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A report on the Sedimentology of the Moolayember Formation, Bowen Basin, Queensland

by

P.J. Alcock

A REPORT ON THE SEDIMENTOLOGY OF THE MOOLAYEMBER FORMATION, BOWEN BASIN, QUEENSLAND

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ABSTRACT

This report covers the second part of an environmental study of the Triassic Moolayember Formation in the Bowen Basin of Queensland.

Results of a drilling programme in the south-eastern (Dawson Range Area) and northern parts of the basin support the two-fold subdivision already proposed for the south-eastern area. Sedimentary cycles can be recognized which conform to cycles of alluvial deposition both in the south-eastern and the northern areas of outcrop.

Detailed field studies in the Carnarvon Range Area have resulted in revision of the 1969 three-fold subdivision to a two-fold subdivision. Probable freshwater tidal and lake deposits are proposed for the lower unit while the upper unit is attributed to alluvial accretion similar to that in the south-eastern and northern areas.

Currents were generally directed towards to the central south of the basin from both eastern and northern provinces.

INTRODUCTION

This report deals with the second phase of an investigation of the Moolayember Formation. The first part of the study (Alcock, 1969) dealt with the general geology of the formation as it appears in areas of better outcrop, namely: the Northern Area, Dawson Range Area, Expedition Range Area and Carnarvon Range Area. Emphasis was placed on the determination of stratigraphic thickness at several places and the recognition where possible of any unit subdivisions. However, some attempt was made to interpret observed features in terms of environment of deposition.

During 1969 some 2800 feet of drilling was done in the Dawson Range and Northern Areas followed later by detailed field studies at selected sites in the Carnarvon Range Area. The results and interpretation of this work are covered in the present report.

DRILLING - DAWSON RANGE AREA

Using a Fox Mobile drilling rig, six holes were drilled to an average depth of 350 feet in the Moolayember Formation between Glenmoral Gap and Flagstaff Hill (Plate 1). Cores were taken at selected intervals and electric logging and gamma ray logging of the completed holes was undertaken. Table 1 summarizes the relevant data.

OBSERVATIONS

1. Unit Subdivision

The drilling supports the division proposed earlier (Alcock, 1969) into a lower sandy conglomeratic unit (D1) with minor mudstone, and an upper unit (D2) of interbedded mudstone and lithic sandstone. The boundary between D1 and D2 is gradational but may be taken at the topmost conspicuous conglomerate bed which occurs about 1700 feet above the base. Some pebbly sandstone horizons do occur above this boundary.

2 Sand - Shale Ratio

Drilling has also shown that a higher proportion of sandstone is present than was supposed from outcrop observations - particularly in the lower part of the section. The stratigraphically lowest hole, Baralaba No. 1, has a sand - shale ratio of 10 whereas successively higher holes within the sequence have ratios of sand to shale of 1.2, 1.7, 1.0, 1.7, 0.8 respectively.

3 Porosity and Permeability

Determinations of porosity and permeability on two plugs from selected sandstone intervals of cores were made by the Petroleum Technology laboratory of the Bureau of Mineral Resources. Porosities and permeabilities were found to be highest in the lower part of the sequence. Baralaba No. 1, which was drilled in unit D1, yielded values up to 27% for effective porosity and 390 Millidarcys absolute horizontal permeability. However, samples from higher in the formation had porosity values generally less than 20% and permeability not exceeding 25 Millidarcys. The results from all cores analyses are set out in Table II.

4 Cyclicity

A feature of the well logs is the recurrence of fining-upwards cycles throughout the section. Examples of some of these cycles, or parts of them, are illustrated by cores in figures 2 to 9.

(i) Baralaba No. 1, core 3, (Fig. 2): The erosion surface at 254 feet marks the interruption of continuous sedimentation and the beginning of a new phase of sedimentation. The basal one foot of this new phase is made up of coarse to very coarse sandstone which is poorly bedded and contains numerous mudclasts. The overlying sandstone becomes successively finer grained upwards and contains a few mudclasts, mud lenses and minor interbedded sandy mudstone.

TABLE 1

1:250,000 Sheet	Hole No.	Grid Ref.	Total Depth (Feet)	Cored Intervals (Feet)	Footage Cored	Core Rec. (feet)	Logs Run	Formations	Water
Baralba SG 55-4	1	28118923	330	70-80, 140-150 250-260, 300-330	40	29	Electric & Gamma	Moolayember	
Baralaba SG 55-4	2	27988920	340	70-80, 190-195 290-30	30	24½	Electric & Gamma	Moolayember	
Taroom SG 55-8	1	27798876	370	100-110, 220-230 270-280, 360-370	40	36	Electric & Gamma	Moolayember	
Taroom SG 55-8	2	27438842	360	70-80, 200-210 270-280, 350-360	40	37½	Electric & Gamma	Moolayember	
Taroom SG 55-8	3	27308823	410	10-20, 20-30 70-75, 180-190 300-310	55	53½	Gamma	Precipice Sst. Moolayember	
Taroom SG 55-8	4	27668864	350	80-90, 140-150, 270-280, 340-350	40	38½	Electric & Gamma	Moolayember	
Mt. Coolon SF 55-7	2	63943588	370	30-40, 120-130 220-230, 330-340	40	38	Electric & Gamma	Teviot Fm. Carborough Sst.	700 gals/hr at 100 ft.
Mt. Coolon SF 55-7	3	63763613	310	70-80, 150-160, 240-250	30	27	Gamma	Teviot Fm. Carborough Sst.	1000 gals/hr at 300 ft.
		Total	2840		315	284			

TABLE II.

POROSITY AND PERMEABILITY OF SANDSTONE CORE SAMPLES

Well Name and No.	Core No	Sample Depth (feet)	Av. effective Porosity (% bulk vol.)	Absolute Permeability (Millidarcy) Vert.	Absolute Permeability (Millidarcy) Horiz.
Baralaba No. 1	1	72	24	85.0	0.63
	2	145	15	4.6	3.7
	3	251	13	1.6	0.56
	3	256	13	0.2	8.1
	4	322	27	62.0	391.0
Baralba No. 2	3	290	21	0.86	1.6
Taroom No. 1	3	271	12	1.1	3.8
	4	368	10	0.19	0.33
Taroom No. 2	1	77	14	0.69	4.2
	2	207	19	5.7	5.0
	4	355	19	6.8	22.0
Taroom No. 3	4	184	12	<0.1	<0.1
	5	300	13	3.4	7.0
	5	307	13	2.3	3.9
	6	401	7	0.24	0.66
Taroom No. 4	1	82	7	1.8	3.8
	1	88	7	1.1	1.8
	2	147	9	<0.1	<0.1
	3	274	18	12	5.5
	4	343	15	1.9	5.5
	4	345	13	0.45	0.58

(ii) Baralaba No. 1, Core 2 (Fig. 3): An erosion surface at 143½ feet in this core is overalin by 6 inches of medium to very coarse sandstone containing mudclasts and coalified fragments. This lower 6 inches is overlain by at least 3 feet of medium to coarse sandstone exhibiting medium-scale cross-stratification.

(iii) Taroom No. 4 Core 4 (Fig. 4): No erosional breaks are recognisable in this section but its lower part resembles the top of Fig. 2 and is characterised by medium to coarse cross-bedded sandstone. Some cross-beds exhibit inclinations up to 70° indicating that they have been over-steepened - probably by mild slumping. An upwards decrease in grainsize from coarse to fine takes place over an interval of 3 feet. This in turn is overlain by silty mudstone and then carbonaceous mudstone.

(iv) Taroom No. 2 Core 2 (Fig. 5): Again an upwards decrease in grain-size is apparent. The basal 3 feet of the core is mostly coarse to very coarse, massive or cross-bedded sandstone. There follows a 3 foot interval of very fine to coarse grained sandstone, parallel laminated or cross-laminated and containing minor undulose or irregular laminae of mudstone and carbonaceous material. The succeeding 3 feet is of still finer grained material - mostly silty mudstone or shale becoming carbonaceous at the top.

(v) Taroom No. 2 Core 1 (Fig. 6): Cross-bedded and massive, coarse sandstone occupies the lower 3 feet and is overlain by about 3 feet of very fine sandstone and siltstone. Carbonaceous laminae and plant impressions are common while parallel laminae, cross-laminae and over-turned cross-laminae are present in this interval. Two feet of massive grey siltstone is then overlain by mudstone.

(vi) Taroom No. 4, Core 2 (Fig. 7): Fine to medium grained, parallel stratified sandstone with laminae of siltstone makes up the lower three feet of this core. A one-foot interval of silty sandstone containing irregular patches of sandy siltstone may have been partly churned by infauna. The overlying very fine sandy siltstone grades upwards to silty mudstone and then to massive mudstone.

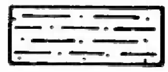
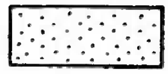
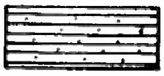
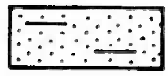
(vii) Taroom No. 4 Core 3 (Fig. 8): This core contains some of the cross-bedded sandstone typical of the lower part of the cycle, but consist mostly of silty mudstone and siltstone with some sandy horizons. Following a five-foot interval of mudstone, sandy mudstone and siltstone, there are two feet of sandy and silty sediments irregularly inter-stratified and containing carbonaceous laminae and cross-laminae. This in turn is overlain by carbonaceous silty mudstone, with plant impressions and coal bands, together with sandy siltstone.

(viii) Taroom No. 1 Core 4 (Fig. 9): In this core three feet of parallel laminated, fine to coarse grained sandstone is overlain by finely cross-laminated and interlaminated fine sandstone and mudstone. A carbonaceous mudstone interval containing plant impressions and tubular sandstone inclusions is overlain by fine sandstone and mudstone which has been partly eroded. The erosion surface near the top of the section marks the beginning of another cycle commencing with coarse sandstone at the base.

The features observed in these nine examples from the south-eastern area together provide evidence for fining upward cycles. The overall fining upwards and the associated features recognizable in the cores have been combined in Fig. 10 to show a generalized cyclothem for the Dawson Range area.

The cyclothem commences with an erosion surface overlain by poorly bedded, coarse sandstone commonly containing mudclasts, pebbles, and fragments of coalified wood. This is overlain by strongly cross-bedded, medium to very coarse grained sandstone which becomes finer grained upwards and grades into parallel laminated sandstone commonly containing undulose or irregular mudstone laminae and laminae of carbonaceous material. Then follows a sequence of cross-laminated and interlaminated fine sandstone, siltstone and mudstone. Commonly the sandstone exhibits load casting and sandstone inclusions resembling root casts or invertebrate burrows occur. This is overlain by a mudstone section containing thin sandy horizons, plant impressions and carbonaceous laminae. The mudstone is mostly laminated but massive mudstone is not uncommon.

FIGURE 1. EXPLANATION OF SYMBOLS & ABBREVIATIONS USED IN FIGS 2-9 & 13.

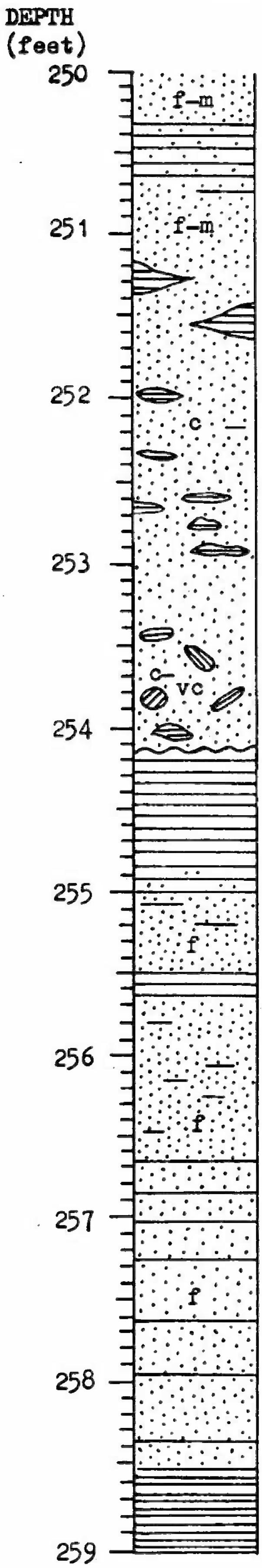
	Coal		Muddy Siltstone
	Mudstone		Sandy Siltstone
	Silty Mudstone		Sandstone
	Sandy Mudstone		Silty Sandstone
	Siltstone		Plant Fossils
			Erosion Surface

ABBREVIATIONS

abd	abundant	md	muddy
altng	alternating	Mdst	mudstone
ang	angular	Mic, mic	mica, micaceous
Bd, Bdg	bed, bedding	mnr	minor
Biot, biot	biotite, biotitic	Mtx	matrix
brn	brown	occ	occasional
c	coarse	Plt	plant
c	with	poss	possible
carb	carbonaceous	prob	probable
cht	cherty	Qz	quartz
Cl, cl	clay, clayey	Rem	remains
cntd	contorted	Sd, sd	sand, sandy
com	common	Sed	sediment
cpct	compact	sh	shaly
diff	different	sl	slightly
dk	dark	slt	silty
f	fine, finely	Sltst	siltstone
Frag	fragment	Sst	sandstone
gn, (gn)	green, greenish	Strat	strata, stratification
grdg	grading	subang	subangular
Grn	grain	subrnd	subrounded
gy	grey	Surf	surface
Imp	impression	tn	thin
Incl	inclusion	uni	uniform
intbdd	interbedded	v	very
intlamd	interlaminated	vc	very coarse
irreg	irregular	vf	very fine
Lam, lamd	laminae, laminated	volc	volcanic
Len	lens	vrtl	vertical
li	lithic	wh	white
lt	light	wthrd	weathered
m	medium	Xbdg	cross-bedding
mass	massive	Xlam	cross-laminae
max	maximum	xlamd	cross-laminated

F55/A/132

FIGURE 2. **BARALABA No.1 - Core 3**



li-Qz.

sd, gy; c̄ some f-m Qz Sd;
grdg downwards to

li-Qz; c̄ Len of gy sd Mdst, mnr carb material.

li-Qz; c̄ Mdst Clast & Len.

li-Qz; c̄ Mdst Clast up to 4cm.

Erosion Surf.

gy.

grdg downwards to

slt, li-Qz.

grdg downwards to

li-Qz; c̄ undulose Mdst Lam. Strat at 10°-30°.

gy to dk gy;
carb at base.

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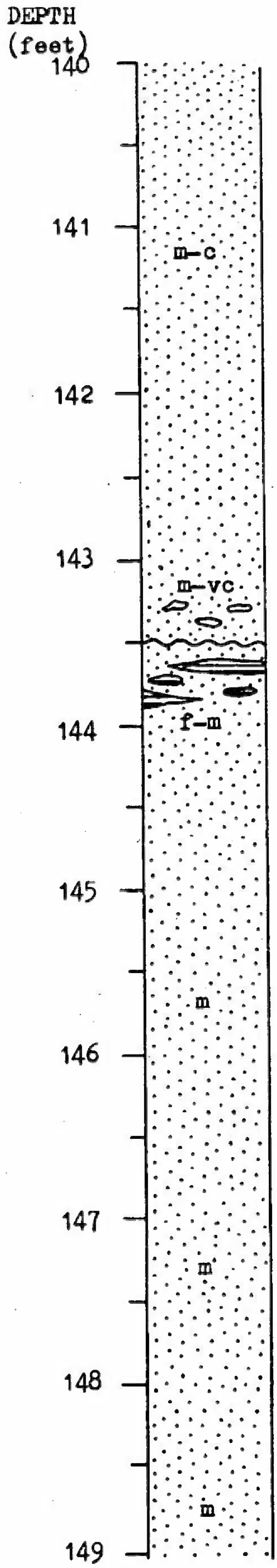
FIGURE 3.   BARALABA No.1 - Core 2.

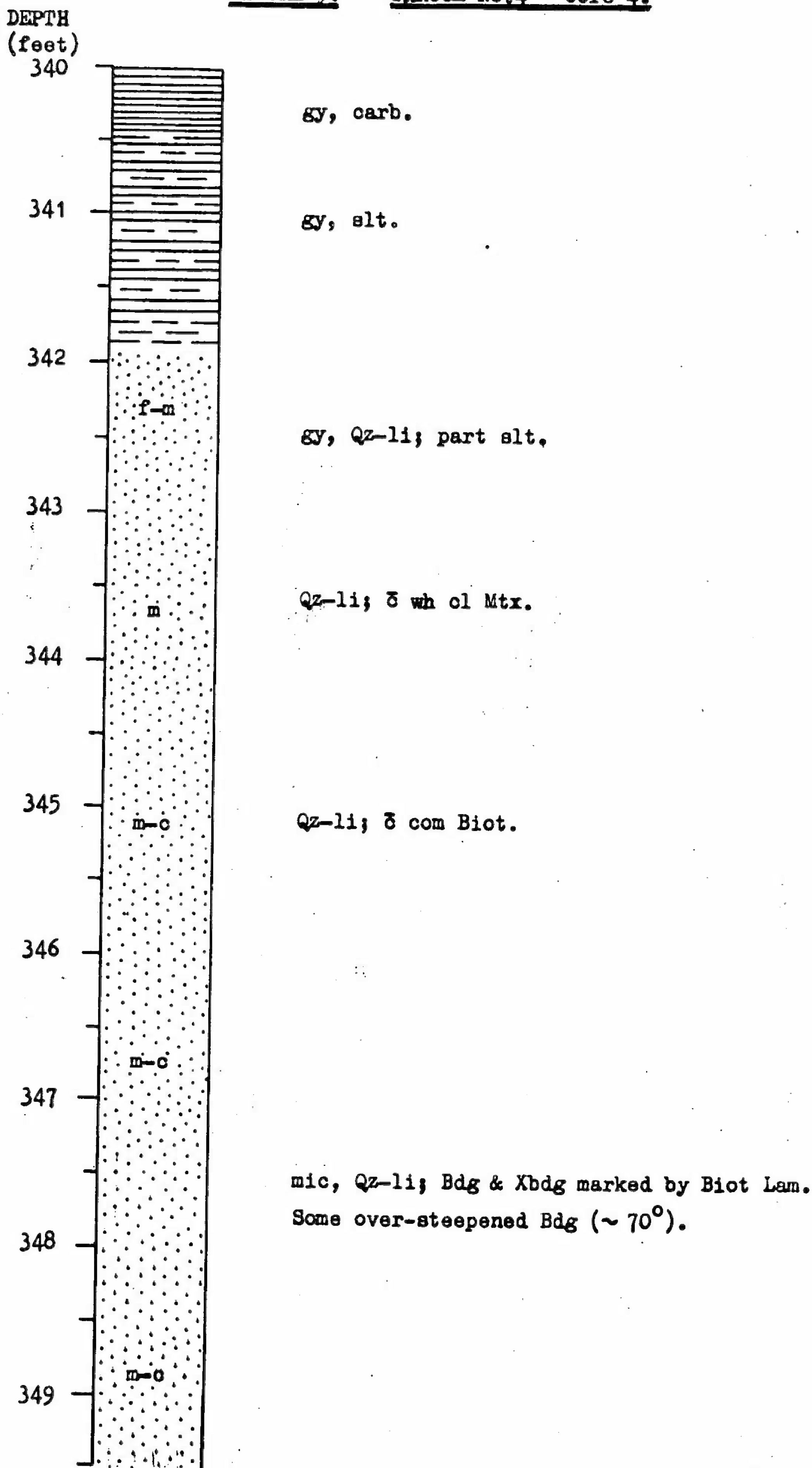


firm, gy, li-Qz; c̄ wh to lt gy Cl Mtx.
Bdg angle variable, max 30°, prob Xbdg.
Biot aligned with Strat.

biot; c̄ carb Frag & Mdst Clast to 1.5cm.
Strat dip 12°, Biot aligned c̄ Strat.
Erosion Surf.
slt; c̄ Mdst Len cpct.

li-Qz to Qz-li.

FIGURE 4. TAROOM No.4 - Core 4.



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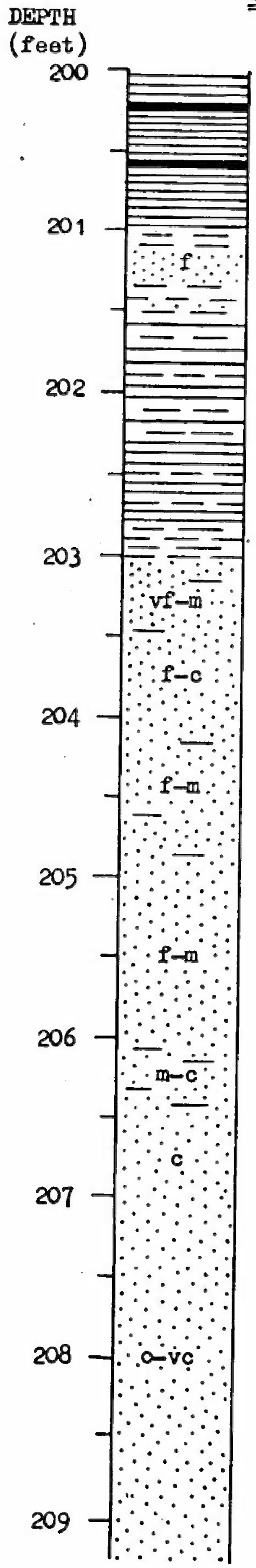
TAROOM No.2 - Core 2.



dk gy, carb; tn 0-2cm coal seams.

gy, sh; & mnr li-Qz Sst.
Few tn, carb, undulose, Mdst Lam.

gy, slt
grdg downwards to
slt.

li-Qz; parts slt; c̄ 1.5cm m Sst band.

gn gy, Qz-li; c̄ com Biot. wh cl Mtx & wh li Grn.

Qz-li; c̄ subang to ang Grn. Strat dip up to 30°.
Some tn, dk Lam of carb material & ? Biot.

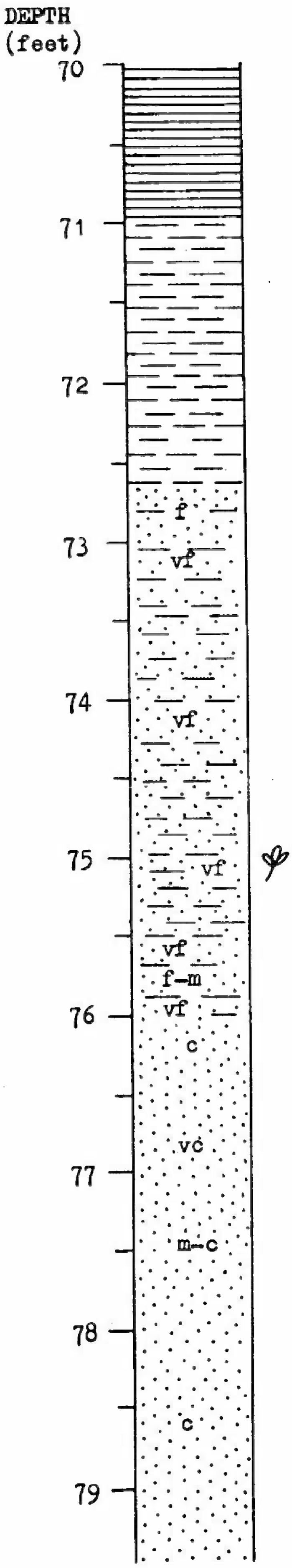
As above c̄ irreg gy Mdst Lam.

Qz-li; c̄ wh cl Mtx & sd Sltst Lam.
poss load casts between Sst & Sltst.

Qz-li; c̄ ang Grn & wh cl Mtx. Some carb Sltst
Lam. Xbdg at 25°-30°.

Qz-li; c̄ ang Grn & wh cl Mtx. Some dk Biot-rich
Lam mark Xbdg at 25°-30°.

FIGURE 6. TAROOM No.2 - Core 1.



lt gy, sh & brn wthrd.

gy, sl sh.

gy, uni, mass.

li-Qz; c̄ mic, carb Lam & gy Sltst Lam.
Sharp breaks between Sltst & Sst ? erosional.

lamd & xlamd, li-Qz; & gy Sltst.

v tn (0.3-2.5mm), lamd; mnr Xlam & overturned
Xlam. Dip 5°-7°.

Few carb Lam.

Qz-li; c̄ com carb Lam 0.3-2.5mm.

Qz-li; c̄ wh cl Mtx, abd gn & gy li Grn.

Grn up to 5mm.

Xbdg at 20°. 1.5-8cm bands altng m-c & vc Sst.
com gn & gy li Grn, some volc Grn.

Qz-li; c̄ abd wh cl Mtx & com Mic. Qz Grn
subrndd to ang.

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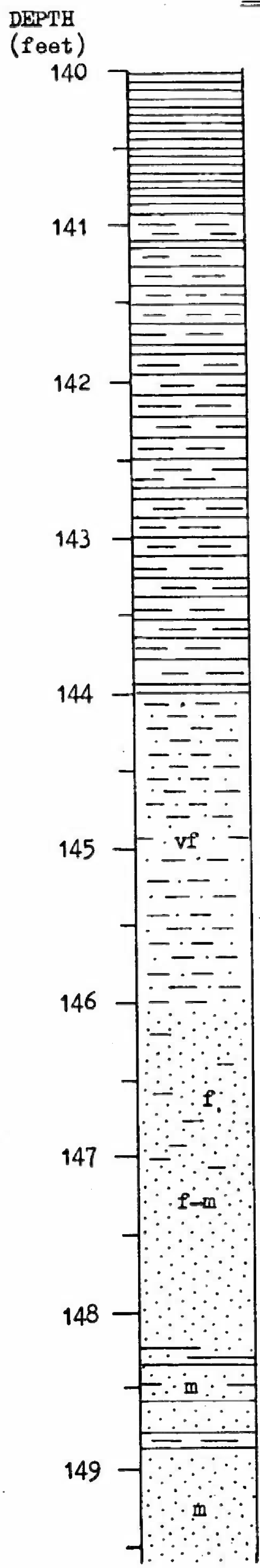
FIGURE 7. TAROOM No.4 - Core 2.



gy, mass.

gy, slt.

gy, sd.

gy, slt; c̄ com Mic.
mnr patches sd Sltst.

(gn) gy; c̄ gy slt Mtx.

mic Qz-li; mic Lam c̄ tn Bd & Lam of
gy, vf, sd Sltst.

(gn) gy, Qz-li; com dk mic Lam.

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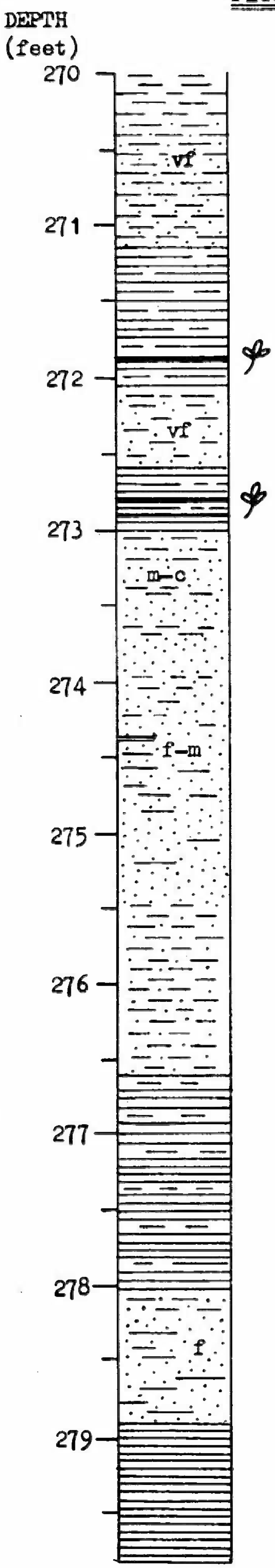
FIGURE 8. TAROOM No.4 - Core 3.



dk gy, carb.

gy, sd; Lam lt gy, vf Sst.

gy, slt.

carb, slt; c̄ tn coal seams.
sd.

gy, sd; c̄ com irreg Lam vf Sst.

carb, slt; c̄ tn coal seams.
sd.

Qz-li; irreg intbdd c̄ gy sd Sltst;
some Len Sltst & carb coaly Lam.

v tn, undulose, intlamd sd Sltst, lt gy slt
Sst & coal.

Qz-li; c̄ wh cl Mtx. Xlam of carb Sltst
& coal stringers.

gy, & lamd, gy, sd.

gy, slt.

brn, v sd Sltst grdg to md Sst.

gy-brn.

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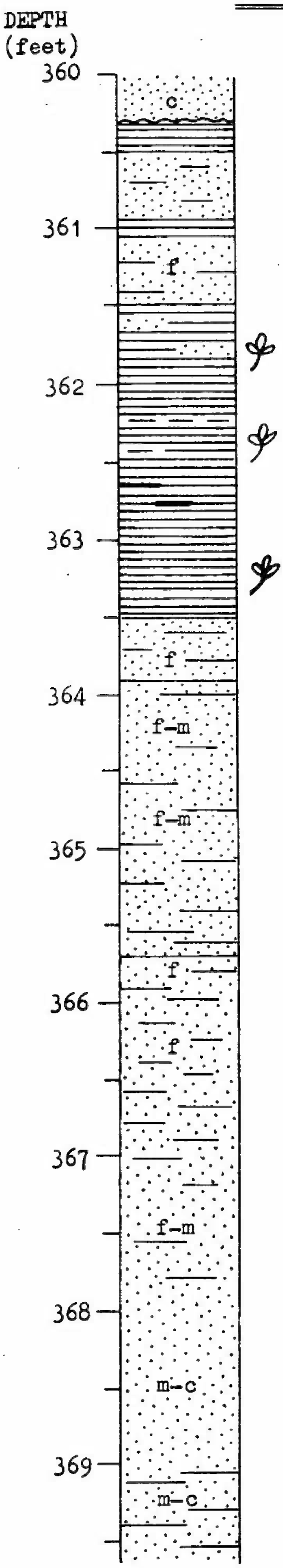
FIGURE 9. TAROOM No.1 - Core 4.

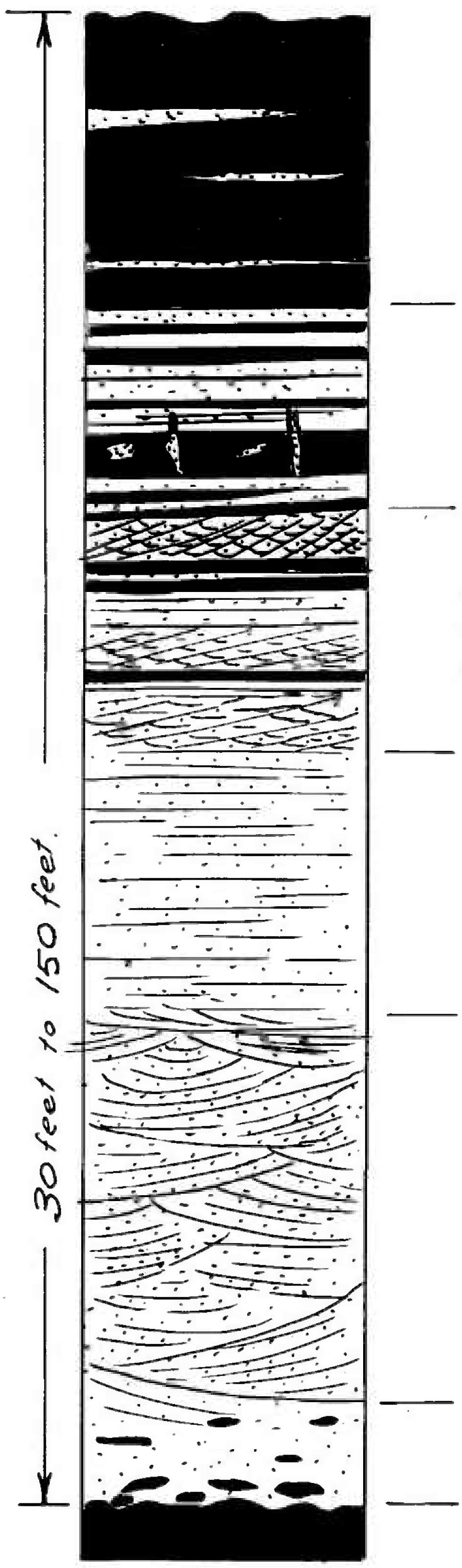


(gn), Qz-li.
Erosion Surf.
gy; part sd.
firm, gy, slt, Qz-li.
dk gy, v sd, carb; grdg downwards to slt; c̄ carb Lam.
firm, carb; c̄ Sst Incl, occ tubular; coalified Plt Rem.
dk gy, firm, carb; part sh; abd Plt Imp.
lt gy, "cht"; some Plt Imp.
li-Qz; intlamd c̄ gy Mdst; intricate Xlam.
Qz-li; c̄ mnr carb Lam.
xlamd Qz-li; c̄ intlamd Mdst, part carb.
xlamd gy Mdst & li-Qz Sst. Intricate pattern.
firm, (gn), li-Qz; c̄ carb Mdst Lam. Some Xlam c̄ Lam 2.5-12.5mm apart. Biot flakes on Bdg. Lam dip 5°-10°.
li-Qz; f lamd but Sst uni Grn. Parallel Lam caused by lt, v tn (1mm) cl bands. Dip 10°.
Qz-li; Grn mostly ang; contains gn-gy li Grn.
Qz-li as above; parallel Lam caused by tn carb bands. Dip 10°.

To accompany Record No. 1970/25.

Figure 10

GENERALIZED CYCLOTHEM COMPILED FROM DRILLING IN DAWSON RANGE AREA



Laminated or massive mudstone, siltstone, sandy mudstone. Few fine sandstone beds, lenses. Mudstone commonly contains thin coal laminae and plant impressions.

Mudstone, siltstone and fine sandstone in discrete laminae or beds, or partially mixed. Mudstone contains sandstone inclusions and vertical tubes (?burrows). Few load cast structures.

Ripple laminated fine sandstone and siltstone interbedded with parallel laminated fine sandstone, siltstone and mudstone. Plant impressions and carbonaceous material common.

Parallel laminated fine to coarse grained sandstone. Contains few mudstone laminae

Cross-bedded medium to very coarse grained sandstone. Well sorted but grainsize layering common

Poorly bedded medium to very coarse grained sandstone with mudclasts

Eroded surface - usually on mudstone or siltstone.

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The cycles recognizable in these sediments closely resemble the vertical profiles of the fluviatile or valley-fill model described by Visher (1965).

DRILLING - NORTHERN AREA

In the northern part of the basin two holes were drilled to over 300 feet in the Moolayember Formation on Redcliffe Vale Station (Figs. 11 & 12). Here the formation is very thin (300 feet) and both wells (Mt Coolon Nos 2 and 3) penetrated the underlying Clematis Sandstone.

OBSERVATIONS

1. Correlation and Lower Boundary

As the only horizon clearly recognisable in both wells is the Clematis - Moolayember boundary it has been used as a basis for correlating the holes. The boundary is taken at the top of the thick, almost continuous sandstone sequence typical of Clematis Sandstone. Quartz content of the sandstone drops from 70% to 50% up the section towards this boundary. In outcrop the boundary is not as distinct as in the subsurface. This is due in part to the gradual increase in lithic content towards the top of the Clematis so that the weathered appearance of the upper part of the Clematis Sandstone is indistinguishable from sandstone of the Moolayember Formation. The lowermost mudstone was used as the base of the Moolayember Formation in the wells, but mudstone is rarely seen in outcrop.

2. Sand - Shale Ratio

Although the two holes are at about the same stratigraphic level, the sand - shale ratios differ markedly, emphasizing the lateral facies changes which characterize these sediments. The ratio of sand to shale in Mount Coolon No. 2 is 1.2 whereas in Mount Coolon No. 3 the ratio is 0.3.

3. Cyclicity

Although the cyclothems are not as well developed, a similar cyclicity of sediments to that seen in the Dawson Range section is recognizable in this part of the Moolayember Formation.

Mount Coolon No. 3 core 3 (Fig. 13) shows several of the features already described from cores in south-eastern area. The lower seven feet is regarded as part of the upper portion of a cyclothem, where the sediments commence with finely interlaminated and cross-laminated siltstone and sandstone containing vertical tubes (possibly invertebrate burrows). This is overlain by siltstone and silty mudstone which contains carbonaceous stringers and plant impressions.

No marked erosional break is apparent at the top of this sequence but there is a sharp change to the overlying medium grained sandstone. This marks the beginning of another, smaller fining upwards cycle.

DETAILED FIELD STUDIES IN CARNARVON RANGE AREA

PURPOSE

The purpose of detailed field study in the Carnarvon Range area was to gain as much information as possible from a small but well exposed area of the formation and then to use this data to reconstruct the geological history and palaeoevironment of the formation in that area. The conclusions drawn could then be extrapolated - although with less confidence - to the formation as a whole.

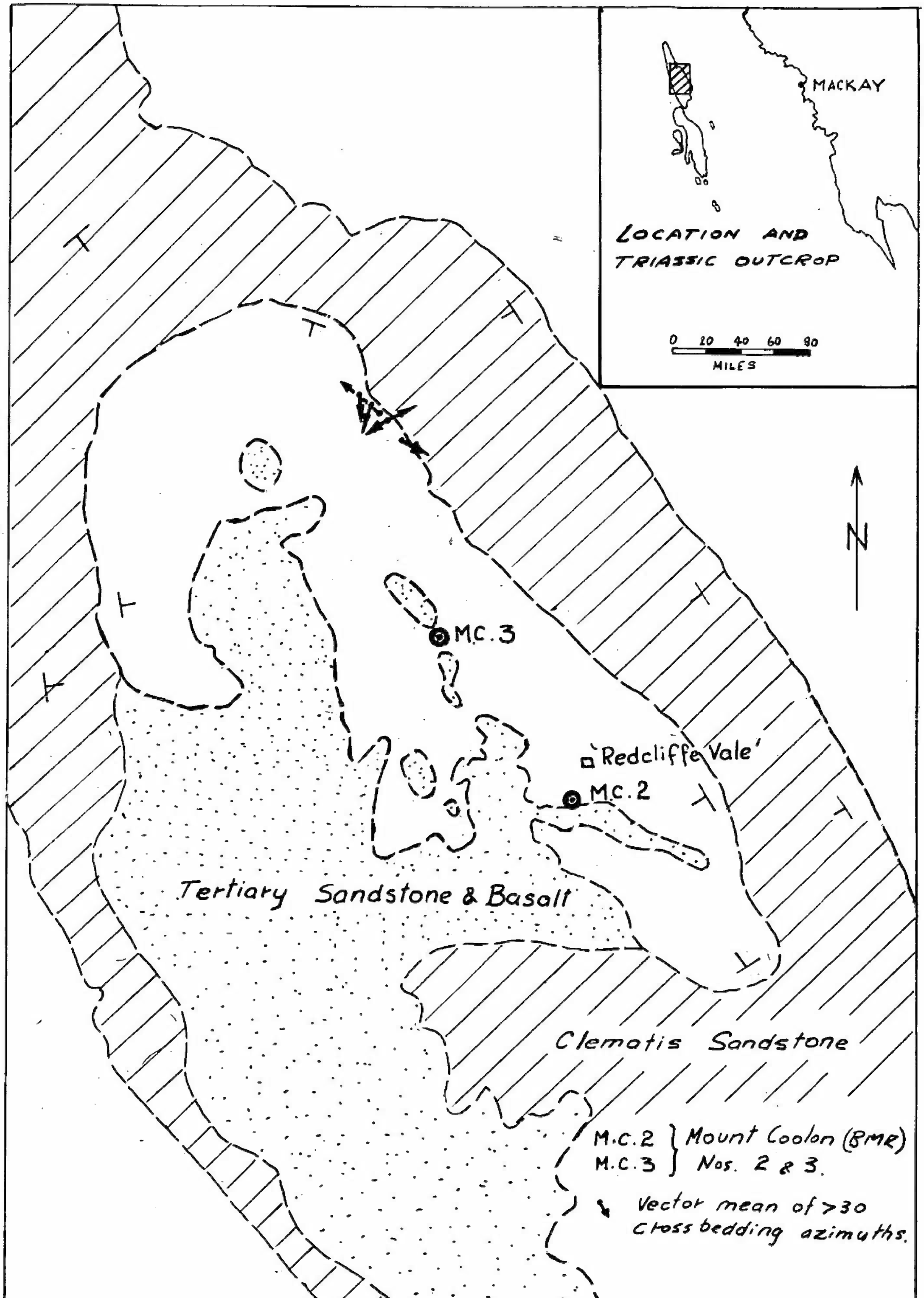

Figure 11 MOOLAYEMBER FM. - NORTHERN AREA
Showing area of outcrop, location of drill holes
and azimuths of crossbedding

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DRILLING RESULTS IN MOOLAYEMBER FORMATION

NORTHERN AREA

FIGURE 12

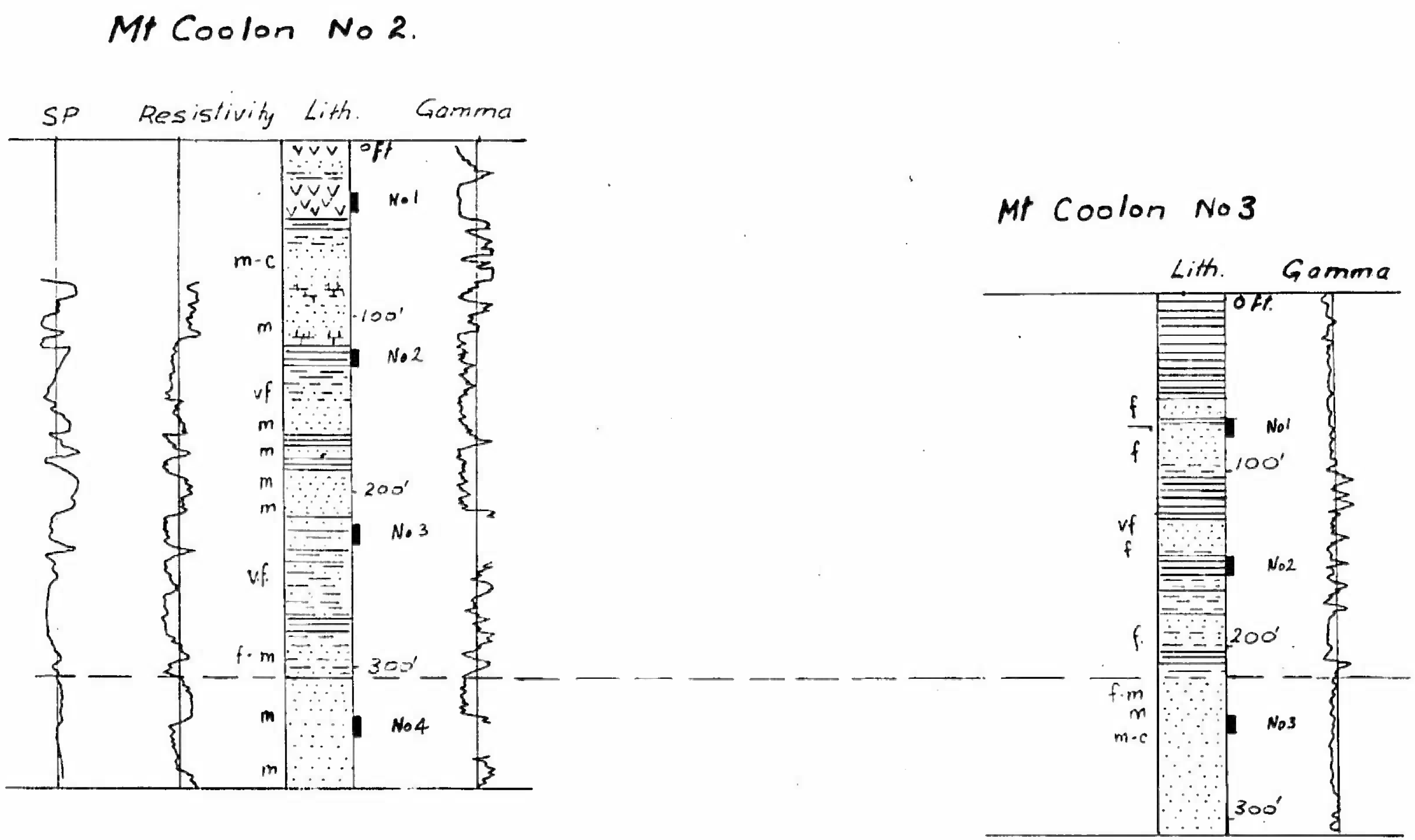

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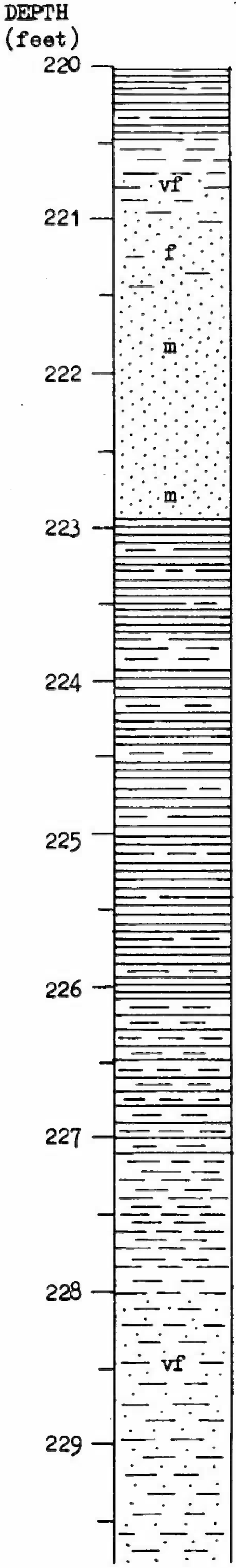
FIGURE 13. MOUNT COOLON No.3 - Core 3.



gy, slt.

sd; grdg downwards to

slt, Qz-li.

li to Qz-li; firm, (gn) gy; wh Mtx.

gy; part slt, part sh.

gy, slt; com slickensided Surf at high angles.

gy, slt; c̄ occ carb stringers.

gy.

gy; lamd & intlamd c̄ vf Sst.

gy, f intlamd & xlamd; cntd Lam; some overturned Xlam; some vrtl tubes of diff Sed.

To accompany Record No. 1970/25.

PROCEDURES

1. Unit Subdivision

The three fold subdivision of the Moolayember Formation in the Carnarvon Range Area (Alcock, 1969) has been revised in this report. Only two units are now recognized and they have been designated C1 and C2. Unit C1 is equivalent to the 1969 definition and is a predominantly sandy unit consisting of well bedded, quartz-lithic and lithic-quartz sandstone along with siltstone and fine silty sandstone. It is approximately 460 feet thick and is the basal unit of the Moolayember Formation in this area. Unit C1 is overlain by Unit C2 (1200 ft.) which comprises Units C2 and C3 of the 1969 classification. Unit C2 contains thick bedded, cross-bedded lithic sandstone, thin to medium bedded quartz-lithic sandstone and mudstone at the base and is overlain by a sequence of mudstone with rare lithic sandstone beds and lenses.

2. Measured Sections: Small detailed sections were measured where outcrop was virtually continuous and plotted at $2\frac{1}{2}$ feet = 1 inch. Two-dimensional sections were drawn where a near-vertical, relatively flat rock face was available, and conventional columnar sections were plotted where such a section was not available.

3. Cross-Stratification: Current directions, as indicated by cross-stratification, were obtained both from beds within measured sections and from isolated outcrops. About 2000 measurements were made in this area. The readings were corrected for regional tilt and resultant vectors for each group of readings computed electronically. The programme (DIRECTN) used the basic data as measured in the field. It corrects for regional tilt and prints out results for each group of readings measured. The allocation of data to the columns on the data card is as follows:

Columns 12 to 20, field location of reading
Columns 31 to 35, unit or group of beds at this locality
Columns 36 to 40, individual bed at the same locality
Columns 55 and 56, tectonic dip
Columns 60 to 62, azimuth of tectonic dip

Columns 67 to 68, dip of cross-strata
Columns 72 to 74, azimuth of dip of cross-strata

For each group of readings specified, the following results are obtained:

1. Azimuth of the resultant vector
2. Magnitude of the resultant vector (measure of the consistency of direction)
3. Rayleigh probability of randomness
4. Standard deviation about the azimuth
5. Frequency distributions of all the corrected azimuths grouped in 10° intervals and expressed as a percentage
6. The number of readings in each group.

However, the results can only be obtained for one type of group at a time. So that to obtain results of readings grouped according to localities, the cards would be run once. To determine results grouped according to units at each locality the cards would be run again, and to find results of readings from individual beds within those units or localities the cards would need to be run a third time.

DIRECTN was developed by Quinlan (pers. comm.) from a scheme outlined by Curray (1956) on the analysis of orientation data.

4. <u>Study of Miscellaneous Sedimentary Structures</u>:

Ripple marks and other sedimentary structures of environmental significance were examined and where practicable measured.

OBSERVATIONS AND INTERPRETATIONS OF MEASURED SECTIONS

1. <u>Sections in Unit C1</u>

(i) <u>Section DA43</u> (Fig. 15).

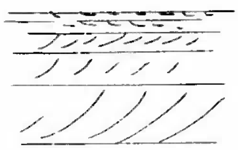
Section DA43 was measured at Spring Creek in Unit C1 and represents about 15 feet of section which extends along strike for 210 feet.

EXPLANATION OF SYMBOLS USED IN MEASURED SECTIONS

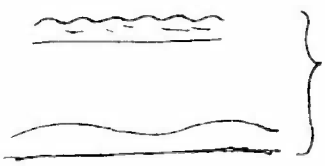
Figure 14

SEDIMENT SYMBOLS

Denotes relative thickness of stratification



Denotes relative scale of cross-stratification.



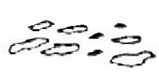
Rippled beds

Clay
Silt
V.F.
f
m
c
V.c

Denotes **modal grainsize**

symbols commonly used in combination eg. clay-silt, f-m, m-c.

Pebbles

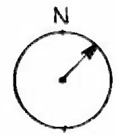


Mudclasts

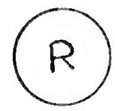
Subvertical tubular structures (burrows or roots)

Erosion surface

CROSS STRATIFICATION SYMBOLS

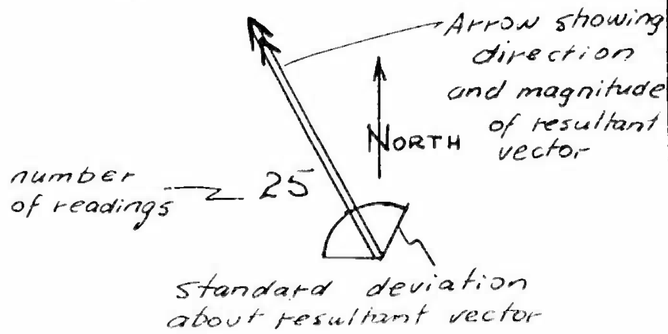


Vector mean of readings taken from single bed

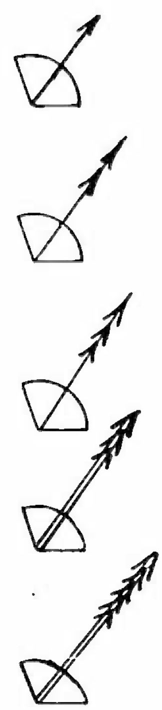


Random distribution of readings

Data from group of beds or whole section



Relative Scales of magnitude (magnitude ≡ measure of consistency of direction of readings)



very low

Low

Medium

High

Very high

FIGURE 15

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The two main elements of the section are the poorly bedded sediments at the north-west end (sub-section I) and the well bedded sediments forming the remainder. At the north-west end the sediments exhibit the following characteristics:

(a) a strongly eroded surface cut in thinly interbedded, fine sandstone and siltstone:

(b) poorly bedded sandstone, with mudclasts at the base, overlying this erosion surface;

(c) three relatively thick, poorly bedded sandstone units, themselves partly separated by erosion surfaces;

(d) a broad shallow trough in these sandstone units trending east-west;

(e) small-scale cross-strata towards the tops of the units, although the bulk of the sandstone is very poorly cross-bedded.

The remainder of the section differs markedly from that at the north-west end. It is largely composed of well bedded, fine to medium grained sandstone and laminated, and cross-laminated siltstone. Fig. 16 shows the contrast which is evident between the strongly outcropping sandstone and the less resistant siltstone. However, the two lithologies occur as related pairs of beds. The pair commences with flat bedded sandstone resting on a flat siltstone surface. This basal contact is usually sharp but non-erosional. The sandstone is poorly cross-stratified except towards the top where small-scale cross-strata culminate in rippled bedding surfaces. This sandstone bed grades upwards to siltstone and mudstone which, although finely laminated in parts (laminae 0.01"), contain current structures in the form of micro-cross laminae and lenses of very fine sandstone up to $\frac{1}{2}$ inch thick showing cross-lamination. None of the laminated sediments examined shows graded bedding but grainsize layering occurs. Carbonaceous plant fragments are common on stratification planes in the finer sediments.

The lower members of this well bedded sequence show a draped relationship with the top of the poorly bedded sandstone described above, but there has apparently been no erosion to produce the sandstone hummock over which draping has taken place.

Another feature of these sediments is the presence of erosion surfaces usually cut in sandstone and overlain by finer grained material.

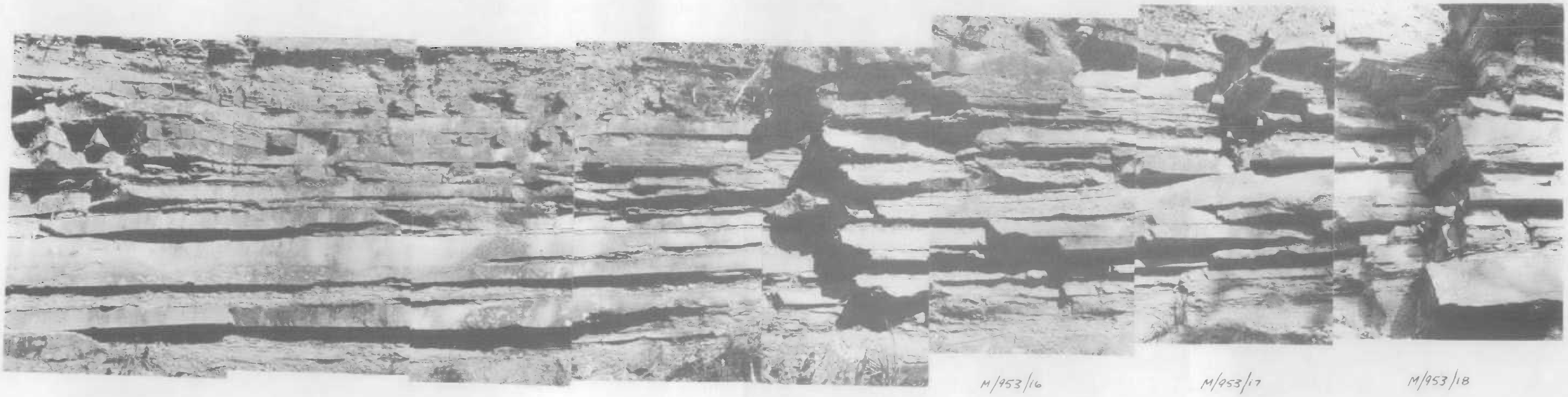
An overall decrease in grainsize and bed thickness is apparent upwards through the section. The top unit consists of a fairly extensive, thinly interbedded, very fine to fine sandstone and siltstone where undulose lamination and small-scale cross-lamination is common.

Some features of the cross-stratification azimuths are noteworthy. Whereas a strong north-west element is evident for the overall current direction, closer examination shows a swing in direction of current movement from westerly in the lower part to northerly in the upper part of the section.

Another feature is the occurrence of northerly and southerly resultant vectors from the same bed in sub-section III and V. Adjacent parts of these beds show diverse current directions but have resultant vectors of weak magnitude in a direction at right angles to the bimodal directions. Collectively these features imply current movement in diverse, and at times opposite directions, during deposition of a single bed. Each circle on the section represents about 10 readings within the indicated interval over a strike distance of 30 feet.

Interpretation of Section DA43: At subsection I, the presence of a strongly eroded profile overlain by sandstone with mudclasts and thin, poorly bedded, cross-stratified sandstone in trough-shaped units provides evidence of deposition in moving water, probably confined at least in part to a channel. In the remainder of the section the regular interbedding of flat continuous beds of sandstone and siltstone point to

FIGURE 16 - COMPOSITE PHOTOGRAPH OF PART OF SECTION DA43
SHOWING REGULAR INTERBEDDING OF SANDSTONE & SILTSTONE



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periodic variation of the energy of the depositing current in a large body of water. This may be the result of tidal influences in an estuary, particularly as the opposing current direction from single beds are most readily explained in terms of flood and ebb tidal currents.

An alternative explanation of current bimodality, however, lies in the formation of longitudinal bars in a fluvial system and the subsequent movement of both current and sediment down opposite slip-off faces of the bar. The resulting current structures would exhibit bimodality with a bias in the downcurrent direction.

(ii) <u>Section DJ</u> (Fig. 17)

Section DJ is one of five sections measured in a small area of relatively good outcrop near "The Basin" homestead in unit C1.

At the base of the section rippled beds of coarse quartz sandstone are separated in part by thin mudstone beds which fill ripple troughs and thin or pinch out at ripple crests . Above an 8 foot interval without outcrop a second sandstone unit occurs which is characterized by the presence of two distinct sandstone types and the gradation from one to the other. Medium to coarse, clean, quartz sandstone (quartz 90%) with some mudclasts at the base gives way to beds consisting of fine to medium, lithic, quartz sandstone (quartz 75%) with silty clay matrix. The transition between the two types contains both lithologies. The finest quartz sandstone and the coarsest silty, lithic, quartz sandstone have a medium sand size mode and each retains its identify at this grainsize. This suggests that the two sandstones are not merely products of sorting.

The remainder of the section is made up of cross-laminated, fine to medium lithic quartz sandstone with ripple marked bedding surfaces interbedded with laminated and cross-laminated siltstone commonly containing plant fragments. This top 15 feet of section closely resembles part of section DA43 13 miles to the north-west.

Interpretation at Section DJ. The large-scale symmetrical ripples of coarse sandstone at the base of the section are probably indicative of the upper part of the upper flow regime where standing waves develop. Harms and Fahnstock (1965) describe examples from the Rio Grande in areas of shallow water (less than 1 foot) where standing waves of both bed and water form at high water velocities. Alternatively they could be wave formed ripples. These structures will be dealt with further in a later section.

Higher in the section the association of two distinct sandstone types implies introduction of sediment to the deposition site from two different sources but processes were such that mixing of sediment did not take place.

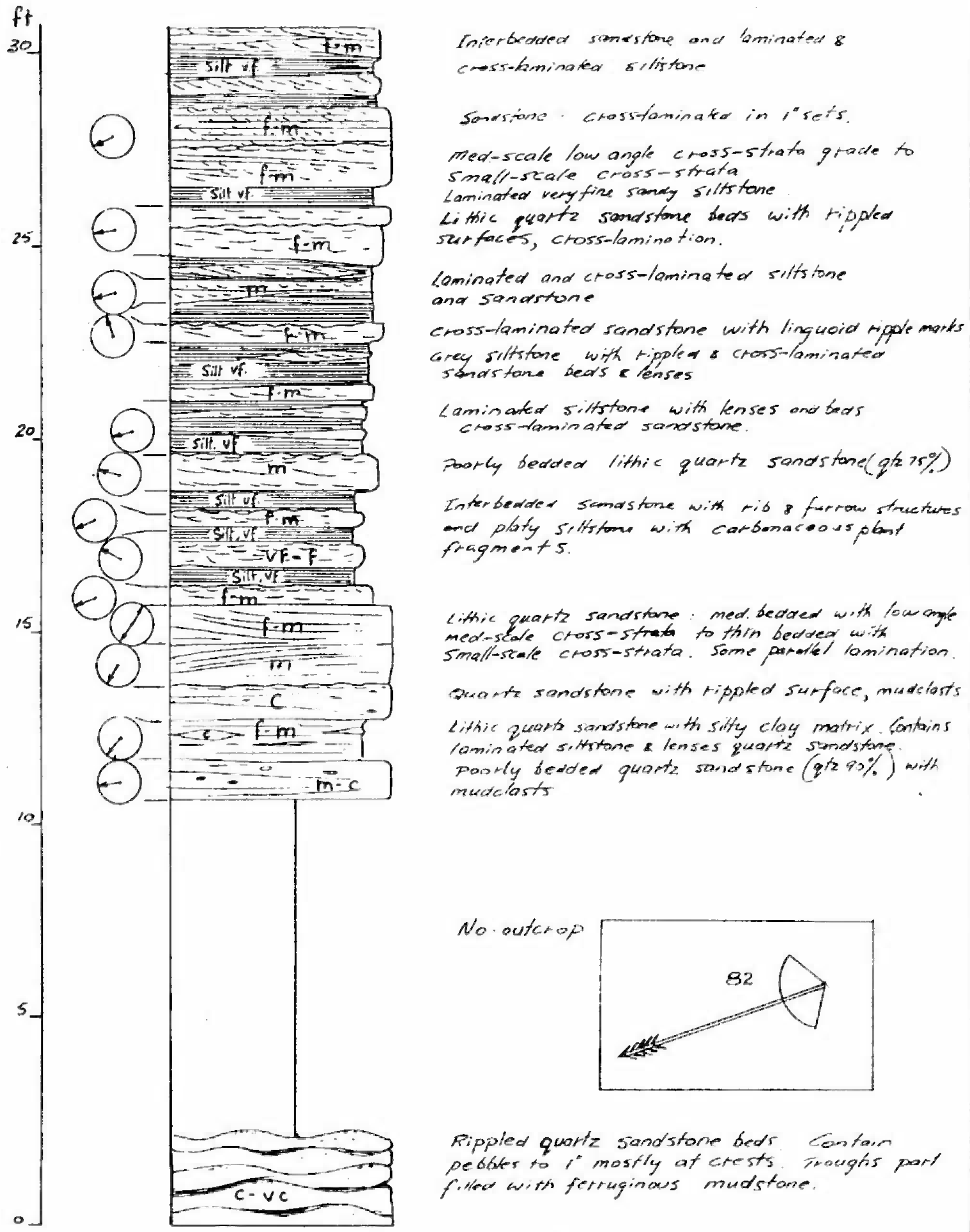
It is unlikely that the two lithologies are purely a result of differential sorting because where the quartz sandstone is medium grained it is still higher in quartz and lower in silt content than the lithic quartz sandstone of similar grainsize. Most deposition in this interval took place in the transitional and upper flow regimes.

The upper 15 feet of the section accumulated under flow conditions ranging from tranquil to lower regime and in parts to transitional flow regime. The cross-laminated sandstone with current ripple marks formed where bed load deposition was dominant while the laminated, silty sediments were deposited largely from suspended load. Cross-stratification measurements indicate a strong overall direction of water movement towards the west-south-west. Results from individual beds indicate a change from dominantly south-west in the lower part to mainly westward higher in the section. As in section DA43, a bimodal distribution for readings from a single bed indicates two directions of current flow.

The evidence at section DJ indicates intermittent shoaling at the base with high water velocities. This was followed by increasing water depth and introduction of sediment from two sources of supply in

SECTION DJ

Figure 17



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such a manner that mixing was minimal. This could take place in an estuary where sediment was being derived from nearby beaches as well as from the river. In an estuarine setting, current reversals would be recorded and high water velocities would be attained in shallow channels.

(iii) Section DK (Fig. 18)

Variation of stratification types is much greater than in either of the previous sections. The 3 columnar sections at DK represent a strike length of 135 feet but beds generally do not continue for even half this distance. Variability extends to the shapes of sedimentary units, the sediment types present and the current directions inferred. Units 5 to 10 feet thick are recognisable although poorly defined in some parts.

Treating the three sections together, Fig. 18 shows that a laminated, carbonaceous, silty mudstone or very fine, silty sandstone is overlain, apparently without any erosional break, by a dominantly sandstone unit 6 to 10 feet thick. This unit is made up of sandstone lenses separated by minor erosion surfaces or by laminated siltstone or sandstone. Mudclasts are common and coarse, quartz sandstone beds occur.

A dominantly silty mudstone unit at DK1 is the continuation of an interval of interbedded sandstone and mudstone at DK2. The upper boundary of the silty mudstone at DK1 is marked by contorted overturned laminae and a partially eroded profile. The intraformational breccia (Fig. 19) which overlies this boundary extends laterally for at least 100 feet before becoming obscured and it represents the most continuous sedimentary unit in the area. It differs from the common sandstone-with-mudclasts lithology (e.g. Fig. 20) in its greater thickness, much greater lateral extent and greater size of clasts.

Many of the sandstone beds in the middle and upper part of the sections are laminated and cross-laminated in grouped, small-scale sets such as fig. 21. Here climbing sets of cross-laminae form ripple-drift cross-lamination.

Interpretation at Section DK The sharp changes in lithology with relatively few erosion surfaces implies rapid changes in flow conditions. The flow varied from the upper flow regime represented by parallel laminated sandstone commonly with mudclasts to tranquil flow represented by the parallel laminated to micro-cross-laminated silty mudstone.

The intraformational breccia at DK1 is distinctive but may be simply a larger-scale example of the sandstone with mudclasts lithology which is common in the area. However, the presence of tabular clasts up to two feet across implies that the mudstone was well consolidated before being broken up and not, as is usually the case, dried out mudclasts which have been redeposited. Furthermore its lateral extent is much greater than most units in the area so the possibility of it being a shoreline feature must be considered.

Ripple-drift cross-laminae probably indicate combined deposition from bed load and suspended load in the lower flow regime.

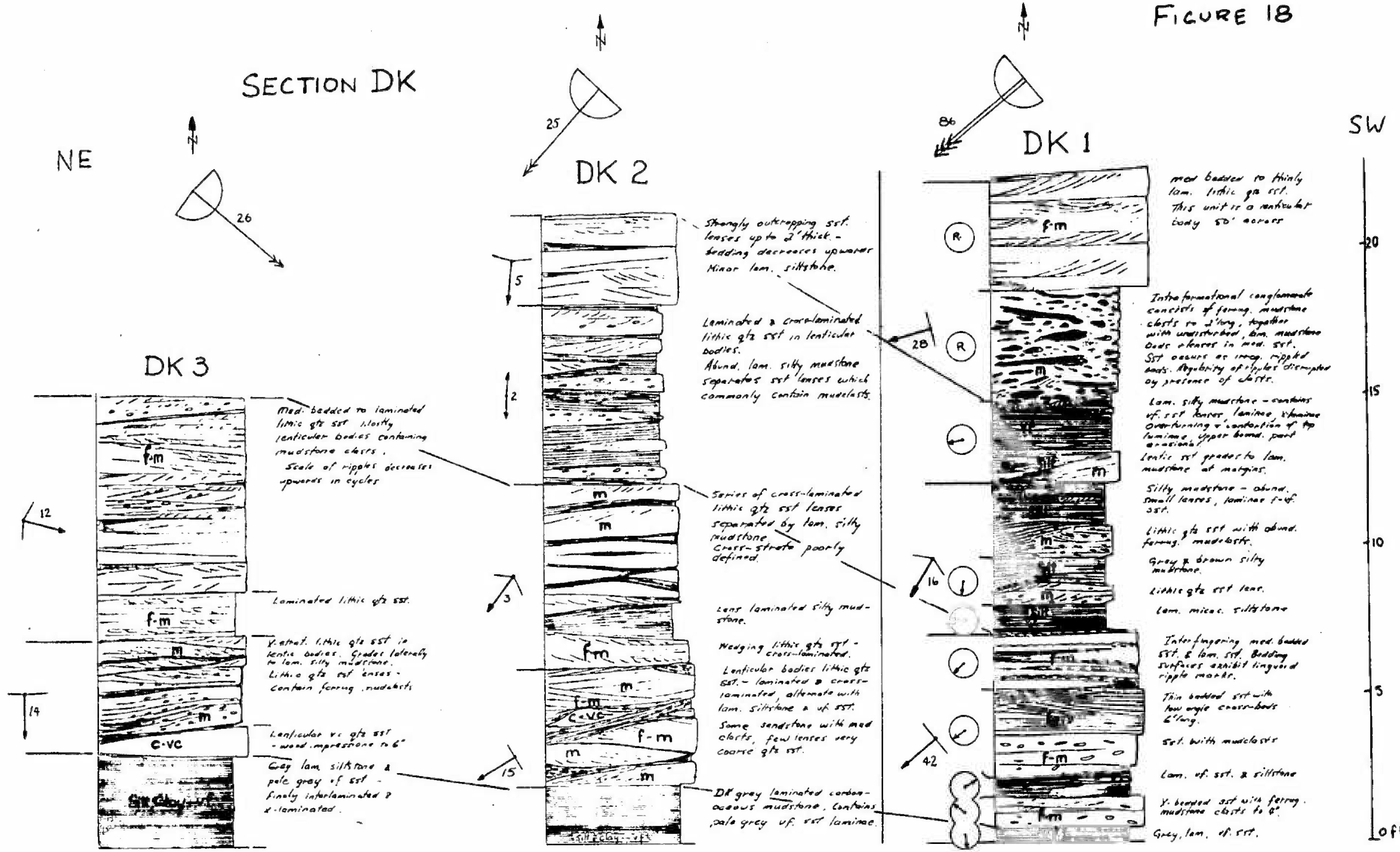
The rapid changes in flow conditions would be compatible with part of an estuarine setting possibly with major sediment contributions from the river and the estuary mouth. The intraformational conglomerate may be a channel lag deposit but also may have formed at a shoreline.

(iv) Section DL3 (Fig. 23)

This two-dimensional section exhibits two marked erosion surfaces which can be traced for the length of the section.

The sediments are made up mainly of parallel laminated and cross-laminated, fine to medium sandstone and siltstone. Fig. 22 illustrates some of these finely stratified deposits which were largely

FIGURE 18



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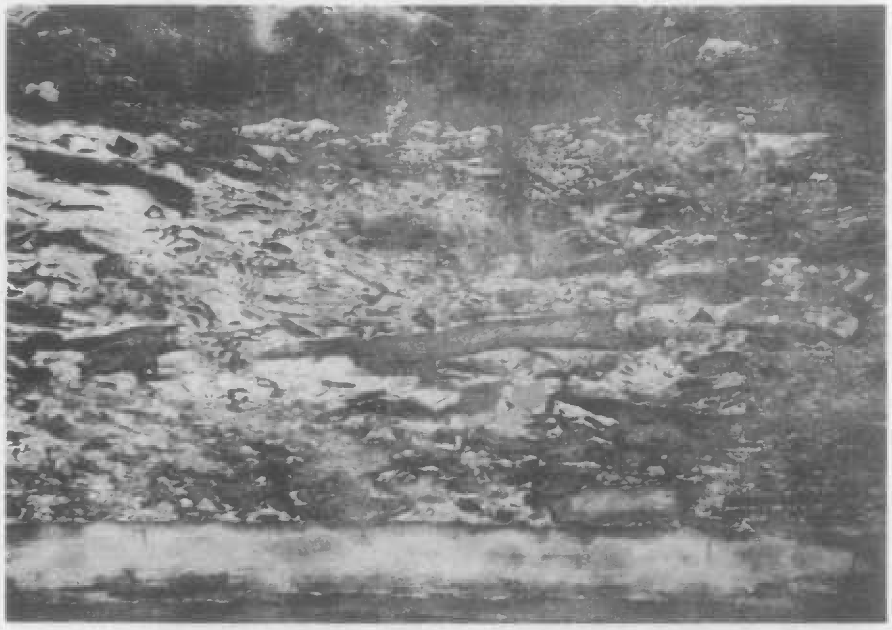


Figure 19 : Intraformational breccia in section DK, Basin Creek. Laminated mudclasts in matrix of fine to medium sandstone overlie laminated mudstone with small sandstone lenses. Neg. No. GA/2562/1

Figure 20 : Laminated sandstone and siltstone with mudclasts at Paradise, Dawson River. Ferruginous mudclasts occur in discrete bands. Typical of channel lag deposits. Neg. No. M/953/23

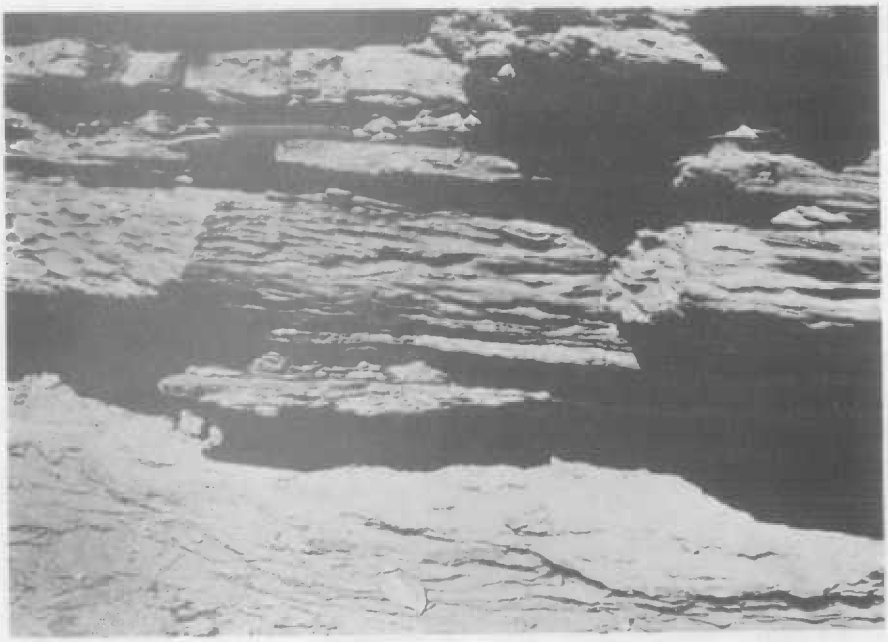


Figure 21 : Small-scale grouped cross-strata in sandstone beds at section DK, Basin Creek. Ripple-drift cross-laminae occur in places. Less resistant interbeds composed of silty mudstone.

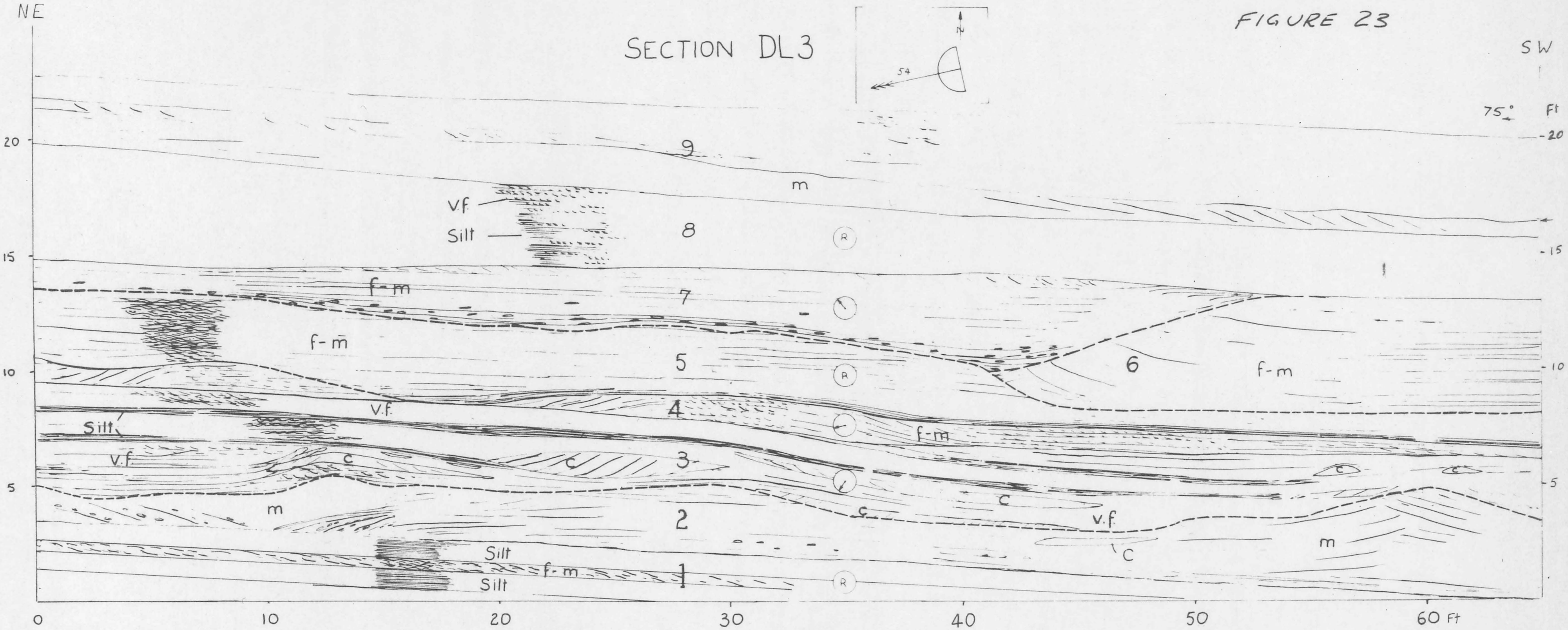
Neg. No. M/933/12

Figure 22 : Finely laminated sediment at section DL3, Basin Creek. Light-coloured, cross-laminated, very fine sandstone and darker-coloured, laminated, silty, carbonaceous mudstone. Some coarse sandstone lenses occur within mudstone at the base.

Neg. No. M/947/27

FIGURE 23

SECTION DL3



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a product of deposition in the lower flow regime. However, immediately above the two main erosion surfaces, lenses of coarse, cross-stratified sandstone or parallel laminated sandstone with mudclasts indicate the former presence of occasional higher velocity currents. In each case current velocities diminish upwards.

Interpretation at Section DL3 The finely stratified and cross-stratified sandstone and siltstone in planar continuous beds is suggestive of deposition in a fairly extensive body of water with low velocity currents operating. As silty cross-laminae are interspersed with sandstone cross-laminae, deposition from both bed load (lower flow regime) and suspended load probably took place concurrently.

However, the two major erosion surfaces overlain by coarse clastic material are compatible with lateral channel erosion and deposition such as occurs in alluvial valleys, but thick, cross-bedded sandstones which characterize alluvial deposits are not present in this area. Accumulation in an estuary would explain the features observed in DL3.

(v) Section DN (Fig. 24)

This section is also near "The Basin" homestead and like section DL3 the bulk of the sediments are laminated and cross-laminated, fine to medium sandstone and siltstone. A common sequence is from parallel laminated sandstone and siltstone grading to undulose laminae then to ripple-drift cross-lamination with climbing sets of leeside laminae.

A conspicuous horizon of sandstone with mudclasts is present. This lithology grades to an intraformational breccia similar to that in DK1.

Lateral transition of stratification type is evident in the lower part where parallel laminated and medium-scale cross-stratified sandstone passes laterally into thinly bedded sandstone with small-scale cross-strata and ripple bedding surfaces.

Interpretation at Section DN For units 1 to 6 the discrete beds of sandstone and laminated siltstone indicate that bed load and suspended load deposition took place largely independently. However, after deposition of unit 8 the combined effects of bed load and suspended load deposition is apparent from the combination of laminated and cross-laminated sandstone and siltstone. This type of sedimentation would take place where a fluvial system meets a standing body of water such as a lake.

As in DK1 the intraformational breccia is difficult to explain as a normal channel lag deposit since it is laterally persistent, uniformly thick, it does not directly overlie an erosion surface and it is overlain by laminated siltstone instead of cross-bedded sandstone with a mudclast content diminishing upwards. This sediment may well be a shoreline deposit.

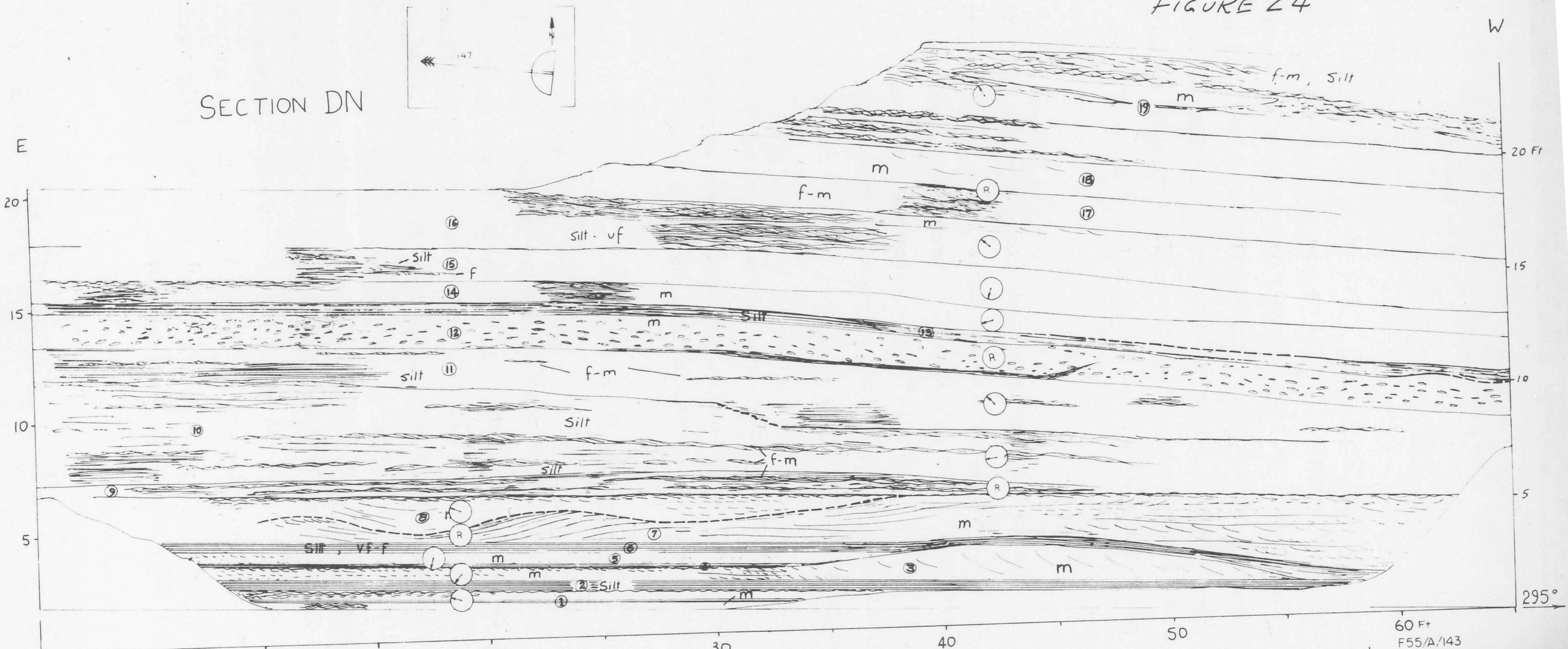
Current movement was generally westward but adjacent beds may show widely differing directions. There appears to be an overall clockwise swing in current directions up section.

(vi) Section DQ (Fig. 25)

Section DQ was measured also in the vicinity of the "The Basin" homestead, from the topmost thick bedded, quartz sandstone characteristic of the Clematis Sandstone. The columnar section was measured across two main outcrops some forty feet apart stratigraphically.

The lower part consists mostly of thinly bedded, cross-stratified sandstone with minor silty mudstone. Erosion surfaces are rare and where present are quite localized. An horizon of partly churned sandstone and siltstone, which was originally laminated, occurs at the top of the lower outcrop.

FIGURE 24



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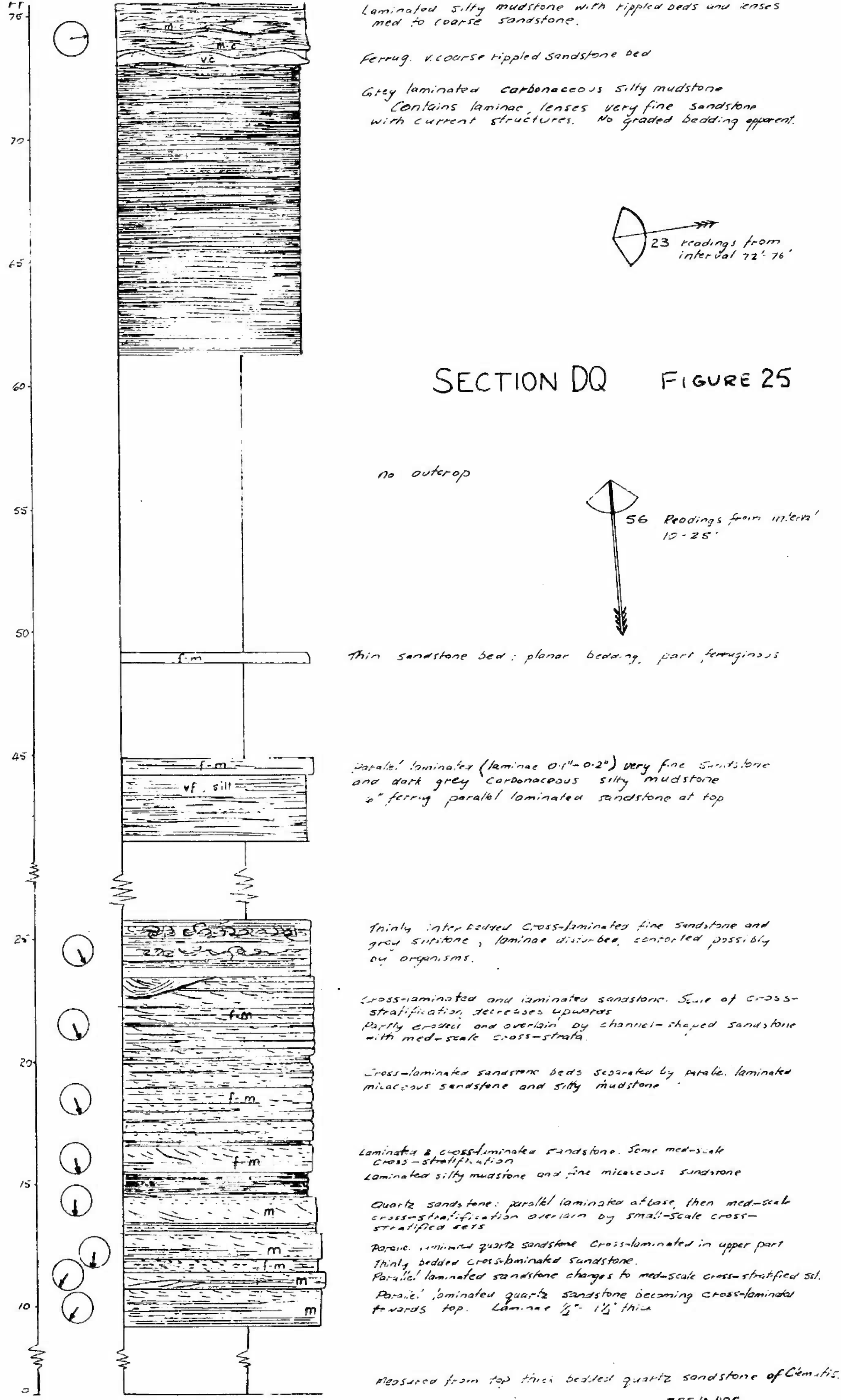

SECTION DQ FIGURE 25

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An interval of about 45 feet of poorly outcropping, finely laminated sandstone, siltstone and mudstone apparently overlies the sandstone interval. Fine sandstone dominates the lower part of the interval whereas the top is mostly laminated carbonaceous mudstone. However, poor discontinuous outcrop hinders detailed study of the interval.

At the top several rippled beds of very coarse grained sandstone with intervening mudstone crop out strongly. The ripples have variable size and surface expression but their ripple indices are mostly in the range 6 to 12 (Table III).

Interpretation at Section DQ The most striking feature of the lower part of section DQ is its comparative uniformity. Compared with other sections in the area DQ has a more uniform grainsize and more regular scale and type of stratification and cross-stratification. Furthermore the current directions show a definite regular anticlockwise change upwards through the section.

The churned sediments are probably a result of sediment ingestion by organisms.

The overlying laminated sediment reflects an increasingly tranquil environment of deposition which probably indicates an increase in water depth.

Exposure is too poor beneath the ripple beds to pick any erosion surface but a sharp change to relatively shallow water is indicated by the coarse grained mega-rippled beds. The presence of mudstone between the coarse sandstone beds present a unique situation which will be discussed later.

(vii) Section DR2 (Fig. 26)

This is a small section measured in the Rewan Syncline where a series of small wedging and lenticular sandstone bodies impinge on one another. By recording the nature of the sediments, the shapes of sandstone bodies, the nature of their bounding surfaces and the direction of cross-stratification from individual beds much can be inferred of the deposit's origin.

Sediments below the main erosional surface are mostly thin bedded, very fine to coarse grained sandstone. Current direction was towards the north-east.

The sediments resting on the main erosional surface are small, discrete units of fine to medium sandstone indicating former current movement towards the north-west.

Interpretation at section DR2 North-easterly flowing currents of the lower and transitional flow regimes deposited sandy sediments ranging from fine silty sandstone to well sorted, medium to coarse sandstone. Erosion of these sediments was followed by deposition of further sandstones by north-westerly flowing currents belonging to the lower flow regime.

It is likely that this sequence of events took place without any significant subaerial exposure of the sediments as mudclasts are absent from the sandstone units overlying erosion surfaces.

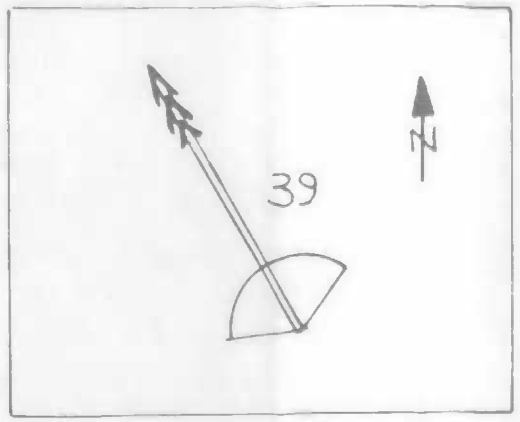
2 Sections in Unit C2

(i) Section DA44 (Fig. 27)

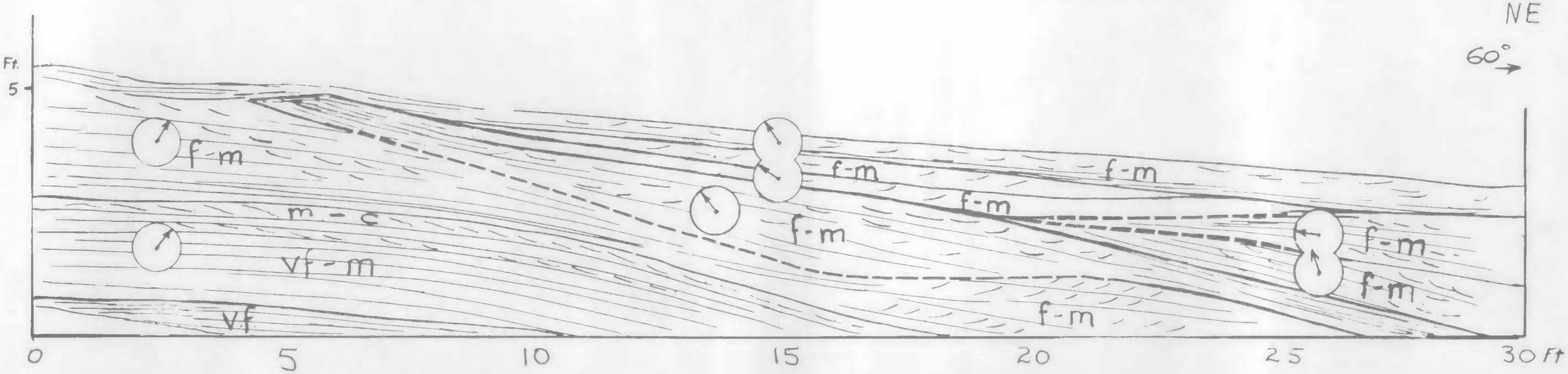
This section was measured in Spring Creek about 120 feet stratigraphically above section DA43 and commencing at the base of unit C2.

The thinly bedded, laminated, very fine sandstone and siltstone at the base of the section is typical of the top beds of unit C1 and C2 rests on a strong erosion surface cut into the C1 sediments.

Figure 26



SECTION DR2



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To accompany BMR Record 1970/25

FIGURE 27

SECTION DA44

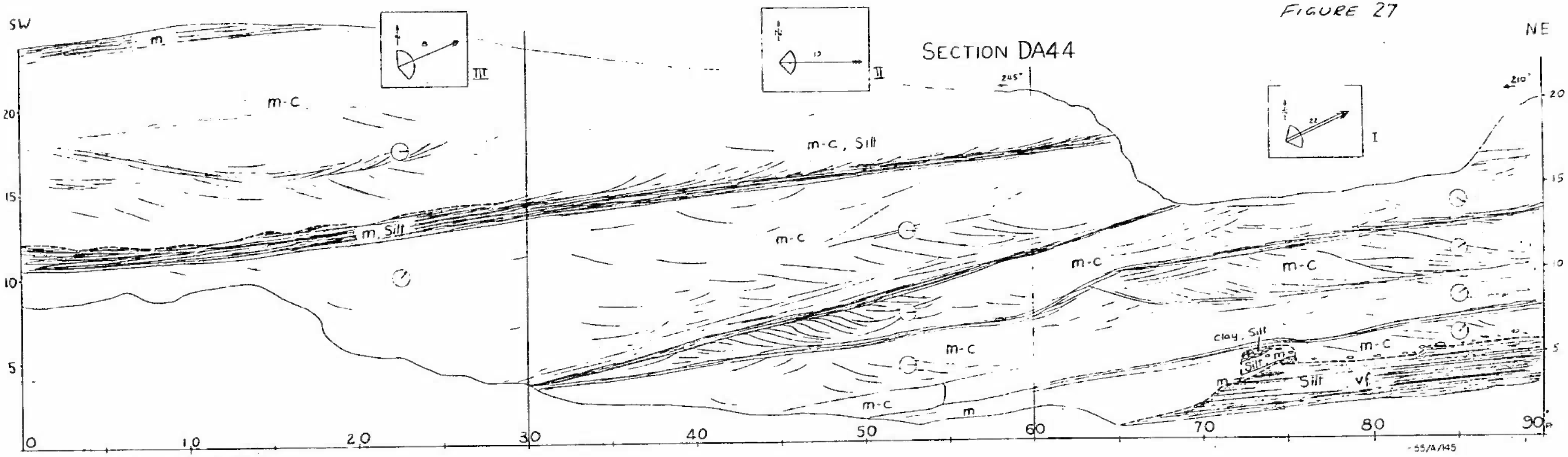

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Figure 28 : Erosion surface at base of section DA44 (see Fig. 27). Thinly bedded fine sandstone and silty mudstone is overlain disconformably by thickly bedded sandstone. The inhomogeneous sediment at top centre is composed of rubble mudstone and sandstone in a sandy matrix.

Neg. No. M/947/17

Figure 29 : Typical outcrop of unit C2 at section DA62 (see Fig. 30) On Carnarvon Highway. Consists of lithic sandstone beds and lenses interbedded with scree-covered, laminated and massive mudstone.

Neg. No. M/953/35

The basal C2 sediments consist of medium to coarse grained, cross-bedded, lithic sandstone with mudclasts at the base. The unusual dome-shaped structure in this lower sandstone is bounded on all sides by a discordant surface and consists of silty mudstone, mudstone clasts and mudstone with irregular patches of sandstone. This is believed to be rubble and fine sediment forming an erosional remnant about which the basal C2 sandstone was deposited. A photograph of the structure is shown in Fig. 28.

The overlying sediments are made up of three main units of medium to coarse grained, cross-bedded, lithic sandstone separated by parallel laminated sandstone containing carbonaceous laminae and leaf impressions. The sandstone is composed of well sorted, mostly angular, medium to coarse grains of quartz, feldspar, chlorite, mica, micaceous lithic grains and possible flow-banded volcanics. Quartz content is less than 50% contrasting strongly with the sandstones of C1 which are mostly fine to medium grained with quartz contents of 65% - 90%. The section line trends north-east to south-west so current movement was from left to right on the section (Fig. 27).

Several features of section DA44 contrast sharply with the underlying sediments of C1. At DA44 the sandstones are coarser grained, have a much higher lithic content and the current directions are towards the east instead of north-westerly. In addition the cross-stratification is of a larger-scale and units are thicker than at DA43.

<u>Interpretation at Section DA44</u> After erosion of the thinly bedded, fine grained C1 sediments, comparitively rapid deposition of highly lithic sands by east-flowing currents took place. Flow conditions in the transitional and upper flow regimes carried large quantities of medium to coarse sand to form foreset laminae and parallel laminated beds. Each main sand wedge was covered by thinly laminated sandstone with carbonaceous, coaly laminae before deposition of the succeeding wedge. These laminated, carbonaceous sediments do not rest on eroded surfaces but in places are eroded themselves. They may be interpreted

as the bottom sets of a small delta whereas the intervening cross-bedded sandstone represent foreset beds of the successive easterly prograding sand wedges.

(ii) Section DA62 (Fig. 30)

With the exception of basal C2 sediments which are dominantly sandy, unit C2 is very poorly exposed even in areas of high relief.

Section DA62 was measured at part of the road cutting where the Carnarvon Highway descends from the Triassic surface through C2 sediments towards Moolayember Creek. A photograph of this outcrop (Fig. 29) shows partly scree-covered exposure even in a recent road cutting. This is typical of C2 outcrops.

The lower part of section DA62 consists of alternate beds of massive and laminated mudstone, silty mudstone and siltstone with two thin sandstone beds. The sandstone is cross-laminated and contains sub-vertical tubes in places. A thin band of brown, poorly sorted sandstone with mudstone fragments, which may be a soil, occurs near the base.

A relatively thick bed of fine cross-stratified sandstone is overlain by further mudstone and siltstone beds with no recognizable stratification.

Interpretation at Section DA62 Apart from the cross-stratified sandstone which is a bed load deposit of the lower flow regime the sediments at section DA62 were deposited from suspended load in tranquil conditions.

The genetic difference between the laminated and massive mudstones may be due to a number of causes. For example a large grainsize range would facilitate sorting by differential settling whereas sorting of muds in a narrow grainsize range would be difficult to recognize. The rate and variability of sediment supply could affect lamination in the mudstones and massive types may be formed by subaqueous mud flows.

FIGURE 30

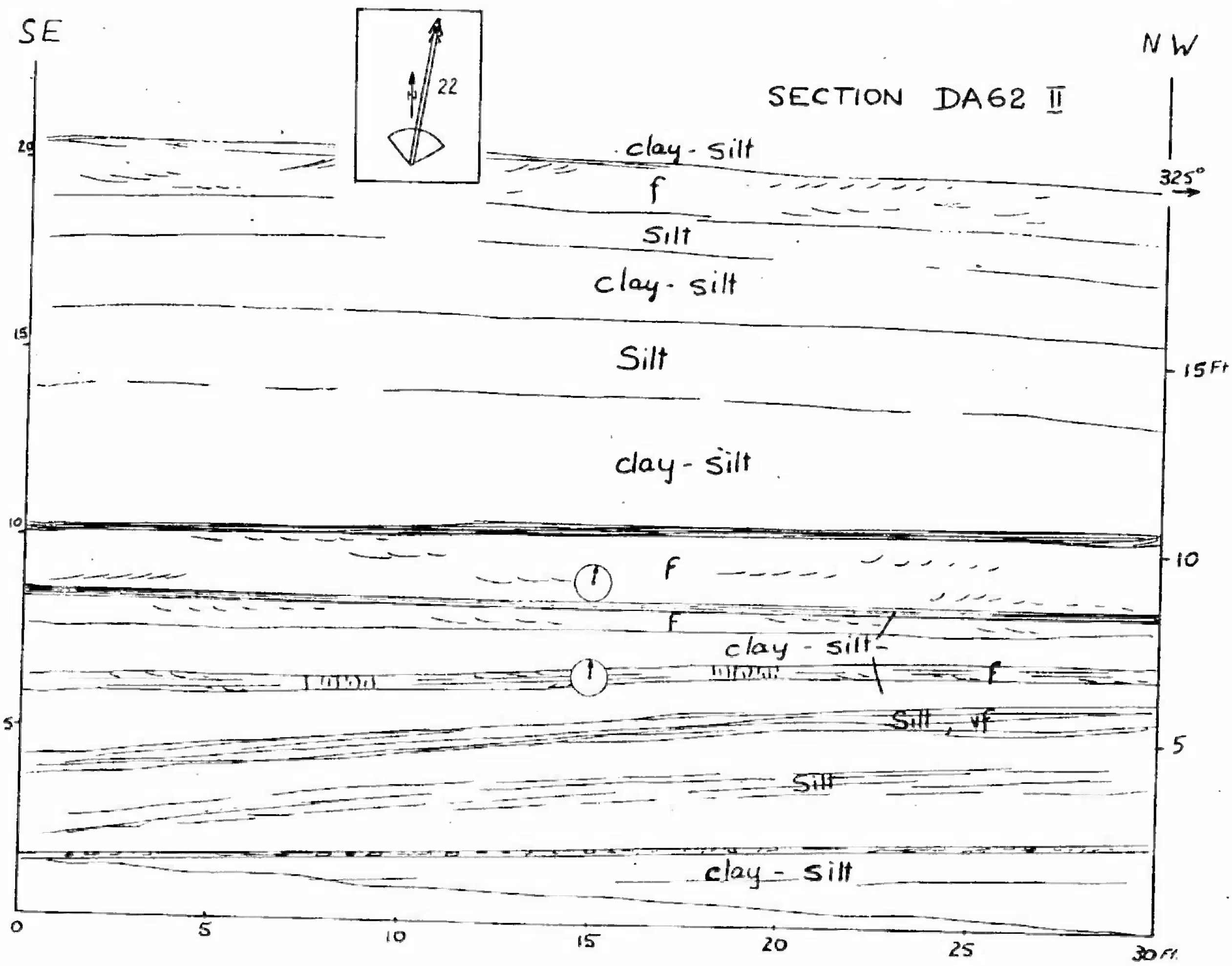

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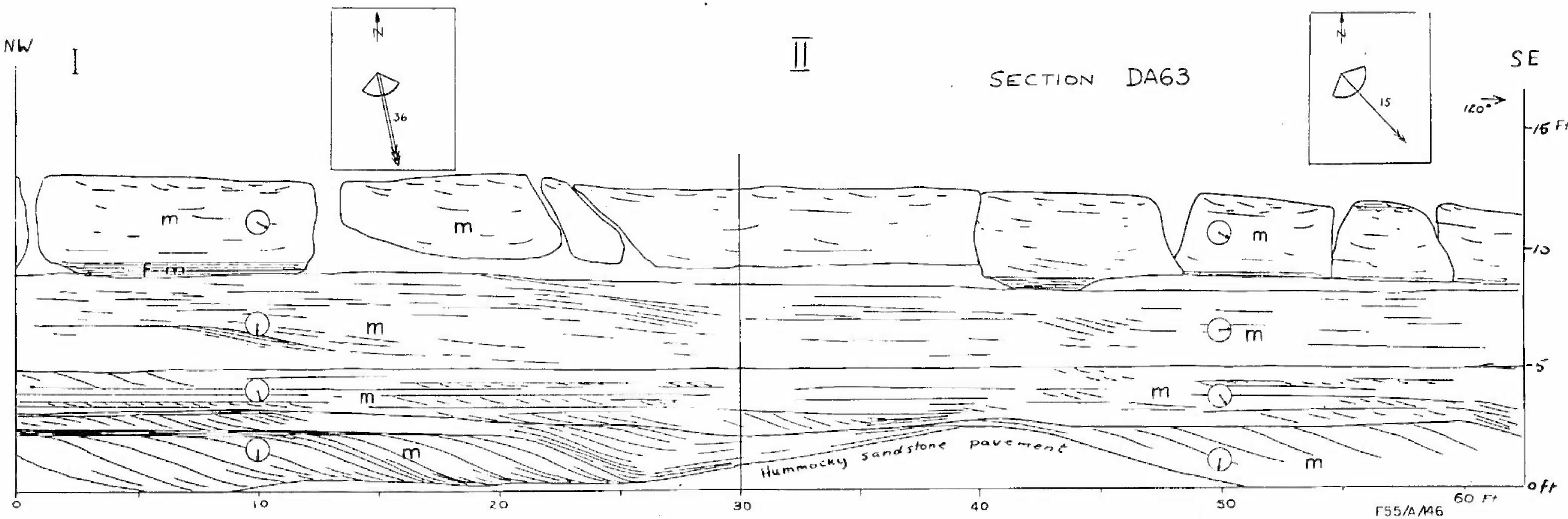
FIGURE 31



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The combination of features at DA62 suggest the sediments formed in a small lake or flood basin.

(iii) <u>Section DA63</u> (Fig. 31)

This section, like section DA44 corresponds to the base of C2, and like DA44 the sediments and relationships between sedimentary units are similar.

Medium grained, cross-stratified and parallel laminated, lithic sandstone makes up the bulk of the section. At the base, prograding ripples with conspicuous foresets indicate that the direction of deposition was towards the south. The foresets exhibit tangential contact with an underlying hummocky sandstone pavement. Higher in the section more thinly bedded, cross-stratified sandstone is overlain by parallel laminated sandstone. At the south-east end of the section foreset beds of the basal unit terminate and are succeeded laterally by foresets developed in the overlying unit where current direction was more easterly. At the top of the section the sandstone becomes calcareous and bedding is obscure.

<u>Interpretation at Section DA63</u> This section demonstrates very well the concept of the delta progradation by successive wedges or en echlelon sandstone bodies. There are at least two units at the base of the section representing the foreset part of a sandstone wedge. The overlying cross-laminated sandstone unit represents top set beds with some foresets being developed at the extreme south-eastern end. The succeeding unit, which is mostly parallel laminated sandstone, represents top set strata of yet another sandstone wedge. However, the top sets represented are further up current from their corresponding foresets than in the underlying unit. This small delta was built out in a southerly to south-easterly direction, probably into a lake.

(iv) <u>Section DA70</u> (Fig. 34)

This section was measured in the upper part of C2 but cannot be related accurately to the other sections because of lack of outcrop.

The section may be considered in two parts: a lower part consisting of medium to coarse grained, cross-bedded, lithic sandstone containing mudclasts, and an upper part made up largely of parallel laminated, coarse grained, lithic sandstone.

In the lower part medium-scale trough cross-stratified sandstone such as that in Fig. 32 is exposed at the base. In places foreset laminae are oversteepened or slumped. The overlying sandstone contains common mudclasts which vary from sand size grains to blocks 3 feet across (Fig. 33) and tend to decrease in abundance upwards. Both massive and laminated mudclasts occur. Overlying this is a discrete bed about 6 inches thick containing abundant mudclasts which grades to an intraformational breccia. This in turn is overlain by parallel laminated sandstone. Sooty coal laminae up to 0.2 inches thick occur.

The overall current direction indicated from both cross-stratification azimuths and mudclast imbrication was towards the south and west or from right to left in the section.

Interpretation at Section DA70 The co-existence of oversteepened trough cross-strata, sandstone with mudclasts, and coarse, parallel laminated sandstone is strongly suggestive of fluvial erosion and deposition. The cross-bedded sandstone probably belonged to part of a point bar or channel bar, the sandstone with mudclasts could be attributed to channel lag deposits, and the succeeding parallel laminated sandstone to the accumulation of sand in an advancing ripple where current flow was in the upper flow regime.

(v) Section DA71 (Fig. 35)

This section in Moolayember Creek, like section DA62 is poorly exposed. In its lower part it consists of trough cross-stratified, medium, lithic sandstone containing a fractured mudstone bed. This mudstone grades laterally to intraformational breccia and then to sandstone with few mudclasts down current. The mudstone contains veinlets of

Figure 32 : Trough cross-stratified granule conglomerate in unit C2 at Moolayember Creek. This is the coarsest sediment observed in C2 apart from the intraformational breccias.

Neg. No. M/954/32

Figure 33 : Dislodged block of mudstone at section DA70 (see Fig. 34). Light coloured sub-vertical lines are hammer marks.

Neg. No. M/954/19

FIGURE 34

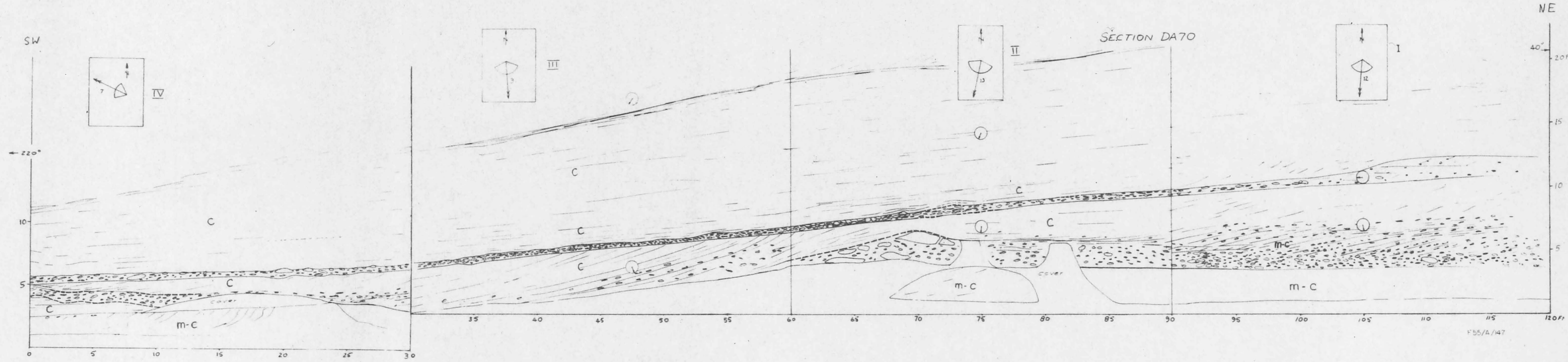

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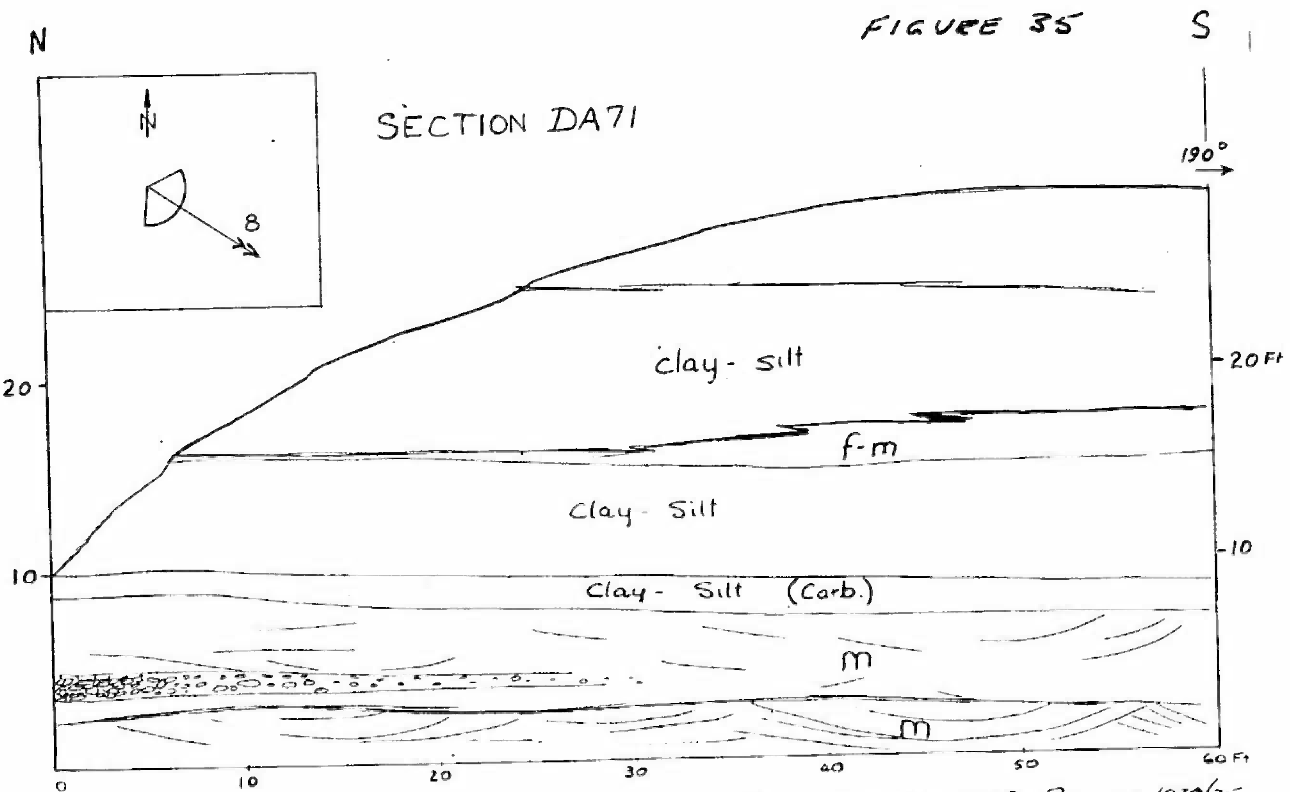
FIGURE 35



To accompany BMR Record 1970/25

sandstone (?mud cracks) at the left of Fig. 35 and commonly contains plant remains with random orientation.

The overlying sediments are mainly carbonaceous and non-carbonaceous massive mudstone. Current direction in the sandstone was towards the south-east which, in Fig. 35, is away from the observer and to the right.

Interpretation at Section DA71 Again fluvial erosion and deposition is indicated by the trough cross-stratified sandstone associated with abundant mudclasts. Lateral channel erosion in an alluvial system apparently broke up part of a mudstone bed which may have been initially disrupted by earlier mudcracking. The resulting mudclasts were carried downstream and deposited with a decreasing density of distribution downcurrent, probably as part of a point bar. Although the upper contact of this sandstone is not completely exposed it is apparently non-erosional, implying that the overlying mudstone resulted from continuing sedimentation at a sharply reduced rate under tranquil conditions. This would occur either in a point bar swale or ox-bow lake where deposition of mud and accumulation of plant debris took place.

(vi) Section DA74 (Fig. 36)

Further up Moolayember Creek (and consequently down section from DA71) section DA74 was examined. The exposure is found to consist of two main sedimentary units. The lower part is medium-scale and cross-stratified, coarse to very coarse, lithic sandstone containing pebble bands and a few mudclasts. The cross-stratification indicates south-flowing currents during this phase of deposition (left to right in Fig. 36). The thickness of cross-stratified sets decreases southward.

Overlying this lower unit is medium to coarse sandstone containing a partly eroded mudstone bed with associated mudclasts up to 3 feet long. At the north end of the section pebbles and mudclasts occur together at this horizon but the relationship between the two parts of what appears to be the same stratigraphic horizon remains obscure because of partial cover. In the upper unit current directions indicated are dominantly westward (towards the observer and slightly to left in Fig. 36) which is in sharp contrast with the south flowing currents of the underlying sandstone.

Interpretation at Section DA74 South flowing currents deposited coarse sediment probably as prograding ripples of a channel bar or point bar in an alluvial system. Truncation of a meander loop would explain the sharp change in current direction of the overlying sediments and would also provide a mechanism for the erosion and redeposition of a consolidated mudstone bed.

(vii) Section DA75 (Fig. 37)

Section DA75, which is slightly lower in the formation than DA74, commences in thinly bedded, silty lithic sandstone overlain by a wedge-shaped unit of massive mudstone up to 9 feet thick. This massive mudstone becomes silty at the top and is overlain by laminated mudstone interbedded with fine to medium sandstone. This gives way to thicker beds of medium grained sandstone which contain sub-vertical tubes some of which bifurcate upwards. The tubes are up to 10 inches long, $\frac{1}{4}$ inch thick at the top and taper downwards.

A thin horizon of finely interlaminated silty mudstone and sandstone is succeeded by up to 5 feet of parallel laminated, fine, lithic sandstone and laminated, silty mudstone. At the top of the section there is silty, lithic sandstone with sub-vertical bifurcating tubes filled with mudstone.

Interpretation at Section DA75 The outcrop represents deposition largely in quiet water. The upwards bifurcation of the tubes suggests they are invertebrate burrows, and colonies of such fauna appear to have been established in the thicker, more sandy sediments.

Once again there is an association of massive and laminated mudstone, the significance of which is difficult to ascertain. Deposition in a lake may account for the combination of features observed at DA75. Alternatively the sediments may have accumulated in protected waters of an alluvial system.

FIGURE 36

SECTION DA74

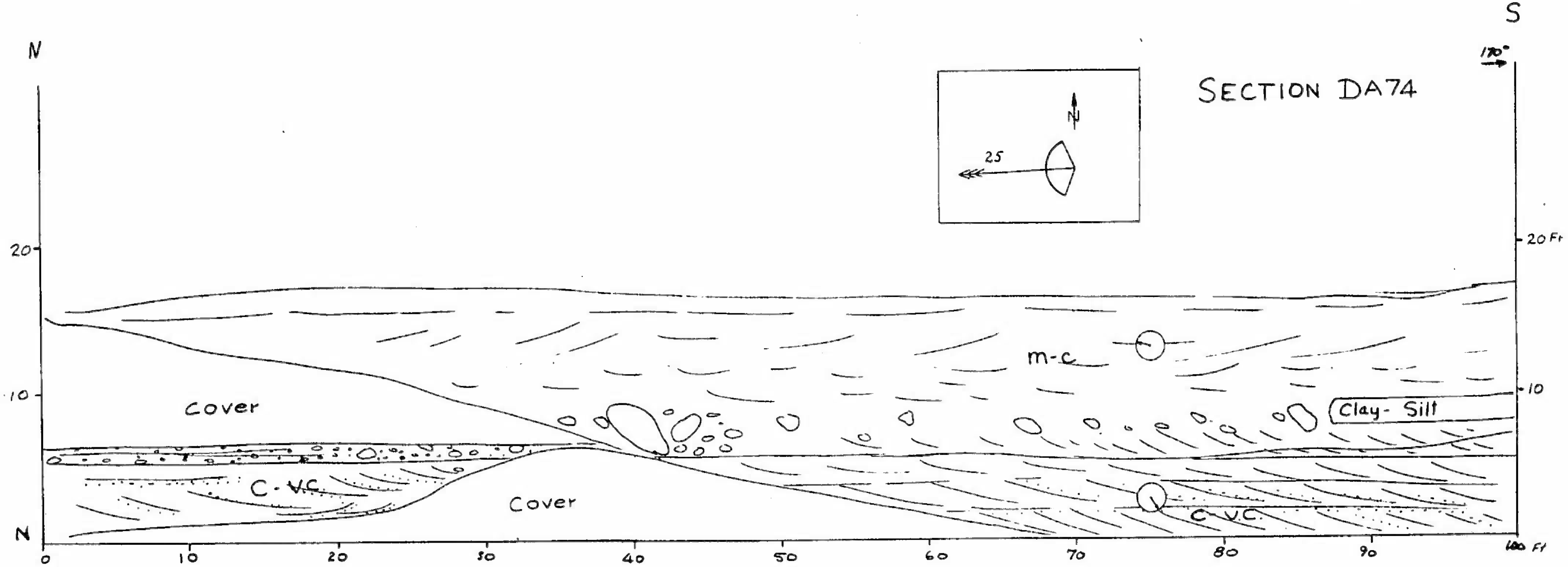


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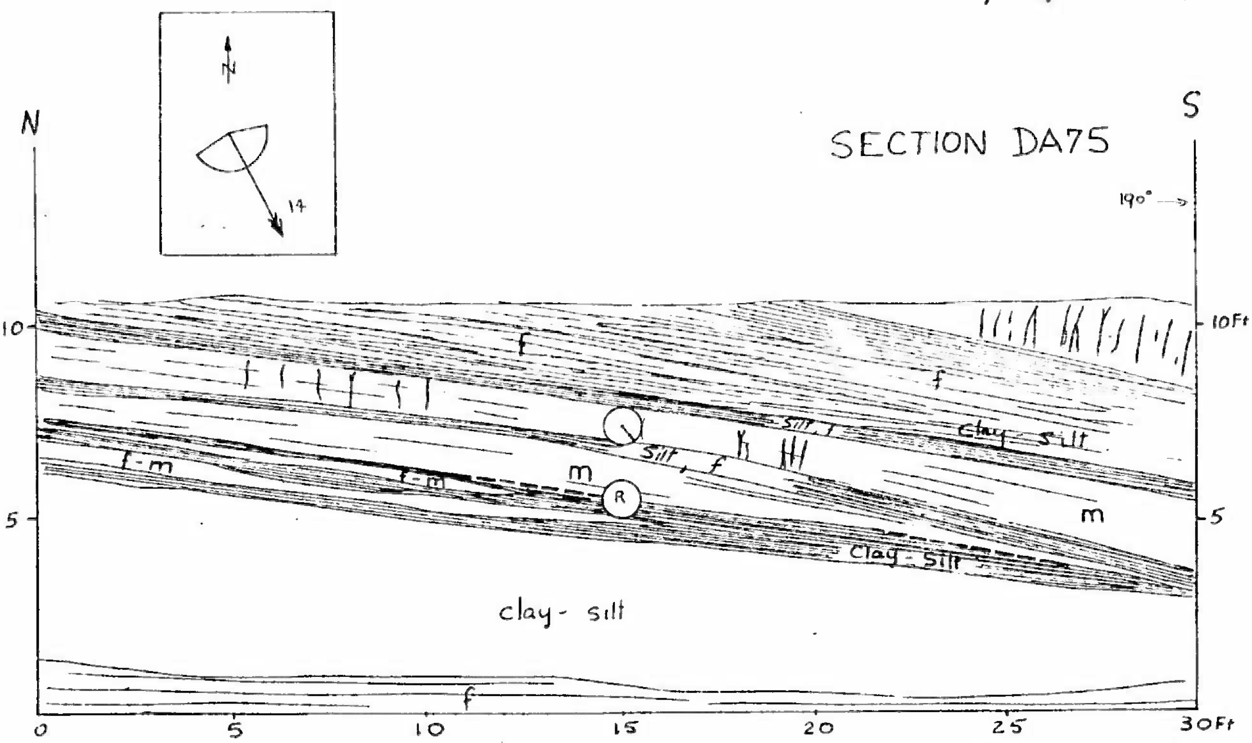
FIGURE 37



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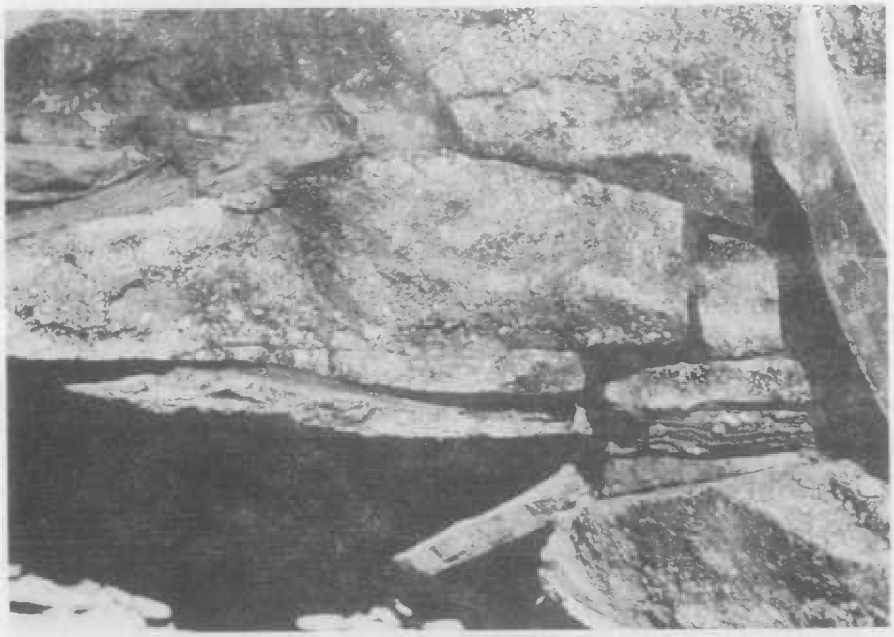

Figure 38 : Section of mega-rippled beds of quartz granule conglomerate separated by ferruginous mudstone.

Neg. No. M/932/22

Figure 39 : Section of asymmetrical mega-ripple in quartz granule conglomerate showing poorly developed cross-strata dipping in opposite directions. In this example RI = 6

Neg. No. M/932/36

MISCELLANEOUS SEDIMENTARY STRUCTURES AND FOSSILS

1 Ripple Marks

(i) Mega-ripples. In the Carnarvon Range Area, in unit C1, a conspicuous horizon containing mega-rippled, granule conglomerate and coarse grained sandstone can be traced from Terrible Gully northwards to "The Basin" homestead. The best exposures are in Basin Creek at DA36 to DA39 and at Section DQ.

These large ripple marks (Figs. 38, 39 and 40) have wavelengths of 1 to 3 feet. Ripple indices (ratio of wavelength to wave height) are typically between 6 and 12, and grains are coarse sand to granule size usually showing coarser grades on ripple crests than in troughs. The ripples are symmetrical to sub-symmetrical and commonly the beds containing them are separated by mudstone or fine to medium sandstone with small-scale ripple marks. In plan (Fig. 40) the ripples are continuous and parallel for at least 20 feet, and they may be straight or sinuous.

Study of sedimentary laminae within the ripples showed that generally such current laminae are poorly developed but when they do occur it is in the form of grainsize layering. Measurement of the azimuths of these laminae give a bimodal distribution which is approximately at right angles to the crest lines of the ripples (Fig. 39).

Intervals 5 to 10 feet thick containing these ripples were measured and properties of the ripples noted at the top of section DQ and further south in Basin Creek at sections DA36 to DA39. The parameters measured have been set out in Table III.
These parameters include:

(1) ripple height (h)
(2) ripple spacing or wavelength (s)
(3) crest length
(4) crest shape on bedding surface
(5) Symmetry of the ripple in cross-section and rounding of the crest

TABLE III

RIPPLE MARK DATA FROM UNIT C1

Ripple height (h)	Crest Spacing (s)	Crest length (l)	Crest shape on bedding surface	Symmetry* (in cross-section) and rounding of crest	Grainsize Crest 1. max 2. min 3. main mode	Grainsize Trough 1. max 2. min 3. main mode	Ripple Index $\frac{s}{h}$
(a) Section DQ							
1½" to 4"	1' to 3'	20'	Straight or slightly curved	Symmetrical to sub-symmetrical, rounded	½" pebble v.c. ¼" pebble	1" pebble v.c. ½" pebble	8
½" to 1"	6"	6" to 8"	Sinuous	Symmetrical to sub-symmetrical, rounded	granule v.c. granule	¼"pebble v.c. granule	5 to 12
½" to 1"	6"	6" to 8"	Sinuous to irregular	Sub-symmetrical, rounded	c f f-m	c f f-m	8
½" to 1"	1' to 2'	3'+	Sinuous	Sub-symmetrical, rounded	granule m v.c.	granule m v.c.	24
5"	3'	6'+	Straight or slightly curved	Symmetrical to sub-symmetrical, rounded	¼"pebble v.c. granule	¼"pebble v.c. granule	7
(b) Section DA36							
1" to 3"	6" to 3'	6'+	Sinuous	Symmetrical rounded	¼"pebble v.c. granule	½"pebble v.c. granule	6 to 12
0.2" to 1"	2" to 6"	6"+	Curved	Sub-symmetrical rounded	v.c. c c	granule c v.c.	6 to 10
0.2" to 0.5'	2" to 6"	?	?	Sub-symmetrical rounded	c m c	c m c	10 to 12

TABLE III (contd)

(c) Section DA37							
1" to 5"	1' to 3'	6'+	Straight or slightly curved	Sub- symmetrical, rounded	¼"pebble v.c. granule	½"pebble v.c. granule	7 to 12
0.2" to 0.4"	4" to 6"	?	?	Sub- symmetrical, rounded	granule c v.c.	granule c v.c.	16 to 20
1" to 2"	1' to 3'	3'+	Curved	Symmetrical, rounded	granule c v.c.	granule c v.c.	12 to 18
0.2" to 0.5"	6"	?	?	Sub- symmetrical, rounded	v.c. m c	v.c. c v.c.	12 to 30
1" to 2"	1' to 2'	?	?	Sub- symmetrical, rounded	v.c. m c	granule c v.c.	12
(d) Section DA38							
2" to 6"	1' to 3'	6'+	Curved	Sub- symmetrical, rounded	½"pebble c granule	¾"pebble c granule	6
0.2" to 0.5"	2" to 6"	1'+	Straight or curved	Sub- symmetrical, rounded	granule c v.c.	granule c v.c.	10 to 12
(e) Section DA39							
0.5" to 4"	3" to 3'	6'+	Straight or curved	Symmetrical, rounded	½"pebble v.c. granule	¾"pebble v.c. granule	6 to 8
0.2" to 1"	2" to 1'	?	?	Symmetrical, rounded	v.c. f-m c	v.c. m c	10 to 12
0.1" to 0.3"	1" to 3"	?	?	Sub- symmetrical, rounded	v.c. f m-c	v.c. m v.c.	10
0.2" to 1"	3" to 9"	6"+	Curved	Symmetrical, rounded	granule c v.c.	granule c v.c.	9 to 15
0.5" to 2"	6" to 1'3"	2'+	Curved	Sub- symmetrical, rounded	granule c granule	granule v.c. granule	8 to 12
0.1" to 0.5"	2" to 6"	6"+	Curved	Sub-symm- etrical, rounded	granule m v.c.	granule c v.c.	12 to 20
0.2" to 1"	3" to 1'3"	6"+	Straight or curved	Symmetrical, rounded	granule m v.c.	granule c v.c.	15
0.2" to 0.4"	3" to 6"	?	?	Symmetrical, rounded	c f m	c f m	15

(6) Grainsize modes in ripple troughs and on ripple crests
(7) Ripple index (s/h)

Included in the table are small-scale ripples (wavelength less than 1 foot) which are interspersed with the mega-ripples. However, these are finer grained than the mega-ripples and are discontinuous.

(ii) Small-Scale Ripples

Apart from the small-scale examples documented in Table III, ripple marks occur frequently in other areas although they appear to be confined to unit C1. Discontinuous asymmetric ripples with crescentic crests occur at the top of C1 in Terrible Gully south of Basin Creek (Fig. 41). At section DK well exposed pavements with linguoid ripple marks occur. U-shaped types (Fig. 42) indicate current movement in the direction of the convex side of the 'U'. Ovate linguoid ripples (Fig. 43) consist of partially overlapping ovate tongues of sediment with long axes normal to current direction and very steep lee sides.

Many other examples were observed at different localities and all have certain features in common. They have a relatively uniform size range (wavelengths mostly 3 to 6 inches), they are asymmetric to sub-symmetric and have ripple indices of 6 to 12. However, bedding surface expression of these ripple marks varies widely. Apart from those types illustrated irregular crest shapes and continuous crescentic crests occur. Rib and furrow structures are another type of bedding surface ripple mark which is not uncommon.

(iii) Interpretation of Ripple Marks

The small-scale ripples described are common features of sand size sediments deposited by water currents. Linguoid ripples can be observed in many inland creek and river beds where intermittent high velocity flow quickly wanes to leave a bed of ripple marked sand.

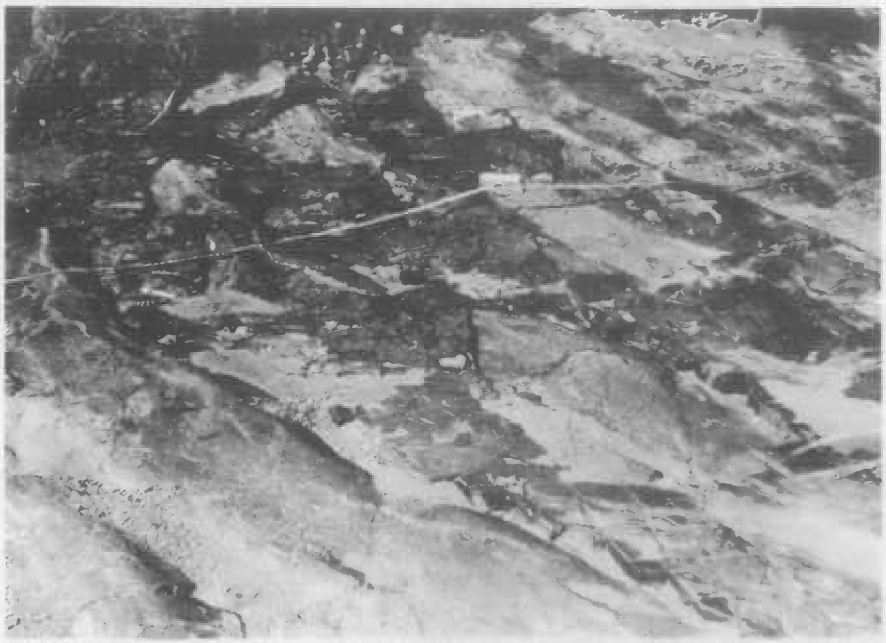

Figure 40 : Symmetrical mega-ripples in granule conglomerate at Basin Creek. Crests are parallel, sinuous to straight and 2 to 3 feet apart. Ferruginous mudstone fills troughs and laps onto ripple crests.

Neg. No. M/947/3

Figure 41 : Discontinuous crescentic ripple marks near top of unit C1 in Terrible Gully. RI = 6.

Neg. No. M/953/7

Figure 42 : U-shaped linguoid ripple marks on surface of sandstone bed at section DK. Current flowed from top right to bottom left of photograph.

Neg. No. M/932/19

Figure 43 : Ovate linguoid ripple marks in sandstone at Basin Creek. Current flowed from right to left.

Neg. No. M/933/7

Linguoid ripples are also common in tidal channels where current velocities are high (Conybeare and Crook, 1968).

Irregular and crescentic, small-scale ripples are common in fluvial settings where current velocities are low. The differences in flow velocity required to produce linguoid ripples and continuous crescentic types was demonstrated in flume studies by Simons, Richardson and Nordin (1965).

The mega-ripples described from C1 are a much more unusual feature of sedimentary deposits than the small-scale type. Two main features which make them unusual are: (1) their large size and large grainsize compared with normal ripple marks; (2) the occurrence of mudstone between individual rippled beds, thickening in troughs and thinning at ripple crests.

The ripples themselves indicate high velocity water movement for their formation since they are composed of a well-sorted, granule-size aggregate. The bed form is the same as that produced in the anti-dune stage of the upper flow regime. In very shallow, fast-flowing water sinusoidal water waves develop in phase with sinusoidal bed waves. Under these conditions deposition may take place on the upstream faces of the sand wave.

Observation of standing waves in the Rio Grande in water less than one-foot deep showed that sinusoidal bed forms may be preserved if the water waves do not break (Harms and Fahnstock, 1965). Such conditions prevail if the discharge rate subsides after formation of the sand wave. The author has observed the formation of these waves in a shallow tidal channel during ebb flow at Mallacoota Inlet, Victoria.

Documentation of this bed form in the geological record is sparse but recent work on the Triassic Mount Toby Conglomerate in Massachusetts (Hand et al, 1969) attributes an antidune origin for large scale ripples which are similar in many respects to those described in this work. Features common to both occurrences are as follows:

(i) both are formed in granule conglomerate

(ii) both have wavelengths from 1 to 3 feet

(iii) wave heights are similar in both

(iv) both have rounded crests and troughs and are symmetrical to sub-symmetrical.

(v) internal cross-stratification is poorly developed in both examples.

Azimuth of cross strata are distributed bimodaly in the Moolayember Formation whereas in the Mount Toby conglomerate cross-strata in the mega-ripples are directed opposite to the regional current direction.

The main difference between the two occurrences lies in the presence of mudstone between the Moolayember mega-ripples whereas the Mount Toby occurrence exhibits coarse sediment filling the ripple troughs.

The intervening mudstone and fine to medium sandstone indicate rapid, periodic reversion to suspended load and bed load deposition under tranquil and lower flow regime conditions.

It is proposed that a tidal estuary would satisfactorily explain the observed structures and lithologic relationships. Deposition during ebb and flood tidal flow in shallow water would explain the formation of mega-ripples. At other times fine river sediment carried downstream and deposited at the estuary mouth would accumulate mainly in depressions formed during the earlier phase of rippling.

2 Disturbed Bedding

(i) Sedimentary processes

Examples of the partial breaking up of mudstone beds have already been described. Fig. 44 is a slabbed section showing an *in situ*, although broken, mudstone bed which formed at the top of a

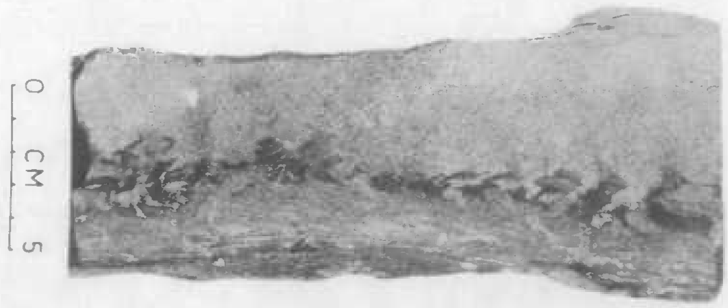

Figure 44 : Polished slab showing disturbed sandstone and mudstone. Dark layer of mudstone has been broken up, probably by sun-cracking. Subsequent inundation by sediment laden currents has displaced some of the mudstone fragments and filled interstices with sand.

Neg No. GA/2539/6B

Figure 45 : Same type of structure as shown in Fig. 44 showing appearance on bedding surface. Thin irregular to subparallel ridges of sandstone protrude from cracks in mudstone layer 0.1 inch thick.

Neg. No. GA/2536/3

laminated, fine sandstone and siltstone horizon. The overlying medium grained sandstone has filled interstices between mudstone fragments. Fig. 45 shows the bedding plane configuration of the same structure. The irregular, subparallel ridges project from cracks in the mudstone.

The structure demonstrates how cracking by desiccation of a thin bed of dried mud was followed by influx of sand-laden currents. The mudstone fragments were moved slightly, then sand filled the interstices and finally completely covered the mudstone. This structure provides evidence of subaerial exposure of part of the basal Moolayember sediments.

(ii) Organic processes

Organic churning by sediment-ingesting organisms is believed to have occurred in parts of unit C1, particularly in the southern area near the Dawson River. Small discontinuous bands of sediment showing discordant relationships with sedimentary laminae were observed at Basin Creek, and intensely disturbed fine sandstone is common where the Formation is traversed by the Dawson River.

Common burrowing organisms are worms and molluscs, which usually colonize the upper sediment layers in areas of slow deposition under a variety of environmental conditions.

3 Subvertical Tubular Structures

Subvertical tubular structures are common at all stratigraphic levels in the Moolayember Formation in the Carnarvon Range Area. Some have already been described from the measured sections.

Fig. 46 shows the typical appearance in fine sandstone from unit C1. They are uniform in diameter or taper slightly downwards and have an average diameter of $\frac{1}{4}$ inch. Some examples noted in an earlier report (Alcock, 1969) contained carbonaceous material and branched downwards. They are attributed to root casts. At DA61 in unit C2 similar structures were found to be 6 to 8 inches long, $\frac{1}{4}$ inch in diameter, tapering downwards with rare downwards bifurcations. Again these are probably root or rhyzome casts. The examples described at section DA75 however, bifurcate upwards so may have been formed by invertebrates.

4 Bedding Surface Markings

Structures parallel to the bedding surface have been observed at Basin Creek and the Dawson River. Some of these structures are almost certainly organic (e.g. Fig. 47) and are probable worm trails. Other markings include curvilinear types (Fig. 48) which may or may not be organic and markings of various shapes and sizes commonly preserved on the underside of planar sandstone beds (Fig. 49). These may be a combination of animal markings and tool marks.

5 Fossil Fauna

The only definite fossil fauna yet observed in the Moolayember Formation occurs in the south-eastern area of outcrop near the Dawson Range.

Ferruginised specimens of a pelecypod occur near Flagstaff Hill 150 feet stratigraphically below the top of the Moolayember Formation.

The individuals are moderately well preserved (Fig. 50) and are believed to be a freshwater form (Dickens, pers. comm.).

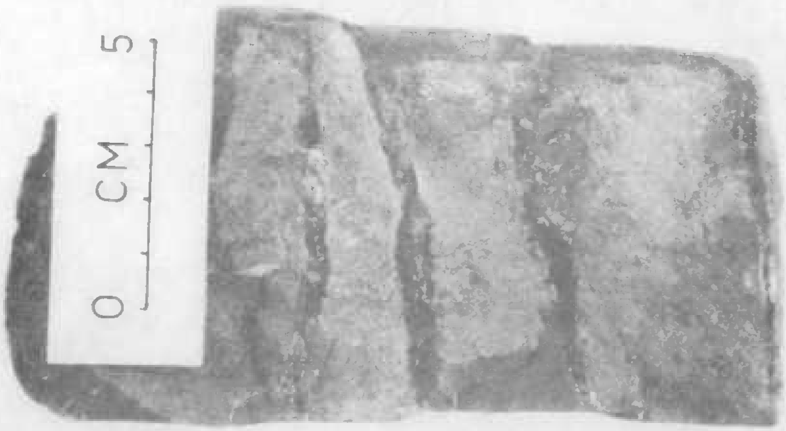

Figure 46 : Sub-vertical tubular structures in fine to medium grained sandstone. Branching upwards and branching downwards has been observed in similar structures suggesting some are root or rhizome casts, others are invertebrate burrows. Neg. No. GA/2534

Figure 47 : Tracks and trails on sandstone bedding surface. Notice large sinusoidal type as well as smaller straight forms.

Neg. No. GA/2542

Figure 48 : Curvilinear trails on sandstone bedding surface at Paradise, Dawson River.

Neg. No. M/953/27

Figure 49 : Markings on lower surface of sandstone bed in Basin Creek. Some may be worm tracks, others probably tool marks. Scale bar at top right marked in inches.

Neg. No. M/947/29

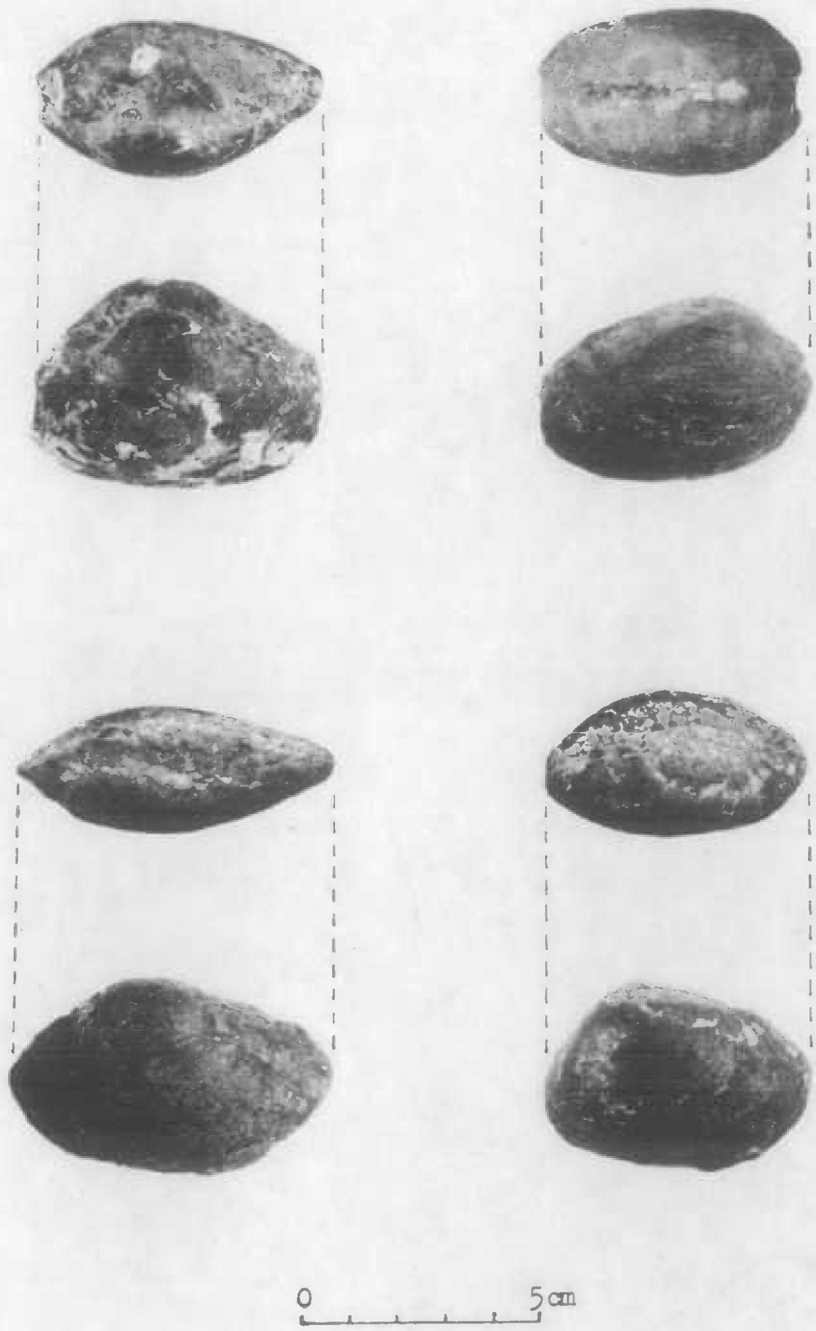

Figure 50 : Side and dorsal views of Pelecypods from upper part of Moolayember Formation in the Dawson Range area.

Neg. Nos GA/2537 & GA/2541

PALAEOCURRENT ANALYSIS

In the Carnarvon Range Area cross-stratification azimuths have been plotted at a number of localities (Plate 2) as well as on the relevant measured sections. The symbols used are explained on Plate 2 and show the reliability of results obtained as derived by computer. The most striking features of the map are:

(1) An overall southward direction of currents north of the Dawson River

(2) A strong trend towards the north-west in the vicinity of the Dawson River

(3) Some marked exceptions such as at DA43

(4) Bimodal distribution at DA36-40 suggestive of current reversal

(5) A generally wide diversity of current directions both vertically within a section and areally, suggesting a complex palaeocurrent system.

In most other parts of the basin, analysis of cross-stratification data has been done mechanically and mean directions obtained from rose diagrams. A summary of all mean directions from the formation together with a proposed palaeocurrent model are shown in Plate 3. A locus of sedimentation in the central southern part of the basin was probably the result of a regional topographic low in the area.

Two main sources of sediment, one in the east and one in the north, are apparent from a combination of current data and heavy mineral distribution.

BASIN WIDE HEAVY MINERAL ANALYSIS

Samples from all main outcrop areas in the Bowen Basin (Table IV) were treated to separate the heavy mineral fraction (S.G. greater than 2.9). The mounted grains were idientified where possible and an estimation of their relative abundance noted. Categories of abundance used were: rare(R), less than 1%; common(C), between 1% and 15%; abundant(A), greater than 15%.

Results of this work have been tabulated (Table V) and assemblages which characterise certain areas are plotted in Plate 3 Only assemblages which appear to show meaningful contrasts or similarities with other areas have been represented. Furthermore minerals in the rare category were omitted from this plot.

The main features to be noted in the distribution of heavy minerals (Plate 3) are:

(1) An epidote - ferromagnesian assemblage which is confined to the south-eastern area.

(2) A tourmaline assemblage common to all three southern areas but absent from the northern area.

(3) A second tourmaline assemblage confined to the south-western and northern areas.

(4) A zircon assemblage found in southern areas but absent from the north.

(5) An assemblage of rounded zircons confined to the northern area.

(6) Three garnet varieties in the south-western and northern areas.

The combination of these assemblages indicates that sediments in the south-western area (Carnarvon Ranges) were probably derived at least partly from the same source as the sediments of the south-eastern area(Dawson Range). Likewise, source rocks for the northern area also appear to have contributed to the Carnarvon Range sediments but bear no

TABLE V. DISTRUBUTION CHART OF HEAVY MINERALS IN SANDSTONES FROM THE MOOLAYEMBER FORMATION

SAMPLE NUMBER	Leucoxene	Ilmenite	Magnetite	TOURMALINE Brown to Dark brown Ang	TOURMALINE Brown to Dark brown Rd	TOURMALINE Pale brown to Olive Ang	TOURMALINE Pale brown to Olive Rd	TOURMALINE Colourless to Honey Brown Ang	TOURMALINE Colourless to Honey Brown Rd	TOURMALINE Colourless to Green Ang	TOURMALINE Colourless to Green Rd	TOURMALINE Blue to Green Ang	TOURMALINE Blue to Green Rd	TOURMALINE Pink to Olive Ang	TOURMALINE Pink to Olive Rd	TOURMALINE Dark blue to Mauve Ang	TOURMALINE Dark blue to Mauve Rd	TOURMALINE Pink to Blue Green Ang	TOURMALINE Pink to Blue Green Rd	GARNET Colourless Ang	GARNET Colourless Rd	GARNET Pale Brown Ang	GARNET Pale Brown Rd	GARNET Pale Pink Ang	GARNET Pale Pink Rd	GARNET Pink Brown Ang	GARNET Pink Brown Rd	GARNET Mauve Ang	GARNET Mauve Rd	GARNET Red Ang	GARNET Red Rd	BIOTITE Honey Brown	BIOTITE Olive	BIOTITE Green	BIOTITE Brown to red brown	ZIRCON Colourless Dipyramidal Ang	ZIRCON Colourless Dipyramidal Rd	ZIRCON Brown Ang	ZIRCON Brown Rd	ZIRCON Colourless Irregular Ang	ZIRCON Colourless Irregular Rd	RUTILE Dark red brown	RUTILE Orange brown	ANATASE Brown	ANATASE Orange brown	ANATASE Yellow brown	ANATASE Blue to yellow brown	ANATASE Colourless to opaque	ANATASE Honey Brown	ANATASE Blue	HORNBLENDE Pale Green	HORNBLENDE Brown	EPIDOTE Yellow Green	EPIDOTE Yellow Ang	EPIDOTE Yellow Rd	Altered ferroing	Cassiterite	Corundum
AA 01	A			C			R	C				R						C														C				C				C			R															R
AA 02	A			C		R												R			C			R					C			R	R			C				R						R		C		R								
AA 05	A			C				C								R		C		R								C				R				R		R		C		R				C		R										
AA 07	A		R	R		C										R									C			C								C				C						R				R								
AA 08	A		R	C		R						R						R							C			A				C		R		R				R						R												
AA 24 A	A			C		R		R								R																C	R			A				C		R						R										
AA 25 B	A															R								R					C							A				A										C								
AA 26 A	A	R																														R					R			R		R											A			C	C	
AA 32	A					R																						R							R	R				R										R				C	R	A	R	
AA 34	A			C			C	C								R													C	R		C			R	C				A		R				R			R									
AA 35 B	A			C		C										R		R															R		C	A	R			C		R	R															
AA 38 A	A																																			R				R													C			C	C	
AA 38 B	A	R																																		R	R	R				R											C			C	C	
AA 40 A	A	R	R			R												R																		C				A	R	R				R												
AA 40 D	A			A		C		C						C																	R	R			R	C	R			R						R												R
AA 46 A	A			R		C		R								R												C			R	R				R				C										R				R				
AA 46 B	A		R	R		C		C		R														C				C						R	R	C						C																
AA 49 B	A													R										R				R								C						R				A										C		
AA 51 A	A	R	R	C			C	R								R																			C	R				A		R	R					R										
AA 56 B	A			C			C	C								R													R			C			C	R				C			R			R				R								
AA 59	A			C		R								C														C				C			R	R	R			A			R			R							R					
AA 60	A			C		R		C								R													R			C	R			C				A	C	R	R															
AA 62	A																																			C		C		C		R											A			A	R	
AA 64	C	A	C																													R		R									R										C				R	
AA 65	A									R																								R	R								R			R							C			A	C	
AA 66	A	C				R																														R		C		C			R			R							A	C		C		
AA 67	A	C	R																															R		R				R														C		R		
AA 68	A	R																																						C						R							R	C		R	C	
AA 70 A	A			C												R								R											R	R		C				C									R							
AA 70 B	A	R		R			C	R						R		R													R							C		R		C						R												
AA 72 A	A			R		C						R																C				R				C		R		C			R			C												
AA 73 C	A					R						R																				C			C	R	R	R		C						R				C								
AA 73 D	A	R		C																					C											C		C		R						R							C					
AA 76 A	A	C		C																																R				R	R												C					
AA 76 C	A	C		C	R																					R										R			R		R	R											C					
AA 78 A	A	R	R	C		R				R						R															C				C	C		R		C		R	R															
AA 86 A	A	C	R			R																							C		R		R			C		C		C		R	R															
AA 86 B	A	C		C		R						R																				R			R	C		R		C													R					
AA 86 C	A			C		C	R	C				R				R								R											R	A	C	R		A	C																	R
AA 90	A			C		C		R						R		C								R				C					C			C				C			R															
AA 94	A		R	C			C	C				R								C								C						R	C	C	R			A	R	R				R												

AA 95 B	A R	C R	R	C	R C R		R		R			
AA 96 C	A	C R C R R C		C	A C C	R	R		R		R	
AA 96 D			NO MINERALS IDENTIFIABLE DUE TO LEUCOXENE COATING.									
AB 01	A	R	R C	C C	C	R						
AB 04	A R	C	C R R	C C	A R	R	C				R	
AB 06	A R R	R	A C C	A C	C A A	R	R C		R		R	
AB 07	A R	R R C	R A C	A C	A C A	R	R R					
AC 01	A R	R R	C R R	C C	C C C C	C	C					
AC 02	A	R R	C R	C C	C C		R					
AC 03	A	C R R C	C A	C C	C C R C A	R	R					
AD 01	A	R R	A R	C C	A C C	R	R					
AD 02	A C	C R R	C	C R	C	R	C A C					
AD 03	A R	C	C R	C C	C C	R	A					
AE 01	A	C C R R	R R R C	R R	C C	R	R A R					
AE 02	A R	C R C R	R	R	R R R A		C A					
AE 05	A R	C C R	R R A	C R	C R	C	C R					
AE 09	A	C R	R A	C R	C R C R	R R	R					
AE 11 i	A	R C R	R A	C R	C C C A R		R					
AE 11 ii	A	R R R C	R C	C R	A R A	R	C					
AE 12	A	C C R	R	R R	R R R C		A					
AF 03	C R	R R R	R		R R R R	R	C					
AF 04 i	A R	C C	R R	C	R C R	C	R R					
AF 04 ii	A	R R R	R R	C	A R C	C	R R C					
AF 05	A	C R R R	R	C R	A C R A C	C C	R					
AF 08	A R	C R R	A R	A R	C R	R	R C					
AF 09	A R	R C	R C R	C R	R C C	R	C R					
AF 10	A R	C R C R	C R	C R	C A R	R	C R					
AF 11	A R	R C	R C	A R	A C C C	R	A R				R	
AF 12	A R R	R	R R C	R R	A A	R	R C					
AF 13	C	R		R	C C	R	C					
AG 01	A	C C R R	C R	-	A A R	R	C C R					
AG 02	A R	R C	C C R	C R C	C R	R	R C					
AG 05	A	C	R R	C	A R C C C	R	C R					
AH 01	A	R	R	C	C R				C			
AH 02	A	R C R R C	R	R	C C	R	R					
AH 04	A R			C	C							
AH 05	A	R R	R		C C		C		R			
AH 06	A	R R R	C R	A	R C C	R						
AH 07	A R	R C C R	C R R	C	C C	R	R R					
AH 08	A			R	C R				C			
AH 10	C	R R	R	C R	C R C	R						
AJ 02	A	R R R C		R R	C R C A	R						
AJ 04	A R	C C R R	R C	C	C A	R	C					
AJ 06	A	R R	R	R	R R C		C A C				C	
AJ 07	A	C R	R R	R	R C R		R					
AJ 08	A R	R C	A C C		C R C		R R					
AK 02	C	R R	R	R	C C		R		A	C		
AK 04	C R	- R		C	C C C	R	R	A			A	
AK 06	C	R		R R	R C		R C		R	A		
AK 07 Ai	C R	R	R	C	R R	R		C	A	A		
AK 07 Aii	A				C					A	C	

AK 07 B	C R	R			C						A	C	
AK 08	A			R	C C	R C	R	R R		A	C		
AK 10	A R C	R	R	R	C C C				C	C			
AL 03	A R	R	R	R	C	C R	R	C C				R	
AL 04	C		R	R	A C	A	R	C R					
AM 03	A R	R	R		C	R A	C R	R R		R			R
AM 06	A R	R R	R R		C	C R		C			R		
AN 01	A	A C R R R		C	C	C R	R	R		R	R		R
AO 01	A	R C R R		C R	C	C R	R			R			
AO 02	A	A R C C		R C	R	C	R	R		R			
AO 03	A R	C R C C	R	C	R	C R		C R					
AO 04	A R	R C R	C C R	R C R	C R	A		R					
AQ 01	A	R R	R		R	C A	R	R					
AR 01	A C	A C A C C		C A	C C	R R		C					
AR 02	A	C R C R C	R C	R R	R	R R	R	C					
AR 05	A	R R R	R C	C R	R		R						
AR 07	A	A C C C	C C R	C	C C		C	C C					
AR 09	A	A C R C R	R C	C	C R	R							
AR 10	A	C R R	C C	R C	C	C		R		R			
AT 01	A	C C C R		C	C C		C	R					
AT 04	A R	C C C R		C	C C		R	R					
AT 06	A	C C C		C	C C		R	R					
AT 08	C	A A C A		C	R R		R						
AT 09	A	A A A		C	C C		R	C					
AT 10	A C	A A A		C	C		R	C					
AT 11	A	C C C R		C	C	C	R	R R					
AT 12	A R	C C C	C C	C	R	R	R	R R					
AT 15	A R	R C R		C R	C R	C		R		R			
AT 16	A	C R C R R	R C	R	C	C				R			
AU 01	A	R R C R	C		C C	A C	R	R					
AU 02	A	C R C R R	C	C	R R	C C		R R					
AU 05	A R	R R R		R	R	R							
AU 10	A C	R	R R		R	C							
AU 14	A	C R	C R R	C	R R	R	R			C			
AU 15	A	R R C	C	R R	C R	A							

TABLE IV

LOCATION OF SAMPLES FOR

HEAVY MINERAL ANALYSIS

Sample No. Field Location No.	1:250,000 Sheet area	Grid Ref.
AA01	Mt Coolon	654289
AA 02	"	654290
AA 05	"	642357
AA 07	"	65073020
AA 08	"	65073025
AA 24/A	Taroom	279887
AA 25/B	"	274884
AA 26/A	"	28148754
AA 32	Baralaba	27968955
AA 34	"	28088962
AA 35/B	"	28088962
AA 38/A	"	277886
AA 38/B	Taroom	277886
AA 40/A	"	27308830
AA 40/D	"	27308830
AA 46/A	"	198872
AA 46/B	"	198872
AA 49/B	"	204870
AA 51/A	"	205869
AA 56/B	"	181872
AA 59	"	182883
AA 60	"	182885
AA 62	Baralaba	27138949
AA 64	"	27128943
AA 65	"	27138939
AA 67	"	27019036
AA 68	"	26409357
AA 70/A	"	24809328
AA70/B	Taroom	24809328
AA 72/A	"	12788646
AA 73/C	"	12518658
AA 73/D	"	12518658

Sample No. Field Location No.	1:250,000 Sheet area	Grid Ref.
AA 76/A	Taroom	13058627
AA 76/C	"	13058627
AA 78/A	"	12988620
AA 86/A	"	14128591
AA 86/B	"	14128591
AA 86/C	"	14128591
AA 90	"	14658576
AA 94	"	14298584
AA 95/B	"	14298581
AA 96/C	"	15728385
AA 96/D	"	15728385
AB01	Mt Coolon	660278
AB04	"	660278
AB06	"	660278
AB07	"	660278
AC01	"	658280
AC02	"	658280
AC03	"	658280
AD01	"	658280
AD02	"	658280
AD03	"	658280
AE01	"	654289
AE02	"	654289
AE05	"	654289
AE09	"	654289
AE11	"	654289
AE12	"	654289
AF03	Mt Coolon	654290
AF04	"	654290
AF05	"	654290
AF08	"	654290
AF09	"	654290
AF10	"	654290
AF11	"	654290
AF12	"	654290
AF13	"	655290

Sample No. Field Location No.	1:250,000 Sheet area	Grid Ref.
AG01	Mt Coolon	656280
AG02	"	656280
AG05	"	657280
AH01	"	644354
AH02	"	644354
AH04	"	644354
AH05	"	644354
AH06	"	644354
AH07	"	644354
AH08	"	644354
AH10	"	644354
AJ02	"	639364
AJ04	"	639363
AJ06	"	638363
AJ07	"	638362
AJ08	"	638362
AK02	Taroom	284877
AK04	"	284877
AK06	"	284877
AK07	"	284877
AK08	"	284877
AK10	"	284877
AL03	"	28338783
AL04	"	28338783
AM03	"	281878
AM06	"	281878
AN01	"	28358867
AO01	"	28228911
AO02	"	28228911
AO03	"	28228911
AO04	"	28228911
AQ01	"	27288835
AR01	"	13618634
AR02	"	13618634
AR05	"	13618634
AR07	"	13618634
AR09	"	13618634
AR10	"	13618634

Sample No. Field Location No.	1:250,000 Sheet area	Grid Ref.
AT01	Taroom	14228603
AT04	"	14228603
AT06	"	14228603
AT08	"	14228603
AT09	"	14228603
AT11	"	14228603
AT12	"	14228603
AT15	"	14228603
AT16	"	14228603
AU01	Springsure	66639094
AU02	"	66689050
AU05	Taroom	15728380
AU10	Springsure	51989470
AU14	"	53109292
AU15		56919310

relationship to sediments in the south-east.

On Plate 3, the combined results of cross-stratification and heavy mineral analysis have been used in the interpretation, showing two main source areas for the bulk of the sediments.

PALYNOLOGY

Earlier work on the palynology of the Moolayember Formation has been carried out by de Jersey and Hamilton (1967) and Kemp (Alcock 1969, Appendix II).

Some additional material examined by Kemp was obtained from 1969 drilling in the south-eastern and northern areas of outcrop. So far the results from only two wells (Taroom Nos 1 and 3) are available. One of four surface samples from the Carnarvon Range Area also yielded identifiable residue. A summary of these results from the work of Kemp (pers. comm.) is included here.

Taroom (BMR) No 1 (3200 feet above base of formation).

MFP5254; depth 100 feet: spores are common but not well preserved. *Alisporites* is most common but the sample also contains *Clavatrilites hammeni*, *Dictyosporites mortani* and possibly *Taeniaesporites*. Age is probably middle Triassic (Kemp, pers. comm.). *C. hammeni* was recorded by de Jersey and Hamilton (1967) from the Moolayember Formation on the western limb of the Mimosa Syncline between 1300 feet and 3200 feet above the base. However, *D. mortani* and *Taenaesporites* were not recorded from any of this section by these workers.

MFP5255; depth 106 feet: Spores are very rare and poorly preserved but the combined presence of *Duplexisporites gyratus* and

Aratrisporites sp. suggests correlation with the lower part (below 2600 feet) of the section studied by de Jersey and Hamilton.

MFP5248; depth 222 feet: Spores are rare and very poorly preserved. Those identified include Aratrisporites sp. Alisporites sp., Tuberculatosporites cf. aberdarensis, Neoraistrickia taylori. Again Aratrisporites sp. suggests correlation with the lower part of the west Mimosa section examined by de Jersey and Hamilton but T. cf aberdarensis and N. taylori were not recorded from that section.

MFP5256; depth 271 feet: An unusual but not very diverse assemblage dominated by Lophotrilites bauhiniae with subsidiary Alisporites and fragments of Nathorstisporites (megaspore) (Kemp, pers. comm.). De Jersey and Hamilton (1967) found C. bauhiniae only in the lower 2600 feet of the west Mimosa section but nowhere in this section was the megaspore Nathorstisporites recorded.

Taroom BMR No 3 (5600 feet above base)

MFP6253; depth 70 feet: Sparse, poorly preserved Triassic but non-diagnostic forms including Alisporites.

MFP5252; depth 180 feet: Poorly preserved assemblage containing Krauselisporites vernicifer and Nathorstisporites "micro-reticulatus" which tentatively suggest an upper Moolayember interval (Kemp, pers. comm.). Neither of the species were recorded from the west Mimosa section by de Jersey and Hamilton (1967).

The two-fold subdivision inferred from palynological study in the Mimosa Syncline probably does not coincide with the two-fold subdivision proposed from lithology. Field study in the south-eastern area of outcrop, has demonstrated an exposed thickness of 5500 feet made up of a lower unit (D1) 1700 feet thick and an upper unit (D2) at least 3800 feet thick (Alcock, 1969).

Although the boundary between lower and upper spore assemblages in the north-western Mimosa Syncline occurs at about 2600 feet above the base (de Jersey and Hamilton 1967) species confined to the lower part here occur 3200 feet above the base in the Dawson Range (south-eastern) Area which is well up into P 2. An overall southwards thickening of the formation in the Mimosa Syncline would explain the occurrence of certain species higher in the south-eastern section than in the north-western section.

One surface sample (MFP5247) from the Carnarvon Range Area yielded Jurassic spores. The assemblage consisted of about 80% Classopollis with some Cardargasporites sp. which indicate a J_1 interval.

The sample was collected at the base of the cliff-forming Precipice Sandstone in carbonaceous mudstone from an interval of thinly bedded quartz sandstone and mudstone. This was initially believed to have been a quartz-rich phase of the Moolayember Formation as it is overlain with slight unconformity by a thick unit of cross-bedded quartz sandstone belonging to the Precipice Sandstone. The palynological evidence however, indicates that this is not so.

ENVIRONMENTAL ANALYSIS IN CARNARVON RANGE AREA

GENERAL INTERPRETATION

Features observed in unit C1 suggest that deposition took place largely in a tidal estuary, although the absence of marine fauna means that the large water body under tidal influence may have been a huge lake. Rapidly alternating planar beds of cross-laminated and laminated siltstone and cross-laminated sandstone accumulated where currents of the lower flow regime operated but current reversals occurred. Areas of relatively slow sediment deposition experienced prolonged subaqueous conditions when an infauna became established and was active in churning sediment. In other parts more rapid sediment accumulation and changing conditions inhibited the development of such fauna, and in some areas subaerial exposure is documented by desiccation of mud. Near the estuary mouth shallow tidal channels provided a setting for the formation of mega-ripples of very coarse sand, presumably derived from nearby beaches. A combination of the lateral movement in tidal channel position and periodic tranquil flow allowed fine sandstone and mudstone carried by the river to be deposited between successive coarse rippled beds. Another feature which appears significant is the occurrence of a conspicuous, relatively extensive intraformational breccia horizon which may be a shoreline feature. The breccia is overlain in most places by flaggy fine sandstone and siltstone reminiscent of lake deposits.

The overlying unit C2 commences with small-scale delta-type sedimentation of a much more lithic and generally coarser grained sandstone than occurs in C1. The overall southerly current movement implies delta progradation into a body of water to the south. Subsequent deposition in C2 closely resembles that of the alluvial or valley-fill model recognised by many workers, e.g. Visher (1965).

Section DA70 and DA74 represent basal sediment of the valley-fill cyclothem where coarse, cross-bedded sandstones with channel lag deposits predominate and are overlain by parallel laminated sandstone and smaller-scale cross-stratified sandstone. This in turn is overlain by thinly interbedded sandstone, siltstone and mudstone with carbonaceous horizons as at DA62 and DA71 or tubular structures attributable to roots and invertebrate burrows as at DA75. A similar repeated sequence has been described from drilling results in the south-eastern and northern areas. This sequence is attributed to accumulation in a river valley from a meandering river which deposits sediment as point bars, point bar swales, levee deposits and flood-plain deposits.

PROPOSED SEDIMENTATION MODEL

With the data available it is possible to develop a model for sedimentation of the Moolayember Formation in the Carnarvon Range Area (Fig. 51).

Alluvial and estuarine sedimentation in the lower part of unit C1 is succeeded by an extensive intraformational breccia which is regarded as a beach deposit. As the beach deposits overlie the estuarine (tidal) sediments, northward transgression by the lake is implied. Inundation of gradually subsiding land resulted in the thinly bedded fine sandstone and siltstone (near shore lake sediments) overlying the breccia e.g. sections DL3, DK and DN.

An event which occurred at the end of C1 resulted in large quantities of highly lithic medium to coarse sand being carried southward by rivers into the lake. This resulted in the building of numerous small deltas (e.g. DA44 and DA63), local contemporaneous erosion of the upper C1 lake deposits and the regression of lake waters southward.

In developing this model for sedimentation the most straightforward and logical explanation has been attempted to explain each of the features in the examples used. It is recognized that alternative explanations are possible and indeed likely in some cases.

For example, the presence of tidal effects implies a marginal marine setting or the presence of a lake far bigger than any known today. As definite evidence of marine conditions has not been found in the sediments under review the tidal origin proposed for some of the sediment is open to question. The main evidence for tidal conditions is the bimodality of current directions in sandstone deposited in the lower flow regime. Only a very few such beds exhibit this bimodal distribution and an alternative explanation may be simultaneous accumulation on opposite sides of a longitudinal bar. If this were the case much of the deposition in Unit C1 could be explained in terms of lake infilling by delta deposits. However, such an explanation would require that special conditions be proposed to explain the observed features of the mega-ripples and the occurrence together of discrete sandstone types.

Further sediment was supplied to the newly formed rivers meandering across low-lying plains. Deposition of this material as point bars, infilling of swales, flood basins, isolated lakes and swamps gave rise to several hundred feet of alluvial sediments.

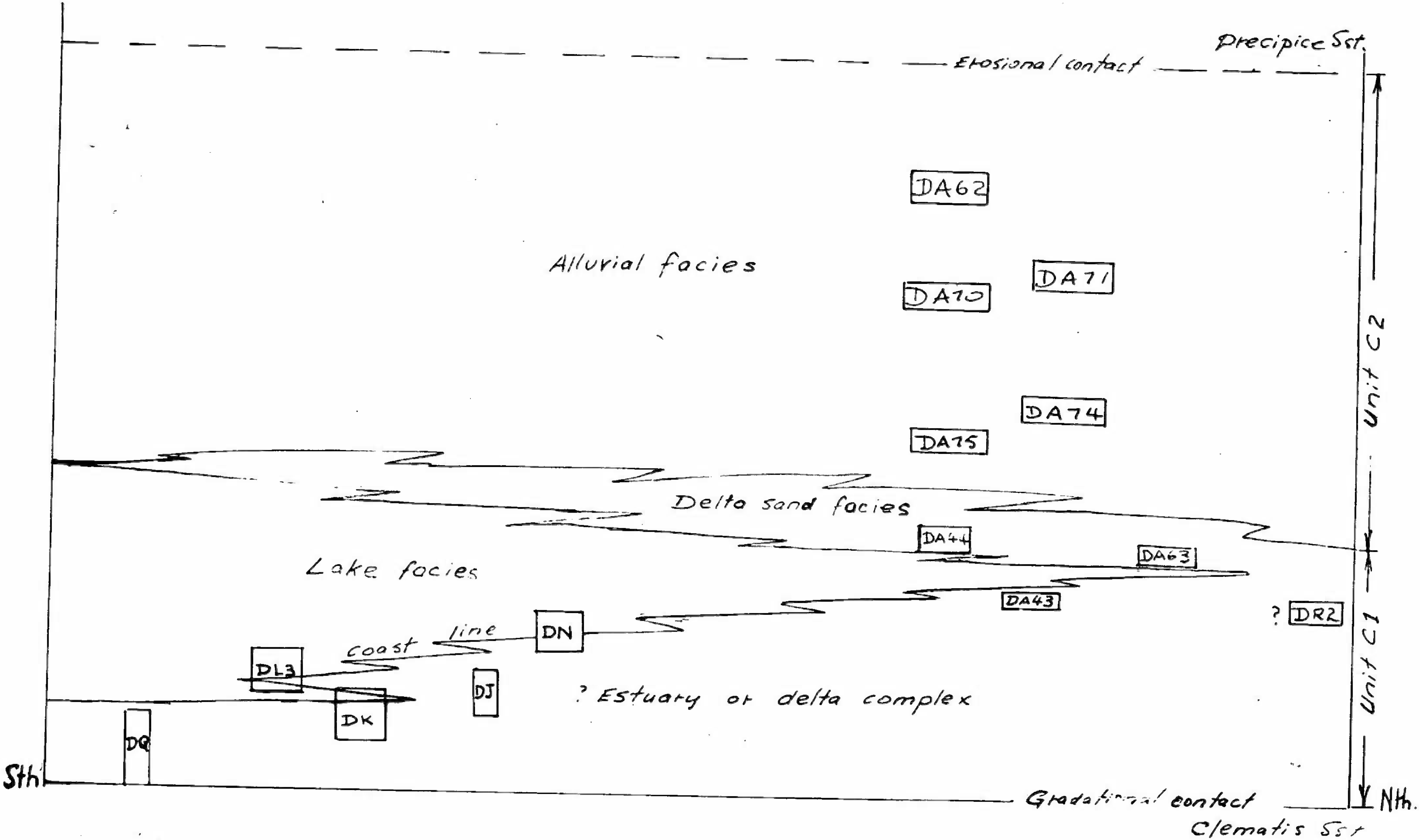

Figure 51 : PROPOSED SEDIMENTATION MODEL IN CARNARVON RANGE AREA SHOWING RELATIVE POSITIONS OF MEASURED SECTIONS.

To accompany BMR Record 1970/25

SUMMARY OF REGIONAL PATTERN OF SEDIMENTATION

The Moolayember Formation is composed largely of alluvial sediment but variations from normal valley-fill type of accretion occurs in some areas.

In the south-eastern part of the basin rivers flowing towards the south-west drained a local elevated area of intermediate volcanic rocks which broke down into grains ranging from sand to cobble size. The resulting sandstones and conglomerates were deposited probably as alluvial fans bordering the hills.

Sedimentation continued in this direction with decreasing abundance and size of pebbles with time. Rapid erosion, transportation and deposition is evident from an abundance of unstable ferromagnesian minerals in the area. Alluvial sedimentation continued in this area while gradual subsidence of the lithotope maintained a gradient towards the south-west. Prolonged contemporaneous subsidence in the area (now the Mimosa Syncline) ensured a much greater thickness of sediment here than elsewhere in the basin.

Further westward in the Carnarvon Range Area the formation apparently received some of its sediment from the east, but contributions from the north were also a dominant factor according to the current data and heavy mineral analyses. A topographic barrier probably existed between the northern area and the south-eastern area, but the regional palaeoslope was generally towards the central south of the basin where an extensive low area was initially occupied by a large body of water.

The northern area, although far removed from adjacent parts of the formation, appears to be most closely related to the Carnarvon Range Area with which it shares the same heavy mineral assemblages.

Palaeoslopes down to the south are also indicated for this northern area where south-flowing rivers developed alluvial sediment profiles.

A more complete study of this formation requires detailed s study of subsurface data beneath the Surat Basin sequence to the south. By relating subsurface data with that from surface a more comprehensive regional sedimentation modal could be developed.

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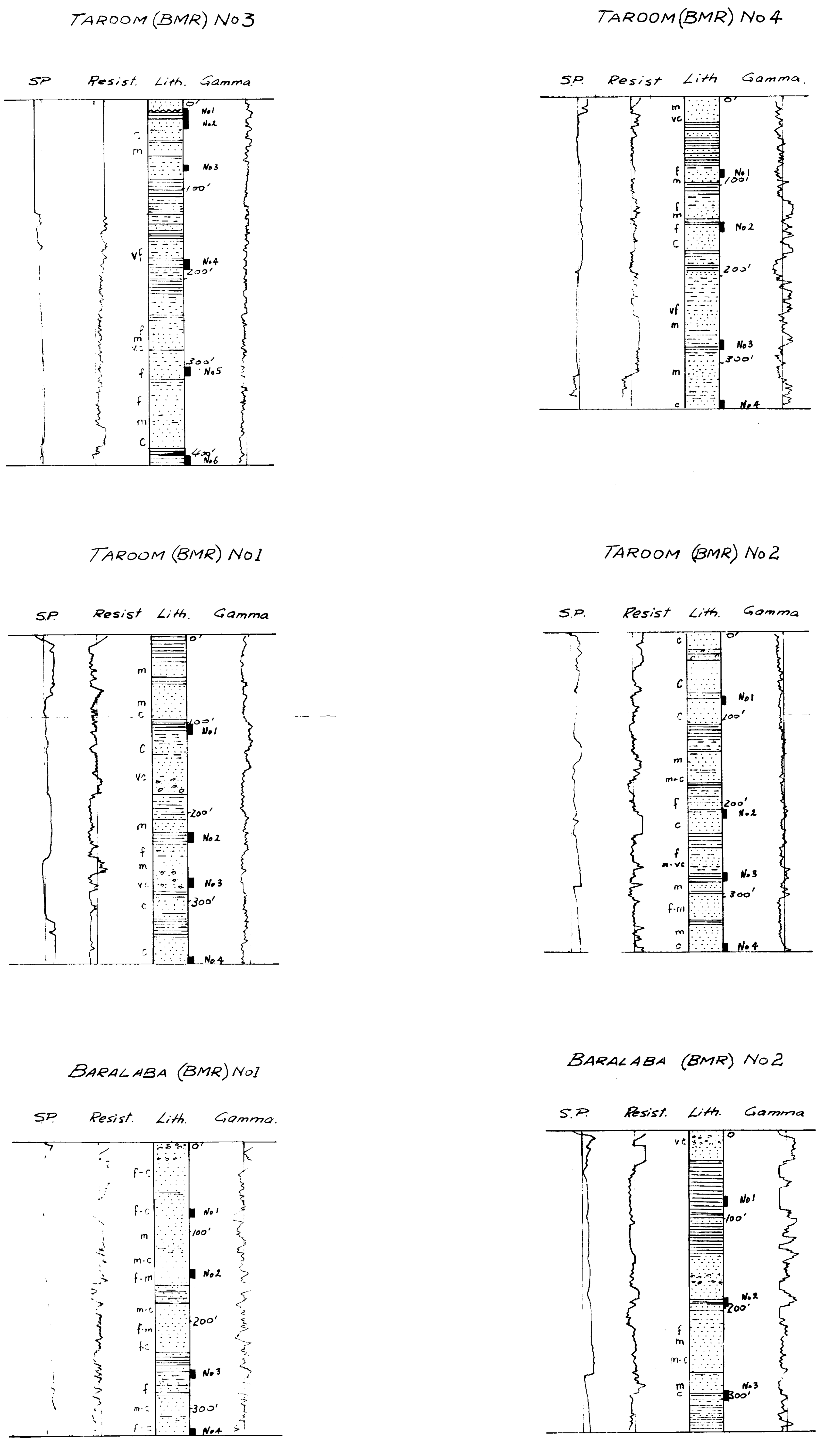
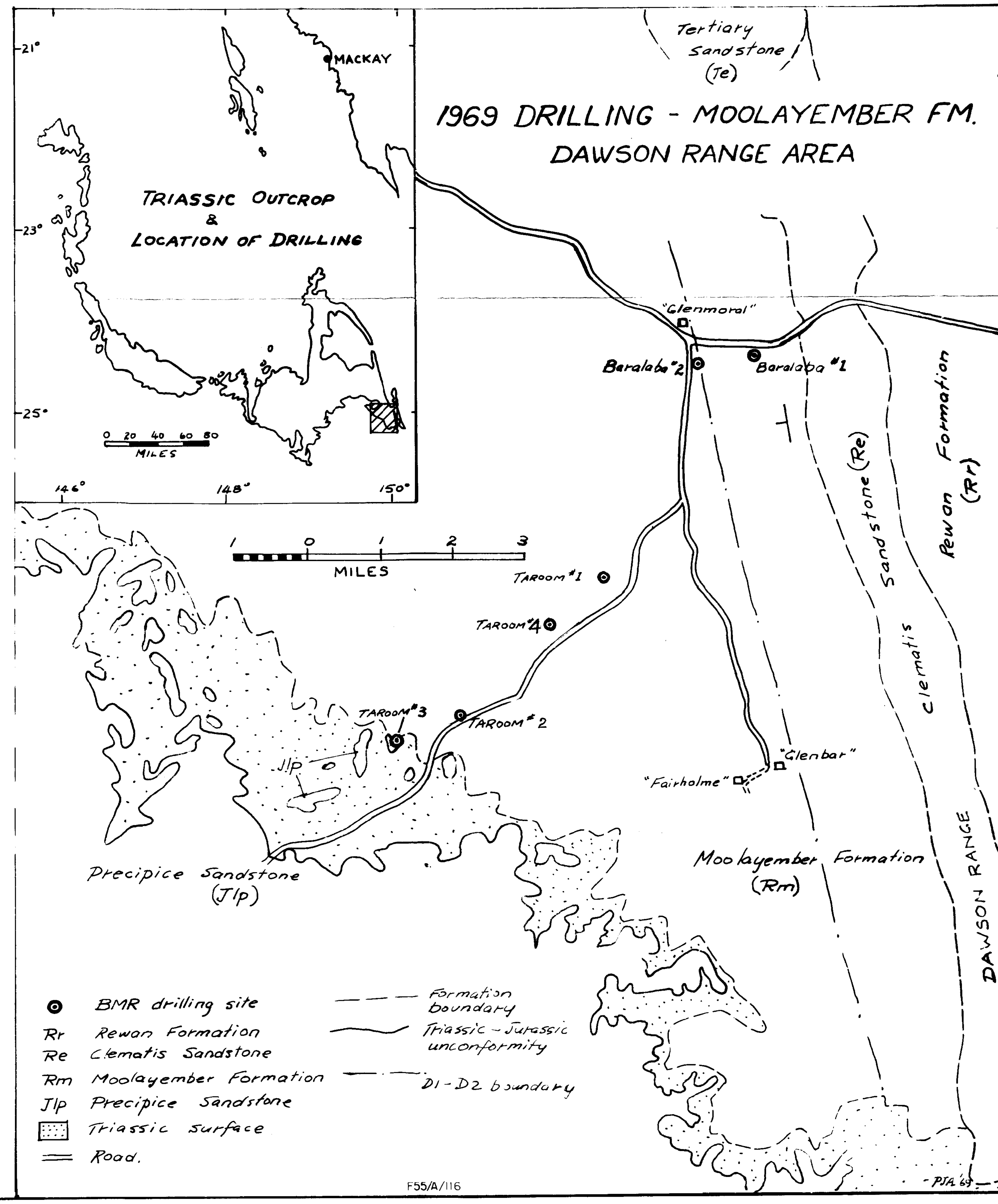
PLATE 1

RESULTS OF DRILLING IN MOOLAYEMBER FM.

DAWSON RANGE AREA



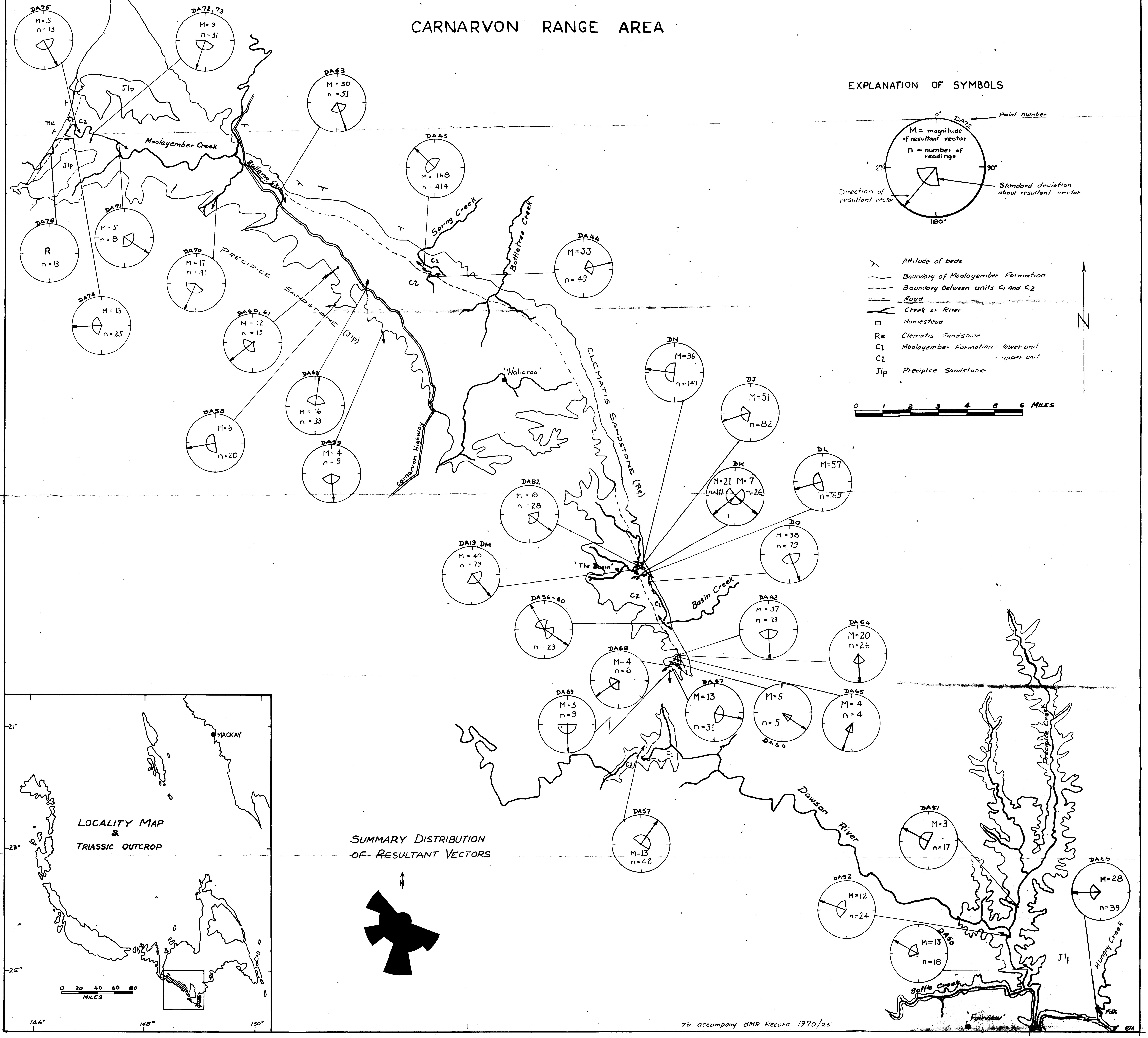


To accompany Record 1970/25

RESULTANT VECTORS OF CROSS-BEDDING MEASUREMENTS

CARNARVON RANGE AREA

PLATE 2



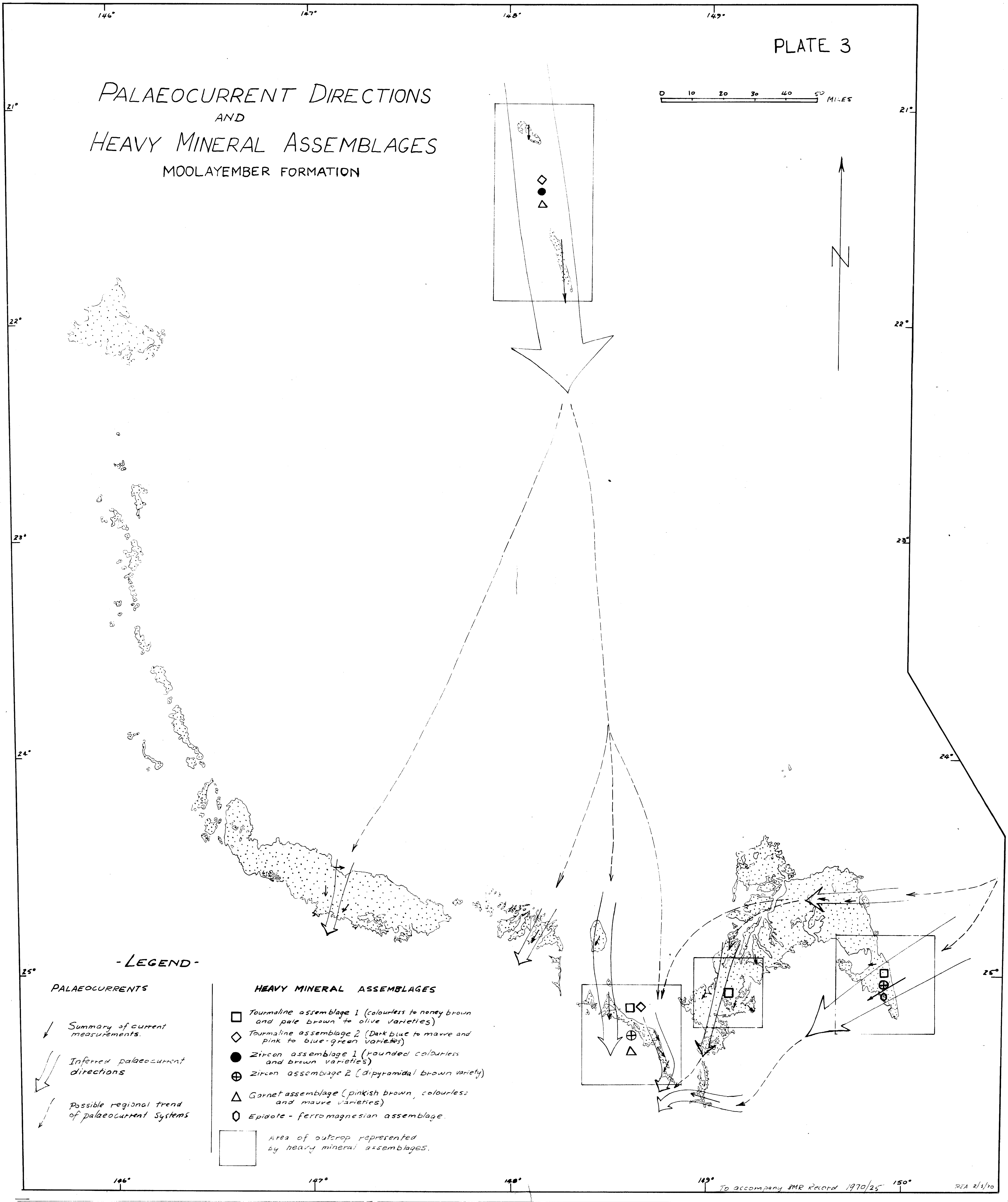


PLATE 3
PALAEOCURRENT DIRECTIONS
AND
HEAVY MINERAL ASSEMBLAGES
MOOLAYEMBER FORMATION
0 10 20 30 40 50 MILES
N
146°
147°
148°
149°
150°
21°
22°
23°
24°
25°
-LEGEND-
PALAEOCURRENTS
Summary of current measurements.
Inferred palaeocurrent directions
Possible regional trend of palaeocurrent systems
HEAVY MINERAL ASSEMBLAGES
Tourmaline assemblage 1 (colourless to honey brown and pale brown to olive varieties)
Tourmaline assemblage 2 (Dark blue to mauve and pink to blue-green varieties)
Zircon assemblage 1 (rounded colourless and brown varieties)
Zircon assemblage 2 (dipyramidal brown variety)
Garnet assemblage (pinkish brown, colourless and mauve varieties)
Epidote - ferromagnesian assemblage.
Area of outcrop represented by heavy mineral assemblages.
To accompany BMR Record 1970/25
PJA 2/1/70