CHAPTER 8

THE PALAEOGEOGRAPHIC SETTING AND SEDIMENTATION HISTORY OF THE KEEPIT CONGLOMERATE

1. Introduction:

The Late Devonian Keepit Conglomerate occurs within the Devonian-Carboniferous regressive sequence of the Tamworth Belt. Petrographic and palaeocurrent studies of the Tamworth Belt sequence (e.g., Crook, 1960a,b,1964; McKelvey, 1966; White, 1966; this thesis) indicate derivation of the terrigenous sediments from a volcanic chain lying to the west of the present day western margin of the belt. Shape studies of the Keepit Conglomerate clasts (Chapter 5) enable the tentative suggestion that during the Famennian this chain lay some 8-16 km west of the Tamworth Belt.

The Tamworth Belt has been termed a fore arc basin by Leitch (1974a,1975) and an arc-trench gap by Crook (1975) and Crook and Powell (1975). Andesitic volcanism prevailed during the Devonian, with dacitic and rhyodacitic volcanism more dominant in the Carboniferous. Contemporaneous volcanism was associated with marine sedimentation of the Late Devonian Baldwin Formation (Jenkins, 1969), Noumea Beds and Lowana Formation (McKelvey, 1966; White, 1966) and the Early Carboniferous Luton Formation (McKelvey, 1966; White, 1966), Tangaratta Formation (White, 1964c) and parts of the Parry Group (Crook, 1960b). Volcanism was widespread during deposition of the Late Carboniferous terrestial sequence.

Volcanism contemporaneous with sedimentation of the Keepit Conglomerate was not reported by these authors, although neither was its apparent absence stressed. Conclusions drawn from this study indicate the Keepit Conglomerate, in marked contrast to older and younger coarse units of the marine sequence, was not associated with contemporaneous volcanism.

Within the Late Devonian-Carboniferous marine sequence of the Tamworth Belt there is a change from turbidity current dominated conditions of sedimentation to conditions of traction current sedimentation (Crook, 1959a,1964; White, 1964c,1966; McKelvey, 1966;

Manser, 1967). Turbidites are most common in the Late Devonian Baldwin Formation (except the uppermost interval), Noumea Beds and Lowana Formation, and the lower intervals of the Early Carboniferous Luton Formation, Tangaratta Formation and Goonoo Goonoo Mudstone. The transition in the Carboniferous from turbidity current activity to traction current sedimentation is well illustrated by interbedded turbidites and traction current sandstones in the Upper Luton Formation.

The conditions which prevailed prior and subsequent to the deposition of the Keepit Conglomerate were not, however, characterised by dominant turbidity current activity, but rather by the accumulation, at unknown depths, of mudstone dominated sequences, i.e., the Eungai Mudstone, the Upper Baldwin Formation, the Mandowa Mudstone. These mudstone dominated units represent conditions of quiet pelagic sedimentation (McKelvey, 1966; White, 1966), with thin sandstones deposited by intermittent traction current activity and/or under distal turbidity current conditions (White, 1964,1966).

Reliable palaeobathymetric data for the Tamworth Belt sequence is virtually non-existent. Crook (1959a,1964), on the basis of the common occurrence of turbidites, inferred deep water depositional environments, with shallowing in the Carboniferous. This interpretation was followed by White (1964c,1966), who considered the Late Devonian turbidites (including the Keepit Conglomerate) to have been deposited at bathyal depths on the continental slope.* More recently, Ellenor (1971), in a brief consideration of the Late Devonian marine sequence in the Timor Valley, and McKelvey (1974) have proposed shallow water shelf conditions for the Late Devonian-Early Carboniferous sequence. Crook (1975) defends his earlier deep water interpretation.

The palaeogeographic setting in which the Keepit Conglomerate was deposited was thus a fore arc basin (arc-trench gap) dominated by conditions of quiet water mud sedimentation, with periodic or intermittent traction current and distal turbidity current activity and an apparent lack of significant active volcanism. Reliable palaeobathymetric data is absent.

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*Crook (1959a,1964) also inferred a deep water environment for most of the Early to Middle Devonian Tamworth Group, an interpretation subsequently challenged by Ellenor (1971,1975a,b) and defended by Crook (1975). The argument over the deep or shallow water setting during these times is well presented in Ellenor (1975b).

2. The Sedimentation History of the Keepit Congomerate:

The period of quiet water mudstone dominated sedimentation which characterised the upper Baldwin Formation, the Eungai Mudstone, and the Mandowa Mudstone was interrupted by an event which produced the coarsest and one of the most spectacular units of the Tamworth Belt sequence - the Keepit Conglomerate.

The remarkable difference in sediment grade between the mudstones and subordinate sandstones of the upper Baldwin Formation and Eungai Mudstone, and the coarse pebble to boulder grade conglomerates and sandstones of the Keepit Conglomerate indicates a drastic change in the nature of the source area. The great volume of coarse sediment which makes up the Keepit Conglomerate would require a rugged high relief source area undergoing vigorous physical erosion. It is considered that the event(s) which affected the source area, and so markedly altered the prevailing conditions of sedimentation, were tectonic.* Conclusions drawn from the petrographic studies, namely the lack of evidence for contemporaneous volcanism, the occurrence of clasts of marine volcaniclastic sediments, and an age (376 + 13 m.y.), for at least some of the volcanics which is significantly older than the Keepit Conglomerate, suggest the sudden rejuvenation of the source area was due to uplift rather than a marked renewal of or increase in volcanic activity. This is in notable contrast to the Baldwin and Luton Formations, and their lateral equivalents, which are characterised by active volcanism

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* The Keepit Conglomerate is herein interpreted as resulting from a significant Famennian tectonic event which affected the quiescent volcanic source area. The source area is presently unexposed, its exact whereabouts being speculative, and thus no information is forthcoming from a study of the source area as to the causes of this tectonic event. Of the numerous existing interpretations of the tectonic evolution of northeastern New South Wales, e.g., Voisey (1959), Marsden (1972), Scheibner (1973,1976), Denmead *et al.*, (1974), and Leitch (1974a,1975), not one is specific enough to demand an event in the Famennian. The Keepit Conglomerate thus indicates a previously unrecognised tectonic event relating at least to the volcanic chain associated with the Tamworth Belt, and possibly of more regional significance; Webby (1972) suggests a major uplift in the eastern part of the Lachlan Fold Belt during the Famennian. Although the Keepit Conglomerate is attributed to uplift of the source terrain, the actual reason(s) for this uplift, and process(es) by which it occurred, are presently unknown. It is beyond the aims and scope of this thesis to attempt, in terms of plate tectonic theory, a tectonic evolution of northeastern New South Wales in order to explain (?) this uplift.

contemporaneous with sedimentation. The occurrence of the terrestial conglomerates and sandstones of the Keepit Conglomerate overlying with abrupt disconformity the marine mudstones of the Baldwin Formation, and the thick (at least 508 metres) accumulation of very coarse terrestial conglomerates, is in character with the uplift of the source terrain.

This uplift of the source area is considered, in view of the sudden and drastic change in the nature of sedimentation, to have been rapid. Continued uplift of the source area during sedimentation of the Keepit Conglomerate is suggested by the lack of upward fining of the considerably thick coarse terrestial deposits.

The rapid uplift created a rugged source area of high relief and steep slopes. During this period of time, i.e., Late Devonian, land plants were virtually non-existent in such terrains, being restricted instead to nearshore and coastal environments (Schumm, 1968; Gould, 1975). Conditions were thus favourable for physical weathering and the production of large quantities of coarse labile detritus. This coarse detritus was flushed from the source terrain by frequent periods of flooding and transported via braiding streams to be deposited as part of large alluvial fan-like bodies fronting this uplifted source block. The labile nature of the sediment is consistent with rapid sedimentation.

Several coalescing alluvial fans probably existed. Nearer the source area, these fans might overlie older Tamworth Belt lithologies and/or source rocks with angular unconformity, but in the present exposed portion of the terrestial domain the contact is a basin edge disconformity between fluvial gravels and sands and the underlying marine mudstones. The fans may have passed downslope to fan-deltas prograding into a quiet water marine environment. Rapid progradation of the terrestial fans is indicated by the absence of passage beds, with coarse terrestial deposits disconformably overlying fine grained marine sediments. If progradation had been slower, perhaps reflecting (1) an increase in sediment supply through an increase in or renewal of active volcanism, (2) slower, less pronounced uplift of the source area, or (3) lateral migration of the sediment feeder system, then a more gradational coarsening up sequence from the marine to the terrestial sediments would be expected.

Abrupt interfingering of quiet water nearshore marine sediments and coarse terrestial deposits is clearly evident in MS25, and also occurs in MS28 and MS31 (facies D interbedded mudstone-sandstone). This interfingering may relate to either lateral migration of the fans or fan-deltas with time, or to sea level fluctuations resulting from contemporaneous tectonic activity in the source area. Other marine incursions, resulting in sandy or gravelly nearshore marine deposits, might have occurred but have not been recognised in this study. Similar interfingering, both recent and ancient, of coarse fluvial gravels and marine or lacustrine muds, has been described by T.R. Walker (1967), Stanley (1971), and Van de Kamp (1973). It is interesting to note that in the situation described by Walker periodic high discharge fluvial conditions, i.e., flash floods, were responsible for the progradation of coarse alluvial fan gravels basinwards over intertidal muds. If subsidence was to occur these muds would bury, and hence directly overlie, the coarse fluvial gravels.

Coarse submarine fans were constructed in deeper waters by the periodic resedimentation of sand and gravel from the front of the advancing terrestial fans. Rapid progradation of fan-deltas would result in unstable piles of sand and gravel accumulating in coastal environments. The periodic dislodgement of such accumulations might be due to:

1. Oversteepening of the fan-delta front slopes through rapid sedimentation and sand and gravel;
2. liquefaction of rapidly deposited sands, causing the slumping of both the sand and any associated gravels;
3. earthquake shocks possibly associated with contemporaneous tectonic activity in the source area.

Terzaghi (1956) has described slumping associated with clean sand and gravel deltaic sediments as the result of slope oversteepening and the development of excess hydrostatic pressures, resulting in reduced resistance to shear stress, in the associated silts. Hendry (1973) attributed the initiation of sediment gravity flows which produced composite conglomerate-sandstone beds to progressive liquefaction of the original submerged sediment mass. After considering recent studies on liquefaction, Hendry noted that medium and possibly even coarse sand might be capable of liquefaction. Morgenstern (1967) discusses the occurrence and mechanics of submarine slumping.

Many of the terrestial sediments of the Keepit Conglomerate were transported during periodic high discharge flood conditions. Introduction of large quantities of coarse sediment by this method to coastal environments might initiate slumping of already unstable sediment accumulations as a result of sudden overloading. If the floods were large their sediment laden waters, being more dense than the sea water, would tend to flow downslope as a density current, and perhaps evolve into some form of sediment gravity flow. Such a mechanism has been invoked to explain certain sandstones (facies O and P) associated with nearshore marine mudstones in MS25. The role of coarse-sediment laden floods in the initiation of turbidity currents or the resedimentation of coarse gravels has been suggested by, e.g., Heezen (1959,1963) and Stanley and Unrug (1972). The breakage of submarine cables off river mouths during high flood stages, in one case unequivocally associated with resedimentation of fluvially derived detritus, has been commented upon by Heezen (1959,1963) and Burke (1967). Griggs *et al.* (1970) explain resedimented gravels (petrographically similar to the Columbia River sediments) present in the Cascadia Deep Sea Channel to resedimentation associated with the extremely high discharge Pleistocene Bretz floods. These floods were channelled down the Columbia River valley, across the exposed shelf and via shelf break canyons to deposit the gravels in water depths now in the order of 3,300 metres. In the case of the Keepit Conglomerate, it is highly likely that during periods of intense flooding, overloading of unstable slopes and/or the pouring of coarse sediment laden flood waters over the front of fan-deltas initiated sediment gravity flows which transported the coarse sand and gravel to deeper waters.

The scarcity of diamictites and the mud-free nature of many of the sandy conglomerate matrices is suggestive of an initiation process for the resedimentation episodes which was unrelated to the underlying mudstones. Thus the slumping of muds as a result of overloading by sand and gravel, or the failure of muds leading to slumps and sediment gravity flows as a result of, e.g., earthquake shocking of the muds, is considered not to have been the method of initiation of the resedimentation episodes. Instead, instability was inherent within the sand and gravel accumulations on the slopes of the fan-deltas due to processes of rapid sedimentation associated with progradation of the fans. The intraformational debris within the resedimented sandstones and conglomerates was derived through erosion by the sediment gravity flows and not during slump initiation of the flow.

The submarine fans of the Keepit Conglomerate were built up by the resedimentation of coarse gravels and sands from the prograding terrestial fans. These sediments were funnelled from shallow to deeper water via either natural depressions or eroded channels. A variety of sediment gravity flow mechanisms, including turbidity currents, grain flows and debris flows, were involved in these resedimentation episodes. A number of laterally adjacent, possibly coalescing, submarine fans were thus constructed. These fans are envisaged as being of relatively small size but great coarseness when compared to most present day examples (e.g., Carlson and Nelson, 1969; Piper, 1969; Haner, 1971; Normark and Piper, 1972; Nelson and Kulm, 1973; Nelson and Nilsen, 1974; Normark, 1974; Nelson, 1976).

There is no reliable evidence as to the depths of water in which these fans were formed. Relatively steep intrabasinal slopes, however, are indicated by:

1. The presence of grain flow conglomerates require slopes in the order of 9° (Lowe, 1976a,p.197), though such slopes may be reduced if matrix strength is a significant contributor to grain support.

2. The frequent occurrence of inverse grading suggests high shear stresses associated with steep slopes (Walker, 1975a, p.745).

3. The proximal attributes of many of the resedimented conglomerates and sandstones suggest deposition nearer the source of the sediment gravity flows, where submarine slopes are more likely to be steep.

4. Diamictites may be indicative of steep slope conditions (Stanley and Unrug, 1972) although for the diamictites of the Keepit Conglomerate these slopes might only be local, e.g., channel walls.

The existence of relatively steep slopes within the depositional basin in association with coarse and thick resedimented deposits in submarine fan environments is suggestive of a deeper water trough-like depositional basin rather than shallow shelf conditions. The only depth implications, though, are that the resedimented deposits were deposited below storm wave base.

The vertical profile of the Keepit Conglomerate submarine fans indicates, initially, progradation of more proximal over more distal fan environments. The rapidity of this coarsening up might suggest that progradation was rapid. The progradation of the submarine fans probably relates to increasing supplies of coarse detritus through the basinwards progradation of the terrestial fans.

The upper part of the vertical profile is a fining up sequence, representing the westward migration towards the strandline of progressively more distal fan environments, i.e., retrogradation of the fans. This retrogradation occurred in response to a period of transgression. Such may have resulted from basin subsidence, either renewed or at an increased rate, or from a reversal of tectonism in the source area resulting in the overall subsidence of both the source and the basin. Whatever the reason(s) and process(es), progradation of the submarine fans ceased and retrogradation began.

Two significant aspects of this transgression are:

1. As a result of transgression the rivers of the terrestial domain had to readjust to a progressively changing base level. This resulted in aggradation by the rivers, with much of the sediment load being deposited inland instead of being transported all the way to the coast (Mackin, 1948, p.496; Picard and High, 1972, p.2691). Progradation was thus terminated by processes which need not have involved a reduction in the sediment supply. The post-glacial sea level rise following the retreat of the Pleistocene ice sheets has resulted, in many instances, in coarse sediment no longer being supplied to the shelf but instead being trapped within the river valleys, within fiords (e.g., Piper *et al.*, 1973, p.21), or coastal environments (e.g., Nelson and Kulm, 1973, p.46,67; Nelson, 1976, p.165).

2. Westward migration of the submarine fan environments in response to retrogradation would result in the backfilling of the feeder channels with coarse, typically inner fan sediments. More significant, however, is the apparent ineffectiveness or absence of headward erosion of these channels. This is suggested by the absence of a fining up vertical profile to the sequence infilling the feeder channel environment (subdivision I), in contrast to the profiles of the more easterly fan environments (subdivisions II and III). A lack of headward erosion of the feeder channels during the transgression would result in their being cut off from the sediment source, thus abruptly terminating the accumulation of resedimented coarse detritus in the fan environments. Mud sedimentation subsequently prevailed, covering the fan deposits. This situation is analogous to many present day submarine fans. During the lower sea levels of the Pleistocene, when coarse sediment was transported closer to the shelf break, the sediments of the associated submarine fans were correspondingly coarser. With the post glacial sea level rise, only those fans whose feeder canyons could maintain connection with their sediment source through rapid backcutting, e.g., the La Jolla fan (Normark and Piper, 1972, p.220), now contain coarse recent resedimented deposits. For those fans whose feeder canyons became cut off from their coarse sediment supply, the coarser older deposits are now mantled by a cover of muds, resulting from both pelagic and mud turbidity current sedimentation (e.g., Navy fan, Normark and Piper, 1972; Astoria fan, Carlson and Nelson, 1969; Nelson, 1976). This situation is remarkably similar to that of the submarine fan deposits of the Keepit Conglomerate.

The marine deposition of mud with subordinate sand over the sediments of the terrestial domain, and the apparent absence of reworking of these coarse fluvial gravels and sands during the transgression, is considered to indicate rapid transgression with a low energy marine environment onlapping a terrestial environment. Occasional instability of some of the retrograding coast is indicated in MS25 by the occurrence of resedimented conglomerates and sandstones (facies F and L). These deposits are considered to have slumped off the retreating coastline into a nearshore marine environment. They may alternatively indicate a minor regressive period with an increased supply of coarse sediment leading to resedimentation of unstable sediment accumulations in coastal environments.

5. Summary

1. The Keepit Conglomerate occurs within a Late Devonian-Early Carboniferous marine sequence deposited within a fore arc basin. This basin, immediately prior and subsequent to deposition of the Keepit Conglomerate, was characterised by quiet water mudstone sedimentation. Turbidite sedimentation prevailed in older and younger formations, changing to shallow water traction current conditions in the Early Carboniferous.

2. The Keepit Conglomerate represents a previously unrecognised significant regressive-transgressive episode within this marine sequence.

3. The Keepit Conglomerate was derived by the vigorous physical erosion of an uplifted quiescent andesitic volcanic chain source area. This is in marked contrast to older and younger coarse units (i.e. Baldwin and Luton Formations and their lateral equivalents) within the marine sequence, for which active volcanism played a more significant role.

4. Coexisting terrestial and marine fans, composed of coarse conglomerates and sandstones, occur within the Keepit Conglomerate. Terrestial fans, constructed by braiding streams, rapidly prograded basinwards over marine mudstones. Resedimentation off fan-deltas, possibly associated with frequent conditions of high fluid-high sediment fluvial discharge, provided coarse sediment for the construction of submarine fans by sediment gravity flows in deeper water, more basinwards conditions.

5. Sedimentation was terminated by a rapid (?),marine transgression, resulting in a return to quiet water conditions of mudstone

deposition. A combination of reduced supply of coarse detritus to the coast and cut off of feeder channels from their sediment source effectively terminated deposition in the submarine fan environments.

6. The palaeobathymetric setting of the submarine fans within the fore arc basin is unknown. Relatively steep slopes are suggested, but the only depth implications are for sedimentation below storm wave base. A shallow shelf setting is rejected in favour of a more trough-like depositional basin.

4. A Present Day Analogue for the Keepit Conglomerate: The Yallahs River Fan-delta, and Submarine Fan of Eastern Jamaica

A present day situation comparable to that inferred for the Keepit Conglomerate is to be found, although on a smaller scale, in eastern Jamaica. This following discussion is based on publications by Burke (1967), MacGillavry (1970) and Gupta (1975).

The steep terrain, rising to 2,200m in 25km from the coast, of eastern Jamaica is drained by short, high gradient rivers carrying abundant silt, sand and gravel but little mud. Of these rivers, the Yallahs has been studied by Gupta (1975). The drainage basin of the Yallahs is of high relief with steep slopes, possesses only a thin soil cover with vegetation mostly removed through the activities of man, and is subject to heavy seasonal rainfall. Runoff is rapid and high, and flooding is common. the Yallahs rises at 1,500m and runs 37km to the coast. The steep gradient and frequent flooding enable a very coarse bedload to be transported. As a result, the Yallahs possesses a braided channel with gravel deposits containing boulders up to 5.5m maximum diameter.

The Yallahs has constructed a gravel rich fan-delta, the subaerial surface of which contains boulders up to 1m across. Much of the detritus of this fan-delta was deposited during flood conditions. The Yallahs fan-delta has built the coastline forward by 2km, and extends a further 0.5km as a shallow underwater surface. Beyond this lies the Yallahs submarine fan, dropping to 1,100m over 4,000m, an average slope of 14° (the same slope calculated from the bathymetric contour map, Fig.2, of

Burke (1967) is 11°). This submarine fan is considered to have been constructed by resedimentation of sediment from the Yallahs fan-delta. Resedimentation during flood periods is indicated by the breakage of submarine cables during the 1963 hurricane.

To the west of the Yallahs fan-delta and submarine fan lies another, similar feature, the Hope River, fan-delta and Hope-Liguanea submarine fan. The Yallahs and Hope-Liguanea submarine fans lie within the Yallahs Basin, a structurally controlled basin up to 1,300m deep and about $100km^2$ in area, and containing at least 500m of sediment derived largely by resedimentation from the subaerial fan-deltas.