CHAPTER 2: SEDIMENTARY PETROGRAPHY AND SEDIMENTATION OF THE ROCKVALE - COFFS HARBOUR REGION

This chapter is concerned with the petrography and sedimentology of the Palaeozoic sediments of each tectonic block. Classification of the rocks using grain-size and the detrital components of sandstone are discussed in Appendix III along with methods of modal analyses and other techniques.

COFFS HARBOUR BLOCK

Redbank River Beds

This unit has been described previously by Korsch (1968, 1971) and is exposed only in one small coastal headland. It consists of red to white well-bedded jaspers and cherts with an interbedded altered basaltic lava. The unit is intensely folded and the thickness of exposed rocks is about 100?m.

Coffs Harbour Sequence

The stratigraphic sequence of Moombil Beds, Brooklana Beds and Coramba Beds consists of lithic to feldspathic greywackes, laminated silt-stones and mudstones, massive argillites, and rare radiolarian-bearing mud-stones. Because of similarities between the three stratigraphic units, a description of the salient petrographic features of each unit will follow a general petrographic discussion.

PETROGRAPHY OF THE GREYWACKES

The most important feature of the greywackes from the Coffs Harbour Sequence is the abundance of volcanic-lithic fragments and plagioclase. The rocks are predominantly quartz-poor (under 25%). The matrix has been considerably altered by low-grade regional metamorphism with the development of new minerals. These replace detrital grains as well as the matrix, and occur also as veins.

Detrital Minerals

Quartz: Detrital quartz ranges from 4% to over 22%, commonly occupying 10% to 15% of the greywackes. They are generally single grains with straight extinction, but composite grains do occur. Grains with undulose extinction are usually composite. The majority of grains are very angular (Plate 3A) to subrounded, but rarer rounded grains do occur. Many fragments show deep embayments (Plate 3B), possibly indicative of derivation from a volcanic source. The embayments are filled with very fine-grained quartz and feldspar, or chlorite. Most detrital grains are clear and lack inclusions, but some grains contain small inclusions of apatite or zircon, and others contain linear bubble trains.

Feldspar: Plagioclase and minor K-feldspar vary greatly in total amount, ranging from as low as 6% to over 60%. Refractive indices (Table 3) indicate that andesine close to An_{40} is dominant. Williams (*in* Williams *et al.* 1954) considers this to be the average composition of plagioclase in andesitic rocks. The main K-feldspar form is orthoclase, but minor microcline and perthite occur. Albitisation and sericitisation of feldspars is extensive, and some partial replacement of plagioclase by epidote is common. The secondary epidote can occur as either a single grain or as a composite group up to 2 mm in diameter. Some plagioclase is almost albitic (e.g. S32588, Table 3) and may be a secondary product, not the true detrital composition.

Feldspar grains range from about 2 mm to less than 0.05 mm in diameter, and also occur as minute fragments in the matrix. They are usually euhedral to subhedral in outline but rare anhedral grains also occur. Deformation, in the form of bent twin lamellae and fractured grains is present. Inclusions are infrequent, usually being aligned along cleavage planes.

Pyroxene: Pyroxene is very rare in greywackes from the Coffs Harbour Sequence, having been found only in the Coramba Beds east of Dalmorton on the Grafton - Newton Boyd Road (approx. GR 5630 3014) and east of the Clarence - Moreton Basin at GR 6365 2946. The pyroxene was observed in 6% of greywackes from Unit D of the Coramba Beds, and was not found in any other unit. It is a clinopyroxene with extinction angles ranging from 29° to 45°, a 2V of approximately 45-55°, and a colourless to very pale-pinkish tinge under plane polarised light. All properties are indicative of augite, and no evidence for pigeonite or hypersthene was found. The grains are almost perfect

Table 3: Refractive indices of feldspars from greywackes of the Coffs Harbour Sequence[+]

Stratigraphic Unit	Petrographic Unit	Thin Section	R.I. (β_{Na})	Composition
a) <u>Plagioclase</u>				
CORAMBA BEDS	D	8939*	1.555	An46
	D	8937*	1.554	An43
	C	8929*	1.554	An43
	C	8931*	1.552	An39
	C	8930*	1.553	An41
	B	32513	1.551	An37
	B	32493	1.551	An37
	A	32554	1.548	An31
BROOKLANA BEDS	-	32584	1.549	An33
	-	32588	1.539	An12
	-	32629	1.554	An43
b) <u>Orthoclase</u>				
CORAMBA BEDS	B	32518	1.529	N.A.
	B	32524	1.532	N.A.

\+ Compositions for β_{Na} for plagioclase read from graph of Smith (*in* Hess 1960)

* From Korsch (1968, p.178)

PLATE 3

A. Angular detrital clast of quartz in a hornblende-bearing lithic greywacke. Unit D, Coramba Beds. S8935, magnification x 45, plane light.

B. Embayments in volcanically-derived detrital quartz from a feldspathic greywacke. Unit C, Coramba Beds. S8929, magnification x 20, crossed nicols.

C. Euhedral crystal of hornblende from a feldspathic greywacke. Unit C, Coramba Beds. S8930, magnification x 45, plane light.

D. Detrital hornblende crystal from a lithic greywacke. Unit D, Coramba Beds. S32456, magnification x 200, plane light.

E. Euhedral twinned hornblende crystal from a lithic greywacke. Unit D, Coramba Beds. S32381, magnification x 45, crossed nicols.

F. Phenocryst of hornblende in a dacitic volcanic fragment from a lithic greywacke. Unit D, Coramba Beds. S32360, magnification x 45, plane light.

G. Extremely fine-grained aggregate of quartz and feldspar forming a devitrified holohyaline volcanic fragment in a lithic greywacke. Unit D, Coramba Beds. S32447, magnification x 50, crossed nicols.

H. Eutaxitic volcanic fragment in a lithic greywacke. Unit A, Coramba Beds. S8964, magnification x 50, plane light.

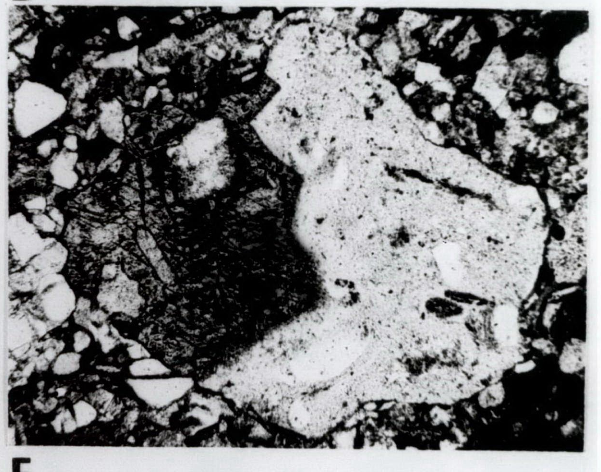
A

B

C

D

E



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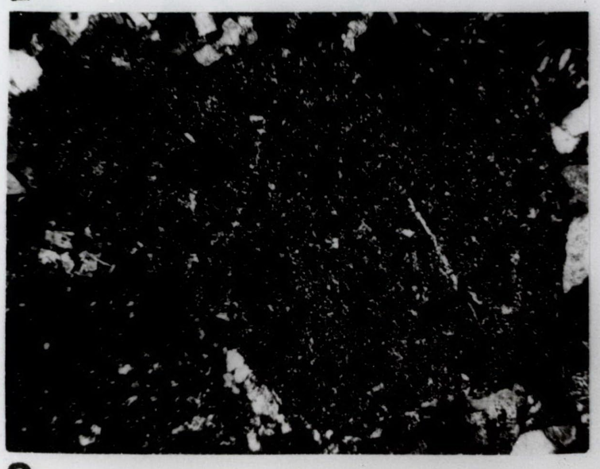

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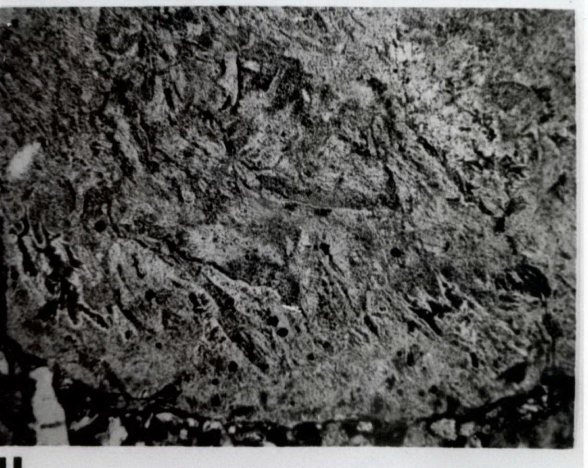

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euhedral crystals up to 1 mm long, or are highly fractured and veined anhedral fragments. Twinning is common, particularly in the euhedral crystals.

Amphibole: Amphibole is very common in Units C and D from the Coramba Beds (0.2 to 12.0%). It occurs as euhedral to anhedral grains (Plates 3C, 3D) with an average grain size of about 0.5 mm but ranging from 0.05 mm to 2 mm. Euhedral twinned crystals occur frequently (Plate 3E). Extinction angles ($Z \wedge C$) range between 14° and 31°. Several pleochroic schemes were observed:

	α	β	γ
S 32513	pale yellow	light green	green
S 32362	straw	green	olive-green
S 8937	pale yellow-brown	yellow-green	green-brown
S 8930	straw	pale brown	brown
S 32490	yellow-brown	red-brown	dark red-brown

These schemes can be related to either common hornblende or basaltic hornblende (Deer *et al.* Vol. 2, p.263 and 315). The hornblende grains are mainly fresh, but some have been partially or completely altered to chlorite and minor epidote. Actinolite is a rare alteration product (S32381). Hornblende has been observed as rare phenocrysts in dacitic volcanic lithic fragments (Plate 3F). Occasionally it occurs in reworked sediments, along with minor opaques, as heavy mineral bands interlayered with quartz, feldspar and lithic fragments.

Hornblendes derived from island arc calc-alkaline andesites and dacites can be distinguished by chemical analysis from the hornblendes of continental rocks of calc-alkaline affinities (Jakes and White 1972). Unfortunately the distinction could not be made for the Coffs Harbour rocks because it proved impossible to separate sufficient fresh hornblende for chemical analysis.

Mica: Plates of biotite and detrital muscovite are minor in occurrence, and are invariably bent or fractured as a result of deformation due to compaction. They are rarely fresh, the biotite usually being altered to chlorite. Pleochroism in the biotite is generally from pale yellow to drab brown, but occasional red-brown varieties occur. Biotite was also observed as rare phenocrysts in volcanic lithic fragments.

Accessory Minerals:

Epidote occurs as small (up to 0.5 mm) single well-rounded anhedral grains, commonly pleochroic from colourless to yellow. Composite detrital grains are extremely rare, being more common as secondary alteration products.

Chlorite plates are common and are often euhedral in outline, being pseudomorphs of the minerals they have replaced. Occasionally they were observed as phenocrysts in volcanic lithic fragments. It is considered that these plates formed as an early alteration product, possibly associated with the volcanism, and that they are not related to the chlorite produced by the low-grade regional metamorphism. The plates are pleochroic from almost colourless to green or yellow-green and are normally about 0.3 to 0.5 mm long.

Zircon occurs in about 20% of greywackes in very minor amounts and the grains are usually less than 0.1 mm long.

Tourmaline occurs in about 5% of the greywackes as single, subrounded or anhedral grains, ranging in size from 0.1 mm to 0.5 mm. Pleochroism is from pale cream to brown, or more commonly, from colourless to deep blue-green.

Sphere is an uncommon accessory mineral and when observed is usually associated with biotite.

Opaque minerals, usually magnetite or ilmenite, occur as subrounded anhedral grains about 0.1 mm in diameter.

Lithic Fragments

Lithic fragments account for 5% to 60% of the greywackes, the characteristic content being 20-30% in feldspathic greywackes, and 30-60% in lithic greywackes. Volcanically-derived fragments predominate over plutonic, metamorphic and sedimentary lithic fragments, with V/L ratios of about 0.8.

A. Volcanic Lithic Fragments

A number of textural types have been recognised among the volcanic lithic fragments, and they can be described using the terminology of Williams *et al.* (1954). The following textures were observed and each is linked with possible source rocks. Staining with sodium cobaltinitrite indicates a moderate rhyolitic component, although the main compositions appear to be dacitic to andesitic.

Texture	Varieties	Possible Rock Type
1. Holohyaline	holohyaline	dacite, rhyolite
	eutaxitic	dacitic ignimbrite (ashflow tuff)
	devitrification texture	dacite, rhyolite
	flow bands	rhyolite, dacite
	perlitic cracking	rhyolite
	spherulites (plumose)	rhyolite, dacite
2. Hemihyaline	vitrophyric	hornblende-dacite, dacite, rhyolite
	porphyritic	dacite, andesite, rhyolite, trachyte
	intergranular-intersertal	andesite, trachyte
	magmatic resorption	dacite, rhyolite
3. Holocrystalline	trachytic and pilotaxitic	andesite, trachyte
	porphyritic	andesite

1. Holohyaline Textures: Holohyaline fragments are the most abundant volcanic lithic fragments if one includes fragments which were originally holohyaline and are now devitrified to an extremely fine-grained aggregate with indistinguishable particles (Plate 3G). Holohyaline fragments have been counted separately in the modal analyses when they could not be grouped into other categories. It is possible to recognise several varieties.

Eutaxitic varieties, characteristic of ignimbrites are common. They have a relict vitroclastic texture formed by crescentic, triangular or tricuspate fragments of glass, attenuated and welded during load compaction. A planar parallel fabric is generally present. Good examples of eutaxtic texture may be seen in slides S8950 and S8964 (Plate 3H).

The devitrification variety, in which the vitric material has been converted to crystalline aggregates of quartz and feldspar, is extremely common. Depending on original composition, the glass devitrifies to quartz and plagioclase or quartz and K-feldspar, as shown by staining.

Flow banding, indicative of siliceous lava flows such as rhyolites and dacites, occurs occasionally and consists of parallel alternating layers which are possibly dissimilar in composition. However the compositional layers cannot be distinguished because of the very fine grain size, due to devitrified glass (Plate 4A). Frequently the flow bands swirl around phenocrysts of quartz or feldspar (e.g. S32472).

Perlitic cracking occurs as a relict structure in some devitrified fragments, and consists of some irregular to spheroidal cracks and markings best observed in plane polarised light. These fragments were originally dacitic or rhyolitic.

Spherulitic (plumose) varieties of holohyaline fragments are common and consist of small, radiating, often concentrically arranged aggregations of quartz and feldspar formed by radial growth from a common centre during the devitrification of glass (S8956, Plate 4B).

Vesicular fragments are uncommon and usually consist of a devitrified groundmass, with the vesicles being filled by chlorite or calcite.

2. Hemihyaline Textures: The most common hemihyaline texture is the vitrophyric variety which consists of phenocrysts of quartz, plagioclase, biotite or hornblende, with an average grain size of about 0.5 to 1 mm, set in a glassy groundmass devitrified to minute blebs of quartz and plagioclase (S8932, S32552, Plate 4C).

Some porphyritic fragments with a devitrified groundmass of quartz and feldspar occur. Magmatic resorption is commonly exhibited by phenocrysts of quartz in dacitic and rhyolitic fragments (Plate 4D), and is indicative of high temperature β-quartz which formed above 573°C (Tuttle and Bowen 1958). Resorbed quartz is also present in detrital grains (Plate 3B) which were derived from acid volcanic rocks.

Intergranular-intersertal textures consist of randomly oriented laths of feldspar with interstitial glass or augite (S8950, S8956, Plate 4E). These features are grouped together, because it is difficult to determine conclusively whether it is devitrified glass or completely altered augite that is interstitial between the plagioclase laths.

3. Holocrystalline textures: Trachytic texture is formed by the alignment of feldspar laths (usually plagioclase) parallel or sub-parallel to flow lines in lavas (S8935, Plate 4F), and is common in trachytes and andesites. A few fragments of quartz trachyte (e.g. S32466) consist of randomly-oriented K-feldspar laths, with irregular outlines of quartz, and minor areas of opaque minerals. Fragments that are pilotaxitic (a fine-grained network of needle-like feldspars, usually subparallel) are included in this category (Plate 4G).

Porphyritic texture describes rocks in which phenocrysts such as twinned feldspar or hornblende are set in a fine-grained groundmass which is not hyaline (Plate 4H). The groundmass usually consists of randomly-

PLATE 4

A. Flow-banded volcanic fragment in a feldspathic greywacke. Unit C, Coramba Beds. S32472, magnification x 20, plane light.

B. Spherulitic volcanic lithic fragment in a feldspathic greywacke. Unit B, Coramba Beds. S32524, magnification x 50, crossed nicols.

C. Vitrophyric volcanic fragment containing phenocrysts of hornblende and plagioclase, from a feldspathic greywacke. Unit C, Coramba Beds. S8932, magnification x 20, plane light.

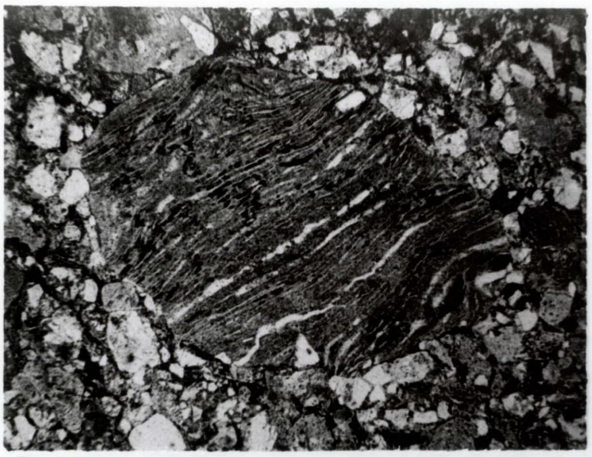
D. Resorbed quartz phenocrysts in a devitrified flow-banded textured fragment from a lithic greywacke. Unit D, Coramba Beds. S32362, magnification x 20, crossed nicols.

E. Intergranular volcanic fragment in a lithic greywacke. Unit A, Coramba Beds. S8950, magnification x 50, plane light.

F. Trachytic textured volcanic fragment in a lithic greywacke. Unit A, Coramba Beds. S8964, magnification x 45, plane light.

G. Pilotaxitic textured volcanic fragment in a lithic greywacke. Unit A, Coramba Beds. S8950, magnification x 50, crossed nicols.

H. Porphyritic-pilotaxitic textured fragment in a feldspathic greywacke. Unit C, Coramba Beds. S8930, magnification x 45, crossed nicols.



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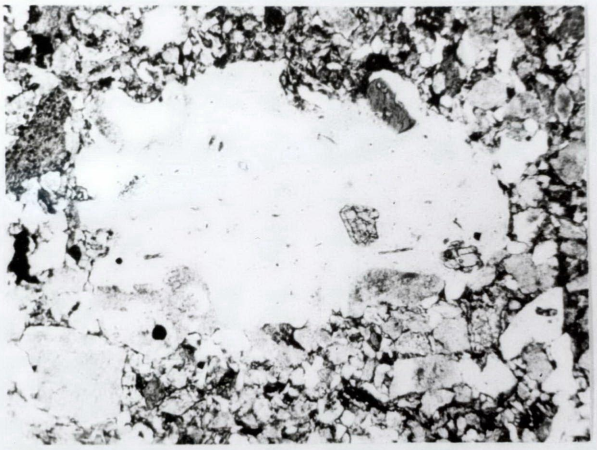

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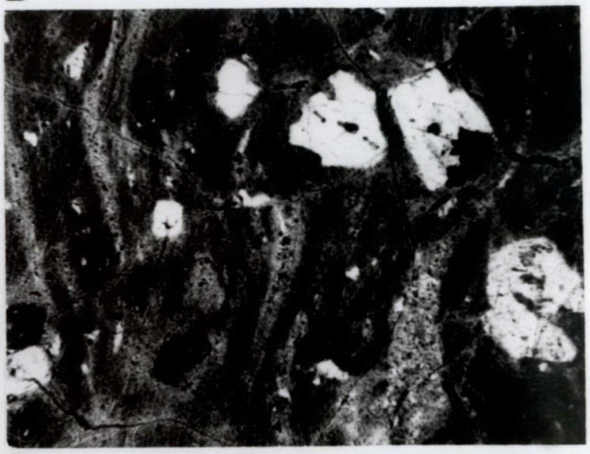

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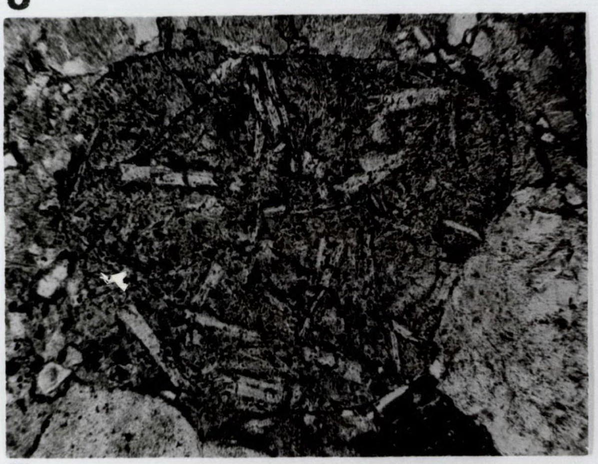

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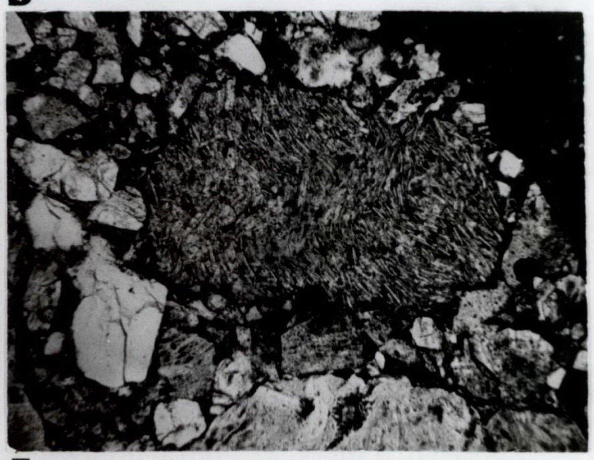

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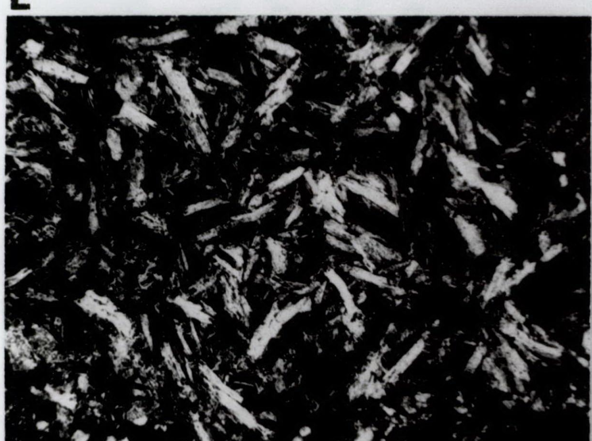

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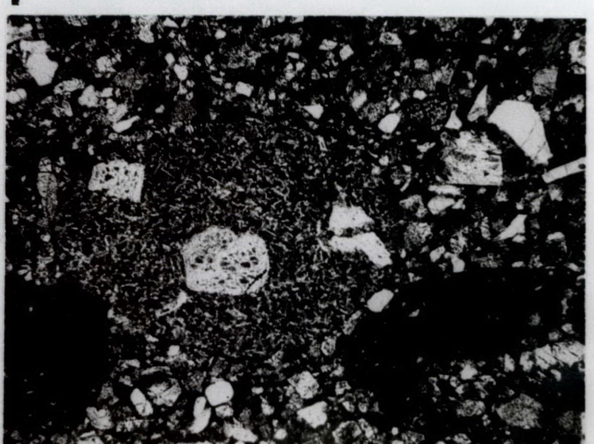

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oriented plagioclase laths, varying in size from needle-like microlites to laths up to 0.5 mm long. The phenocrysts usually have a stumpy rectangular form. Examples are S8956 and S8964.

B. Plutonic Fragments

Acid plutonic fragments up to about 2 mm in diameter, and derived from a granitic distributive province, occur throughout the greywackes in small amounts, ranging from zero to 10% (average of less than 1%). The following combinations of composite mineral grains are observed:

quartz-plagioclase
quartz-orthoclase
quartz-orthoclase-plagioclase
quartz-orthoclase-plagioclase-biotite
quartz-orthoclase-plagioclase-hornblende-opaques

The larger fragments show an hypidiomorphic-granular or allotriomorphic-granular texture (Plate 5A). The hornblende is pleochroic from yellow to blue-green, and the biotite from straw to red-brown, and both have been partially replaced by chlorite. Very rare fragments of dioritic material (abundant hornblende and plagioclase) and myrmekite were also observed.

C. Metamorphic Fragments

Metamorphic fragments are a minor but persistent constituent, occupying from zero to 6% of the rock (average less than 2%). Schistose fragments, occasionally with a distinctive slaty appearance (S32359), consist of parallel bands of quartz-biotite-muscovite-feldspar with a pronounced foliation (e.g. S32400). Other fragments are metasedimentary, with angular to subrounded grains of quartz in a clay matrix which has been totally converted to muscovite with a pronounced parallelism of grains (e.g. S32430, S32449). Both types are indicative of a low-grade metamorphic terrain.

D. Sedimentary Fragments

Sedimentary fragments are a persistent component occupying up to 20% of the rock. Modal analyses (Table 4) list percentages of sedimentary fragments excluding intraformational mudstone chips, which are very common (Plate 5B). Sedimentary fragments, other than intraformational debris, occupy 0-3%, and include fine quartzose sandstone (angular clasts of quartz in a fine-grained matrix), chert, radiolarian chert (Plate 5C) and radiolarian-bearing mudstones. The radiolaria have been replaced by silica or recrystallised, and are frequently flattened to ellipsoidal outlines.

PLATE 5

A. Granitic clast from a lithic greywacke. Unit D, Coramba Beds. S32357, magnification x 45, crossed nicols.

B. Intraformational mudstone chips in a coarse-grained lithic greywacke. Unit A, Coramba Beds. R32546, magnification x 3.

C. Radiolarian chert clast in a lithic greywacke. Unit D, Coramba Beds. S32360, magnification x 45, plane light.

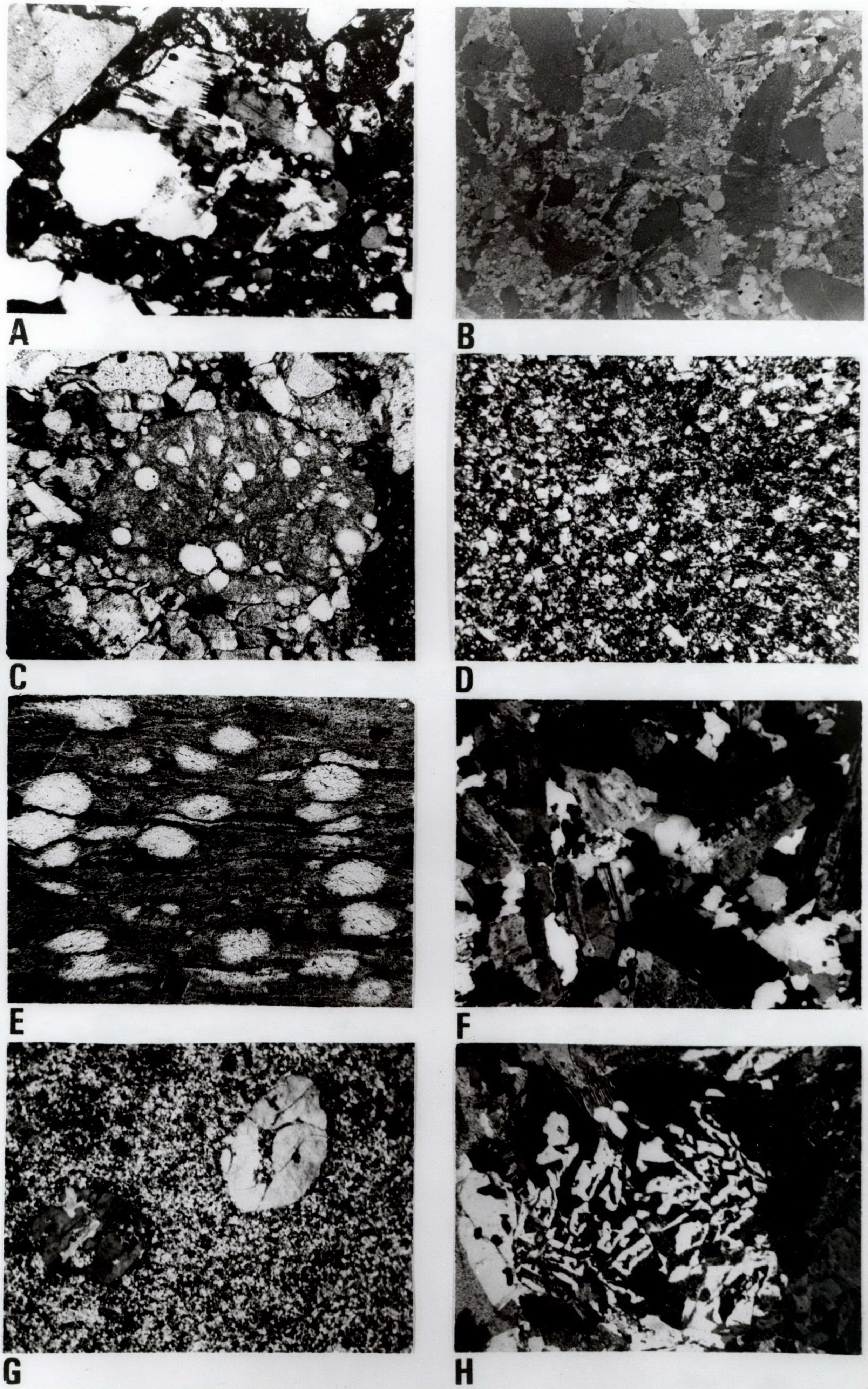
D. Mudstone showing fine-grained nature of detrital material. Unit D, Coramba Beds. S32409, magnification x 50, crossed nicols.

E. Radiolarian-bearing mudstone showing ellipsoidal nature of radiolarian tests possibly deformed by compaction. Brooklana Beds. S32620, magnification x 50, plane light.

F. Hypidiomorphic-granular texture in a granodiorite clast from the orthoconglomerate. Unit D, Coramba Beds. S32363, magnification x 20, crossed nicols.

G. Porphyritic textured plutonic clast from the orthoconglomerate. Unit D, Coramba Beds. S32364, magnification x 20, crossed nicols.

H. Granophyric texture in plutonic clast from the orthoconglomerate. Unit D, Coramba Beds. S32365, magnification x 20, crossed nicols.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Matrix and cement

The matrix (less than 0.03 mm) and cement are variable components ranging from 2.5% to 44%. The matrix is prominent in greywackes containing a high proportion of intraformational mud, but becomes less important in rocks where mudstone fragments are rare or absent. For modal analyses (Table 4), matrix and cement have to be counted together, because of metamorphic reconstitution to minerals such as chlorite, epidote and white mica.

PETROGRAPHY OF THE QUARTZ-RICH SANDSTONE

The one specimen of this rock type (S32819) consists of subangular to rounded detrital single grains of quartz set in a once clayey matrix that has been recrystallised, mainly to white mica. Only rare feldspar grains are associated with the quartz, so that the rock is essentially monomineralic.

PETROGRAPHY OF THE MUDSTONES AND SILTSTONES

These rocks occur as laminated sequences (1 mm to several cm thick) and as thick massive units (particularly in the Moombil Beds). They have a relatively uniform composition of quartz, feldspar and minor volcanic lithic fragments set in a very fine-grained matrix (Plate 5D), and have suffered secondary alteration to a variable extent. Minor detrital hornblende occurs in some siltstones from Units C and D of the Coramba Beds.

Rare radiolarian-bearing mudstones occur in the sequence (S32620, Plate 5E) and consist of laminations (3 mm - 1 cm), with radiolarian tests found along the laminae. The tests have been flattened by compaction and are recrystallised to fine-grained, granoblastic aggregates of silica.

Siliceous (almost cherty) sediments occur throughout the sequence, and consist of fine-grained, microcrystalline or cryptocrystalline quartz, occasionally with mud or small feldspar clasts. These siliceous sediments contain no radiolarian tests, and are distinct from the cherts and jaspers of the Redbank River Beds.

PETROGRAPHY AND SEDIMENTATION OF THE ORTHOCONGLOMERATE

Only one outcrop of orthoconglomerate (10 m wide) was observed in the Coramba Beds (GR 5627 3014), where it occurred interbedded with coarse sandstones and mudstones. Contacts were not observed but are considered to be sharp. Clasts constitute 50-90% of the rock, the remainder being a coarse sandy matrix. The orthoconglomerate is extremely well indurated.

Clasts

The clasts consist of three main types: sedimentary material (about 70% of the clasts), acid plutonics (25%) and volcanic fragments (5%).

A. Sedimentary clasts consist mainly of dark-grey mudstone which is considered to be intraformational. The clasts are mostly rounded but some angular ones do occur and many have been flattened, possibly by compaction. Rarer sandstone clasts occur and are similar to the greywackes interbedded with the conglomerate. A small component of siliceous mudstones or cherts is also present and quartzose sandstones are very rare. The sandstones and cherts are subrounded to well rounded.

B. Acid plutonic clasts consist of three main types:

(a) Adamellite and granodiorite clasts have a hypidiomorphic-granular texture (Plates 1F, 5F) and a coarse grain size of 0.2-4 mm with an average of 1-2 mm. Modal analyses (see below) and the QPKf diagram (Fig. 2A) indicate the clasts lie close to the adamellite-granodiorite boundary.

	S32363	S32364
Quartz	21.9	23.0
Plagioclase	46.7	40.3
K-feldspar	19.0	21.6
Biotite	7.0	8.8
Hornblende	2.4	6.0
Opaques	0.4	0.2
Secondary Minerals	2.5	0.1

Quartz has a weak undulose extinction, and randomly-oriented plagioclase laths are abundant over K-feldspar (P/F = 0.71 and 0.65). Chlorite pseudomorphs after biotite are common and hornblende (pleochroic yellow-green to brown-green, or light green to deep green) is also present. Accessory minerals include sphene and zircon. Secondary epidote (pleochroic colourless to yellow) is evident replacing feldspar.

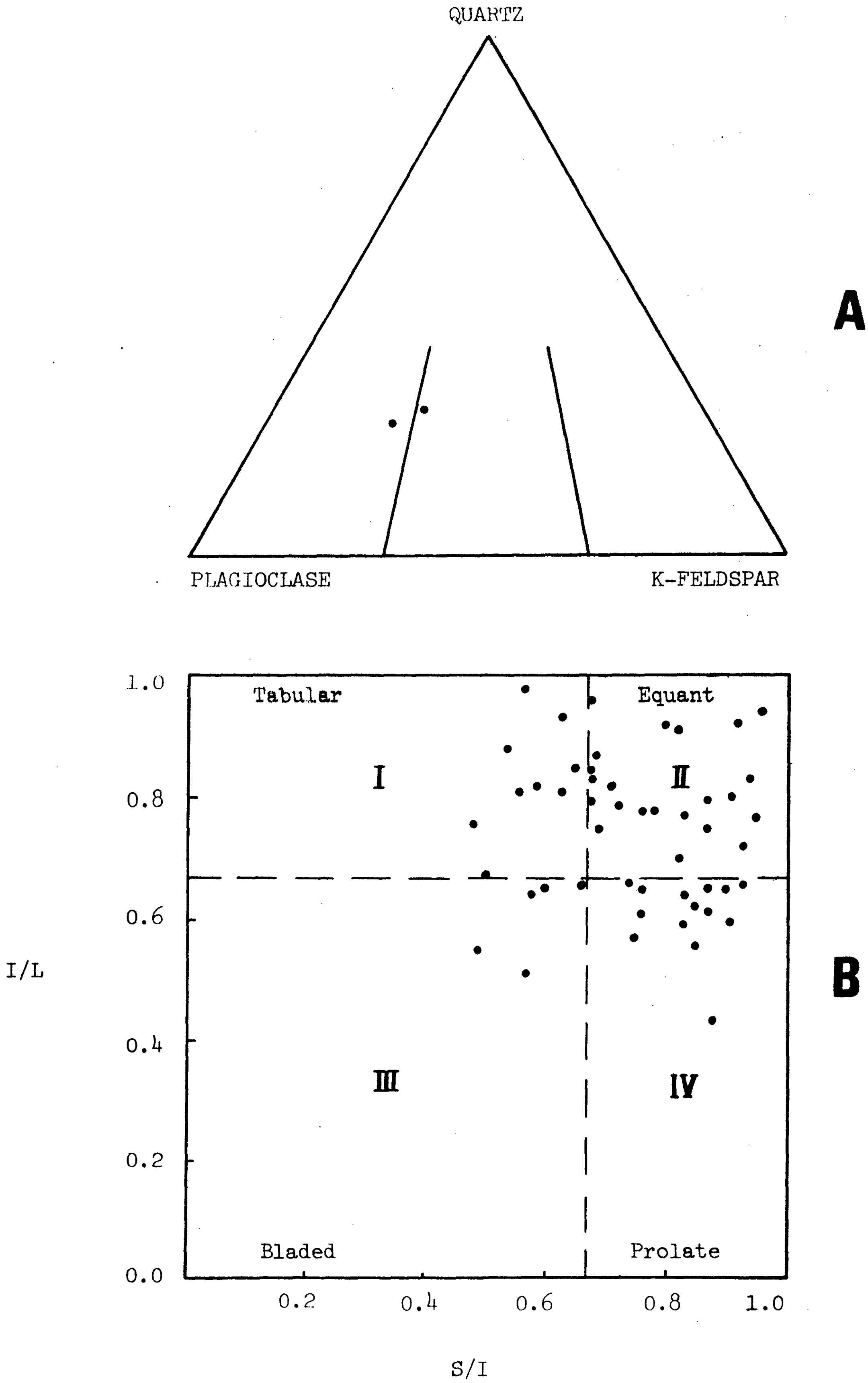


Fig. 2 A: QPKf diagram for two plutonic clasts from conglomerate unit within the Coramba Beds.

B: Shape classes (after Zingg, 1935) for clasts from the conglomerate.

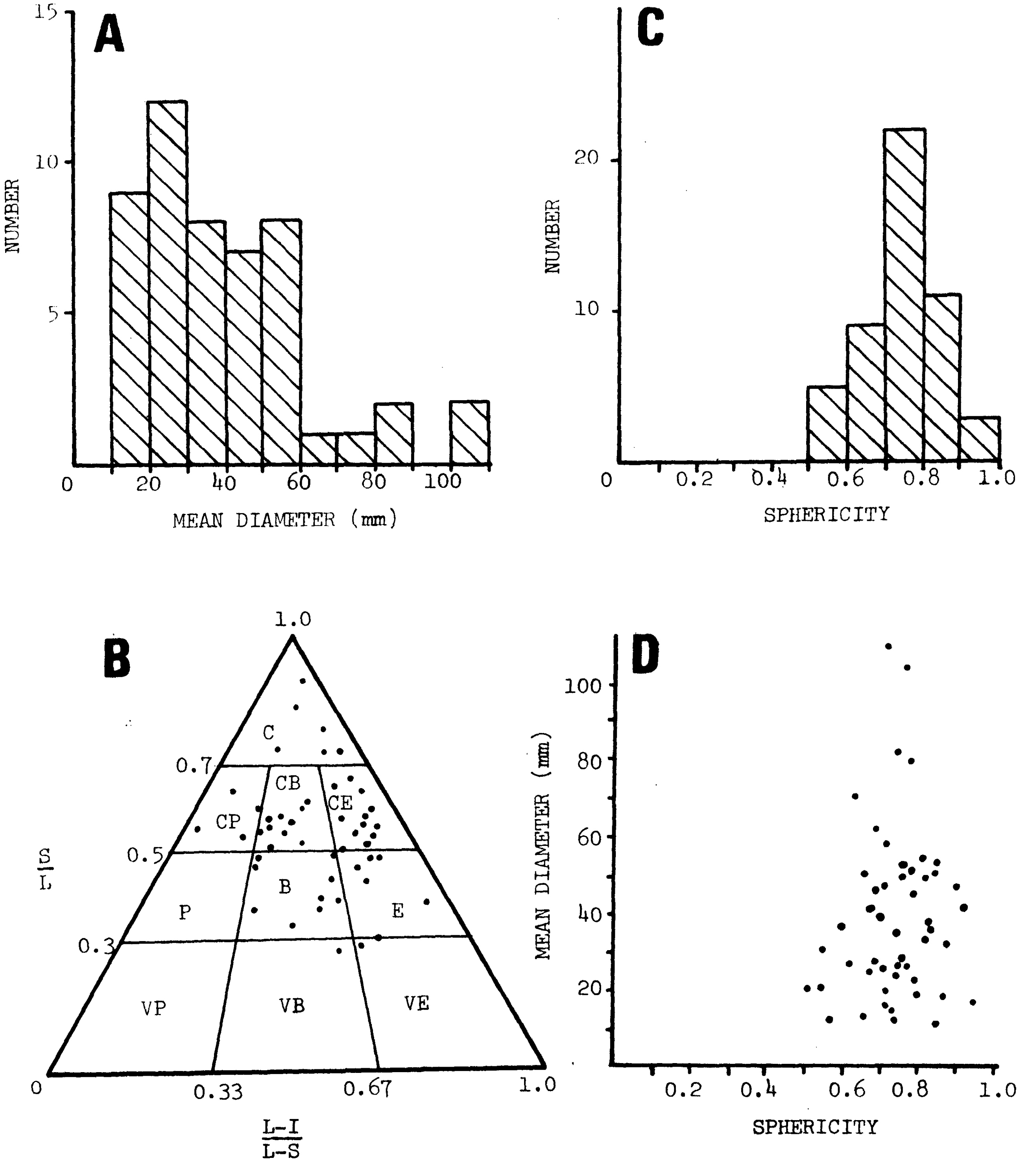


Fig. 3 A: Histogram for mean diameter of conglomerate clasts.

B: Triangular diagram based on Sneed and Folk (1958) to determine form sizes: C = compact, P = platy, B = bladed, E = elongate, V = very.

C: Histogram for maximum projection sphericity of Sneed and Folk (1958).

D: Mean diameter of the conglomerate clasts compared with sphericity.

(b) Porphyritic clasts consist of phenocrysts of anhedral quartz and euhedral to anhedral orthoclase and plagioclase up to 3 mm long, set in a very fine-grained (0.01-0.05 mm) holocrystalline groundmass of quartz, feldspar and biotite which is pleochroic from dark brown to very dark brown (Plate 5G). Some quartz phenocrysts consist of composite grains, but the majority are single crystals.

(c) Granophyric clasts are not as common as the adamellite-granodiorites or porphyries. Microscopically they consist of quartz, microcline and orthoclase crystals being surrounded by graphic intergrowths of quartz and feldspar (usually orthoclase) up to 2 mm wide (Plate 5H).

C. Volcanic clasts are very similar to those described earlier from greywackes. Typical textures observed were intergranular-intersertal, vitrophyric, porphyritic, flow banded, spherulitic and holohyaline.

Sedimentation of the Orthoconglomerate

A. Grainsize and sorting. The grainsize of the clasts ranges from sand size to at least 15 cm, and is bimodal. For this analysis no grains smaller than 1 cm were measured as they were considered to be matrix. Fifty measured clasts have a mean diameter of 39.4 mm (Fig. 3A). Because of the range of grain sizes present the rock is poorly sorted.

B. Sphericity and Shape. The clasts fall into all four shape classes of Zingg (1935): equant 44%; tabular 18%; prolate 28%; bladed 10% (Fig. 2B). Sphericity was determined using the maximum projection sphericity of Sneed and Folk (1958): $\psi_p = \sqrt[3]{\frac{S^2}{L \times I}}$.

Data were plotted on the triangular diagram of Sneed and Folk and grouped into form sizes (Fig. 3B). The clasts fall mainly into the bladed, compact-bladed, compact-elongate and compact form sizes. The sphericity of the clasts shows a normal distribution with a maximum between 0.7 and 0.8 (Fig. 3C). The sphericity is independent of clast size (Fig. 3D). Roundness ranges from 0.6 to 0.85 on the scale of Powers (1953).

Matrix

The sand size matrix is deep brown-green in colour and consists mainly of volcanic fragments, intraformational mud, plutonic fragments and detrital minerals associated with a very fine-grained clayey material now altered to chlorite. Detrital minerals are quartz, plagioclase, minor orthoclase, hornblende, clinopyroxene and rare opaques. The matrix is very similar in composition to the greywackes interbedded with the orthoconglomerate.

PETROGRAPHY OF INTERBEDDED VOLCANIC ROCKS

Rare interbedded lava flows up to 10 m thick were found in the Coramba Beds. An acid lava at GR 5939 2767 (R32810, R32811) has well developed flow banding and consists entirely of material devitrified to quartz and feldspar (Plate 6A).

An intermediate-basic lava at GR 5886 2826 consists of:

(a) Fine feldspar needles and surrounding devitrified material with a pilotaxitic to intersertal texture. The rock originally contained vesicles, now filled with calcite (Plate 6B). Phenocrysts of stumpy feldspar up to 1 mm diameter are rare (S32817).

(b) Sheared severely proplyitized intermediate to basic lava, with large phenocrysts of relict pyroxene which have been replaced in part by talc. Extremely rare relict needles of feldspar occur, but because of the severe shearing the original texture cannot be determined (S32818).

The intermediate-basic lava types are associated with silica-rich rocks containing jasper, haematite and rhodonite, and bear little resemblance to the volcanic detritus observed in the greywackes.

PETROGRAPHIC SUMMARY OF UNITS FROM THE COFFS HARBOUR SEQUENCE

Moombil Beds

The Moombil Beds (Fig. 4) consist predominantly of mudstone (78%) with rarer sandstones (12%) and siliceous siltstones (10%). The mud-sized material is mainly black massive argillite with no recognisable sedimentary structures. The structures have either been obliterated by metamorphism or were not developed in the first place.

From an inspection of QFR diagrams (Fig. 5) quartz appears to be more abundant in this unit compared with the overlying formations, but values of 14.0 to 22.3% (mean 16.9%) indicate this is not the case (Table 4). The preferential metamorphism of lithic fragments and plagioclase with the resultant products counted as secondary minerals explains this apparent enrichment of quartz. Plagioclase is dominant over K-feldspar (P/F = 0.65-0.90, mean 0.79) but all greywackes have lithic fragments greater than

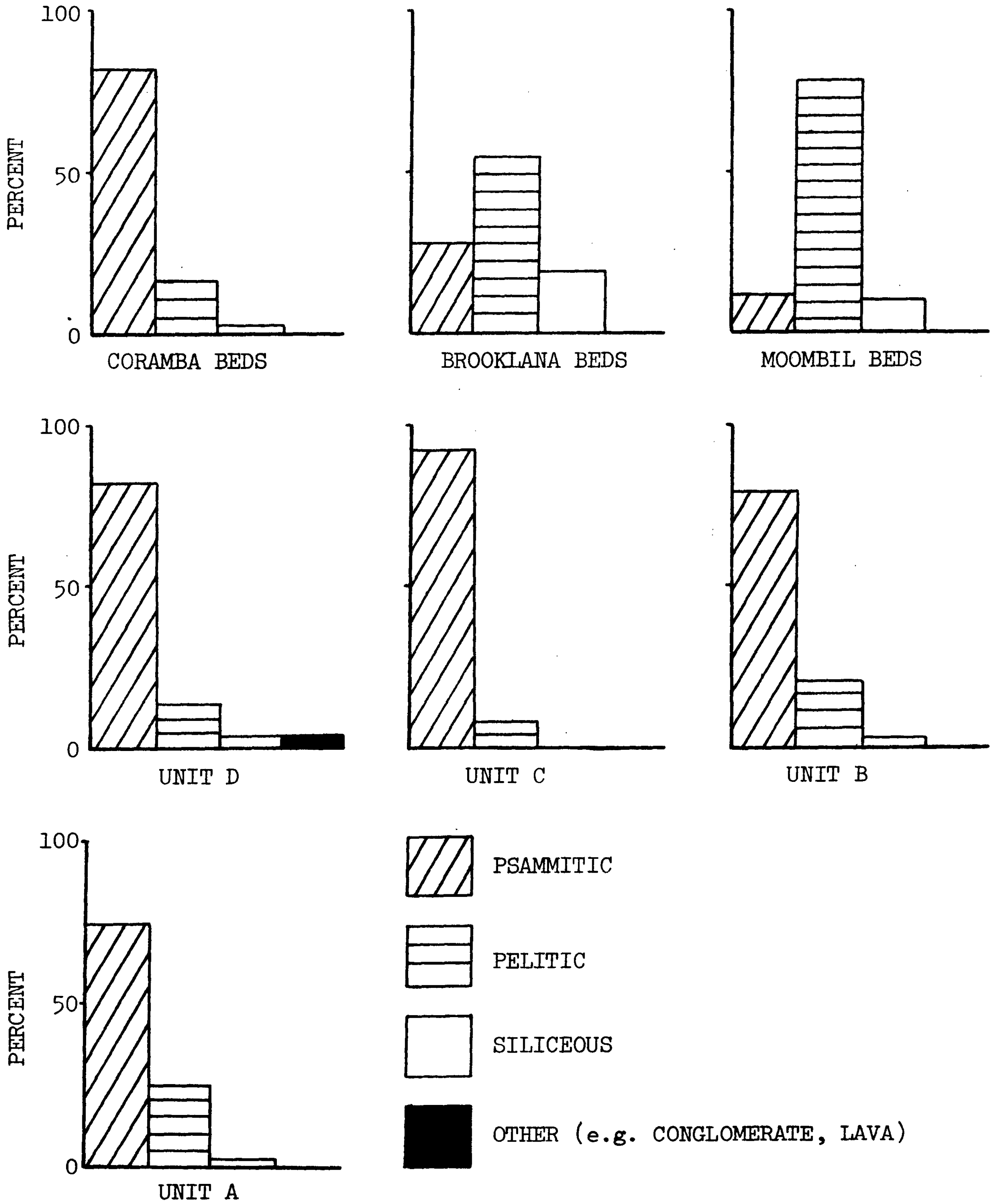


Fig. 4: Variation in abundances of the main sediment types for the three stratigraphic units from the Coffs Harbour Sequence. The Coramba Beds is also subdivided into the four petrographic units recognised in this thesis.

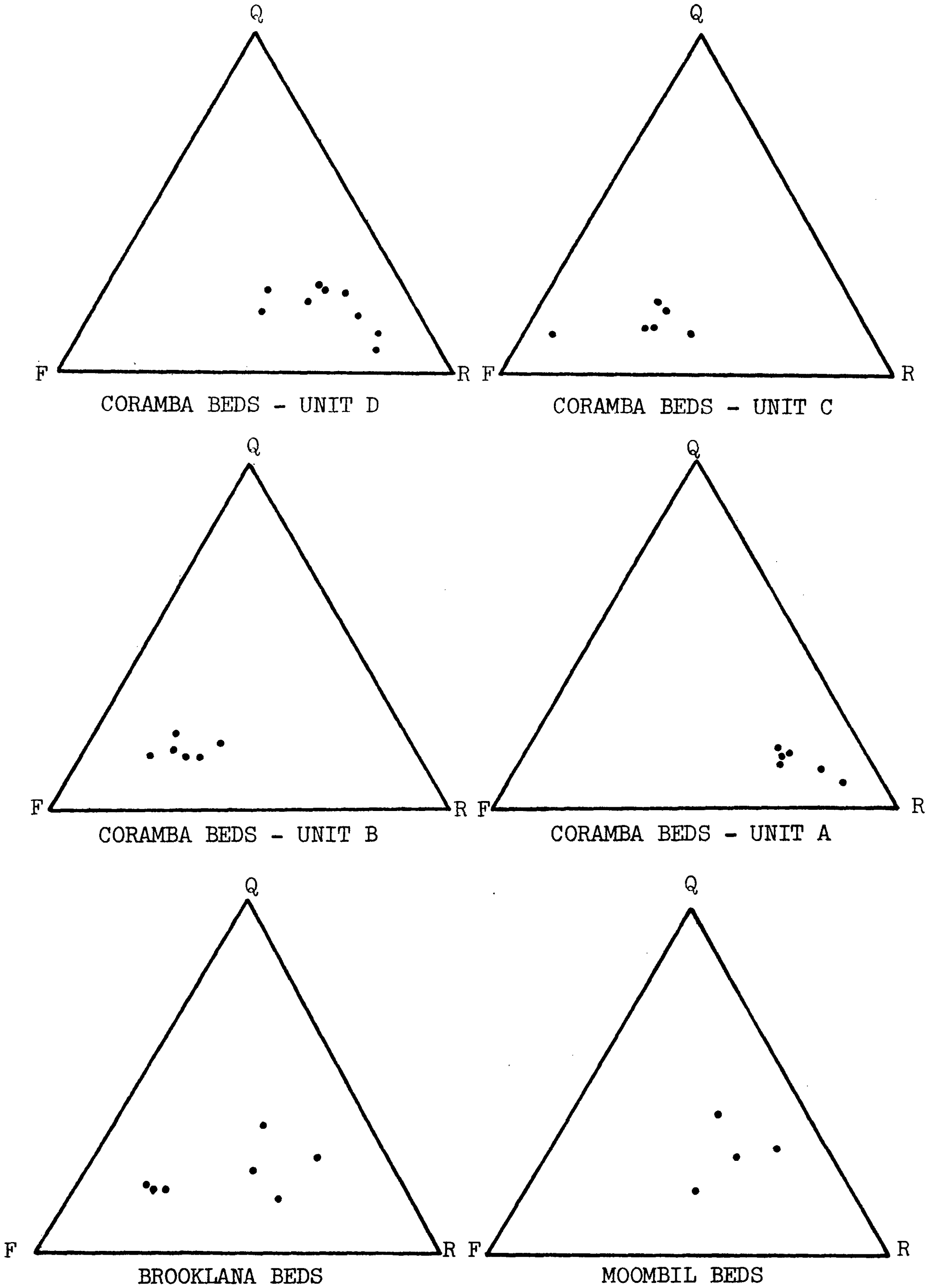


Fig. 5: QRF diagrams for greywackes from the Coffs Harbour Sequence (Q = quartz, F = total feldspar, R = total lithic fragments).

Table 4: Modal analyses of greywackes from the Coffs Harbour Sequence

Specimen	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CORAMBA BEDS															
UNIT D															
32362	5.6	10.8	1.9	4.6	0.1	5.6	12.1	21.8	4.6	9.9	10.2	6.2	6.6	0.85	0.61
32358	18.2	13.8	1.4	4.0	0.4	3.0	21.3	3.9	1.1	24.6	0.6	3.6	4.3	0.91	0.78
32382	13.8	9.5	2.4	1.2	0.6	2.4	17.4	8.4	5.9	23.9	1.8	6.6	6.1	0.79	0.73
32394	16.1	10.7	3.0	4.3	0.3	4.3	24.5	2.7	2.7	28.1	1.0	0.2	2.0	0.78	0.91
32431	9.6	8.1	2.7	0.2	0.5	1.4	15.5	16.7	9.4	25.2	1.8	7.2	1.6	0.75	0.83
8943[a]	12.9	28.6	0.4	3.9	3.5	0.4	19.2	30.2[b]			0.9[c]			0.99	0.97
8936[a]	13.5	17.1	-	0.4	8.4	0.5	26.6	30.7[b]			2.8[c]			1.00	0.92
8920[a]	16.9	23.3	0.3	1.2	3.2	1.5	26.0	25.4[b]			2.2[c]			0.99	0.92
32465	17.5	9.4	2.3	0.4	0.3	4.3	21.7	9.1	5.7	20.6	0.9	3.1	4.7	0.80	0.80
Mean[d]	13.5	10.4	2.3	2.5	0.3	3.5	18.7	10.4	4.9	22.0	2.7	4.5	4.2		
S.D.[d]	4.9	1.9	0.6	2.0	0.2	1.5	4.6	7.4	2.9	6.4	3.7	2.7	2.1		
UNIT C															
32479	16.4	37.7	3.8	1.1	0.2	8.6	8.1	5.9	4.5	11.4	-	0.4	1.9	0.91	0.98
32490	8.4	34.2	3.0	12.0	-	4.7	16.0	9.5	0.3	11.5	-	-	0.4	0.92	0.98
32481	10.1	42.6	3.7	2.2	0.1	1.4	15.1	11.7	0.8	10.8	-	0.4	1.2	0.92	0.94
8924[a]	8.1	60.0	0.1	11.0	3.2	-	12.4	5.2[b]			-				
8932[a]	10.1	30.0	-	6.0	6.9	-	28.0	17.9[b]			1.1[c]				
8927[a]	6.9	29.2	-	4.4	3.4	1.5	27.7	23.9[b]			3.0[c]				
Mean[d]	11.6	38.2	3.5	5.1	0.1	4.9	13.0	9.0	1.9	11.2	0.0	0.3	1.2		
S.D.[d]	4.2	4.2	0.4	6.0	0.1	3.6	4.3	2.9	2.3	0.4	0.0	0.2	0.8		
UNIT B															
32523	12.9	37.0	10.9	-	-	9.4	8.5	14.1	2.8	4.4	-	-	-	0.77	1.00
32493	10.6	35.1	3.9	-	0.2	12.5	17.5	11.0	1.8	7.0	0.1	-	0.4	0.90	0.98
32499	12.7	46.2	5.7	-	0.2	15.2	7.0	4.9	0.6	7.2	0.3	-	-	0.89	0.98
32510	12.9	40.0	5.2	-	0.1	20.2	5.9	5.1	1.1	8.5	0.4	0.2	0.4	0.88	0.94
32526	16.8	31.6	11.2	-	0.1	7.0	5.0	23.3	0.3	2.7	0.3	1.5	0.2	0.74	0.93
32530	13.8	28.4	6.4	-	0.4	7.0	31.7	2.0	0.8	6.6	0.6	0.5	1.6	0.82	0.77
Mean	13.3	36.4	7.2	0.0	0.2	11.9	12.6	10.1	1.2	6.1	0.3	0.4	0.4		
S.D.	2.0	6.3	3.1	0.0	0.1	5.2	10.4	7.8	0.9	2.1	0.2	0.6	0.6		

Table 4: Continued

Specimen	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
UNIT A															
8949[a]	10.2	14.4	0.3	-	2.7	0.1	30.2	39.9[b]			2.2[c]				
8950[a]	4.5	7.0	-	-	1.8	-	29.8	52.7[b]			4.2[c]				
8955[a]	7.5	9.7	-	-	1.7	0.3	25.4	50.3[b]			5.1[c]				
8958[a]	9.9	16.4	0.2	+r	4.5	0.2	21.0	45.9[b]			1.9[c]				
8963[a]	8.8	14.7	0.5	-	4.8	0.2	26.7	41.9[b]			2.4[c]				
8967[a]	10.6	13.3	0.1	-	6.8	-	22.0	44.9[b]			2.3[c]				
BROOKLANA BEDS															
32625	14.7	46.9	5.9	-	-	15.7	2.5	11.3	0.3	1.7	0.3	0.3	0.4	0.89	0.93
32590	15.4	52.9	2.4	-	0.3	9.3	3.7	6.0	0.2	8.6	0.1	0.7	0.3	0.96	0.93
32626	13.0	39.6	6.0	-	0.4	18.0	6.5	10.4	0.1	5.4	-	0.8	-	0.87	0.95
32582	12.1	21.2	3.5	-	0.1	8.2	14.6	26.2	0.6	8.1	0.2	4.7	0.5	0.86	0.87
32624	17.5	21.4	4.2	-	0.2	11.4	15.4	7.4	1.3	18.6	0.1	1.8	0.7	0.83	0.91
32607	22.9	12.5	4.5	-	0.1	30.0	4.4	8.0	0.7	13.4	0.2	2.6	0.9	0.74	0.86
32617	22.5	11.5	2.3	-	0.3	3.8	14.0	25.6	0.3	17.1	-	1.3	1.2	0.83	0.95
Mean	16.9	29.4	4.1	0.0	0.2	13.8	8.7	13.5	0.5	10.4	0.1	1.7	0.6		
S.D.	4.3	16.8	1.5	0.0	0.1	8.5	5.7	8.6	0.4	6.2	0.1	1.5	0.4		
MOOMBIL BEDS															
32666	14.0	25.5	2.6	-	0.1	20.2	6.3	15.8	1.1	11.8	-	1.7	1.0	0.91	0.92
32665	16.1	9.3	3.1	-	0.2	40.3	5.1	9.5	0.6	13.0	0.2	2.0	0.7	0.75	0.89
32668	22.3	10.1	1.7	-	0.2	2.6	43.4	13.2	2.7	2.6	0.2	-	1.1	0.86	0.94
32669	15.2	4.1	2.2	-	0.1	6.7	44.0	17.7	1.2	7.0	0.1	0.6	1.1	0.65	0.93
Mean	16.9	12.3	2.4	0.0	0.1	17.4	24.7	14.1	1.4	8.6	0.1	1.0	1.0		
S.D.	3.7	9.2	0.6	0.0	0.1	17.0	22.0	3.5	0.9	4.8	0.1	0.9	0.2		

1. Quartz
2. Plagioclase
3. K-feldspar
4. Hornblende
5. Accessory Detrital Minerals
6. Secondary Minerals
7. Matrix-Cement
8. Acid volcanic fragments
9. Intermediate-basic volcanic fragments
10. Holohyaline volcanic fragments
11. Plutonic fragments
12. Sedimentary Fragments
13. Metamorphic fragments
14. P/F ratio
15. V/L ratio

a. Results taken from Korsch (1971, Table 1, p.69)
b. Includes all volcanic lithic fragments
c. Includes all lithic fragments other than volcanic fragments
d. Does not include values quoted from Korsch (1971)

PLATE 6

A. Devitrification texture in a rhyolitic rock interbedded with greywackes and mudstones. Unit D, Coramba Beds. S32810, magnification x 20, plane light.

B. Vesicles filled with calcite in a basic lava flow interbedded with sediments. Unit D, Coramba Beds. S32817, magnification x 20, crossed nicols.

C. Laminated bedding with minor displacement along a quartz vein. Girrakool Beds. R32789 magnification x 4. (View photograph on side from right to left).

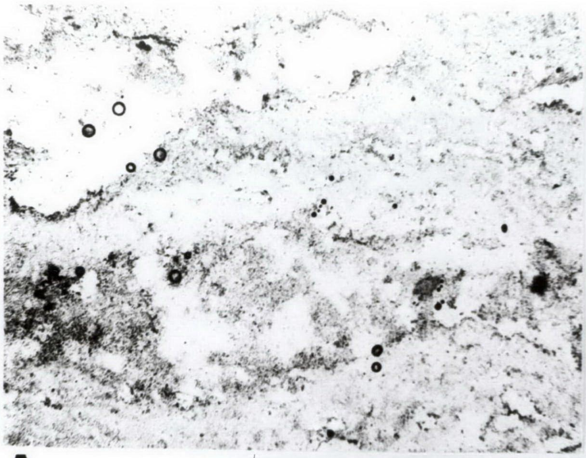
D. Very coarse intraformational mudstone chips with a sandy matrix. Coramba Beds. R32546, magnification x 2.

E. A symmetrical flame structure in siltstone. Girrakool Beds. R32769, magnification x 4. (View photograph on side from left to right).

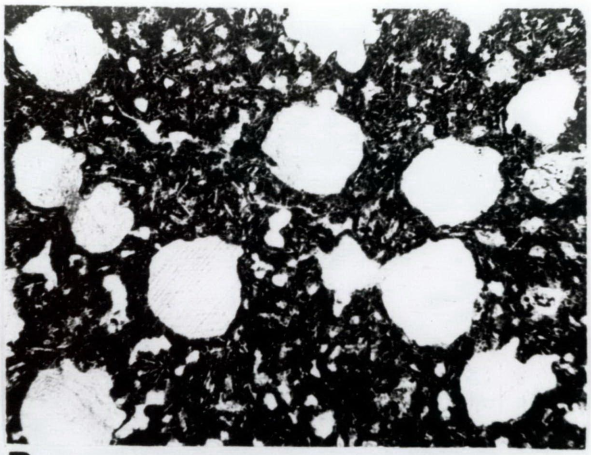
F. Convolute laminations in siltstones and mudstones from Look-at-me-now (GR 6310 2614). Unit D, Coramba Beds.

G. Polished slab of a contourite from Ocean View (GR 6324 2746). Banding defined by alternating layers of mainly plagioclase and hornblende. Unit C, Coramba Beds. Scale in cm. R17081.

H. Contourite showing two heavy mineral bands. Girrakool Beds. S32771, magnification x 4.



A



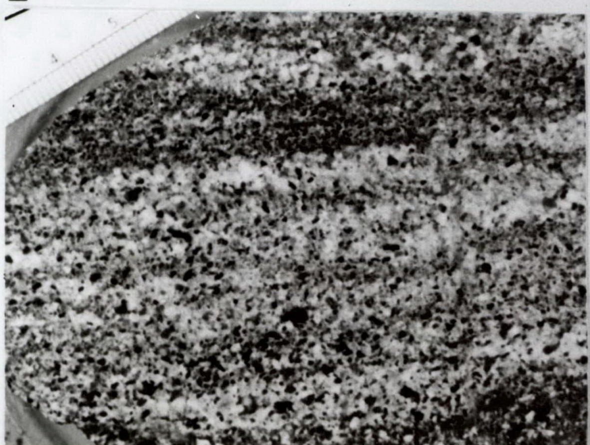
B

C

D

E

F



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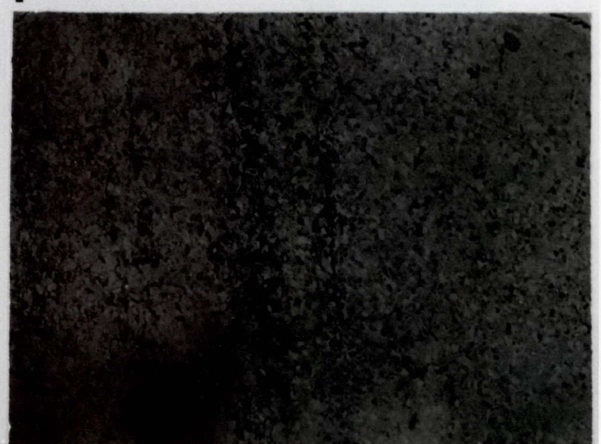


H

feldspar.

Volcanic lithic fragments predominate over other lithic types (V/L = 0.89-0.94, mean 0.92). The most common types are acidic (9.5-17.7%, mean 14.1%) which are abundant over intermediate to basic varieties (0.6-2.7%, mean 1.4%) and holohyaline types (2.6-13.0%, mean 8.6%). Holohyaline textural types were observed in 93% of thin sections examined, compared with 50% for acid vitrophyric and porphyritic types. Spherulites (29%) and flow banding (21%) were more common than trachytic or intergranular-intersertal types. No eutaxitic textures were observed from the Moombil Beds. Minor accessory minerals are biotite, zircon, epidote and opaques. A minor contribution from a plutonic source, and some intraformational mud occur but no metamorphic fragments were observed.

Matrix and secondary minerals together account for 26-50% of the material in the greywackes. The modal analyses in Table 4 should not be regarded with the same accuracy as those of younger formations in the Coffs Harbour Sequence because of the higher grade of metamorphism suffered by the Moombil Beds. Sorting is poor and the grains are angular to subrounded (0.15 to 0.40 on the scale of Powers 1953). Visual sphericity appears to be low.

Brooklana Beds

The Brooklana Beds represents a sequence of interbedded greywackes, siltstones, mudstones and siliceous rocks. Greywackes are more common than in the Moombil Beds (Fig. 4) and dark massive argillite is not present. Both lithic and feldspathic greywackes occur and visual estimates of lithic to feldspar ratios indicate that lithic greywackes are more abundant than feldspathic types (63% to 13%, with 24% indeterminable). Modal analyses (Table 4) and the QFR diagram (Fig. 5) show a strong sampling bias towards the feldspathic varieties.

Acid volcanic fragments with holohyaline, porphyritic (including vitrophyric) and spherulitic types are common but most of the textures outlined previously occur in minor amounts. A small eutaxitic contribution is noted. Acid volcanic fragments range from 6.0 to 26.2% (mean 13.5%) and contrast with the poorly represented intermediate to basic types (0.1 to 1.3%). Holohyaline fragments of unknown affinities are also common (1.7-18.6%, mean 10.4%). Volcanic lithic fragments predominate over other lithic detritus (V/L = 0.86-0.95, mean 0.91).

Plagioclase is more common than K-feldspar in both lithic and feldspathic greywackes (P/F = 0.73-0.96, mean 0.85), and ranges from 40% to 53% in the feldspathic greywackes and from 11% to 21% in the lithic greywackes. K-feldspar ranges from 2.3% to 6.0% (mean 4.1%) and is slightly more common in the feldspathic varieties. Accessory detrital minerals present are zircon, epidote, tourmaline, biotite and rare chlorite plates. Plutonic, metasedimentary and intraformational mudstone fragments also occur but are of minor importance. Sorting is generally poor but may become moderate in some coarser greywackes. A low degree of rounding from angular to subrounded (0.15 to 0.45 on the scale of Powers, 1953) is also found. Most siltstones and mudstones are poorly sorted and fragments tend to be angular to subangular in outline.

Coramba Beds

The Coramba Beds (Fig. 4) consists of a sequence of greywackes (82%), mudstones (16%) and siliceous rocks (2%) with very rare acid to basic volcanics, orthoconglomerates and quartzose-sandstones. There has been a marked increase in the amount of coarse material at the expense of mud compared with the underlying formations.

Petrographic subdivision of the Coramba Beds

The Coramba Beds can be subdivided into four petrographic subdivisions on the basis of detrital composition of the greywackes. These subdivisions are parallel to stratigraphic boundaries and may be regarded as lithostratigraphic units within the Coramba Beds, their areal distribution being shown on Map 1. From youngest to oldest the units may be defined by the presence of the most common greywacke type as:

Unit D: hornblende-bearing, quartz-poor, volcanic lithic greywacke
Unit C: hornblende-bearing, quartz-poor, volcanic to tuffaceous feldspathic greywacke
Unit B: quartz-poor, volcanic to tuffaceous feldspathic greywacke
Unit A: quartz-poor, volcanic lithic greywacke

Modal analyses (Table 4) have been used to construct the histograms of Fig. 6. For the oldest unit (A) volcanic lithic fragments predominate (40-50%) and there is a minor contribution from other rock types (about 5%). Plagioclase occupies 8-18% and K-feldspar is rare. There is a marked change in Unit B, where plagioclase (mainly volcanogenic) becomes dominant over volcanic lithic fragments. Other lithic fragments become rarer and there is a noticeable increase in K-feldspar. Unit C is similar to Unit B but is

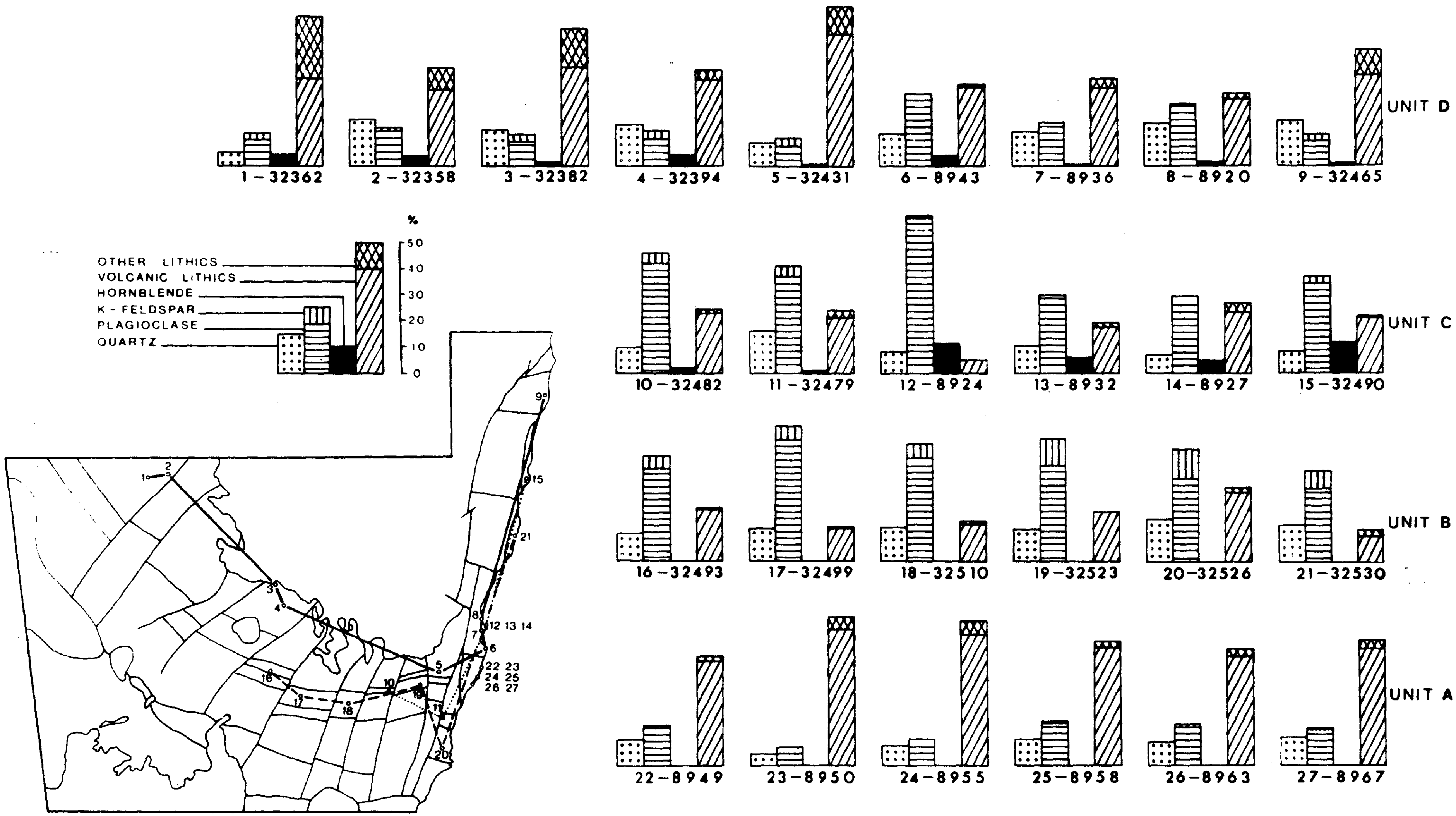


Fig. 6: Histograms illustrating differences in detrital composition of greywackes for the four petrographic subdivisions of the Coramba Beds.

distinguished by the presence of green to brown hornblende as a detrital constituent which can be abundant (up to 12%). In the youngest unit (D) lithic fragments are more abundant than feldspar and there is an important increase in the amount of plutonic, metamorphic and sedimentary fragments. The amount of K-feldspar decreases slightly. Throughout the Coramba Beds quartz remains relatively uniform in abundance ranging from 5 to 18% (mean 14%).

An inverse relationship exists between plagioclase and volcanic lithic fragments on Fig. 7A. Units B and C occupy a common field which is on the opposite side of the 1:1 ratio line from the field of Units A and D. Unit A is more restricted than Unit D in its occurrence within their common field.

The petrographic subdivision of greywackes from the Coramba Beds is applicable to coarse sediments in the New England Geosyncline over very large areas to the south and west of the Coffs Harbour Block (see Section II).

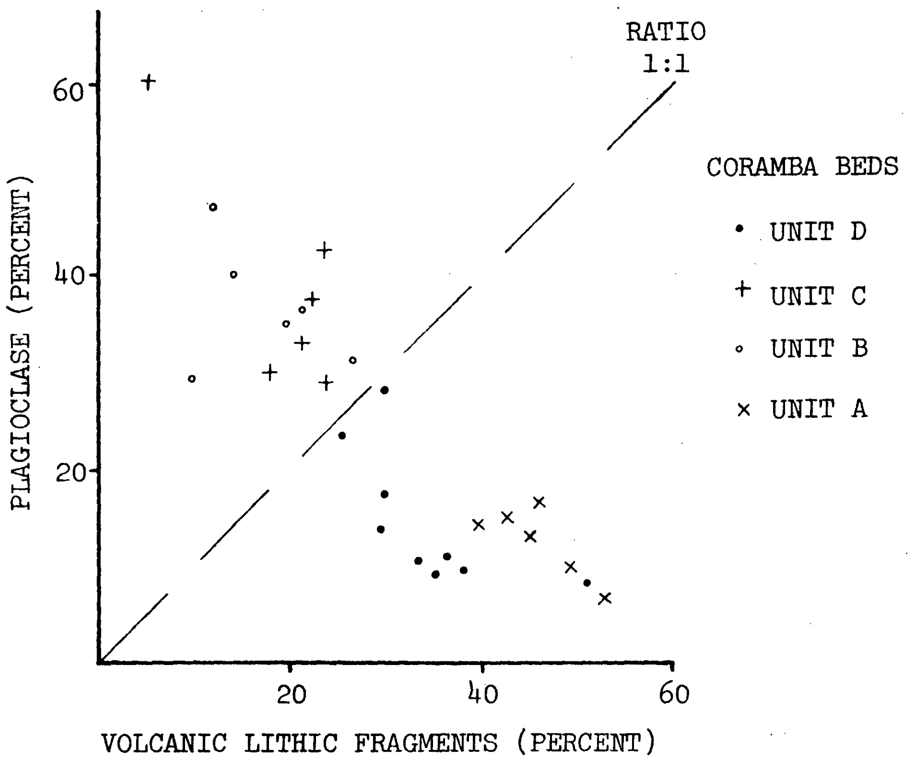
QUANTITATIVE ANALYSIS OF THE COFFS HARBOUR SEQUENCE

Several quantitative methods (Appendix III) were used to recognise differences in sediments of the Coffs Harbour Sequence.

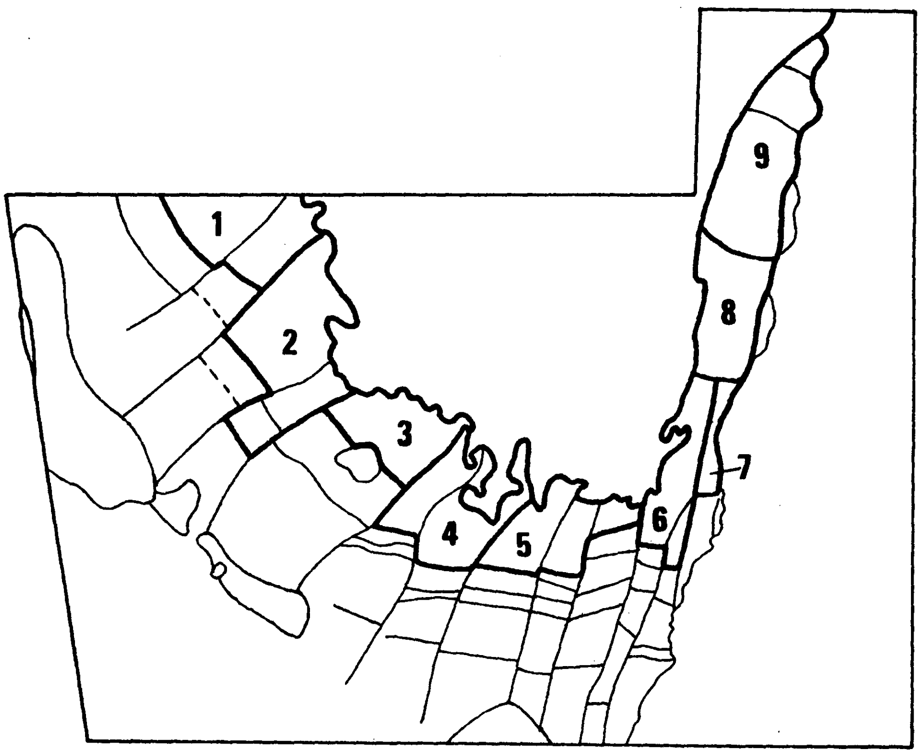
1. Modal analyses and triangular diagrams

Data collected for modal analyses (Table 4) were processed by computer program MODES (Appendix II). Full statistical data on frequency, estimate and confidence limits are not included here, but computer print-outs of the results are held by the author. Several points for discussion arise from an examination of the modes (Table 4) and QFR diagrams (Fig. 5).

(a) Detrital percentages of quartz range from 4.5 to 22.9% (mean 13.5%). All modally analysed greywackes therefore fall in either the quartz-poor field (less than 15%) or the adjacent part of the quartz-intermediate field (15-65%) of Crook (1974). Crook thought there are three distinct fields separated by frequency discontinuities for mineral compositions of greywackes on a QFR diagram. This appears to be not so for greywackes from the Coffs Harbour Sequence, because the Brooklana and Moombil Beds fall mainly within the quartz-intermediate field and the Coramba Beds fall mainly within the quartz-poor field. Overlap between the two fields occurs. Nevertheless the QFR plots of the Brooklana and Moombil Beds are biased towards the quartz end of the triangular diagram (Fig. 5) because the lithic component has been altered by metamorphism and hence some of this material has been counted as



A



B

Fig. 7A: Comparison of plagioclase with volcanic lithic fragments for the Coramba Beds greywackes.

B: Division of Unit D, Coramba Beds into nine subareas used to determine lateral petrographic variations.

secondary minerals in the modes (Table 4). Therefore it is considered that all greywackes from the Coffs Harbour Sequence fall within the quartz-poor field of Crook (*op. cit.*). Dr. K.A.W. Crook (pers. comm.) considered all modes reported by Korsch (1971) to fall within his quartz-poor field.

(b) Crook (1974) lists three subdivisions in his quartz-poor greywacke division (volcanic-lithic greywacke, plagioclase greywacke, serpentinite greywacke). The Moombil Beds contains only volcanic lithic greywackes whereas the Brooklana Beds contain both volcanic-lithic and plagioclase greywackes.

(c) Several differences are noted in the four lithostratigraphic units from the Coramba Beds. Both plagioclase greywackes (Units B and C) and volcanolithic greywackes (Units A and D) occur. This formation was further subdivided using the presence or absence of detrital hornblende as an indicator. There is no allowance for the plotting of hornblende on the QFR diagrams and it is included in the R component (rock fragments plus unstable mineral grains).

(d) If all modal analyses were plotted on one QFR diagram (see Appendix II) they would form a continuous spectrum within the quartz-poor greywacke field from extremely lithic-rich greywackes to extremely feldspathic-rich greywackes.

(e) Hornblende is more abundant in Unit C (1.1-12.0%, mean 6.1%) than in Unit D (0.2-4.6%, mean 2.2%) and is virtually absent from Units A and B only occurring in 4% of these greywackes in very minor amounts (1 or 2 grains per thin section).

(f) The predominant lithic material was derived from an acid volcanic source rather than an intermediate or basic source, but there is a noticeable increase in the contribution from intermediate and basic sources upwards in the sequence from 1% in Unit B, 2% in Unit C to 5% in Unit D. Holohyaline fragments of unknown affinities are an important component within the sequence, also becoming more abundant upwards in the Coramba Beds (Unit B - 6%; Unit C - 11%; Unit D - 22%). Lithic fragments, other than volcanically-derived ones, become more abundant both in percentage and variety in Unit D, indicating an increased contribution from acid plutonic, low-grade metamorphic and sedimentary sources.

2. <u>P/F and V/L ratios</u>

These ratios, based in the formulae of Dickinson (1970), are summarised for the Coramba Beds below:

Unit	P/F		V/L	
	Range	Mean	Range	Mean
D	0.75-0.99	0.86	0.61-0.97	0.83
C	0.91-0.99	0.93	0.89-0.98	0.93
B	0.74-0.90	0.83	0.77-1.00	0.93
A	0.97-0.99	0.99	0.91-0.96	0.94

It is obvious that plagioclase is the dominant feldspar present and that volcanic lithic fragments are the most common lithic detritus. A trend in the mean of V/L from Unit A to Unit D indicates increased contamination from a non-volcanic source towards the top of the sequence.

3. Lateral Petrographic Variation within Unit D of the Coramba Beds

Unit D of the Coramba Beds was subdivided into nine subareas (Fig. 7B) bounded by faults indicated on Map 1. Only Unit D was analysed because of the large number of available specimens and the greater variety in detritus than in the lower units. Results are presented in Table 5 and salient elements are graphed in Fig. 8. The volcanic lithic fragments have been divided into seven groups:

1. holohyaline (includes devitrification and perlitic cracking)
2. plumose (spherulitic)
3. porphyritic (includes vitrophyric)
4. flow bands
5. eutaxitic
6. intergranular (includes intersertal)
7. trachytic

To obtain the results the percentage of greywackes containing the various detrital fragments have been plotted against areal variation. Percentages within a specimen are not taken into account and only the presence or absence of the element is used. Several points of interest arise from the data.

(a) The following fragment types show a similar distribution pattern: intergranular texture, metasedimentary (quartzose sandstone), metamorphic, plutonic, biotite, epidote, chlorite and tourmaline. There is a different distribution of flow banded volcanics and eutaxitic textures.

(b) The biotite, epidote and tourmaline have an inverse relationship with hornblende for most of the area. Around subarea 4 hornblende occurs in over 50% of the greywackes whereas the other detrital minerals are rarer. In subarea 7 hornblende is abundant along with the other minerals.

Table 5: Lateral petrographic variation in detrital elements from Unit D of Coramba Beds. Numbers are the percentages of greywackes containing the detrital elements

Subarea	1	2	3	4	5	6	7	8	9
Number of Samples	32	15	58	23	24	28	14	32	20
Minerals									
Hornblende	72	47	45	57	42	36	71	41	25
Biotite	78	67	31	30	25	57	64	69	75
Chlorite	56	53	28	17	38	43	79	88	65
Zircon	41	27	32	30	33	25	14	19	35
Epidote	25	33	28	17	21	21	36	17	20
Muscovite	15	13	10	9	4	-	14	9	15
Pyroxene	16	-	-	-	-	4	7	22	5
Tourmaline	25	13	7	-	-	4	7	9	10
Opaques	-	-	2	-	8	-	-	-	-
Volcanic Textures									
Porphyritic	41	40	64	49	67	54	71	59	60
Plumose	31	20	19	17	17	25	86	38	55
Flow bands	9	20	16	13	21	18	7	13	-
Ignimbritic	19	13	17	13	25	21	21	3	10
Pilotaxitic	34	13	21	22	33	25	64	38	40
Trachytic	9	-	9	17	13	14	14	13	15
Holohyaline	91	100	95	96	100	96	93	100	95
Other									
L $>$ F	84	80	90	91	92	75	93	88	90
F $>$ L	-	20	5	-	4	14	-	9	5
Plutonic	19	13	17	13	13	14	29	3	10
Metamorphic	22	13	24	13	8	14	29	22	25
Metasedimentary	66	60	49	30	50	54	64	84	85
Mudstone	50	60	50	61	54	79	64	59	75
Radiolarian Chert	6	7	2	-	4	7	7	3	5
Chert	3	-	-	-	-	4	-	-	-

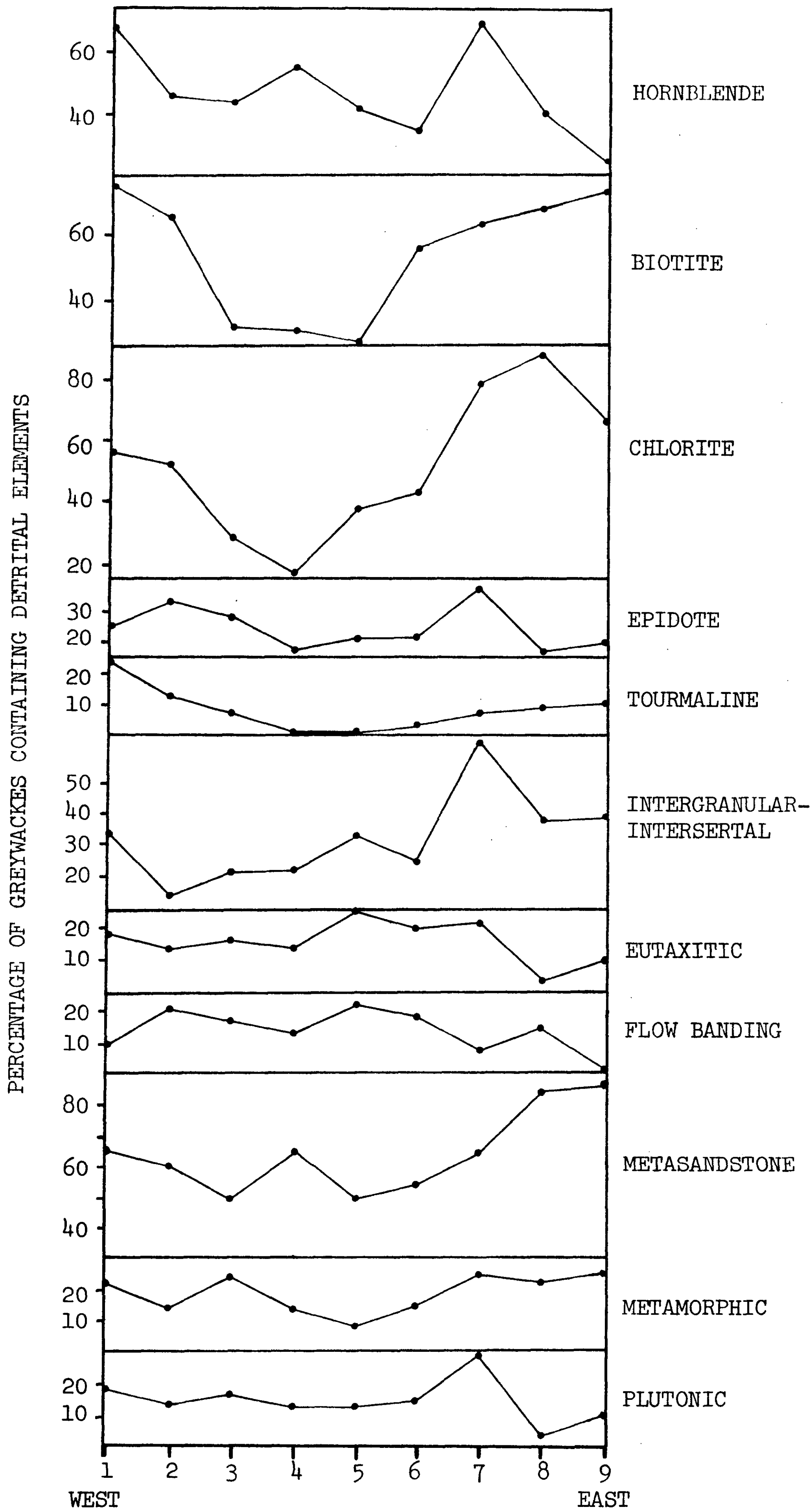


Fig. 8: Lateral petrographic variation within greywackes from Unit D, Coramba Beds. Note change in scales between some adjacent elements.

(c) There is some correlation between hornblende and intergranular textures. When hornblende occurs as phenocrysts in lithic fragments it is in porphyritic and vitrophyric fragments and is not observed associated with intergranular types.

(d) Subareas 1 and 2 are very similar to subareas 7, 8 and 9. This may be due to a structural relationship (See Section I).

Hence within Unit D there is some lateral variation from west to east with two recognisable associations of detrital fragments.

4. Vertical Petrographic variation within the Coffs Harbour Sequence

Use has been made of modal data (Table 4), triangular diagrams (Fig. 5) and percentages of samples containing various detrital fragments (Table 6, Fig. 9) to show some pronounced changes in the petrography from the Moombil Beds to Unit D of the Coramba Beds.

(a) Hornblende is virtually absent in the lower parts of the sequence and only becomes common in Units C and D. Biotite has a similar trend to hornblende but is slightly more common in the lower parts of the sequence. Zircon and tourmaline both increase in Units C and D. Chlorite shows a marked increase in occurrence in Unit A where it is approximately as common as it is in Unit D.

(b) Flow banded volcanic fragments decrease consistently upwards through the sequence with only a slight resurgence in Unit D. This contrasts with eutaxitic textured fragments which are very common in Unit A but are much rarer in the rest of the sequence. Intergranular volcanic, plutonic, metamorphic and sedimentary fragments all have similar trends. They are common in Units A and D compared with the rest of the sequence. The Brooklana Beds and Moombil Beds have similar greywacke components compared with the four units from the Coramba Beds.

(c) Unit B, and to a lesser extent Unit C, have less variety than the other units of the Coramba Beds.

(d) Epidote is not as common in the Moombil Beds or Brooklana Beds as in the Coramba Beds. Muscovite is limited to Units A, C and D, and pyroxene was only observed in Unit D.

(e) Porphyritic textures, and to a lesser extent spherulites, are very common in rocks from all units, and holohyaline fragments of unknown affinities

Table 6: Vertical petrographic variation in detrital elements from the Coffs Harbour Sequence. Numbers are the percentages of greywackes containing the elements

Element	Coramba Beds				Brooklana	Moombil
	Unit D	Unit C	Unit B	Unit A	Beds	Beds
Number of Samples	246	38	45	53	40	14
Minerals						
Hornblende	48	52	2	6	-	-
Biotite	52	21	13	24	10	21
Chlorite	48	37	11	47	5	-
Zircon	30	29	11	13	15	21
Epidote	24	26	11	22	2	7
Muscovite	10	3	-	6	-	-
Pyroxene	6	-	-	-	-	-
Tourmaline	9	-	4	6	5	-
Opaques	1	5	-	4	-	7
Volcanic Lithic Fragments						
Porphyritic	57	66	53	72	58	50
Plumose	30	45	44	49	30	29
Flow banding	13	8	13	19	23	21
Eutaxitic	16	5	4	45	3	-
Intergranular	30	37	7	23	5	14
Trachytic	11	8	4	28	10	14
Holohyaline	96	95	98	93	98	93
Other						
L $>$ F	87	32	11	88	63	86
F $>$ L	6	68	84	6	13	-
Plutonic	14	16	2	22	5	14
Metamorphic	20	11	9	23	10	30
Metasedimentary	58	47	16	57	13	-
Mudstone	59	55	7	57	30	14
Radiolarian Chert	4	3	-	4	-	-
Chert	1	3	2	4	-	-

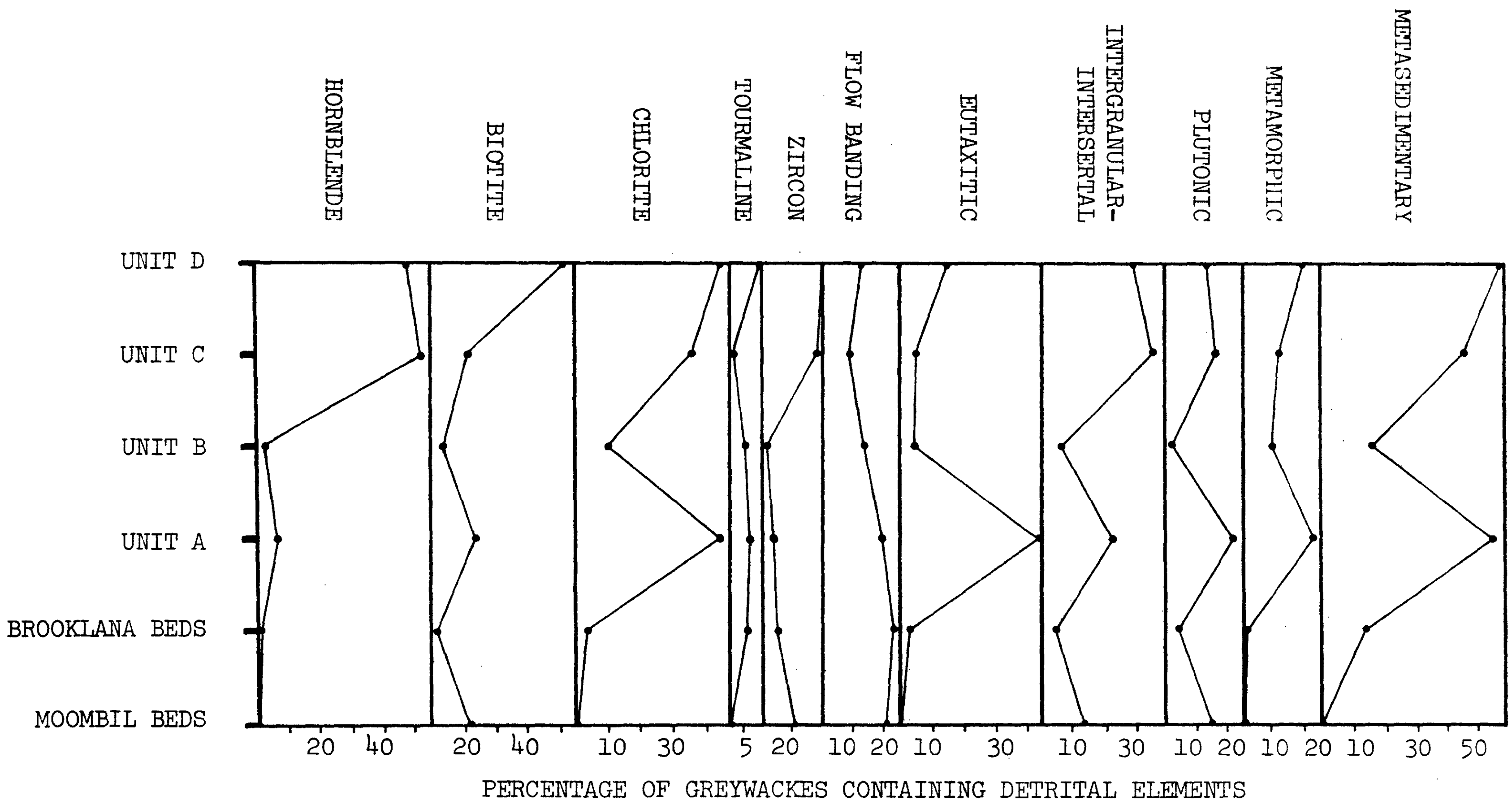


Fig. 9: Vertical petrographic variation within greywackes from the Coffs Harbour Sequence. Note change in scales between some adjacent elements.

were observed in over 93% of rocks from every unit in the Coffs Harbour Sequence.

While variations occur both vertically and laterally within the Coffs Harbour Sequence the rocks all occur within one sedimentary petrographic province as defined by Pettijohn (1957, p.573) as an area of sediments with a common provenance and characterised by a distinctive mineral association.

PROVENANCE OF THE COFFS HARBOUR SEQUENCE

The main features of the provenance of the Coffs Harbour Sequence are:

1. Dacitic, and minor andesitic and rhyolitic volcanic rock fragments constitute over 90% of the lithic detritus.
2. Flow-volcanic lithic detritus predominates over pyroclastic detritus. Ash flow (ignimbritic) detritus is common in Unit A of the Coramba Beds.
3. Basic volcanic, acid plutonic, low-grade metamorphic and radiolarian-chert fragments are minor in amount and are most common in the youngest horizons. Intraformational mudstone debris is abundant.
4. Minerals commonly observed are quartz, plagioclase, hornblende and biotite. Clinopyroxene is virtually absent from the sequence.
5. Some petrographic trends are discernable:
   - (i) Detrital hornblende is common in the youngest horizons (Units C and D of the Coramba Beds) but is absent from all older rocks.
   - (ii) Biotite is common only in Unit D.
   - (iii) The feldspathic horizons of Units B and C indicate reworking of contemporaneously deposited non-lithified tuffs derived from an ash fall source.

Type of Volcanism: Calc-alkaline or Tholeiitic?

It is important to know whether the volcanism had calc-alkaline or tholeiitic affinities. Kuno (1959) lists a tholeiitic series of tholeiitic basalt $\longrightarrow$ andesite $\longrightarrow$ dacite $\longrightarrow$ rhyolite, and a calc-alkaline series of olivine basalt $\longrightarrow$ andesite $\longrightarrow$ dacite $\longrightarrow$ rhyolite. Hence the chemistry and mineralogy of these rocks becomes very significant. Because no chemical analyses have been attempted on sediments from the Coffs Harbour Sequence, the detrital mineralogy becomes important. Hornblende and biotite do not occur in the volcanic tholeiitic series but phenocrysts of these two minerals do occur in highly evolved members of the calc-alkaline series (Kuno 1959).

Wilkinson (1971) has described the petrology of vitrophyric dacites, ignimbritic dacites, and rhyodacites from a Carboniferous volcanic sequence in the Hunter Valley of New South Wales. The features described by Wilkinson include plagioclase (usually sodic labradorite or calcic andesine), hypersthene and augite phenocrysts in vitrophyric dacites, and hypersthene, hornblende and biotite in ignimbritic dacites which frequently have well-developed eutaxitic textures. The presence of hornblende in Units C and D from the Coramba Beds indicates derivation from a calc-alkaline dacitic source area. The features of the calc-alkaline volcanics described by Wilkinson (*op. cit.*) are very similar to those found as detritus in the Coffs Harbour Sequence with one notable exception : hypersthene is absent from the sequence and augite is extremely rare.

It is considered that all units of the Coffs Harbour Sequence were derived from one acid volcanic provenance, which is thought to be calc-alkaline, where dacites (both lava flows, ash falls and ignimbrites) were more abundant than andesites or rhyolites.

Recent workers such as Jakes and Gill (1970) and Jakes and White (1971, 1972a) have separated island arc calc-alkaline volcanic rocks from Andean continental-margin types. The main differences are SiO_2 variation, trace element abundances and phenocryst mineralogy. Jakes and White (1972b) also describe chemical differences in hornblendes from the two associations. The hornblendes occur as phenocrysts in dacites with SiO_2 from 59% to 67%. Because of the absence of chemical data on hornblendes from the Coffs Harbour Sequence no firm conclusions can be drawn as to whether the rocks were derived from a continental margin calc-alkaline volcanic province, or island arc calc-alkaline volcanic province. Nevertheless, Jakes and White (1972b) show biotite to be rarer in island arc volcanics than in continental rocks and they consider the Carboniferous rocks of the Hunter Valley to be an example of calc-alkaline continental margin volcanism.

It is concluded that the rocks forming the Coffs Harbour Sequence were derived from a calc-alkaline volcanic provenance which was possibly of Andean-type.