CHAPTER 4

4 MESOZOIC SHELF & SHELF MARGIN SEDIMENTS & ASSOCIATED IGNEOUS ROCKS

4.1 UPPER TRIASSIC - LOWER CRETACEOUS SHELF SEDIMENTS

4.1.1 The Upper Triassic Sadong Formation is a shallow marine sedimentary facies associated with the Serian Volcanics, mainly in Sarawak and comprises moderate to steeply folded shale, felspathic sandstone, conglomerate and tuffaceous sediments with thin beds of coal, chert and limestone (Fig 4.1). A distinctly arkosic sequence forms a separate member. The conglomerates contain clasts of gneiss, mica granite, mica schist, carbonaceous phyllite, chert and limestone. The thickness is at least 2,300 m. Shoreline deposits occur SW of Serian and contain chert debris from the Lower Permian Terbat Formation. Kon'no (1972) has identified Late Triassic (Late Carnian) plant remains from just above the basal conglomerate at Krusin, near the border (1°4¼'N, 110°30'E). The floral assemblage is characteristic of the SW Pacific floral province in Late Triassic times and there are no European or Siberian floral elements present. The Krusin flora is different to that on Bintan island but there are similarities with the Tonkin flora in N. Vietnam (Kon'no,E. 1972). The base of the Sadong Formation is probably unconformable with the Terbat Formation and the top is overlain unconformably by the Kedadom

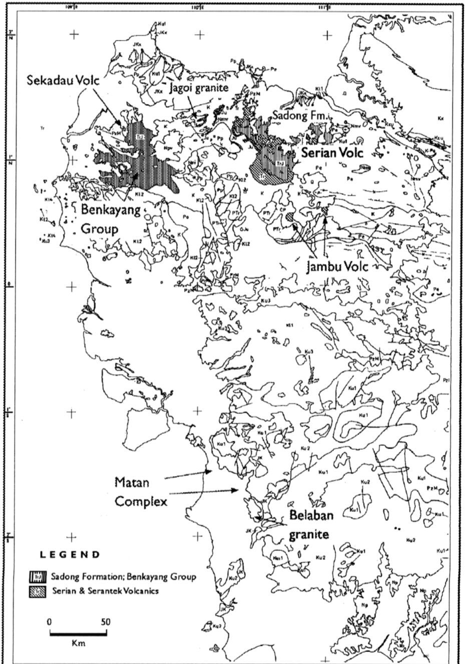

Fig 4.1 Distribution of Triassic & Triassic-Jurassic sediments and associated igneous rocks, W Kalimantan & W Sarawak.
(after Tan, 1982, Sudana & Jamal, 1989 & Pieters & Supriatna, 1990.)

Formation, the Upper Jurassic part of the Bau Limestone Formation and elsewhere by the Lower Cretaceous Pedawan Formation.

4.1.2 The equivalent, in part, of the Sadong Formation in Kalimantan is the Bengkayang Group which outcrops extensively in NW Kalimantan SE of Sambas where it unconformably overlies the Seminis Formation (Fig 4.1). The lower part of the Benkayang Group consists of sandstone and minor conglomerate overlying carbonaceous sandstone and shale with tuffaceous and lithic sandstone and acidic tuff at the base. The upper part, locally tuffaceous, comprises fossiliferous sandstone, siltstone and mudstone with graded bedding, low-angle, trough cross-bedding, parallel and convolute lamination, indicating turbiditic deposition. The upper part is 1500m thick and dated by Early Jurassic (Toarcian) fossils and the lower part is more than 1000 m thick and is probably Late Triassic (Norian) from a reported occurrence of *Monotis Sp.* by Wing Easton (1904). The basal tuffaceous and lithic clastics, tuffs and black sandstones may correlate with the near-shore marine sandstones of the Sadong Formation (Wilford & Kho, 1963).

4.1.3 There was a period of sedimentary non-deposition from Middle Permian to Middle Triassic in Sarawak and in Kalimantan and marked in Sarawak by a major unconformity representing a period deformation and possibly of uplift; the Permo-Triassic, igneous-metamorphic Embuoi and Busang Complexes appear to have been formed at this time.

4.1.4 Another unconformity between Late Triassic and Lower Jurassic has been recorded in West Sarawak but the break is probably a period of non- deposition as the ?Late Triassic-Lower Jurassic shallow marine Bengkayang Group was deposited 50 km to the SW in Kalimantan.

4.1.5 The Late Triassic/Jurassic unconformity has not been identified with certainty in the Bengkayang Group, although it may be present between the upper and lower parts in Sanggau. In Singkawang, there is a conformable relationship between the two. The turbiditic nature of the upper part of the Bengkayang Group indicates a deepening of the paleoenvironment prior to the onset of a period of tectonism which deformed the Benkayang Group sediments during the middle Jurassic.

4.1.6 The Bengkayang Group is unconformably overlain by the Cretaceous Pedawan Formation and Raya Volcanics and intruded by Cretaceous, Miocene and Pliocene igneous rocks.

4.1.7 The Ketapang Complex in the SW part of the Schwaner Mountains occurs as small inliers within Cretaceous granitoids (De Keyser & Rustandi, 1989). The rocks comprise thin-bedded pelites and psammites, siltstones, sericitic sandstones, lithic and volcanigenic arenites, grits, shales and slates. Calcareous horizons are transformed to calcsilicate rocks by contact metamorphism. The rocks are strongly folded with moderate to steep dips. The age and stratigraphic position of the Ketapang Complex are ambiguous. The rocks resemble the Upper Triassic-Lower Jurassic Bengkayang Group but a mid-Cretaceous microflora was identified in shales collected from the Ketapang Complex (Haile,1974).

4.2 UPPER TRIASSIC VOLCANIC ROCKS

4.2.1 The Serian Volcanic Formation comprising generally andesitic lavas and tuffs occurs widespread in Sarawak (Wilford & Kho, 1965, Pimm, 1965) and continues S for 10 km across the border into the Sanggau quadrangle (Fig 4.1). The silicified Jambu Volcanics are lithologically similar to the Serian Volcanics and occur at the western end of the Boyan zone some 25-50 km to the SE (Fig 4.1) . The relationship of the Serian and Jambu Volcanics with older units in Kalimantan is unknown but in Sarawak, there is an angular unconformity with Permo-Carboniferous rocks (Terbat Formation). In Kalimantan, volcanics are interbedded with sediments of the Sadong Formation as in Sarawak.

4.2.2 The Sekadau Volcanics form a restricted area lying to the NW, 20 km SSE of Sambas, in Sambas - Siluas quadrangle and their stratigraphic position, as already mentioned, is problematical and speculative. They are reported to intrude and overlie unconformably the Seminis Formation and are in turn overlain unconformably by the Bengkayang Group. The Sekadau Volcanics are probably equivalent to the Serian Volcanics although in the S show affinities with the younger Raya Volcanics which outcrop in Singkawang (Suwarna *et al.*,1989) and western Sanggau (Supriatna, S. *et al.*, 1989b).

4.2.3 Chemical analyses of the Serian Volcanics (Kirk,1968) indicate calc-alkaline to high-K calc-alkaline characteristics. Hon,(1975) shows that the predominantly basalt-andesite (with extension to rhyodacite) association has tholeiitic affinities indicating that they formed on the oceanic side of an island arc (Hall,1987).

4.2.4 The Jagoi granodiorite which straddles the international border has been dated by the K-Ar method, at 195 Ma (Early Jurassic)(Bladon, *et al.*, 1989). If the K-Ar age represents the time of intrusion, the Jagoi granodiorite would appear to be younger than the extensive Upper Triassic Serian Volcanics and perhaps also partly equivalent in age to the basic volcanics and intrusives of the Serabang and Sejingkat Formations. There is some doubt concerning the validity of the age determination on the Jagoi samples as previous determinations give younger ages on samples collected near fault/shear zones. The granite mass is strongly sheared along the northern margin (Ting,1991) and shearing is also reported on the Indonesian side of the border. The Early Jurassic age may therefore be spurious as a result of argon loss due to shearing and the pre-Triassic stratigraphic age given by Kirk (1965) may be still valid. The presence of hornblende and magnetite suggests it is an I-type granite. Relationships with other rocks are poorly known; in Kalimantan, the Jagoi granite has a faulted contact with the Pedawan Formation and the shearing is thought to have occurred during the Cenozoic. (Rusmana at el.,1989). In Sarawak, Ting (1991) has shown that the Bau Limestone forms fringing reefs around the Jagoi hills and the Pedawan Formation was deposited mostly in deeper water.

4.2.5 Hamilton (1979) noted that the Jagoi pluton is overlain by unmetamorphosed Upper Jurassic strata and is perhaps correlative with the Upper Triassic volcanic rocks and Hamilton's argument seems plausible. The oceanic nature of the Serian Volcanics as indicated from geochemistry and the I-type nature of the Jagoi granodiorite indicate that they formed in an island-arc setting with the Sadong Formation shelf sediments being deposited concomitantly in an emergent volcanic chain. However, the occurrence of continental clasts in the conglomerates is anomalous. Subsequent development of fringing reefs and basinal sediments occurred in the Upper Jurassic and Cretaceous.

4.2.6 Hutchison (1989) was tempted to assign the Serian Volcanics to a continental arc relationship. The inter-relationships of the Serian/ Jambu andesites and the Jagoi I-type granite would repay further study and analysis of the volcanic rocks further S may show a clearer polarity and reveal whether there is a Late Triassic volcano-plutonic island arc.

4.3 UPPER TRIASSIC-LOWER JURASSIC VOLCANICS & INTRUSIVES

4.3.1 Associated with the Ketapang Complex are a series of volcanic rocks termed the Matan Complex introduced originally by van Bemmelen (1939) to include all the volcanic rocks within the Ketapang and Kendawangan quadrangle areas. The preliminary report of the Ketapang quadrangle area (De Keyser & Rustandi, 1989) retains the term for volcanics regarded as older than most of the Cretaceous granitoid plutons. They are highly altered and weathered in outcrop and show a wide variety of rock types ranging from andesites and basalts to rhyodacites, rhyolites and quartz keratophyres and are tentatively placed between Upper Triassic-Lower Cretaceous. The JICA(1982) report correlated the Matan volcanics with volcanics in the Bengkayang area and were assigned to an Upper Triassic-Jurassic age. Unaltered and clearly younger volcanics in the same quadrangle (and formerly included in the Matan Complex of Van Bemmelen) are the Bunga basalt and Kerabai volcanics which have been shown be to be related chemically and mineralogically to the Upper Cretaceous phase of granitoid plutonic activity and radiometric dates confirm a Cretaceous age.

4.3.2 The Belaban granite, a hornblende-quartz monzo-diorite/monzonite located at Bukit Belaban Tujoh, 55km due E of Ketapang (2 10'N, 110°30'E) lies within the Matan Complex area and has yielded a date of 154Ma (Upper Jurassic) (Haile, *et al.* 1977). The granite appears to be a separate and earlier intrusive event and older than the main Cretaceous plutonism which is widespread in this part of Kalimantan. Whilst petrologically similar to the other plutonic granitoids, the Belaban granite contains sedimentary xenoliths, unlike the other plutons where the xenoliths are igneous. The genetic relationships of the Belaban granite and the Matan volcanics are difficult to determine due to the absence of detailed field, chemical and radiometric data.

4.3.3 The Ketapang and Matan Complexes may be, in part, time equivalents of the Bengkayang, Sadong and Serian volcanics.

4.3.4 A number of areas of Triassic volcanics have been mapped on the Penkalangbun (Sheet 1513) and Palangkaraya (Sheet 1613) 1: 250 000 sheets. Those in the Sampit area have been identified as volcanic breccia, basalt and tuff (Nila & Rustandi, unpublished) and are excessively weathered (S. Paramanthanam, pers. comm.) and it is likely that they all are similar to the problematic Matan Complex further west. The IAGMP map

(Pieters & Supriatna,1990) has not differentiated the Matan Complex and included all rocks belonging to the Matan Complex as part of the Cretaceous igneous-plutonic episode.

4.4 JURASSIC-CRETACEOUS SHELF SEDIMENTS

4.4.1 The Bau Limestone Formation covers an area of about 280 km^2 is up to 900m thick in Sarawak and comprises massive, poorly to moderately fossiliferous limestone with thin calcareous shales and conglomerate near the base (Malaysia,1988). Dips are generally sub-horizontal indicating that the W Sarawak area has been stable since the Cretaceous. In the Jagoi-Serikin area close to the international border, the Bau Limestone forms fringing reefs around the Jagoi granite with a classic reef arrangement of back reef, reef complex and fore reef containing slumped blocks of reef material; further from the shoreline, there is a rapid transition to deep water sediments of the Pedawan Formation (Ting,1992). The Bau Limestone Formation continues marginally across the border into NW Kalimantan.

4.4.2 The paleontology of the Bau Limestone Formation has been investigated by Lau (1974) who reports the rediscovery of rudists and associated fauna. The rudists are comparable to Tethyan genera and hence this part of Borneo was within the Tethyan realm and perhaps further north than it is now. The Bau Limestone Formation ranges from Late Jurassic to Lower Cretaceous.

4.4.3 The Pedawan Formation is more widespread and is about 4,500m thick in Sarawak (Fig 4.2) and comprises thick sequences of marine

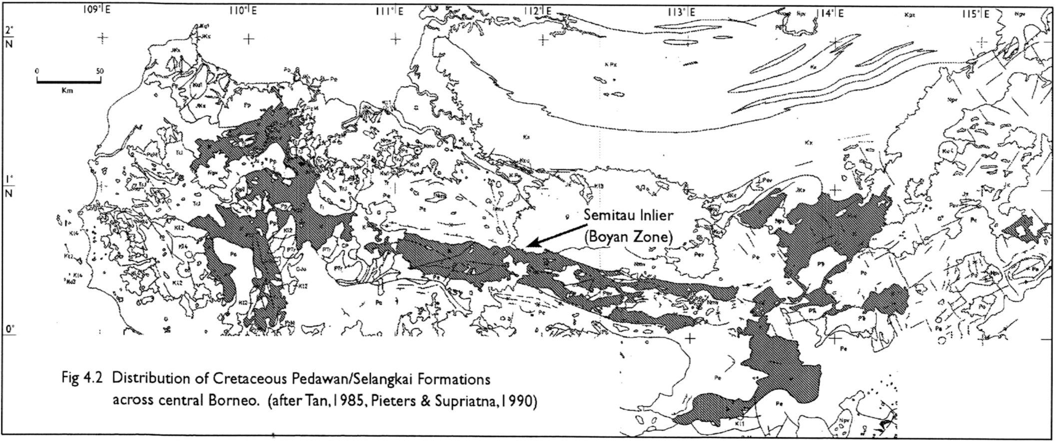

Fig 4.2 Distribution of Cretaceous Pedawan/Selangkai Formations across central Borneo. (after Tan, 1985, Pieters & Supriatna, 1990)

shale, mudstone and sandstone with subordinate beds of conglomerate, limestone, chert and andesitic to rhyolitic tuffs and subordinate lavas. Oolitic limestones indicate formation within wave base, probably on an isolated high. The lower horizons show interfingering with the Bau Limestone Formation whereas the higher horizons contain abundant pelagic foraminifera. The early reconnaissance mapping in Sarawak interpreted the Pedawan largely as a marine deposit in a deepening basin and evidence of catastrophic slumping is shown by a channel filled with clay clasts (Wilford & Kho,1965: Fig 25). Turbiditic rocks and major slump breccias have been found recently at no great distance from the Bau Limestone indicating that the Pedawan Formation was deposited in deep water and that the shelf edge was a steep slope (Azhar, 1991; Ting,1992). The Pedawan Formation in Sarawak ranges from late Jurassic to Upper Cretaceous (Upper Santonian), the lower age based on its interfingering with the Bau Limestone Formation and Upper Jurassic- Lower Cretaceous radiolaria (Wilford & Kho, 1965; Wolfenden, 1965 & Pimm,1967). In Kalimantan, the Pedawan Formation is more than 2,000 m thick.(Marked K on the 1:1 million composite map). Underlying the Bau Limestone and Pedawan Formation in Sarawak is an arenaceous paralic to shallow marine sequence with tuffs and carbonates termed Kedadom Formation containing Late Jurassic faunas but the sequence has not been found further south in Sambas-Siluas. However, the Brandung Formation in Sanggau forms isolated outcrops of fossiliferous, calcareous shallow marine deposits containing Kimmeridgian - Tithonian ammonites (Upper Jurassic) with a total thickness of more than 100m and is probably the lateral equivalent of either the Kedadom or Bau Limestone Formation.

4.4.4 There is some doubt whether the Pedawan Formation should be considered as part of the Jurassic-Cretaceous Shelf Margin Sediments if turbiditic rocks are proved to occur throughout the Formation. If the rocks are mostly deep water turbidites, the Pedawan Formation could be correlated with the Selangkai Formation in NW Kalimantan, indicating that the late Jurassic- Cretaceous in W Sarawak & NW Kalimantan was essentially a deep ocean with steep submarine slopes to immediately offshore. Moreover, the Lupar Line therefore does not form a major geological division between Cretaceous turbiditic rocks to the N and the W Sarawak "basement" to the S. Turbidites of the same age occur on both sides of the Lupar Line. The Line is therefore unlikely to represent a Cretaceous suture.

4.5 CRETACEOUS SHELF MARGIN SEDIMENTS & ASSOCIATED VOLCANICS

4.5.1 NW Kalimantan

4.5.1.1 The Selangkai Formation is the time equivalent of the Pedawan Formation (Appendix II) and distributed in an E-W belt across central Borneo, especially in the fault-bounded Boyan zone (Fig 4.2). The Selangkai Formation is poorly exposed in E. Sanggau and occurs widespread in Sintang (Williams & Heryanto,1985, 1986)and Long Pahangai where there are thick marine sequences of tightly folded calcareous mudstone with intercalations of pebbly and bouldery mudstone, graded sandstone, rare limestone and conglomerate. The conglomerate contains a wide variety of rock types including quartzite, granite, volcanic rock and rare gneiss. Some areas are dominated by turbidites and/or mass flow deposits including large limestone blocks (olistostromes) in a calcareous mudstone matrix. Mass flow deposits indicating large-scale collapses have been described by Azhar(1991) from the Pedawan Formation in West Sarawak. The Selangkai Formation contains quantities of carbonaceous material, particularly at the top of some of the turbidite sequences indicating that the source area was heavily vegetated. The limestones consist of algal and coralline micrites with *Orbitolina* species of Cenomanian age. The total thickness of the Formation is estimated to be about 3,000m. Fossils identified from samples of sandstone and mudstone indicate a Turonian (Upper Cretaceous) age. The age of the Selangkai Formation ranges from Lower Cretaceous (Valanginian) to Upper Cretaceous (Turonian) based on fossil assemblages collected by Zeijlmans van Emmichoven (1939) and the IAGMP survey. The turbidite and olistolithic mass flow deposits suggest an unstable shelf area at the edge of a steep slope. Paleocurrents indicate transport from the SE. The field descriptions show much similarity to the Lupar Formation in Sarawak but the latter is somewhat younger (Maastrictian) and paleocurrents indicate a source from the SW (Tan,-1979). Williams & Heryanto, (1986) indicate that the Selangkai Formation appears to young towards the north and perhaps the Lupar Formation represents a slightly younger equivalent. Tight folding indicates a period of tectonic deformation and the overlying sediments rest with unconformity.

4.5.1.2 The Selangkai Formation together with the Pedawan Formation further NW were probably formed along the edge of a steep submarine scarp marking the edge of a platform to the S. The zone of mass flow deposits interspersed with more coherent sedimentation appears to be intermediate between true platform deposits to the S and pelagic turbidites of the Lupar and lower part of the Belaga Formation in the Rajang basin. Thus, the Lupar Line during the Cretaceous would not have had the apparent importance that is seems to have in separating two areas of different geology today. The Lupar Line was probably not extant at that time.

4.5.1.3 Haile (1991) queried the juxtaposition of Cretaceous abyssal rocks to the N and Cretaceous shelf sediments to the S in the region of 114°E, 1°N. If the Selangkai Formation comprises both shelf and abyssal sediments along a steep slope, the anomalous juxtaposition would be feasible.

4.5.2 Meratus Mountains

4.5.2.1 The Manununggal Group is defined by Sikumbang (1986) as all Upper Cretaceous sedimentary strata, andesitic lavas, pyroclastics and associated volcanoclastic sediments that occupy a trough-like basin in the central axis of the Meratus Mountains area. More precisely, the Manunggul Basin lies in the NE part of the Meratus Mountains and is sandwiched between thrust slices of Meratus ophiolites on the SE and the Tambak-Tamba volcano-plutonic arc on the NW (Fig 4.3). The basin is 85 km long and up to 35 km wide and continuing northeastwards to Kotabaru & Sampanahan. The Manunggul Group forms the thickest and most continuous pre-Cenozoic sequence in SE Kalimantan.. Steep dips on the NW margin of the basin mark a major strike-slip fault. The Manunggul Basin is subdivided into two sub-basins, Riam Kiwa and Riam Kanan, NW and SE of the intervening ophiolitic Boboris range.

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4.5.2.2 The stratigraphic sequence of the Manunggul Group is as follows:

Top	Kayujohara Fm.	10 - 800m	Lavas & pyroclastics
	Rantaulajung F.	>5m	Estherid-bearing black shale
	Tabatan Fm.	300 - 1800m	Conglomerate & Sst
	Benuariam Fm.	400 - 1000m	Volcanoclastic deposits
Base	Pamali Fm.	200 - 5000m	Sed'y breccia, sst, calcarenite

4.5.2.3 The Riam Kanan sub-basin is essentially a coastal plain/lagoonal/shallow marine sequence beginning with a basal unit, the Pamali Formation comprising conglomerates, pebbly sandstones and minor calcarenites. The conglomerates contain about 70% quartzite and schist together with ultramafics and volcanic clasts indicating that oceanic rocks were exposed and being eroded during the Upper Cretaceous. It is un-conformably underlain partly by Meratus ophiolite and partly by metamorphic rocks of the Hauran Schist and intruded by microdiorite. is composed essentially of the weathered products of ophiolite deposited in a shallow marine environment. The Formation contains a gastropod - bivalve fauna.

4.5.2.4 The Pamali breccia, comprising a conglomerate of wholly ultrabasic clasts was initially identified as an intrusive breccia and the source of nearby alluvial diamonds; however, its rugose,sedimentary origin was established by Bergman *et al*,(1987) as a serpentinite conglomerate derived from the erosion of uplifted oceanic crust. The breccia appears to be a talus slope deposit resting upon the source parent material. The breccia contains diamonds which are reworked probably from the cratonic part of

Sundaland to the west (Hutchison,1992) although Bergman, *et al.*,(1988) have described minettes from C. Kalimantan and suggest a minette pipe is the source of the diamonds. In the Riam Kiwa sub-basin, there are two facies of the Pamali Formation, moderate to steeply dipping Bouma sequences of sandstone-mudstone and graded packstone in the NW and conglomerate-sandstone strata towards the SE. The conglomerates contain clasts of volcanics, granites, metamorphics, limestone, rare radiolarian chert, ultrabasics and broken mollusc shells. A chaotic fabric and lack of mud matrix suggests rapid deposition by grain flow of reworked sediments in the steep slope of a submarine fan.

4.5.2.5 The age of the Pamali Formation is deduced by Sikumbang (1986) as middle to upper Turonian (early to middle Upper Cretaceous) determined from molluscan and Orbitolina faunas. However, it is possible that these faunas are re-worked and that, from regional stratigraphic evidence of a somewhat later major unconformity indicated by Hutchison (1992), the age of the Pamali breccia and hence, of the Manunggul Group as a whole, is topmost Upper Cretaceous. The radiometric age of the Julong microdiorite which intrudes the Benuariam Formation (63.3Ma) supports an Upper Cretaceous age.

4.5.2.6 The sediment source comes from exposed oceanic rocks of the Meratus ophiolite and granitoids of the Tamban-Tambak arc, Hauran Schist, Paniungan Formation and Alino Group.

4.5.2.7 There are important conclusions to be made regarding the tectonics of the Meratus region from the evidence outlined in paragraphs 4.5.2 .2 and 4.5.2.5 , namely that the Lower Cretaceous oceanic crust was uplifted *rapidly* during the Cretaceous and was exposed at the surface in the topmost Upper Cretaceous allowing the deposition of sediments derived from the weathering of that crust. Sikumbang (1986) indicates there are two phases of tectonism affecting the Meratus ophiolite. The first phase occurred during or soon after formation ; a radiometric age of 116Ma (Lr.Aptian) on a sample of metadolerite could represent the age of metamorphism during creation of oceanic crust. Ophiolitic detritus is found within the pre-Albian Alino sediments. A second phase of thrusting post-dates the Alino volcanic activity but pre-dates deposition of the Manunggul Group.

4.5.2.8 The volcanic rocks within the Manunggul Basin form a discrete and separate sequence of rock units attributed to a volcanic arc source and described in more detail in the following chapter, Chapter 5.