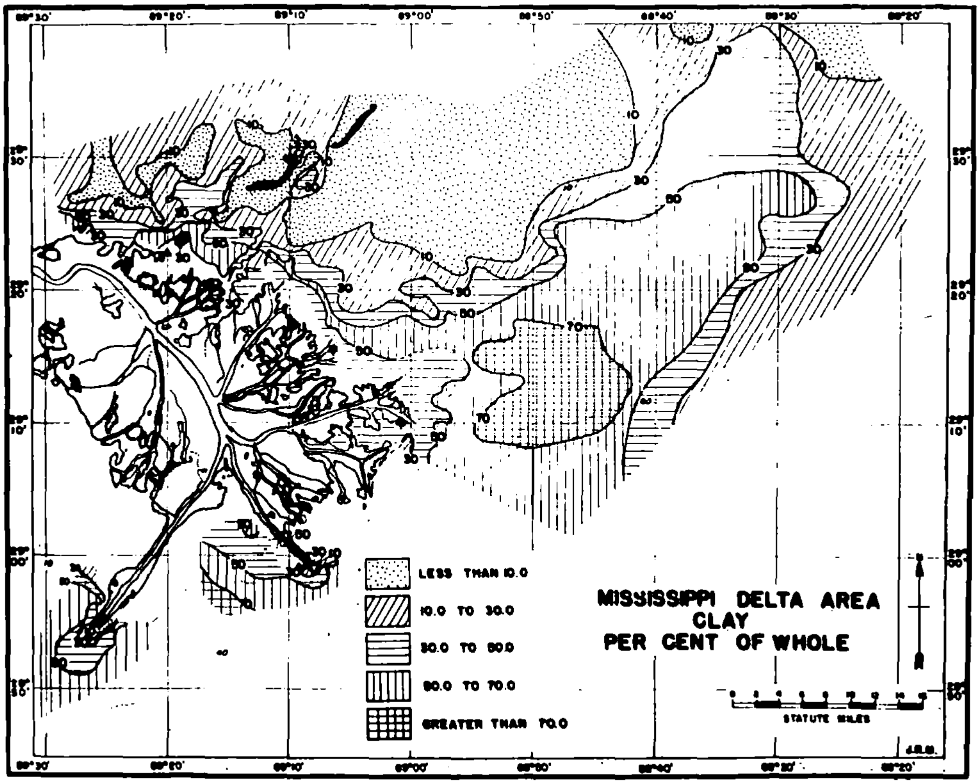


Fig. 8.11 Variation in clay content of sediments marginal to delta.

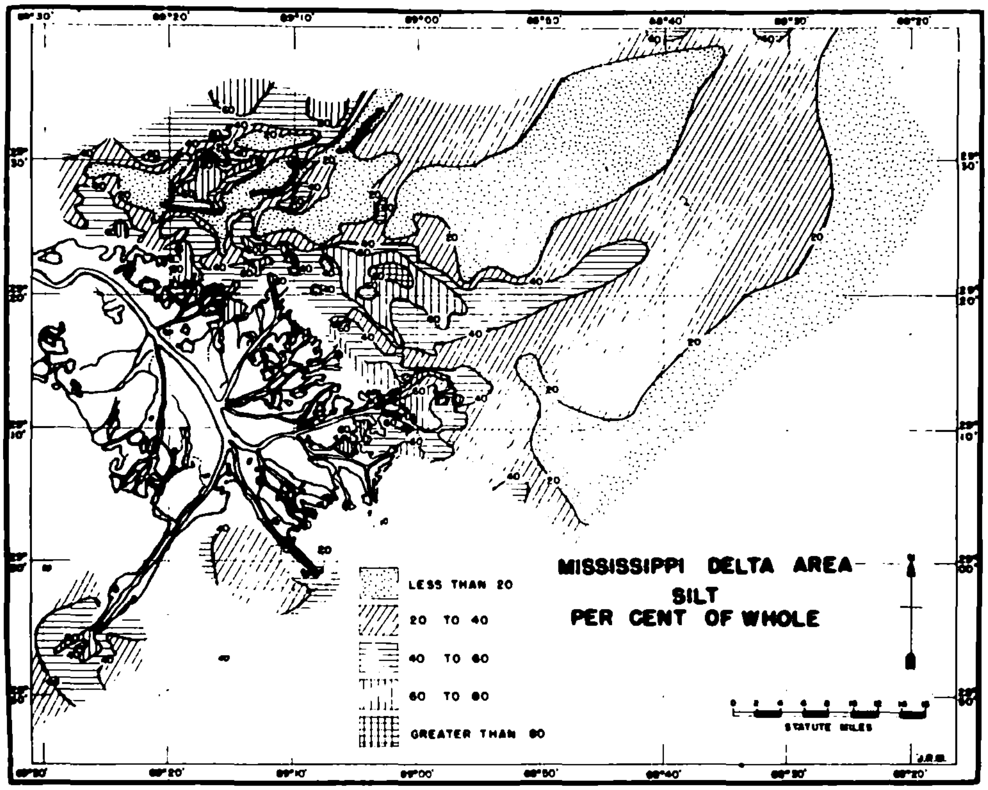


Fig. 8.12 —Variation in silt content of sediments marginal to Delta, varying from high concentration near distributaries to low values off shore.

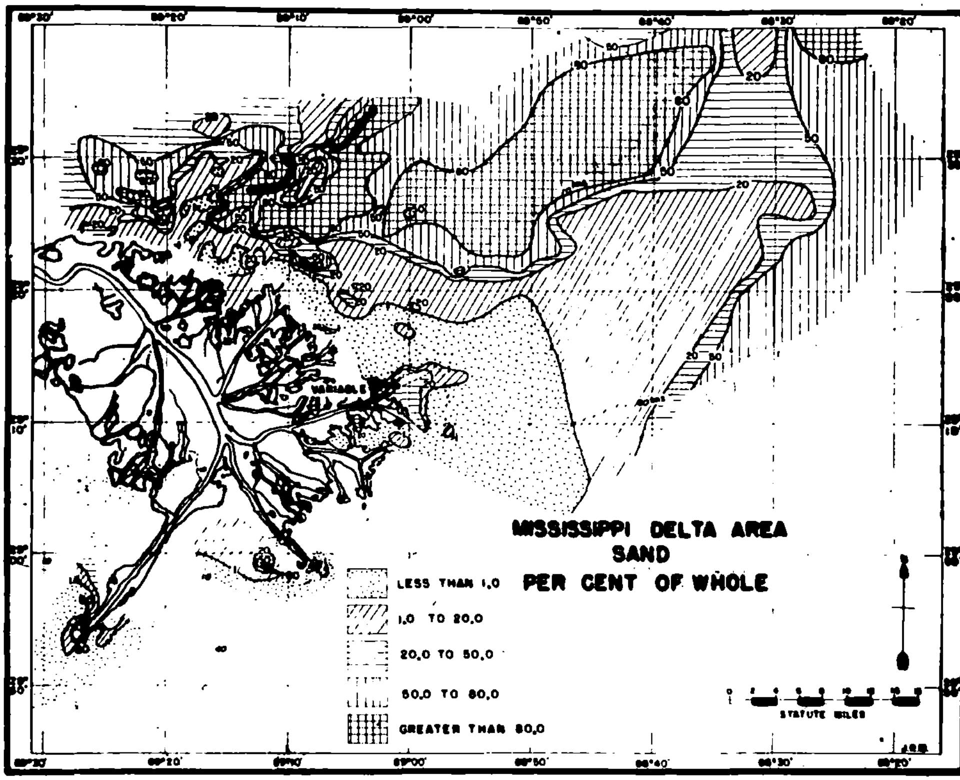


Fig. 8.13 Variation in sand content shown by contours based on percentage of sand. Decrease of sand followed by increase away from eastern passes is indicated. Fig. 10 provides depth relationship and Figures 35 and 37 show percentages off North and Main Pass including month of sampling.

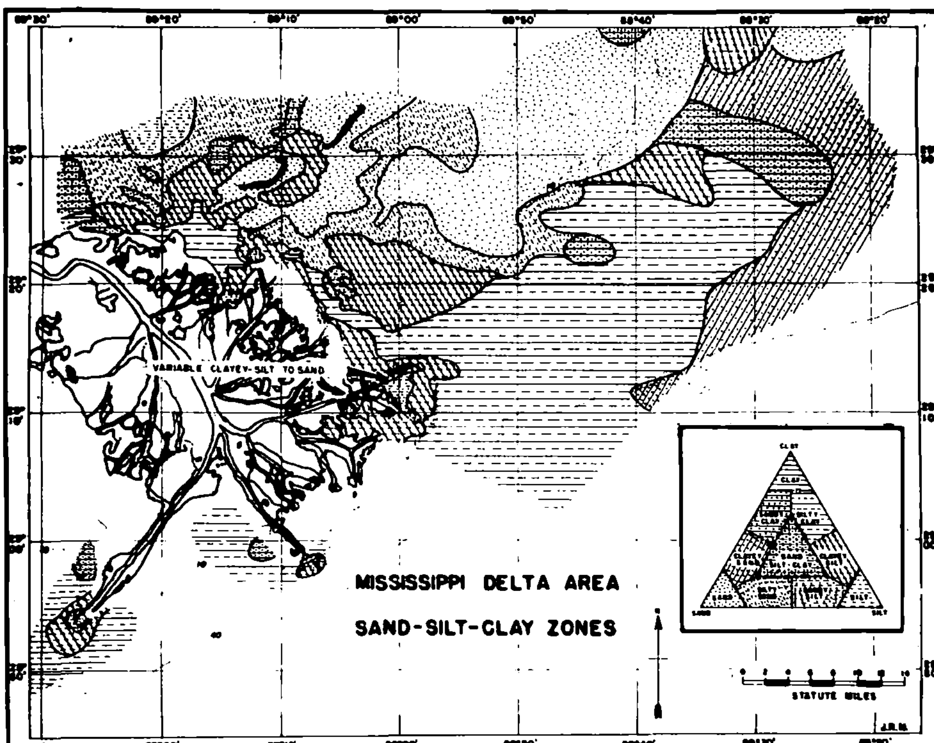


Fig. 8.14 —Sediment distribution based on sand-silt-clay content in area marginal to delta. For interpretation of symbols, see triangle diagram.

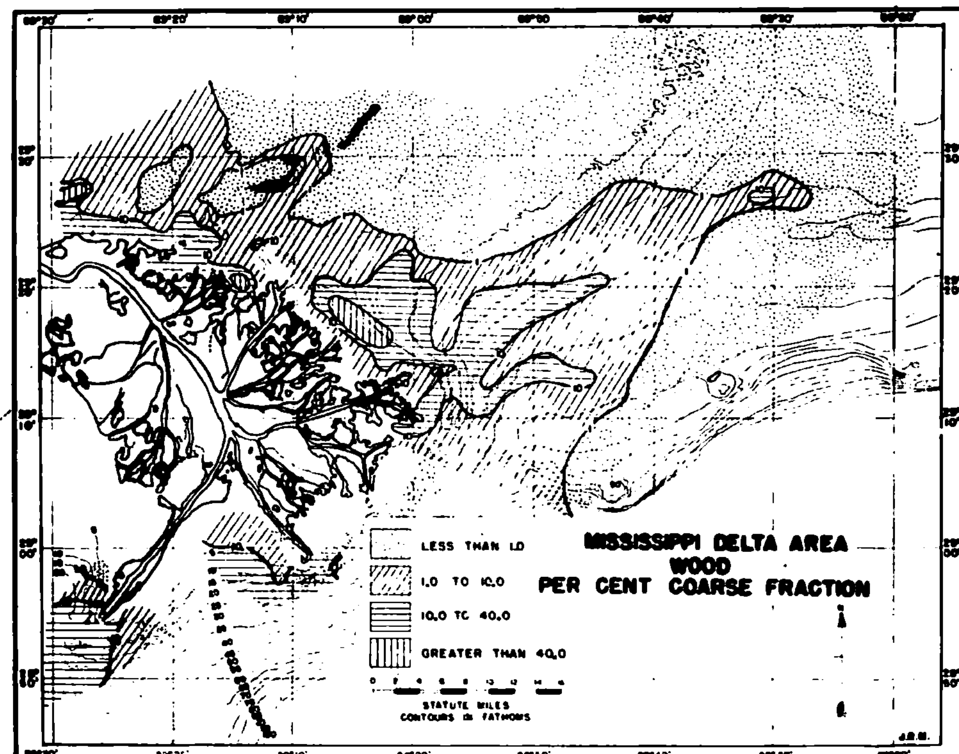


Fig. 8.15 —Abundance of land plant constituents (wood) in coarse fraction. Indicates large tongue of woody materials extending well east of Pass a Loutre.

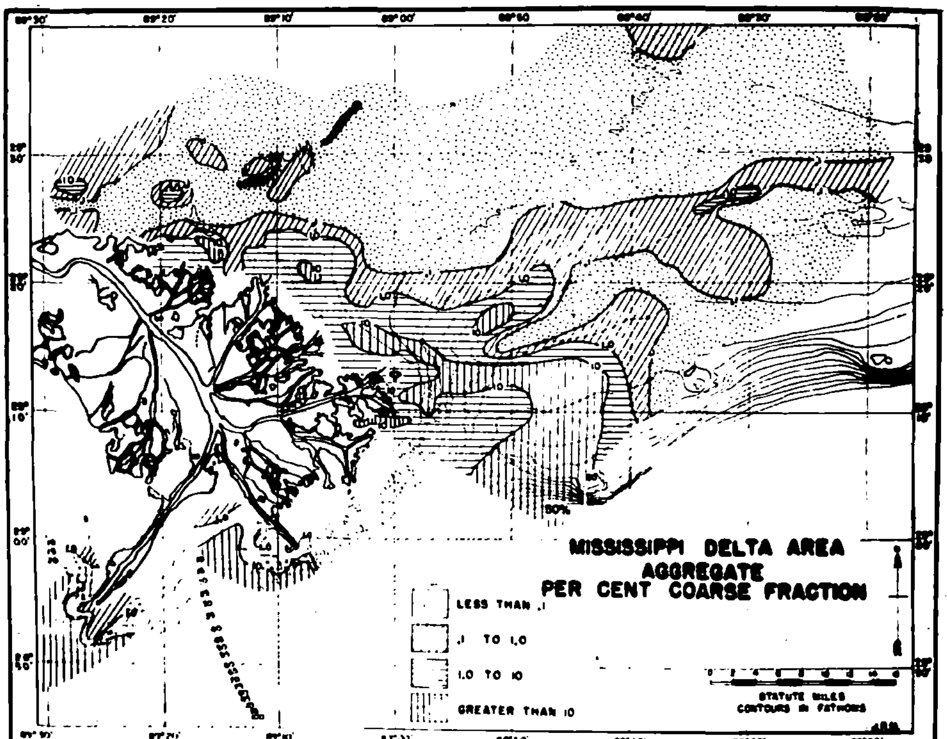


Fig. 8.16 Abundance of aggregates in coarse fraction. General resemblance to wood distribution and relation to distributaries are indicated.

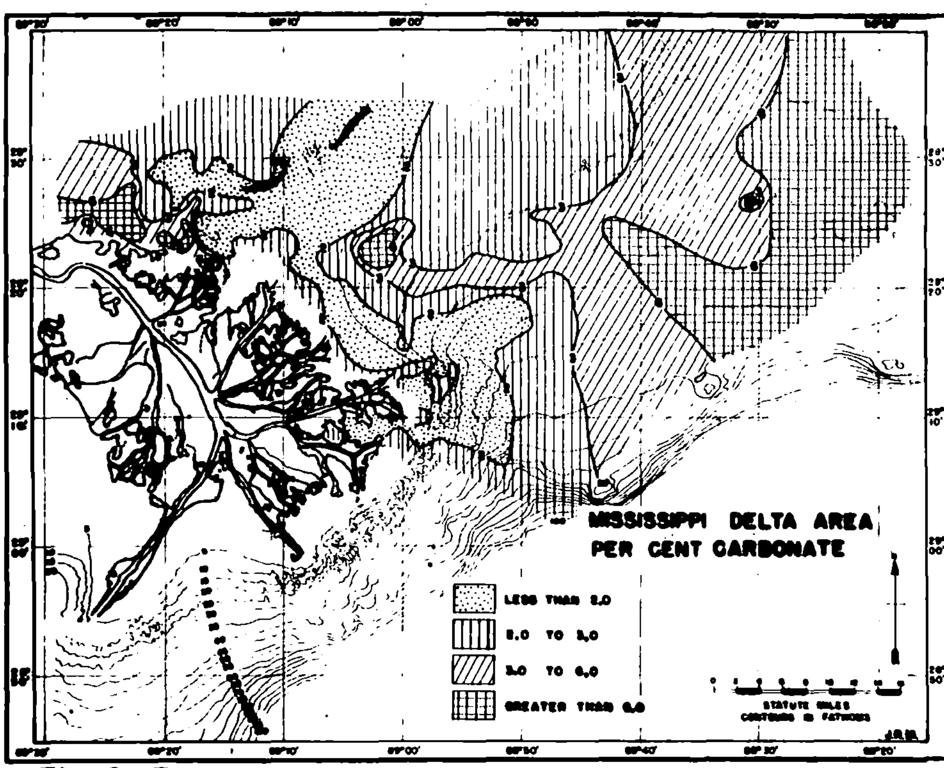


Fig. 8.17 -Percentages of calcium carbonate in area east and north of Mississippi Delta. These percentages are comparable with those for Foraminifera and echinoids (Figs. 18 and 21).

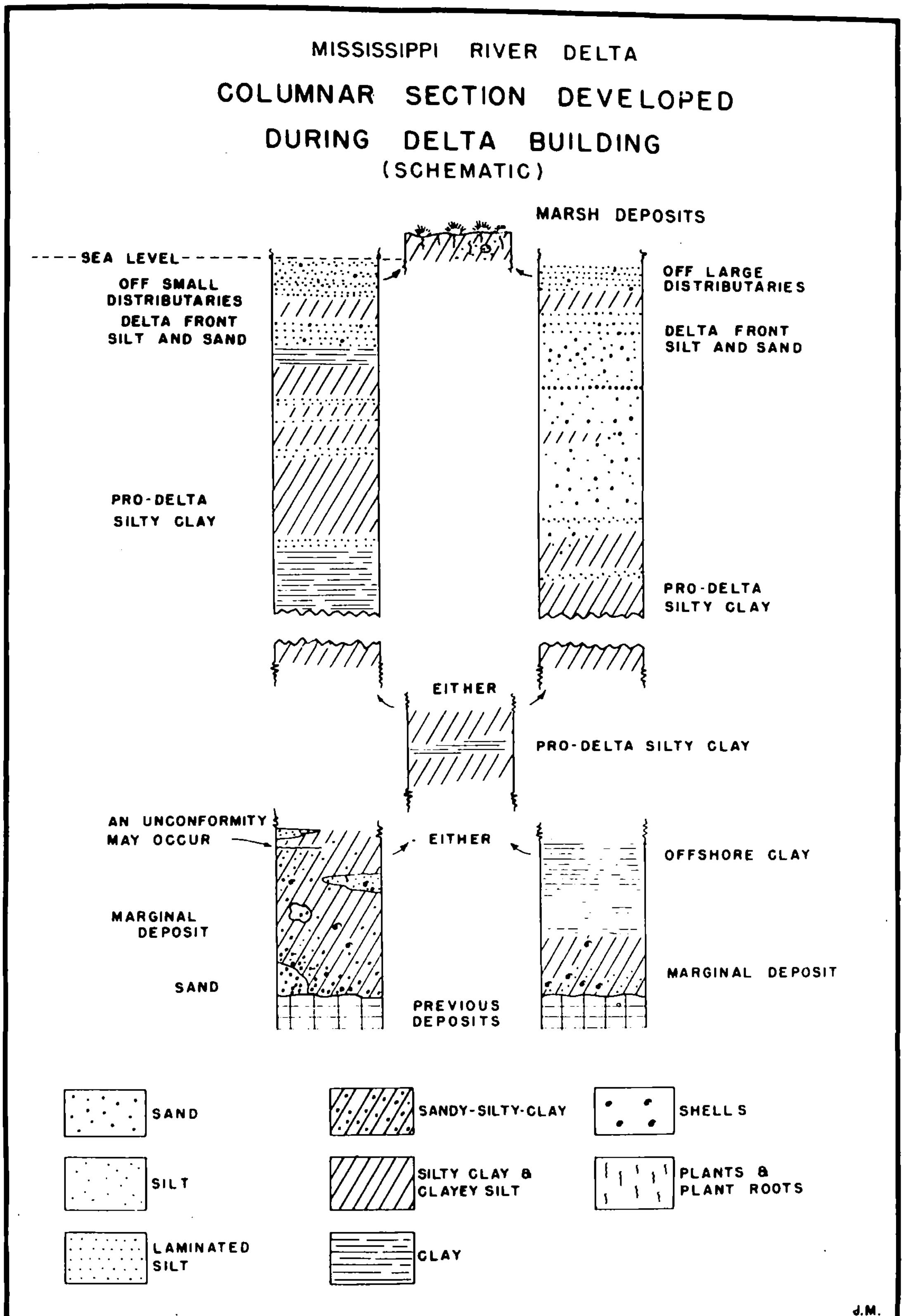


Fig. 8.18 Shows the vertical distribution of sediment units in the completed delta. Because of areal variations, some differences exist in the vertical sequence from place to place. Either of the sequences may occur at the indicated positions.

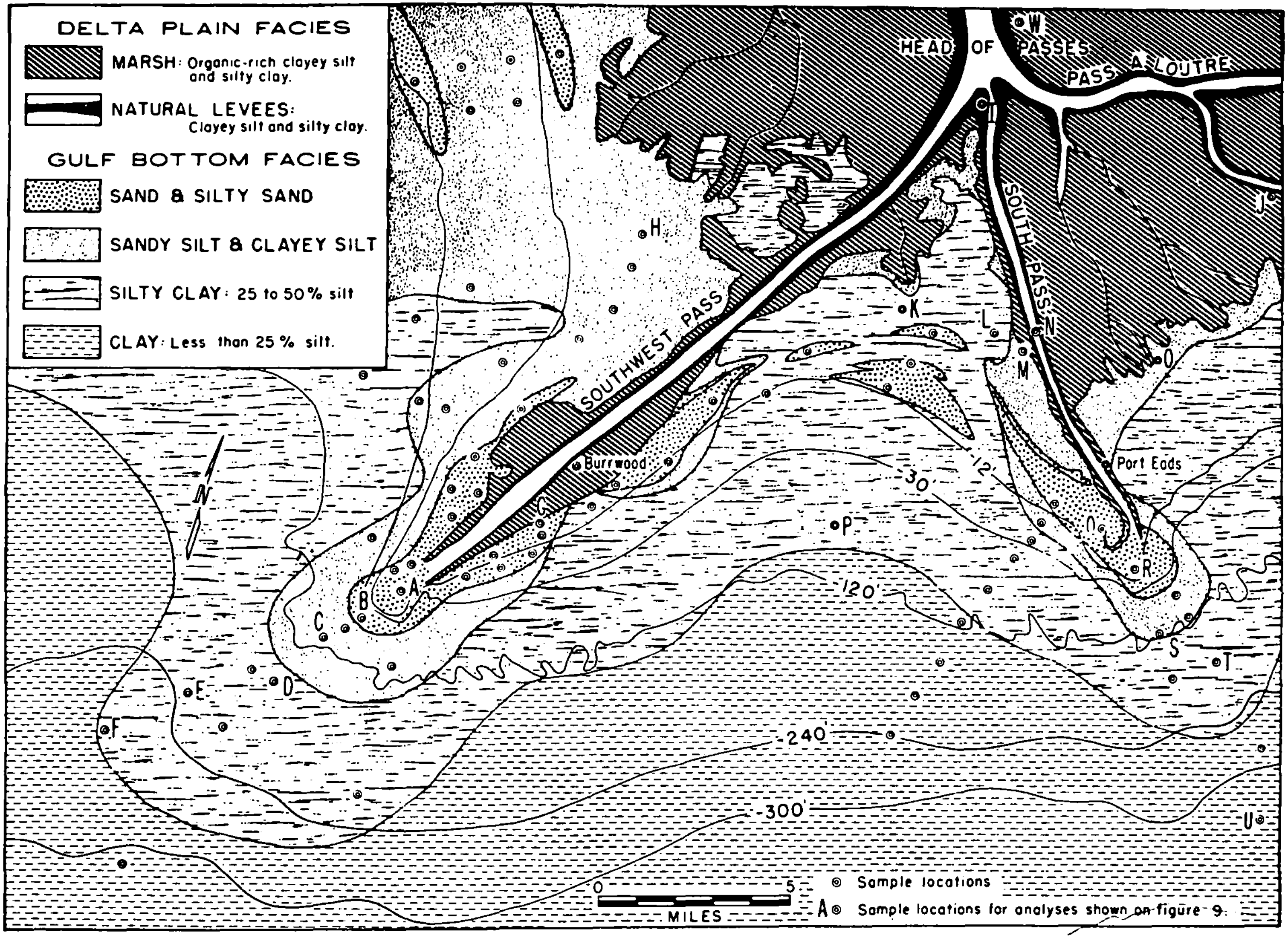

DELTA PLAIN FACIES
MARSH: Organic-rich clayey silt and silty clay.
NATURAL LEVEES: Clayey silt and silty clay.
GULF BOTTOM FACIES
SAND & SILTY SAND
SANDY SILT & CLAYEY SILT
SILTY CLAY: 25 to 50% silt
CLAY: Less than 25% silt.
HEAD OF PASSES
PASS A LOUTRE
SOUTHWEST PASS
SOUTH PASS
Burrwood
Port Eads
N
12'
30'
120'
240'
300'
0
5
MILES
Sample locations
A Sample locations for analyses shown on figure 9.

Fig. 8.19

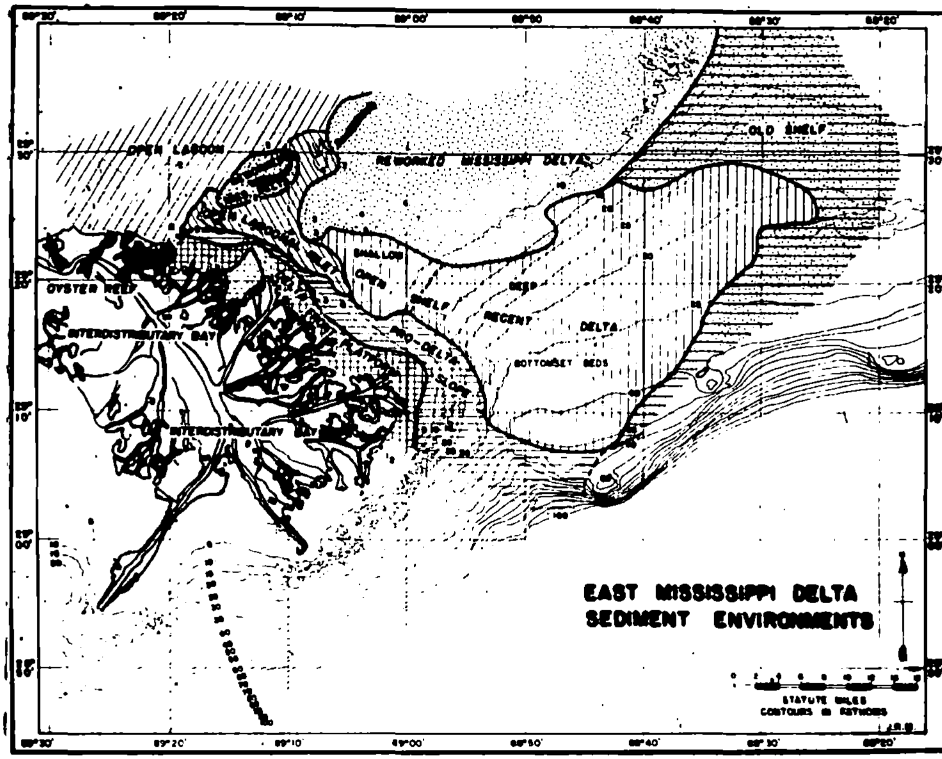


Fig. 8.20 Sediment environments proposed for area east and north of birdfoot delta.

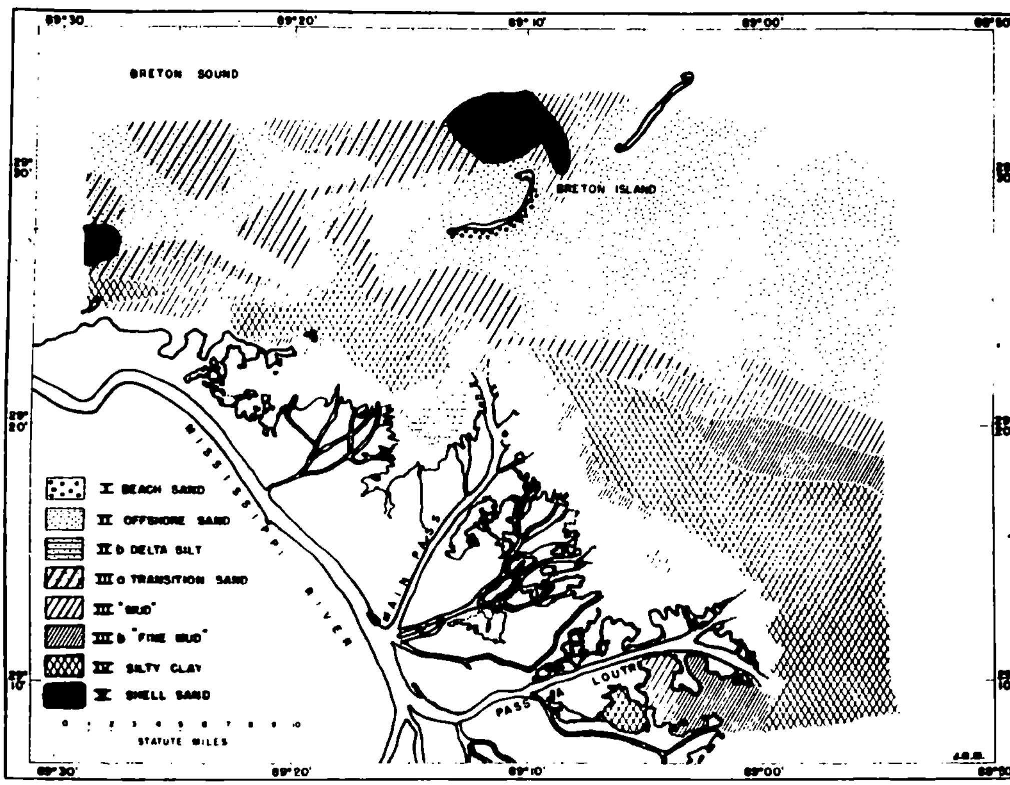


Fig. 8.21 Area distribution of sediment types based on median diameter, phi deviation, and phi skewness. From Inman and Chamberlain (1955, Fig. 12).

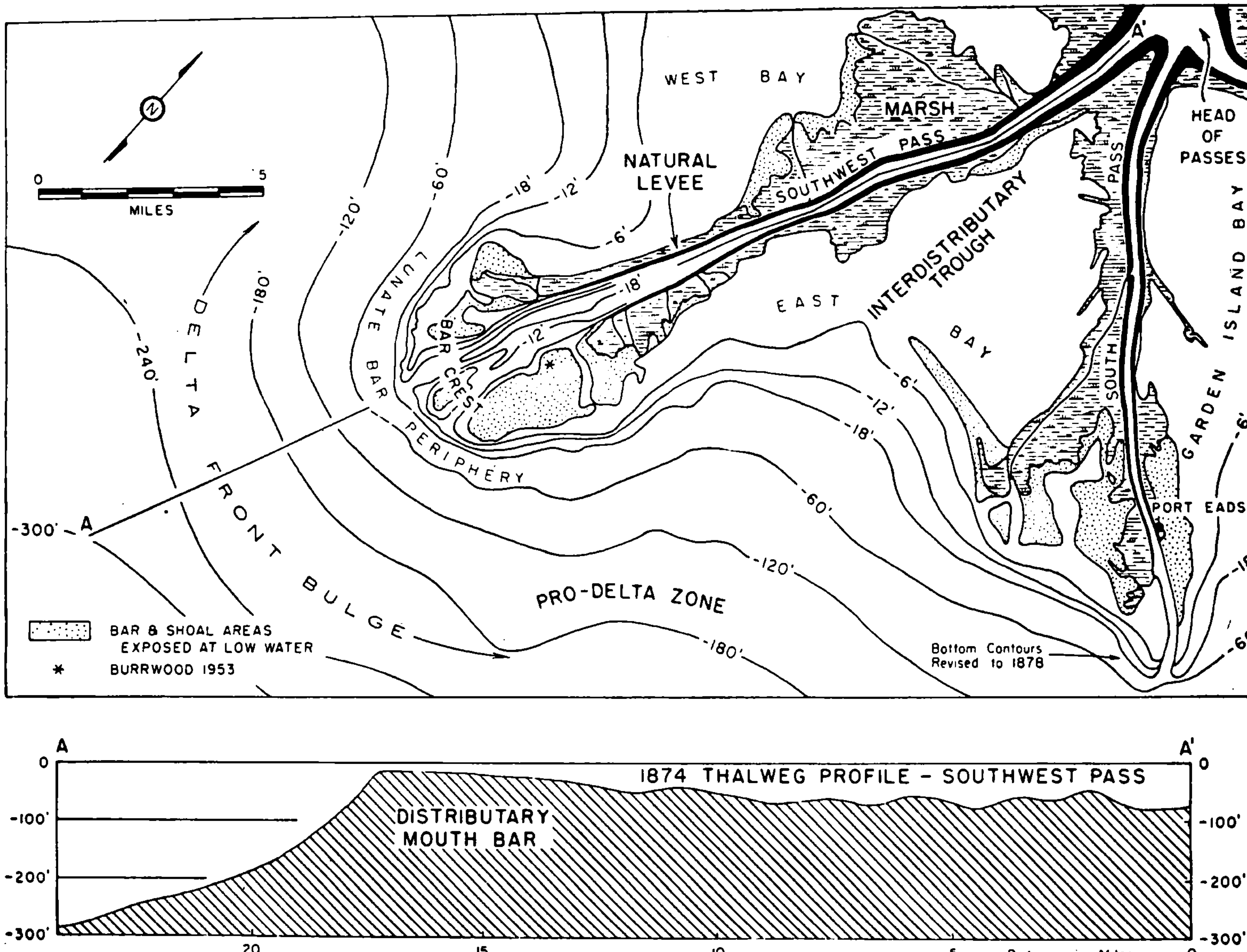

WEST BAY
MARSH
SOUTHWEST PASS
NATURAL LEVEE
INTERDISTRIBUTARY TROUGH
EAST BAY
SOUTH PASS
HEAD OF PASSES
GARDEN ISLAND BAY
PORT EADS
LUNATE BAR PERIPHERY
BAR CREST
DELTA FRONT BULGE
PRO-DELTA ZONE
MILES
BAR & SHOAL AREAS EXPOSED AT LOW WATER
BURRWOOD 1953
Bottom Contours Revised to 1878
1874 THALWEG PROFILE - SOUTHWEST PASS
DISTRIBUTARY MOUTH BAR
Distance in Miles

Fig. 8.22

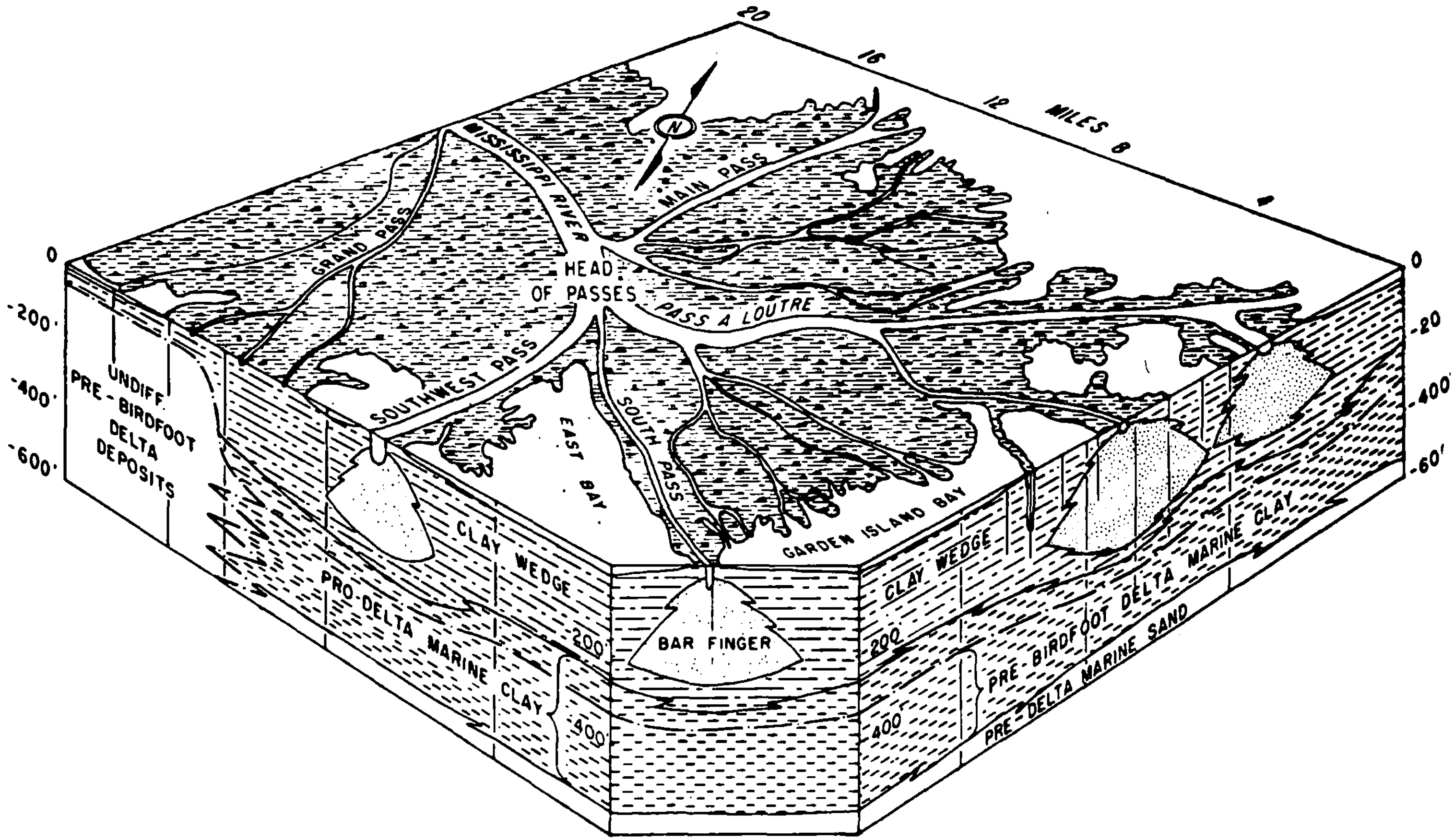

20
16
12
MILES 8
4
N
MISSISSIPPI RIVER
MAIN PASS
GRAND PASS
HEAD OF PASSES
PASS A LOUTRE
SOUTHWEST PASS
SOUTH PASS
EAST BAY
GARDEN ISLAND BAY
0
-200'
-400'
-600'
0
-20
-400'
-60'
UNDIFF. PRE-BIRDFOOT DELTA DEPOSITS
CLAY WEDGE
PRO-DELTA MARINE CLAY
200'
400'
BAR FINGER
CLAY WEDGE
200
400
PRE BIRDFOOT DELTA MARINE CLAY
PRE-DELTA MARINE SAND

Fig. 8.23

Processes That Form Most Minor Internal Sedimentary Structures
(Capitalized methods are considered most important)

Type		When Formed	Process of Formation: If there is one major sediment source (simple source)	Process of Formation: If there are two or more sediment sources (compound source)
Regular Layers		P*	FLUCTUATIONS IN SIZE OF MATERIAL TRANSPORTED AND DEPOSITED	TRANSPORTATION OF CONTRASTING MATERIAL FROM TWO OR MORE SOURCES
Regular Layers		S*	WINNOWING RESULTING FROM SUSPENSION BY CURRENTS (wave, tide, wind induced, etc.) Organic activity resuspending sediment with winnowing of fines	
Irregular Layers		P	Fluctuations in size of material deposited on irregular bottom	Interrupted transport from both sources with deposition on irregular bottom
Irregular Layers		S	ORGANIC ACTIVITY RESUSPENDING SEDIMENT WITH WINNOWING OF FINES. Local slump	
Mottles	Distinct	P	Open animal burrows or surface irregularities filled with contrasting material. Mud pebbles eroded from stream bank; rarely formed	Open animal burrows or surface irregularities filled with contrasting material. Dessication clasts from tidal flats and natural levees (clay galls); rarely formed
Mottles	Distinct	S	BURROWING ORGANISMS DISTORTING LAYERED DEPOSITS OR CONCENTRATING MATERIAL COARSER OR FINER THAN MATRIX BY WINNOWING OR INGESTION. Local slump	
Mottles	Indistinct	P	Possibly by soft clay balls; rarely formed	Interstitial sedimentation of clay in sand; rarely formed
Mottles	Indistinct	S	PARTIAL DESTRUCTION OF EARLIER FORMED LAYERED OR DISTINCTLY MOTTLED STRUCTURES BY BURROWING AND CRAWLING ORGANISMS	
Homogeneous		P	DEPOSITION OF UNIFORM SEDIMENT or deposition at very high rate	DEPOSITION OF UNIFORM SEDIMENT
Homogeneous		S	TOTAL DESTRUCTION OF MINOR INTERNAL STRUCTURES BY BURROWING ORGANISMS WITH COMPLETE SEDIMENT MIXING	

P* Primary feature formed at time of initial deposition.
S* Secondary feature formed as alteration of initial deposit.

Table 8.A

TABLE 10.1. X-RAY POWDER DATA ON CRUSHED METAMORPHOSED SHALE, T.380

d in Å		Intensity, estimated visually
14.49		Weak.
7.10		Medium.
6.44	x	Very weak.
4.72	x	Very, very weak.
4.23		Very weak.
4.03	x	Medium.
3.78	x	Very weak.
3.67	x	Medium-weak.
3.52		Weak.
3.37	x	Very weak.
3.20	x	Strong.
2.95	x	Weak, broad.
2.856	x	Very weak.
2.656	x	Very, very weak.
2.552	x	Very weak.
2.454		Very, very weak.
2.395		Very, very weak.
2.319		Very, very weak.
2.268		Very, very weak.
2.130		Very, very weak.
2.089		Very, very weak.
1.998		Very, very weak, diffuse.
1.892		Very, very weak.
1.853		Very weak.

Chlorite with labradorite-anorthite lines (x)

Camera: 11.4 cm. Radiation: CuKα, Exposure: 3 hrs.

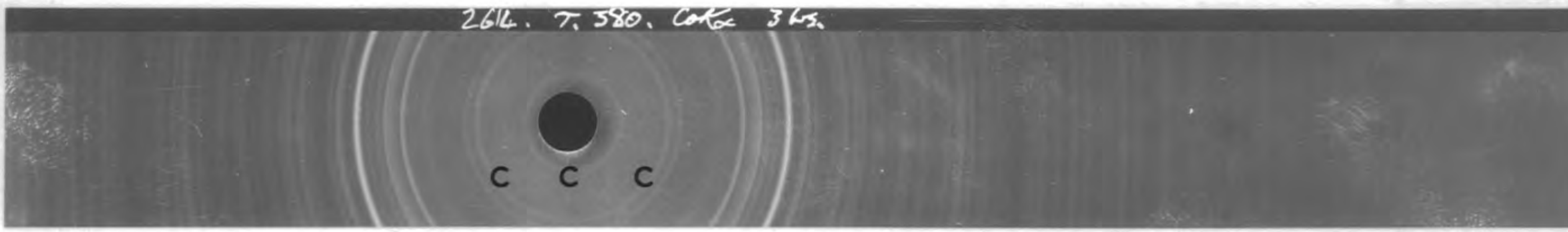


Figure 10.1. X-ray powder photograph of metamorphosed shale, T.380., showing chlorite (c) and feldspar lines, (see Table 10.1).

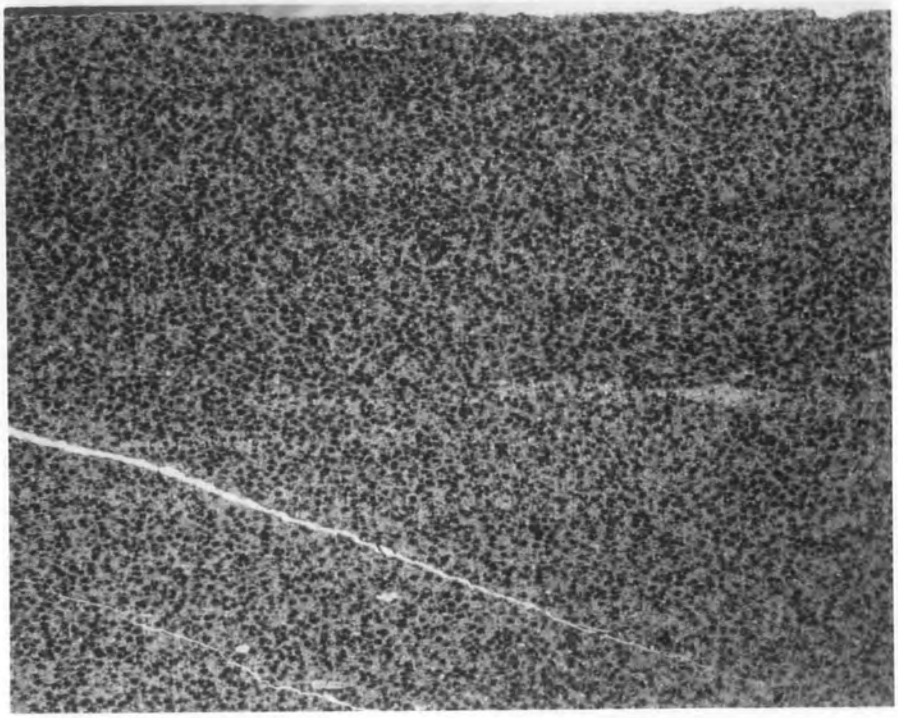


Fig. 10.2. Fine spotting in shale, T.276.
Ordinary transmitted light X 10

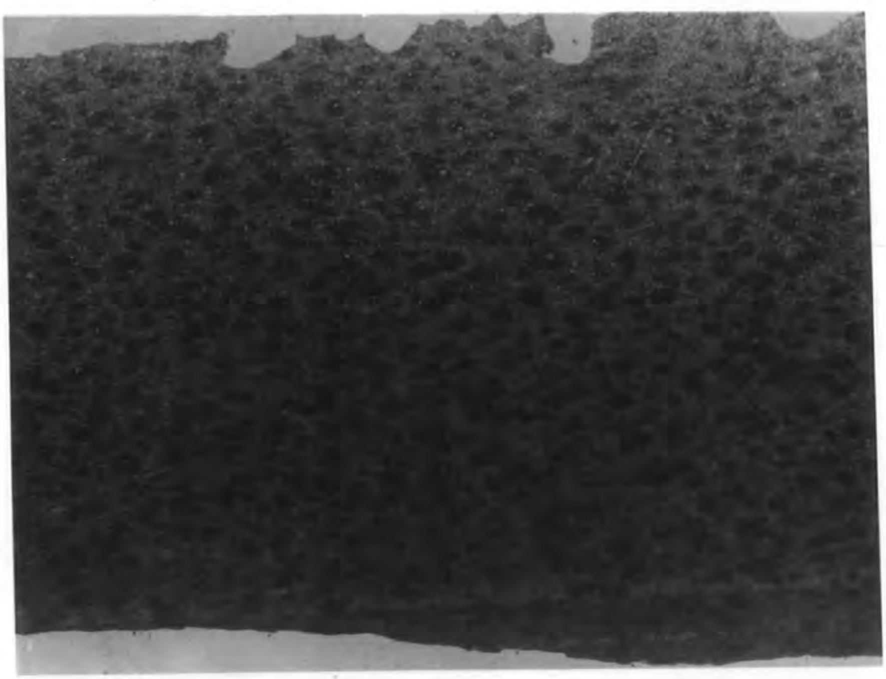


Fig. 10.3. Coarse spotting in silty shale, T.134.
Ordinary transmitted light X 10

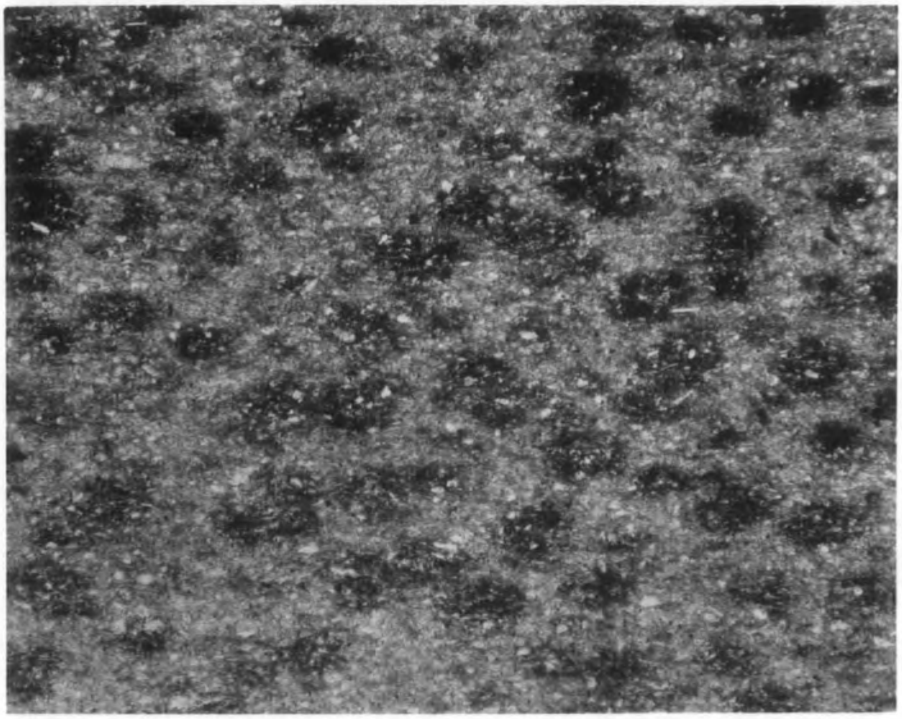


Fig. 10.3a. Detail of spots in Fig. 10.3.
Ordinary transmitted light X 40.

TABLE 10.2. X-RAY POWDER DATA ON SHALE, T.43, AND SPOTS DUE TO METAMORPHISM

Shale (crushed, natural) d (Å)		Intensity	Spots d Å		Intensity
			13.96	x	vw.
9.92		s.	9.97		wm.
4.97		vw.	5.00		vw.
4.72	x	vvw.	4.71	x	vw.
4.43		s.	4.46		m.
4.24	+	s.	4.25	+	m.
			3.87		vvw.
3.62	x	vvw.	3.68	x	vvw.
3.49		vvw.	3.48		w.
3.33	+	vs.	3.34	+	vs.
3.20		w.	3.21		vvw.
2.99		w.	2.94		vvw.
2.857		vw.	2.851		vvw.
2.784		vw.	2.789		vvw.
2.559		m.	2.559		m.
2.452	+	mw.	2.452	+	m.
2.380		w.	2.382		w.
2.277	+	w.	2.279	+	mw.
2.235	+	w.	2.233	+	mw.
2.125	+	mw.	2.154	+	m.
1.980	+	wb.	1.975	+	mwd.
1.814	+	m.	1.815	+	ms.
1.667	+	vw, vvb.	1.667	+	w, vd.
1.539	+	mw.	1.540	+	m.

Camera: 9 cm. Radiation: CuKα. Exposure: 3.5 hours.

Intensities estimated visually.

x = chlorite, + = quartz. Unmarked = illite.

Abbreviations: v-very, w-weak, m-medium, s-strong, d-diffuse, b-broad.

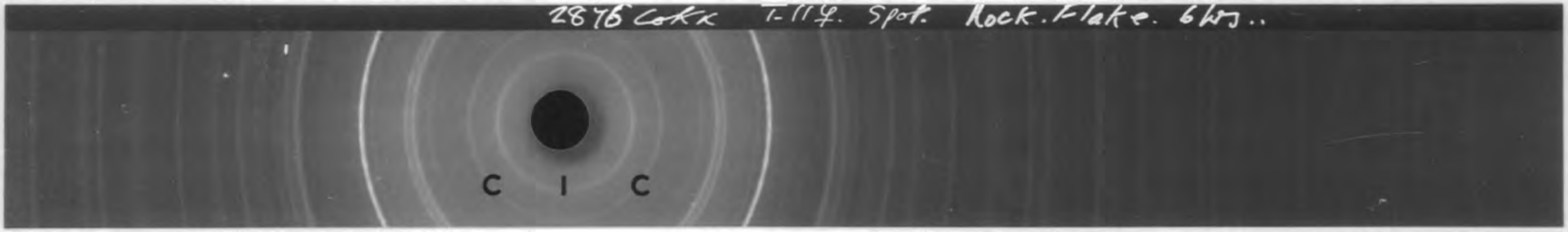


Figure 10.4. X-ray powder photograph of spots from shale, T.117., showing chlorite (C) and illite (I) lines.

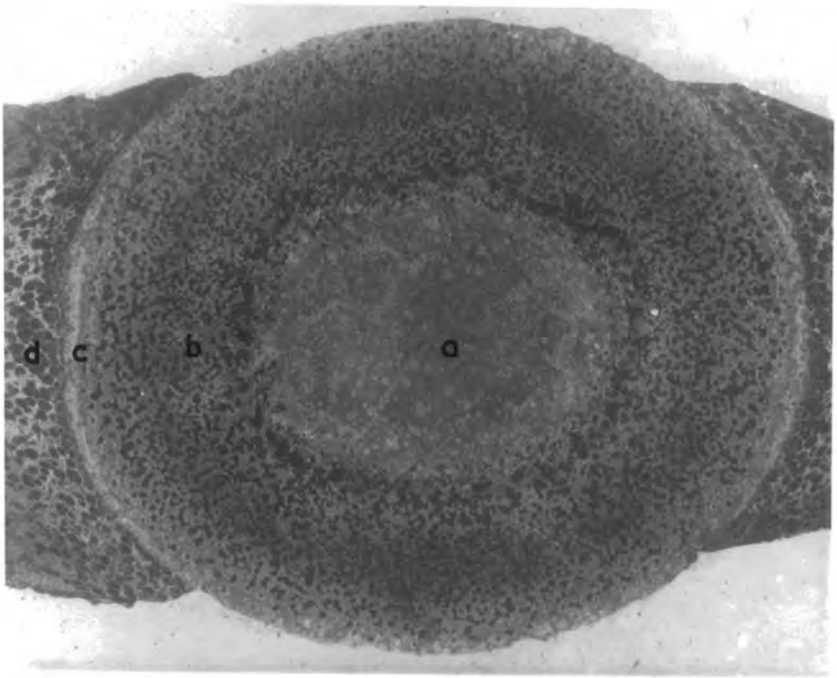


Fig.10.5. Metamorphic nodule from shale below Whin Sill, Dine Holm, T.111, showing inner zone of ?devitrified glass? and chlorite (a) and an intermediate zone of ?devitrified glass? and pyrite (b) and an outer zone of ?devitrified glass? and chlorite (c).

Note the growth of the nodule has caused the spots in the surrounding shale to coalesce,(d).

Ordinary transmitted light X 10.

TABLE 10.3. X-RAY POWDER DATA ON ?DEVITRIFIED GLASS IN NODULES OF SHALE T.111.

d (Å)		Intensity, estimated visually
10.14		Medium.
7.10	x	Medium.
5.02		Weak.
4.50		Medium.
3.89		Weak.
3.53	x	Weak-medium, diffuse.
3.35		Strong.
3.24		Very weak.
3.09		Weak.
2.87		Very weak.
2.67		Weak.
2.57		Weak.
2.454		Medium.
2.388		Medium.
1.999		Weak.
1.500		Weak, diffuse.

Lines due to illite (unmarked) and chlorite (x).

Camera: 11.4 cm. Radiation: CoKα. Exposure: 4 hours.

Figure 10.6. X-ray powder photograph of centre of metamorphic nodule, T.111., showing lines due to illite (I) and chlorite (C).

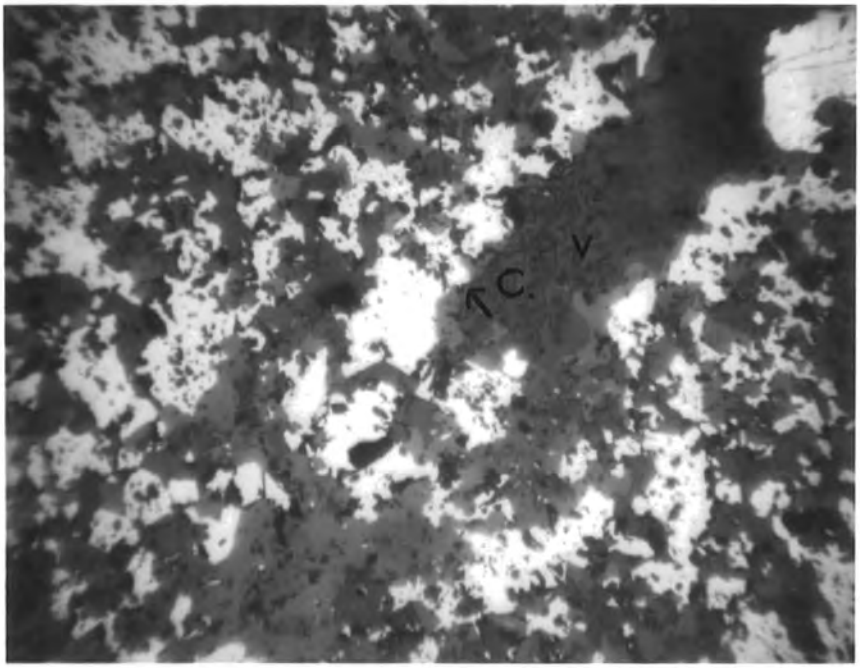


Fig.11.1. Shale nodule, T.93a, showing chalcopyrite (C) with pyrite in calcite veinlet (V). Groundmass of pyrite, pyrrhotite and marcasite.

Ordinary reflected light X 100

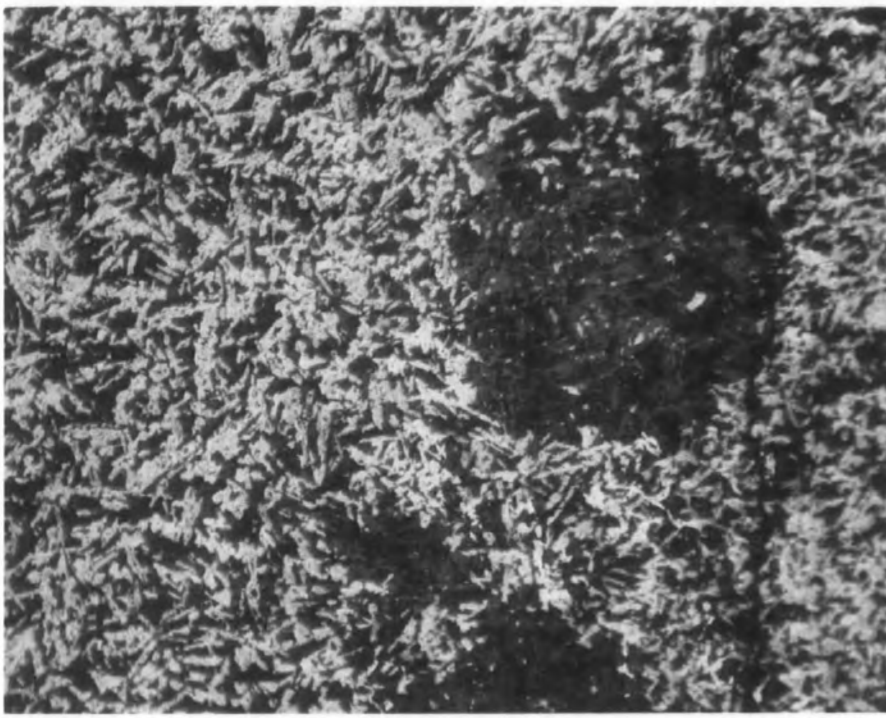


Fig. 11.2. Nodule from shale, T.79, showing pyrrhotite laths in vermiform aggregates.

Ordinary reflected light X 100.

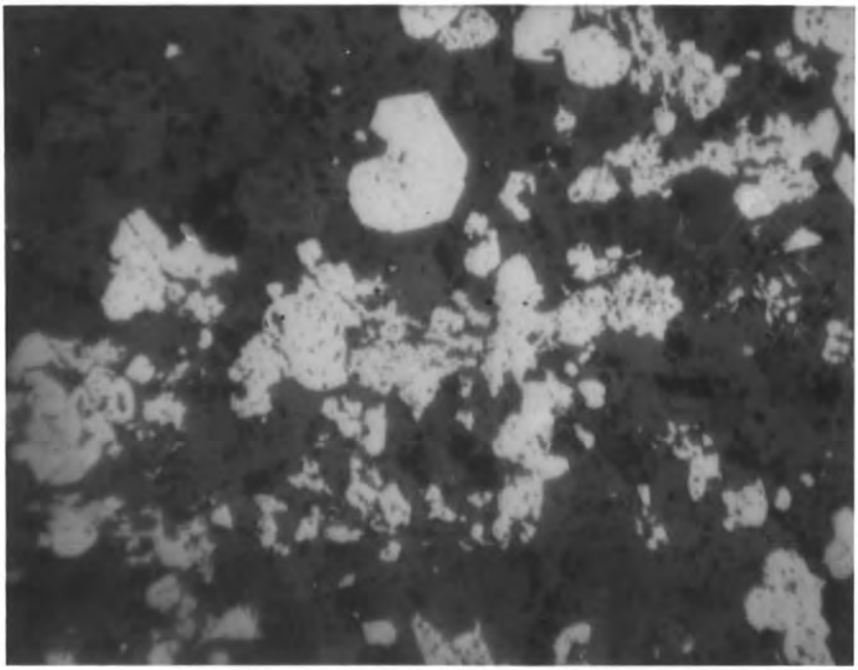


Fig.11.3. Nodule from shale T.142b, showing euhedral pyrite grain in matrix of clay material and carbonate containing irregular pyrrhotite.

Ordinary reflected light X 200.

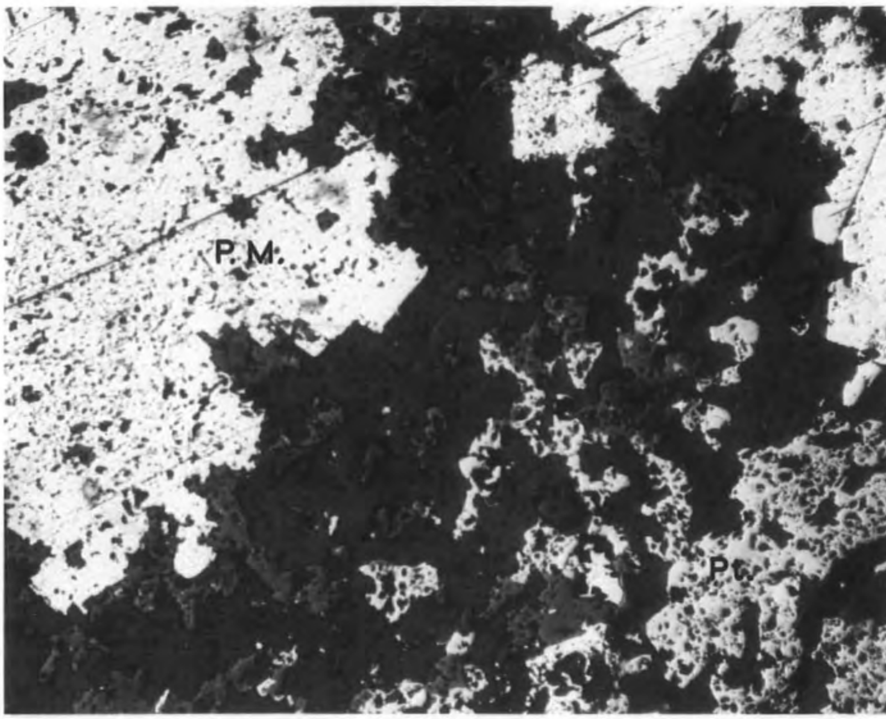
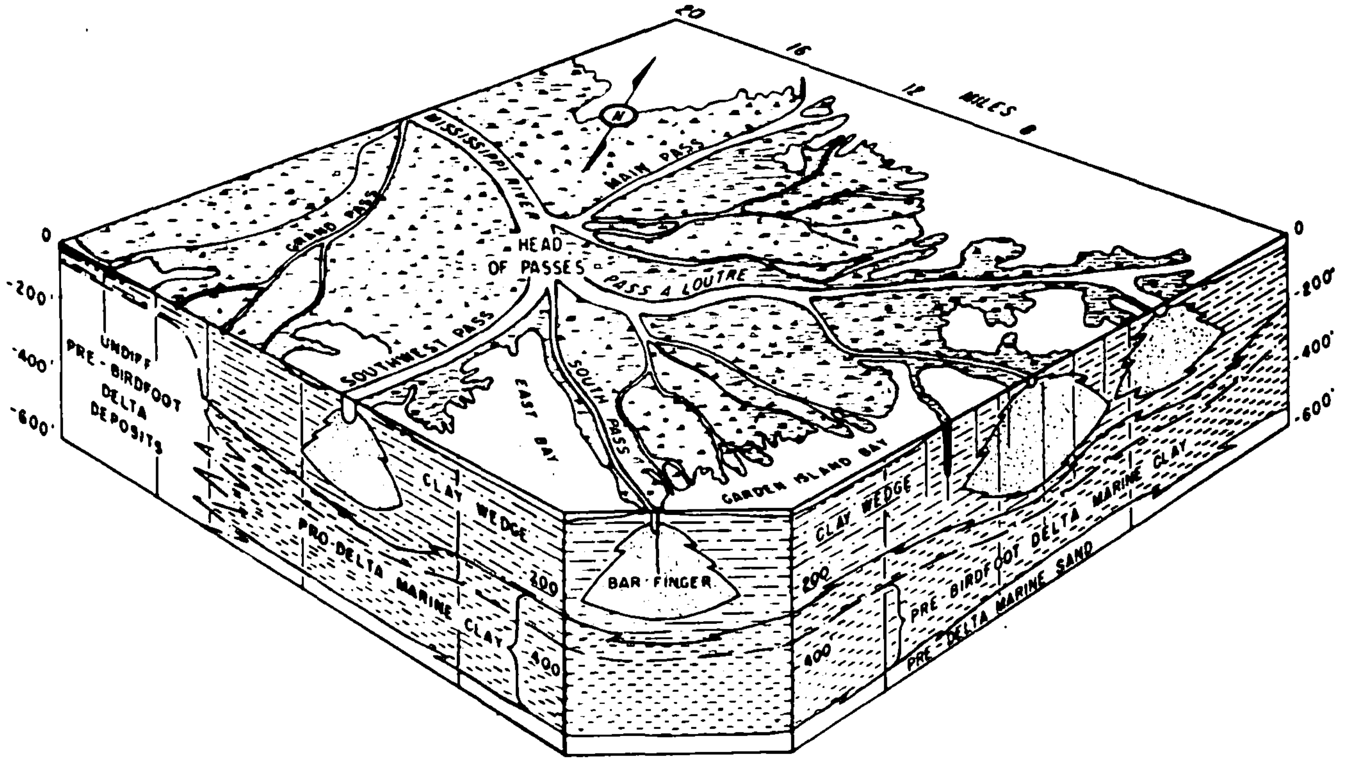


Fig. 11.4. Nodule from shale T.142B, showing area of pyrite and marcasite (P.M.) with pyrrhotite (Pt.).

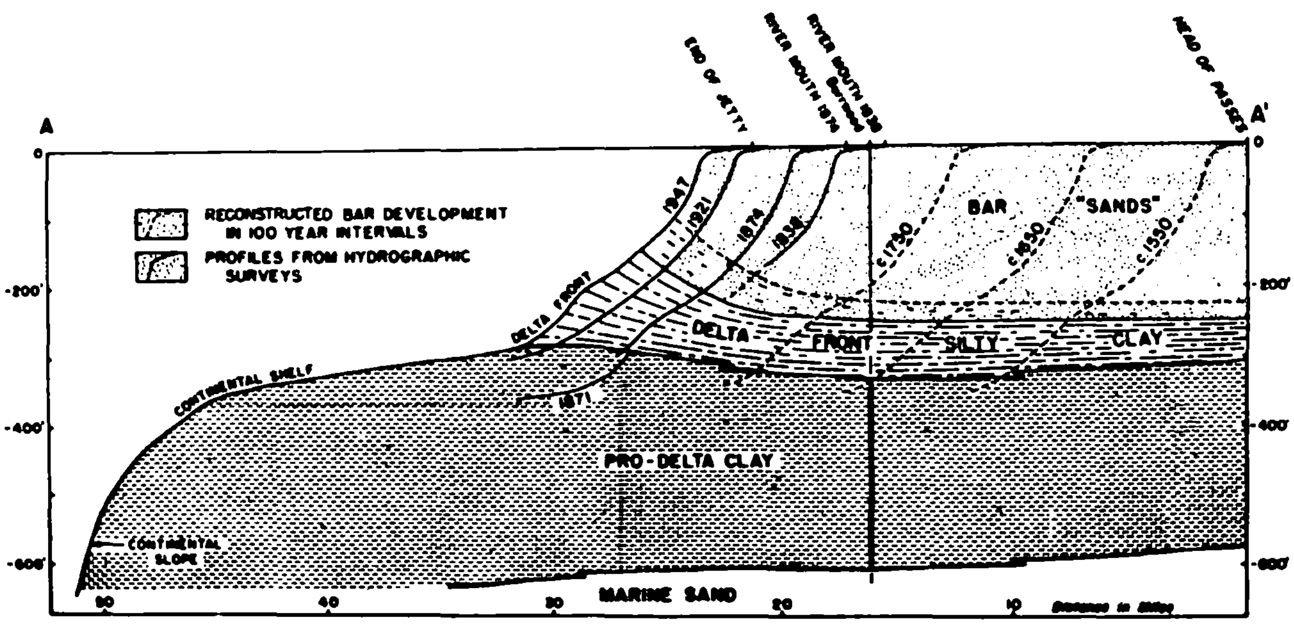
Ordinary reflected light X 200

Fig. 11.5. Nodule from shale, T.99B, showing development of euhedral laths of pyrrhotite.

Ordinary reflected light X 100.



Sedimentary framework of the modern, or birdfoot, delta of the Mississippi River.



Development of the birdfoot delta platform as shown by comparison of data from hydrographic surveys dating from 1838.

PLATE 22.