ASPECTS OF EARLY TRIASSIC SEDIMENTATION IN THE ESK TROUGH, SOUTHEAST QUEENSLAND

by **M.J. Irwin**

(with 7 Text-figures)

ABSTRACT. New morphometrical and textural data from Triassic sedimentary rocks of the northern Esk Trough are presented. In the Neara Volcanics near Kinbombi (west of Kilkivan), two sedimentary sequences contain andesitic boulder conglomerates, polymictic conglomerates, sandstones, and shales, and show evidence of littoral and fluviatile deposition. In the Early Triassic, volcanic cones set in a large lake were eroded by lacustrine littoral wave action to form the boulder conglomerates and by torrential fluviatile action to deposit the finer sediments. Subsequently, in the Middle Triassic, the lake contracted to the east and was fed by small streams flowing eastward from the Palaeozoic Yarraman Block. The increasing proportion of non-volcanic clasts to the east of the area studied, coupled with the presence of lava-agglomerates to the west, suggest westerly centres of eruption.

INTRODUCTION

The Esk Trough is a narrow, elongate, north-northwest trending basin which contains Triassic volcanic and sedimentary rocks. The sedimentary rocks have been described by numerous authors (J. Reid 1925; Hill 1930, 1960; Tommerup 1931; Dunlop 1951; Derrington 1954; Pulley 1957; Williams 1958; A. Reid 1966; Jell 1968). Jell (1969) has also considered the palaeogeography in some detail. In the present paper, these rocks are examined using morphometrical and textural techniques of palaeoenvironmental analysis to give new insight into the palaeogeography of the trough during the Early and Middle Triassic.

Regional setting

The Esk Trough is bounded by two Upper Palaeozoic blocks (Text-fig. 1): the metasediments, metavolcanics, and granites of the D'Aguilar Block to the east; and the granites and metamorphic rocks of the Yarraman Block to the west. Permian marine sedimentary and volcanic rocks outcrop in the subparallel Northbrook and Cressbrook Fault Blocks (Hill 1960) on the southeastern and southwest margins of the trough. The Triassic rocks have been deformed into north-northwest trending folds and intruded by the Upper Jurassic-Lower Cretaceous Brisbane Valley Porphyrites and Tertiary? dolerites and trachytes.

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Stratigraphy of the Esk Trough

The Triassic rocks of the Esk Trough unconformably overlie or are down-faulted against Palaeozoic rocks of the adjacent blocks. The trough contains 5 000 m of Lower to Middle Triassic sedimentary and volcanic rocks forming the Toogoolawah Group, which consists of three conformable formations (Cranfield & Schwarzböck 1972). The basal Bryden Beds comprise lithic and feldspathic sandstone, mudstone, conglomerate, and minor tuff, and outcrop along the southeastern margin of the trough. The Neara Volcanics interfinger with the underlying Bryden Beds, and consist of andesitic and trachytic flows, tuffs, agglomerates, conglomerates, and minor mudstone. The uppermost Esk Formation is made up of conglomerate, sandstone, and mudstone.

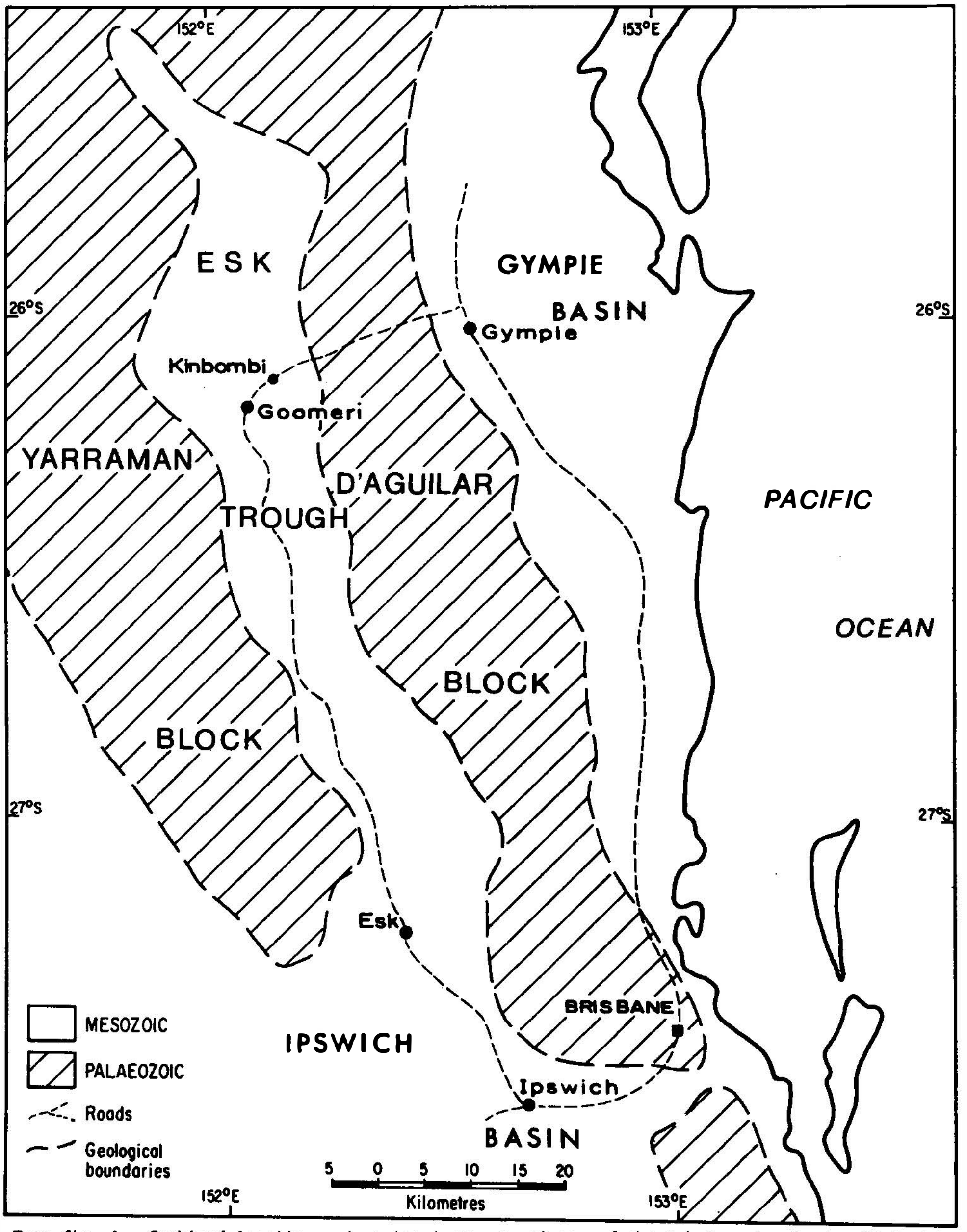
In the northern part of the trough a similar trio of sedimentary units is recognized by some authors (J. Reid 1925; Derrington 1954) as the Manyung Sandstone, Goomeri Volcanics, and Mondure Beds. However, Murphy *et al.* (in prep.) believe the Manyung Sandstone may belong to the Esk Formation. At its northern extremity the trough is not fault-bounded and contains the Triassic Gayndah Beds and Aranbanga Beds (Ellis 1968). The former unit consists of sandstone, conglomerate, siltstone, mudstone, acid volcanics, and rare coal; the latter comprises rhyolitic, andesitic and trachytic flows, tuffs, some sediments, and basalt.

After deposition of the Toogoolawah Group, the trough underwent east-west shortening as a result of extensive folding, with subsequent intrusion of numerous high-level granites and diorites. Following this deformation, sediment accumulation was no longer restricted to an elongate basin. This is evidenced by the encroachment of the Late Triassic Ipswich Coal Measures into the southern Esk Trough area and the much more extensive area of deposition of the Lower Jurassic Bundamba Group.

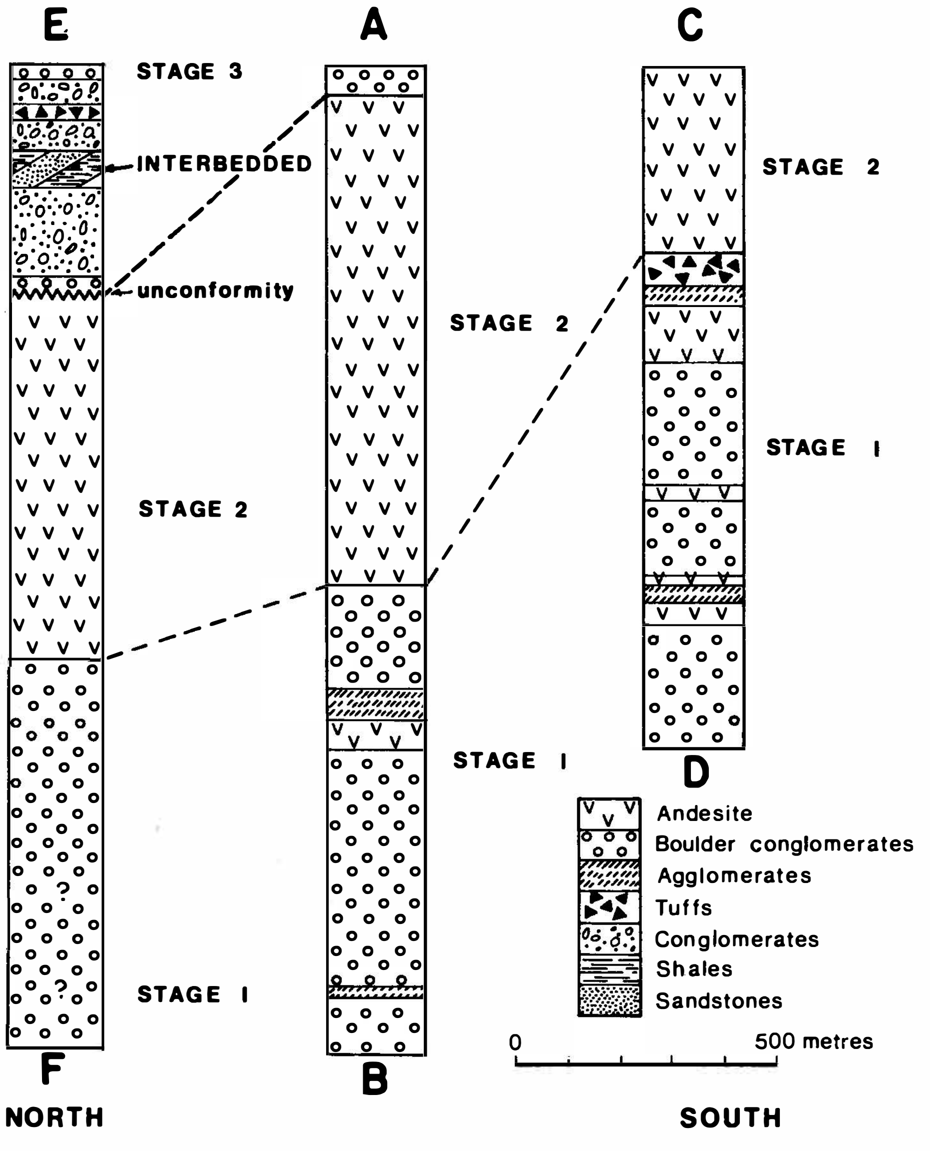
STRATIGRAPHY OF THE KINBOMBI AREA

The Kinbombi district is located in the mid-northern Esk Trough (Text-fig. 1). The only formation exposed in the area is the Neara Volcanics, which includes a lithology known formerly as the 'Kinbombi Boulder Beds' (Reid 1925) and occurring at several discrete stratigraphic levels in the sequence. Stratigraphic sections (Text-fig. 2), each spaced one km apart in a north-south direction, illustrate the complexity of the sequence, which forms the eastern limb of the north-northwest trending Goomeri Syncline. The succession consists of westerly dipping andesitic lavas, boulder conglomerates, agglomerates, tuffs, sandstones, and shales. Two major sedimentary horizons can be observed in this sequence (Text-fig. 2: 'stages 1, 3').

To the east of the area studied, there are 3 000 m of andesitic boulder conglomerates and lavas extending to 'Claddagh' where the Triassic rocks nonconformably overlie the Carboniferous Claddagh Granodiorite (Smith 1964; Hayden 1971).



Text-fig. 1 Combined locality and regional structural map of the Esk Trough, showing Kinbombi area.



Text-fig. 2 Generalized stratigraphic sections through Neara Volcanics, east-west, spaced ca 1 km apart in a north-south direction. E-F, 0.5 km north of Kinbombi; A-B and C-D, both on Kinbombi Creek.

Radiometric ages

Four radiometric ages have been obtained from the Kinbombi area utilizing hornblende and whole rock K-Ar techniques. The analytical work was carried out by D.C. Green, A. Mateen, and D. Stubbs in the laboratories of the Department of Geology and Mineralogy, University of Queensland.

Dates of 237±5 m.y. and 234±5 m.y. have been obtained, respectively, from a basaltic andesite whole rock sample and from hornblende separated from a stratigraphically higher andesite. A hornblende porphyrite dyke, which does not show the fracturing characteristic of the surrounding lavas, gave an age of 214±5 m.y.. A date of 216±5 m.y. has been obtained from hornblende in a granodiorite boulder from the uppermost conglomerates of the Neara Volcanics. The presence of tourmaline and chlorite in association with this hornblende suggests that hydrothermal alteration may have occurred, and the date may be spurious. The first three dates clearly indicate an Early Triassic age for deposition and possibly also folding, both prior to intrusion of the hornblende porphyrite.

SEDIMENTARY ROCKS

Boulder conglomerates

There are two horizons of boulder conglomerates in the area under consideration: one outcrops at the base of the section (Text-fig. 2: F, B, D) in the gorge of Kinbombi Creek and the second occurs in the upper sedimentary unit (Text-fig. 2: E, A) exposed along the Nanango Branch railway line, north of Kinbombi.

The lower horizon consists of well-rounded porphyritic andesite boulders of high sphericity, 5-100 cm in diameter. The tuffaceous matrix of the boulder conglomerates contains subangular plagioclase feldspars (up to An30) in a groundmass of chlorite and clays cut by veins of zeolite (mostly laumontite).

The upper horizon contains mostly well-rounded andesite, diorite, and adamellite boulders, as well as clasts of breccia, agglomerate, and siltstone. In this bed the proportion of boulders to matrix is lower and the matrix is more compact. The boulders are 5-50 cm in diameter and the matrix, containing 5 per cent of subrounded andesitic fragments, is similar in composition to that of the lower horizon.

The boulder conglomerates and conglomerates of the southern part of the Esk Trough have been described in detail by various workers, in particular Hill (1930) who recognized four types:

1. Large rounded boulders of andesite in a matrix of flow andesite;
2. Angular boulders of andesite of various sizes in a tuffaceous matrix;
3. Large rounded boulders of andesite in a tuffaceous and clastic matrix; and
4. Polymictic conglomerate containing rounded pebbles in a clastic matrix.

Williams (1958) showed that all boulder beds with an andesite matrix (type 1) are characterized by angular, rather than rounded, boulders. He believed that type 1 formed by brecciation of a chilled flow margin by movement of the flow, and incorporation of the resulting fragments into the lava. Dunlop (1951) considered that type 2 formed by heavy rain falling on semiconsolidated volcanic ejecta, forming a lahar-like mud flow. Types 3 and 4 seem to be regarded by most authors (e.g. Reid 1925; Hill 1930) as sedimentary. However, other workers have regarded the roundness of the clasts as being due to abrasion in an explosive volcanic vent (pyroclastic origin).

A pyroclastic origin of type 3 boulder conglomerates can readily be dismissed: although extensive rounding of boulders may result from abrasion in diatremes, significant transport of the boulders away from the vent seems unlikely. In addition, granitic, jasperoid, gabbroic, and schist boulders have been noted and significant quantities of granitic and metamorphic boulder types occur towards the eastern margin of the trough (J. Innes, unpublished data). The great extent of boulder conglomerates would tend to rule out the possibility of pyroclastic origin, and intercalated cross-bedded sandstones also suggest a sedimentary origin.

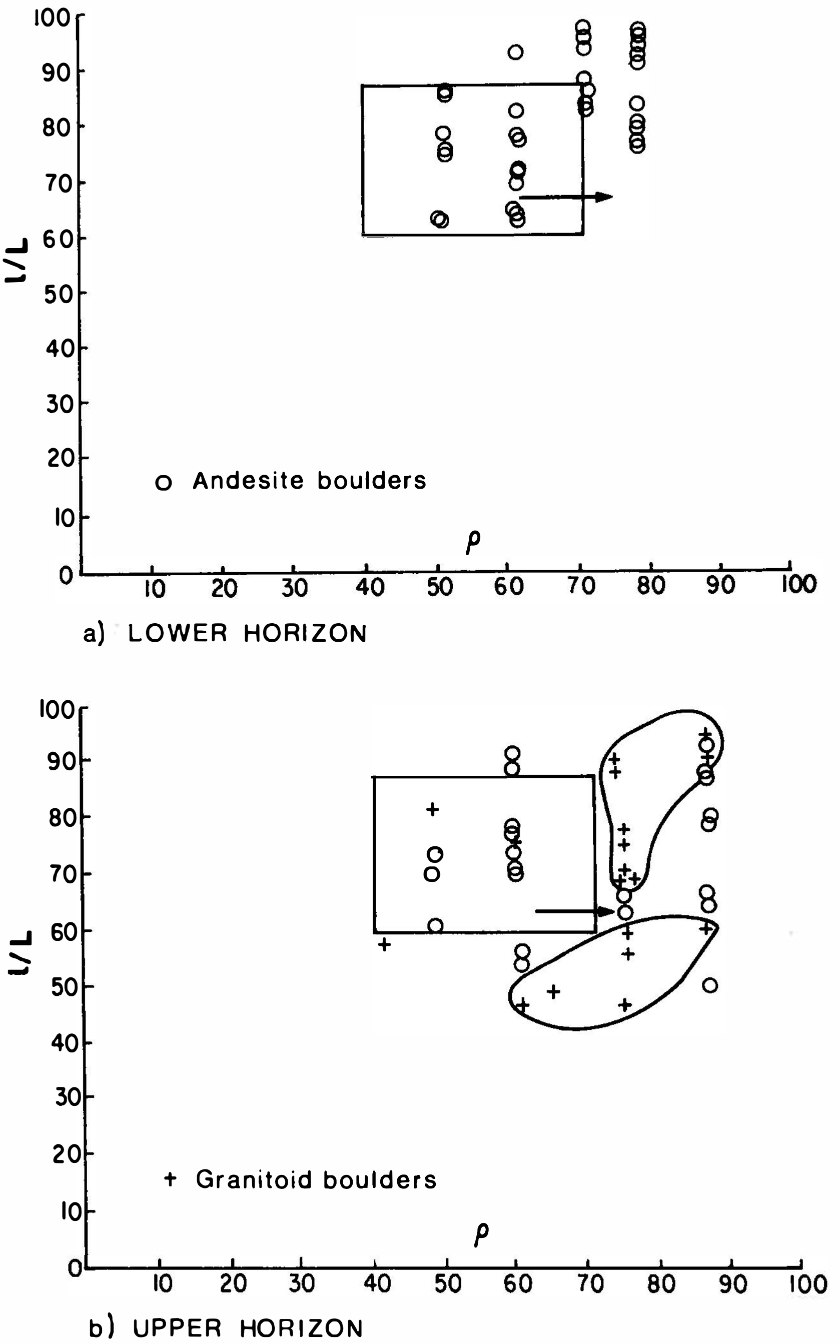
A method used by Sames (1966) to distinguish clasts from littoral and fluviatile environments has been applied to the boulder conglomerates. Sames used a plot of ρ (roundness) against sphericity $1/_{L}$ (ratio of minimum axis length to maximum axis length) to distinguish chert and quartzite pebbles abraded in the two environments. Only rocks which are mechanically homogeneous can be used in this method.

Plots of ρ against $1/_{L}$ for the boulder conglomerates (Text-fig. 3) show that their morphometrical parameters are typical of those characterizing a littoral environment. The upper sedimentary horizon shows two groupings of granitoid boulders, corresponding to adamellitic (high $1/_{L}$) and dioritic (low $1/_{L}$) compositions. The greater sphericity of the adamellitic boulders may be due to their greater susceptibility to abrasion resulting from their coarser texture (see Sames 1966) or to a longer abrasional history. The latter would suggest that the diorites originated closer to the site of sedimentation than did the adamellites. However, as so many Permo-Triassic granitoid intrusions are present in southeast Queensland it is not possible to comment on specific sources for the boulders, although the Claddagh Granodiorite resembles some of the boulders in hand specimen and thin section.

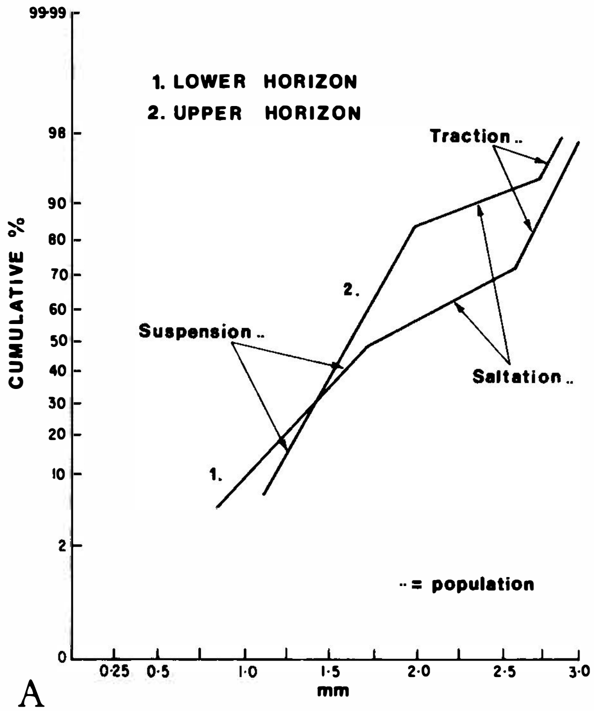
A cumulative plot of ρ (after Sames 1966) of the boulders of the boulder conglomerates and pebbles of the associated polymictic conglomerates shows that the boulder conglomerates have a greater littoral component than the other conglomerates (Text-fig. 5).

The tuffaceous matrix of the boulder conglomerates was examined to obtain further data on environment of deposition. Approximately 200 measurements of 'a' (longest) grain axes per thin section were corrected to true grain size, using the graph obtained statistically by Smith (1966). The corrected grain sizes were then plotted cumulatively using the method of Visher (1969) to separate the grain sizes into suspension, saltation and traction populations.

The cumulative graphs for two samples from the lower and upper horizons (Text-fig. 4A) show that both have coarse suspension populations (up to 1.7 and 1.9 mm respectively) comprising 50-80 per cent of the samples.



Text-fig. 3 Morphometrical parameters of boulder conglomerates in Kinbombi area; arrow indicates littoral trend. Method based on Sames (1966).



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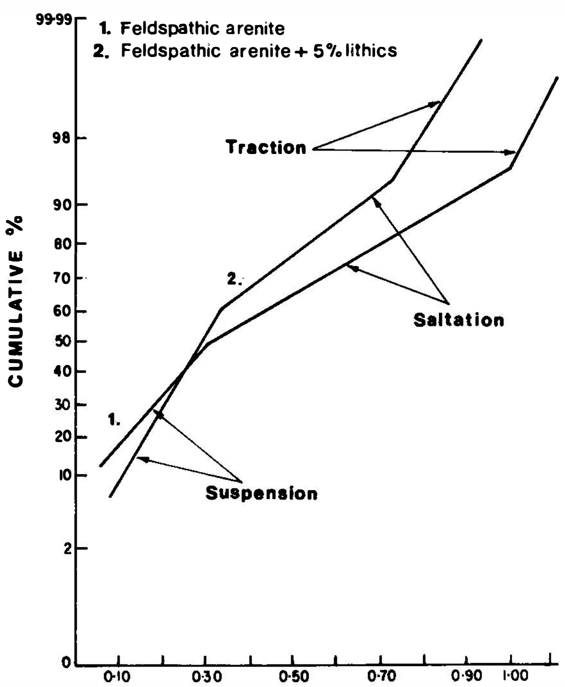

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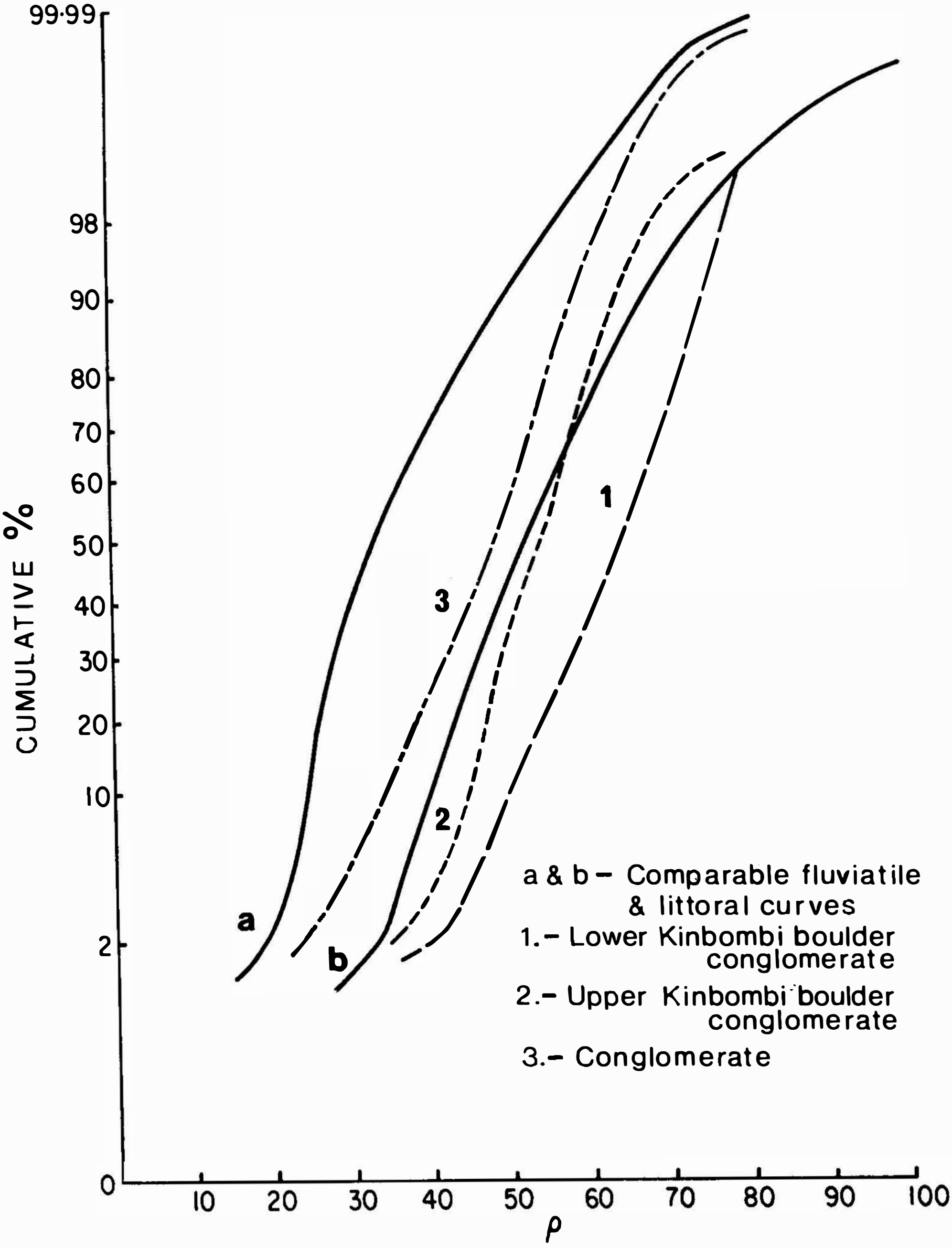
Text-fig. 4 Textural characteristics of boulder conglomerate matrices (A) and of sandstones (B). Method follows Visher (1969).



Text-fig. 5 Cumulative curves of ρ for boulder conglomerates and ortho-conglomerates in Neara Volcanics (method based on Sames 1966).

The saltation populations of both samples are relatively poorly sorted, compared to most of Visher's (1969) data.

A large and coarse suspension population is usually associated with high concentrations of suspended sediment in the fluid and rapid sedimentation rates (Visher 1969). A well-sorted saltation population results from a slow rate of sedimentation and oscillating currents of high velocity (Visher 1969, p. 1103). Small traction populations as seen in the Kinbombi Boulder Beds reflect the lack of selective removal of finer sediment by winnowing. The fact that the traction population is coarse possibly indicates that the sediment was fairly coarse grained and had not been broken down by transport. As the sandy matrix is composed dominantly of subangular plagioclase feldspars and andesitic fragments, it is apparent that the surrounding volcanics constituted the provenance.

From the above, the environment of deposition appears to have been characterized by rapid sedimentation, high turbulence (and thus a great amount of suspended material), and current velocities which were not necessarily high (see discussion of sedimentological data below). Visher (1969) has obtained similar results for sediments from unstable littoral environments.

Polymictic conglomerates

The type 4 conglomerates which occur in the study area are largely confined to the upper part of the sequence and lie with slight unconformity on the andesites of stage 2 (Text-fig. 2, Section E-F). They form lenses up to 500 m long which trend north-south and include subparallel lenses of sandstone and shale. The upper horizon of the boulder conglomerates (i.e. top of stage 3) overlies these conglomerates. Outside the area mapped, conglomerates outcrop on the western limb of the Goomeri Syncline.

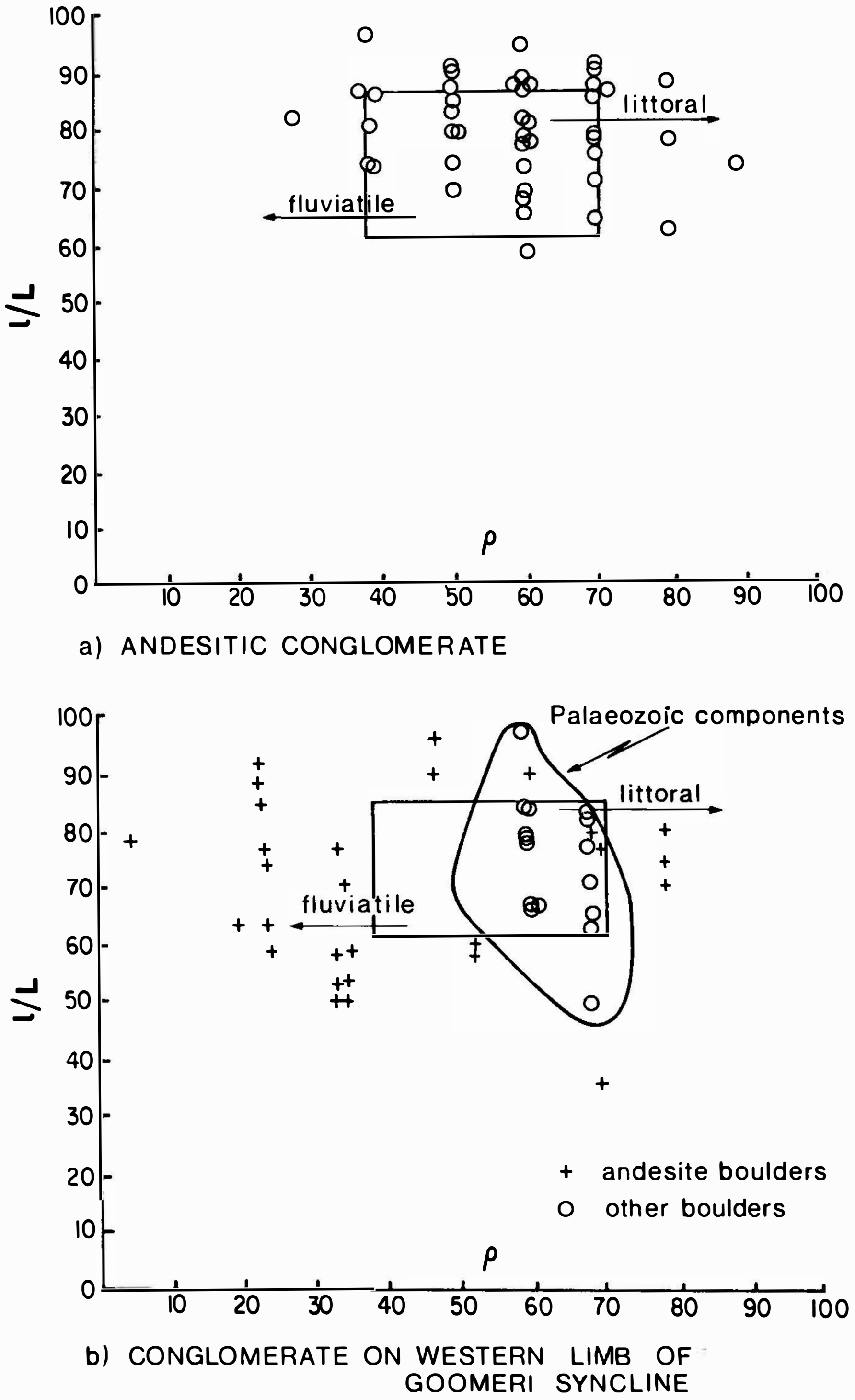
For the greatest part polymictic orthoconglomerates predominate, with clast types of andesite, mudstones, cherts and granites being common. Some conglomerate containing only andesitic clasts occurs to the south of Kinbombi Falls. The matrix of the conglomerates consists of andesitic, quartz, and feldspar fragments; interstitial clay and limonite give the conglomerates a rusty brown appearance in outcrop.

Sames's (1966) method has been applied to conglomerates from the eastern and western limbs of the Goomeri Syncline (Text-figs 5, 6). The chert, mudstone, and granite pebbles fall into the littoral field, whereas less rounded andesite pebbles show a tendency towards the fluviatile field.

Sandstones

The sandstones occur in thin beds associated with the conglomerates or as small lenses interbedded with shales. There is also one band of coarse cross-bedded lithic sandstone intercalated in the lower horizon of the boulder conglomerates.

Most of the sandstones are feldspathic arenites (Okada 1971) with grains of plagioclase and quartz predominating, and rare fine-grained andesite fragments. The proportion of matrix (chlorite, clays, limonite, and calcite)



Text-fig. 6 Morphometrical parameters of conglomerates in Neara Volcanics (method based on Sames 1966).

decreases up sequence, and calcite occurs as a cement in upper parts of the sequence. No sandstones containing potash feldspar or large amounts of quartz were found in the Kinbombi area.

The method of Smith (1966) was used to determine true grain sizes from thin section measurements. These were then plotted cumulatively (Text-fig. 4B) and compared empirically with Visher's (1969) results. Frequency vs grain size plots were also made (Text-fig. 7) and textural parameters [mean (M), standard deviation (g.s.d.), skewness (σ)] were calculated from these plots (following Friedman 1961). The cumulative plots (Text-fig. 4) based on Visher (1969) show that the suspension population accounts for and contains material up to 0.25 mm whereas the saltation populations represent 20-50 per cent and range up to 0.95 mm in size. This would imply that deposition was from a turbulent flow without winnowing of finer suspension material. The presence of appreciable amounts (up to 20 per cent) of quartz suggests derivation from adjacent Palaeozoic structural blocks.

The coarseness of the sandstones implies rapid transportation. Comparison with Visher (1969) and Friedman (1961) shows that the sandstones in the Kinbombi area are most likely of fluviatile, possibly deltaic origin.

Shales

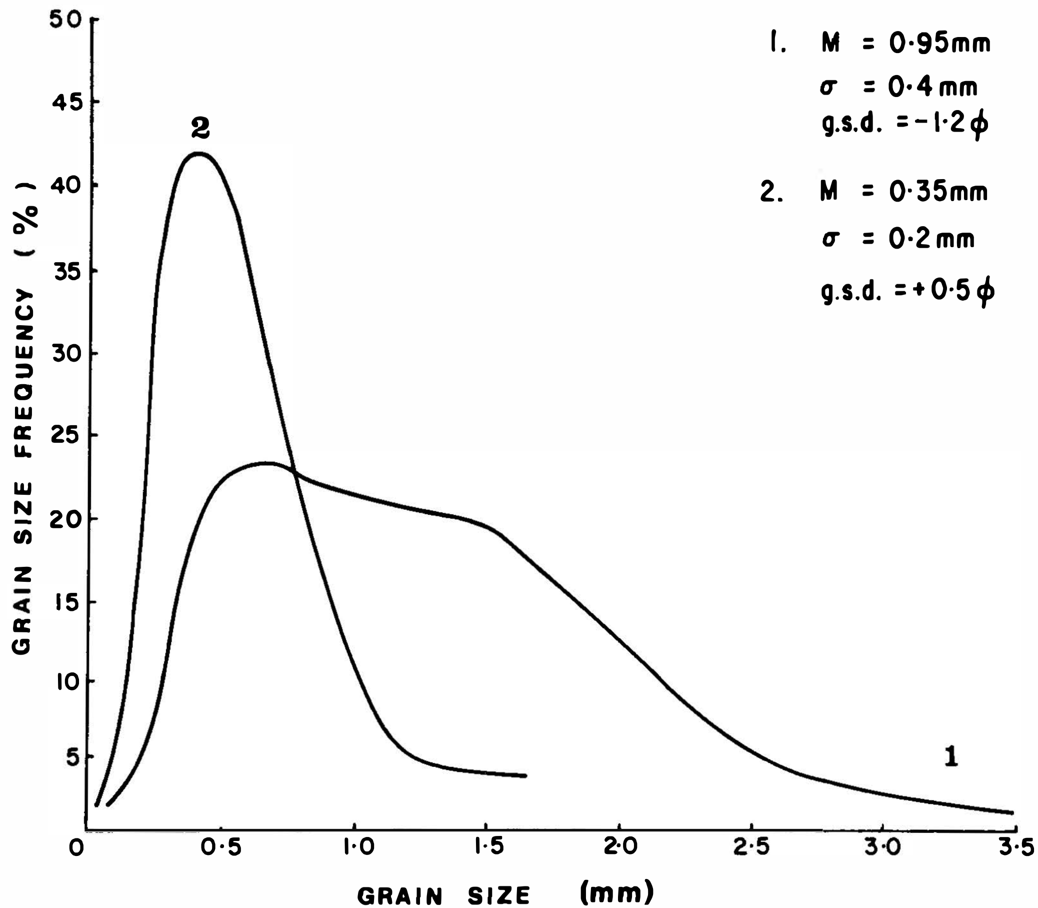
Silty shales occur throughout the sequence as thin beds, usually within sandstone. The best exposures are in railway cuttings north of Kinbombi.

The shales in the lower horizon of the boulder conglomerates are purple, finely laminated, with montmorillonite clay dominant. The shales in the upper part of the sequence are olive-green to black and dominantly silty, and contain montmorillonite, illite, and kaolinite. Reid (1925) reported *Dicroidium* and *Phyllopteris* in these shales, and these indicate a probable Triassic age.

Zeolitized tuff beds up to 20 cm thick are interbedded with the shales. Laumontite is dominant and occurs near the margins of each tuff band. This mineral typically forms as a result of moderate temperature hydrothermal alteration of acidic tuffs (Coombs *et al.* 1959) and thus it is probable that zeolitization occurred immediately after deposition of the tuff in a quiescent aqueous medium. The alteration of acid tuffs may have also contributed to some of the kaolinite in the shales.

Discussion of sedimentological data

The new data presented above enable some deductions to be made in relation to sedimentation in the Esk Trough during the Early Triassic. Indication of a dominantly littoral environment for deposition of the boulder beds and conglomerates suggests that a large lake existed on the floor of the trough during the Early Triassic. Surf action on such a lake need not have been strong, as Sames (1966) has found that chert pebbles on beaches of the Baltic Sea attain ρ values greater than 60 per cent in weak surf. The boulders therefore need not have moved extensively to become highly rounded and spherical. The most important agency of abrasion would be the coarse sand



Text-fig. 7 Textural parameters of sandstones in Neara Volcanics (method based on Friedman 1961).

material moving freely through the close-packed framework of boulders. Such an abrasive mechanism could also explain the unusually large and coarse suspension population, coupled with the poorly sorted saltation population. Surf action on a close-packed boulder framework would create high turbulence within the boulder-strewn area, but winnowing of suspended material would not occur due to decrease of turbulence in open water adjacent to the beach. This is due to the inverse relationship between turbulence and diameter of a flow passage. The high turbulence caused very coarse material to remain in suspension and yet winnowing of such material could not occur as high turbulence was restricted to the boulder-strewn beach area.

Special physiographic conditions may have been necessary for boulder beaches to form rather than sandy beaches. Brothers & Searle (1970) described well-rounded andesitic and plutonic boulders set in a pyroclastic matrix at the base of seashore cliffs on Raoul Island of the Kermadec Group, southwest Pacific. In the Early Triassic Esk Trough, syndepositional fault scarps may have existed, and the numerous volcanic cones would have had steep slopes. Thus the origin of type 3 boulder conglomerates can be explained in terms of wave erosion of andesitic volcanic island built up on the floor of the trough, surrounded by a lake which could have occupied the entire area of the trough. The matrix of the boulder beds could be reworked pyroclastic material or rapidly eroded rubble from the slopes of the volcanic cones themselves.

The occurrence of granitic and metamorphic boulders in the eastern part of the trough suggests that the rocks of the Palaeozoic D'Aguilar Block were not covered extensively or to any great depth by lava flows during the Early Triassic. A boulder conglomerate collected by J. Innes (near Kilkivan), from east of the Esk Trough, consists entirely of granite boulders in quartzose matrix; this suggests that very little andesitic material existed on the D'Aguilar Block in the Kilkivan area. The occurrence of type 1 'lava-agglomerates' (Williams 1958) near Goomeri (Irwin 1973) suggests that a major volcanic centre existed to the west of the area. Hill (1960) and Reid (1925) also suggested volcanic sources in the middle of the trough.

The morphometrical characteristics of conglomerates in the western limb of the Goomeri Syncline show a greater fluviatile component than those in the eastern limb. This indicates that the most significant influx of stream-borne material came from the west. Textural data from the sandstones indicate a mostly fluviatile origin, possibly deltaic; whereas the lensoidal form of the sandstone and shale beds on top of the conglomerates suggests a river channel. As these polymictic conglomerates and sandstones are stratigraphically above the main portion of the andesitic lavas and boulder conglomerates, it would appear that a significant influx of non-volcanic detritus came from the west after cessation of the main volcanic activity. This could explain the restriction of the Esk Formation to the western side of the trough.

Shales throughout the sequence are dominantly montmorillonitic, reflecting the high proportion of volcanogenic detritus in the basin. Numerous magnesite veins, which occur throughout the shales filling early joints and bedding planes, are probably the result of diagenetic expulsion of magnesium from the montmorillonite in the shales. The presence of abundant carbonaceous plant remains indicate reducing conditions during deposition, which could be due to either ponding or rapid burial in fine sediments.

POSTULATED PALAEOGEOGRAPHY

The northern end of the Esk Trough during the Early Triassic is regarded as an intermontane laucustrine basin containing numerous steep-cliffed andesitic islands. Boulder beaches formed on the shores of the islands, and much sandy detritus was carried into the lake by small, possibly torrential rivers discharging off the volcanic islands and to the east, off the D'Aguilar Block. The centres of andesitic eruption were in the centre of the trough, while the deepest part of the trough was in the east. Shorelines around the lake would have been very variable due to the tectonic instability of the graben, and repeated build-up of new volcanic cones. Later, as the volcanic activity died down and the trough became filled with volcanic and sedimentary rocks, influxes of stream-borne material from the Paleozoic Yarraman Block moved east. The presence of an apparent fluviatile deposit in the Kinbombi area suggests that the streams may have discharged into a smaller lake restricted to the eastern part of the trough. The occurrence of plant-bearing shales in this fluviatile environment need not suggest the existence of stagnant pools as has been suggested in Dunlop (1951).

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M.J. Irwin
Department of Geology and Mineralogy
University of Queensland
St Lucia, Queensland 4067

Text-fig. 1 Combined locality and regional structural map of the Esk Trough, showing Kinbombi area.

Text-fig. 2 Generalized stratigraphic sections through Neara Volcanics, east-west, spaced ca 1 km apart in a north-south direction. E-F, 0.5 km north of Kinbombi; A-B and C-D, both on Kinbombi Creek.

Text-fig. 3 Morphometrical parameters of boulder conglomerates in Kinbombi area; arrow indicates littoral trend. Method based on Sames (1966).

Text-fig. 4 Textural characteristics of boulder conglomerate matrices (A) and of sandstones (B). Method follows Visher (1969).

Text-fig. 5 Cumulative curves of ρ for boulder conglomerates and orthoconglomerates in Neara Volcanics (method based on Sames 1966).

Text-fig. 6 Morphometrical parameters of conglomerates in Neara Volcanics (method based on Sames 1966).

Text-fig. 7 Textural parameters of sandstones in Neara Volcanics (method based on Friedman 1961).