Chapter II

Geology of Timor-Leste

A. *History of geological work in Timor Leste*

The physical features of Timor are described in some early works including the following: (i) H. Zondervan: *Timor en de Timoreezen* (Tijdschr. Aardr. Gen , 1888, Vol. V with bibliography); (ii) K. Martin and A. Wichmann: *Sammlungen des geologischen Reichsmuseums Leiden*, (1881-1884); (iii) A. Wichmann: *Bericht über eine Reise nach dem Indischen Archipel,* (Tijdschr. Aardr. Gen.1890-1892); (iv) A. Rothpletz: *Die Perm-, Trias-, und Jura Formation auf Timor und Rotti im Indischen Archipel* (Paleonographica, pp. 57-106, 1892); (v) A. Rothpletz: *Natural History of Timor* (abs) American Naturalist, Vol. XXV, pp. 959-962, 1891). The first bibliographies of the geology of Portugal and its colonies in which references to Timor are included were compiled by P. Choffat (1898, 1909, 1911, 1913, 1914.). Early detailed geological sections measured in *eastern* Timor were made by a Japanese geologist, F. Hirschi, who made several traverses around Manatuto and the south coast in 1904 to define the petroleum and asphalt potential (Hirschi, 1907).

The German expeditions to Timor were led by J. Wanner in 1909 and 1911. These were major geological expeditions which also visited Misoöl, Obi, and Halmahera. The concept of the Alpine type overthrusts in Timor was first referred to by Wanner (1913) in a short paper entitled "Geologie von West Timor". Paleontological research expeditions lead by Wanner began in 1906 and resulted in several major monographs on the fauna of Timor by Wanner, Welter and Haniel in 1907-1911. These studies culminated with Wanner's classic 16 volume study, "Paleontology of Timor".

The Dutch Geological Expeditions to the Lesser Sunda Islands began in 1910 and continued for eight years. Brouwer published more than 24 papers including several monographs on the islands of the Banda arcs over the next 37 years. The work was published in the Jaarboek Mijnwezen Nederlandsch Oost-Indië. The structural complexity of Timor was emphasized. Molengraaff, Brouwer, Marez Oyens and Weckherlinde reported the presence of six major tectonic units in western Timor.

The geological reconnaissance map of the Portuguese part of Timor on the scale of 1:500,000 was prepared by S. St. Clair, J.P.M. Cullock, A.A. Stoyanov and C.R. Bontz in 1920-1921. A geological map of Timor, Geologische overzichskaart van het Eiland Timor, was prepared by L.J.C. van Es, a Dutch geologist, in 1926 and published in the Jaarboek Mijnwezen Nederlandsch Oost-Indië. L. F. de Beaufort (1920) studied fossil vertebrates from the deep sea deposits and Gerth (1926) described the Permian coral faunas in a report entitled "Die Korallenfauna des Perm von Timor und die Permische Vereisung" (Leidsche Geol. Meded., Vol. 2, Pt. 1, pp. 7-14).

In 1949, the three-volume geological monograph entitled "The Geology of Indonesia" was completed by van Bemmelen. The work included a summary of all of the Dutch work that had been completed at that time. The geology and mineral resources of the eastern part of Timor were described with reference to the work of the Allied Mining Corporation.

Notable studies of the geology and structure of Timor-Leste were made by H.R. Grunau and F. Escher, presented in a series of papers by Grunau (1953, 1956, 1957A, 1957B) including the report entitled "Geologie von Portugiesisch Ostimor".

Audley-Charles (1968) carried out field work in East Timor between 1959 and 1961 for Timor Oil Ltd., an Australian oil and gas company. One of the outputs of this work was a geologic map on the scale of 1:250,000 and a thorough review of the geology, in which for the first time a concise description of the stratigraphy of East Timor was attempted. The work has led Audley-Charles into a life-long dedication to the geological research on and near Timor-Leste and resulted in a large number of papers and reports. The ophiolites of Timor have been studied by Barber and Audley-Charles (1976), Audley-Charles and others, (1979), Berry and Grady, 1981, and Berry and Jenner (1982). The high grade metamorphic rocks of the Mutis Complex in the Boi Massif of West Timor were studied by Earle (1981).

The geologic mapping of the Timor area by the Geological Survey of Indonesia (GSI) began in the early and mid-1970s but most of this work, with the exception of one map (Rosidi and others, 1979) was not published until the mid- and late 1990s. The basic principles of the structure of Timor were worked out by Rosidi and others, (1979) and mapped at a scale of 1:250,000. The first Kupang-Atambua map sheet was published in 1979. Maps published in the 1990s are the Baucau Quadrangle (Partoyo, Hermanto and Bachri, 1995); the Dili Quadrangle (Bachri and Situmorang, 1994), and the rest of West Timor.

A complete review of the geology and tectonic framework of eastern Indonesia and the application of plate tectonic concepts to its development was completed by Warren Hamilton (1979) and published by the United States Geological Survey as Professional Paper 1078, "Tectonics of the Indonesian Region". Hamilton's eight-year study included the development of tectonic, earthquake and sedimentary basin maps of eastern Indonesia including the Banda Arc area.

Dating of the Banda Arc volcanics in Wetar and Atauro was done by Abbott and Chamalaun (1981). A series of studies of the geology of Timor and adjacent parts of the Timor Sea, northern Australian shelf and craton were carried out by F.H. Chamalaun and his students of Flinders University. The first work that was carried out by Falvey (1972) indicated that rifting had occurred in the Wharton Basin west and northwest of the Australian continent. The rifting was dated as the Late Jurassic-Cretaceous based on the sea floor magnetic stripes and age dating. His discovery of paleomagnetic anomalies on the floor of the basin opened up a whole new perspective on the structural history of the Banda Arc and adjacent arcs.

Berry and Grady (1981) proposed that "…all of the rock units now seen in Timor and all the structural events which have affected them, originated while Timor formed part of the continental margin of Australia (Barber and others,1981)". Evidence cited indicated that these rocks had been affected by major deformation of 17 Ma – 6 Ma (Mid to Late Miocene) on greenschist and amphibolite facies rocks of the Aileu Complex of

Timor-Leste and that these rocks resulted from the peak metamorphic event that occurred during the most intense phase of plate collision.

The Timor Trough was interpreted to be a present-day subduction zone according by Hamilton (1972, 1979). Jacobson and others, (1979 and 1981) analyzed seismic reflection data from studies of the Timor-Aru troughs in 1976 and showed that these two troughs are underlain by typical continental crust up to 40 kilometres thick (Hartono and others, 1981). The Timor Trough data were collected from nine seismic refraction profiles made along the axis of the trough by the *R/V Thomas Washington* and the *R/V Atlantis*. These data showed that the Moho lay at a depth from 29 to 40 kilometres beneath the trough (Anonymous, 1980 citing data from Jacobson and others, (1981) and Bowin and others, 1980). Seismic evidence collected by the Australian Bureau of Mineral Resources shows that the overthrust block on the Sahul shelf side of the Trough is imbricated and folded. Extensive gravity slides characterize the slopes of the south side of the Trough. Seismic profiles (Beck and Lehner, 1974) show that Timor is underthrust by the Australian Craton although the Mesozoic and Tertiary formations can be traced beneath the Trough. Hamilton (1974) and Hatherton and Dickinson (1969) provided data on the configuration of the Benioff Zone beneath the Banda Sea based on contours of earthquake hypocenters. In 2002, the United Nations undertook a survey of the geology and the mineral and hydrocarbon resources of Timor-Leste.

B. Regional geologic and tectonic setting of Timor-Leste

Geologically, the Timor Island is a part of the Banda Arc (figure 2.1). The tectonic history of Timor is complex and has been the subject of considerable attention. According to one theory, the Banda arc marks the zone of collision between the northwestern edge of the Australian continent and a former oceanic subduction zone. The outer arc, including the island of Timor, is structurally a fold and thrust belt, consisting of the imbricated outer edge of the Australian continental margin, overlain at high structural levels by remnants of the pre-collisional oceanic fore-arc complex (Charlton, 2002).

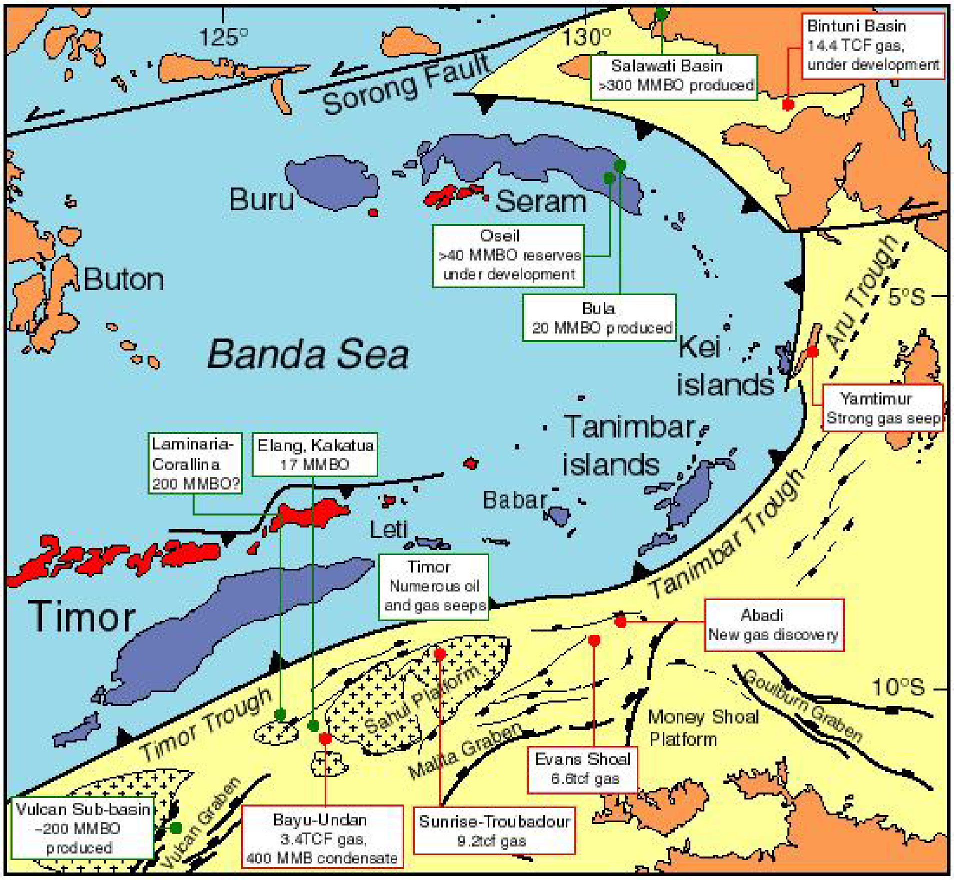


Figure 1: Banda Arc structure and regional hydrocarbon occurrences

Source: Charlton, 2002.

Figure 2.1 Location, structural elements and hydrocarbon resources of the Banda Arc

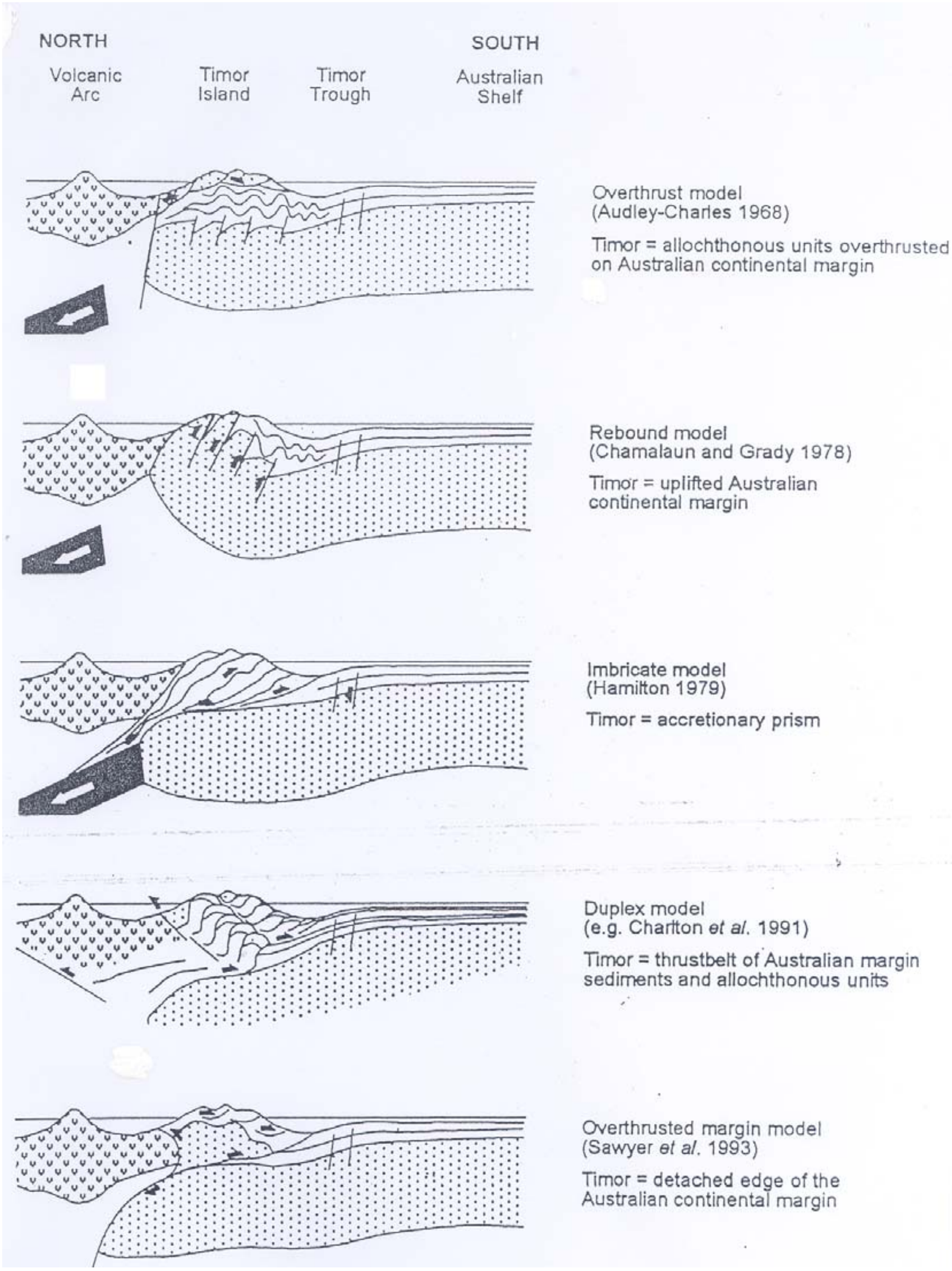
There are, however, several other theories attempting to explain the tectonic and formational history of Timor. Several of these theories are represented in figure 2.2 adapted from Harris and others, 2000.

The oldest of these theories proposed in the 1970s suggests that Timor is the leading edge of the Australian continental plate which had 'stubbed its toe' against Asia in the Middle-Late Miocene (Audley-Charles, 1968). The relationship (distance) between Australia and the island of Timor remained fixed until the collision because they were part of the same plate (Audley-Charles and others, 1972; Carter and others, 1976; Barber and others, 1977). This theory agrees with the ideas of Wanner (1913) who considered that Timor consisted of two types of formations, para- autochthonous Australian strata and allochthonous Asian strata, with the allochthonous strata thrust onto the autochthonous sequence during the collision (figure2.3).

Another concept, involving the subduction of the Australian Craton along a nearly flat subduction zone resulting in the underthrusting of the Australian Plate beneath the Eurasian Plate was proposed by Fitch and Hamilton (1974) and Hamilton (1977). This theory was termed the imbrication model by Chamalaun and Grady (1978). The underthrusting of Australia was to have begun some time before Timor was formed, although ultimately Timor was built as a result of accretion related to subduction (Hamilton 1979 and 1980). The trace of the subduction zone at the surface usually corresponds to the Timor Trough (figure 2.2).

A modification of this theory suggests that Timor is formed as a result of the grounding of a micro-continental sliver with Eurasia. According to this theory, the Australian cratonic rocks were thrust, as a series of slices onto Timor during the gradual descent of the plate (Carter and others, 1976, Bowin and others, 1980; von Rad and Exon, 1983; Audley-Charles, 1983).

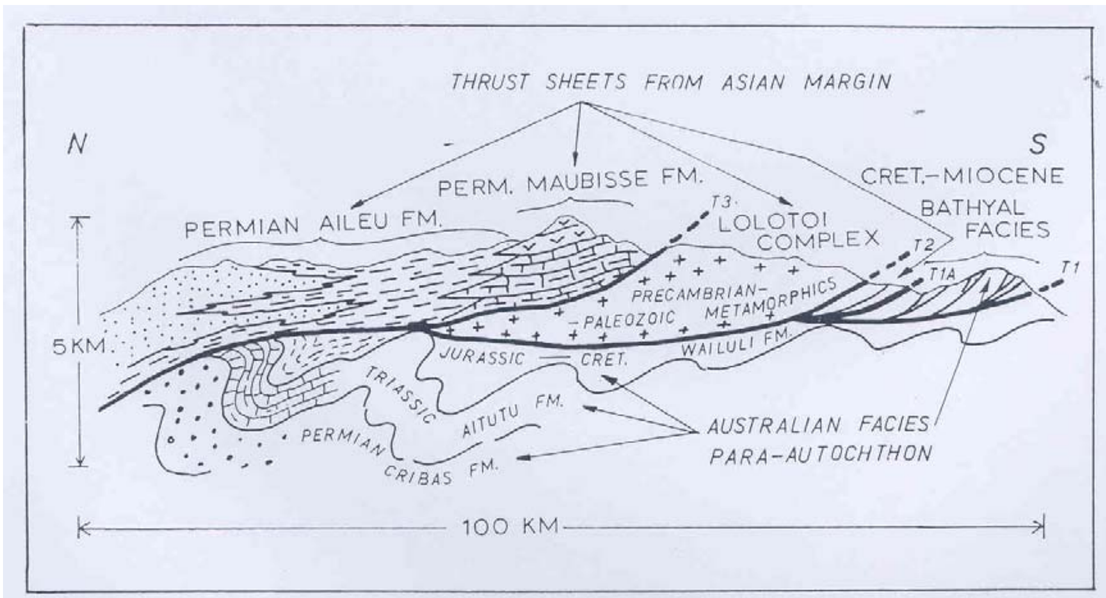
Based on seismic reflection data, Hamilton (1979 and 1980) suggested that a thick accretion prism derived from sediments and slices of old Australian cratonic rocks was built on the surface of the subducting plate, which was at continental slope depths but moving landward at a very gentle angle. This mixture glided under the edge of continental slope of Eurasia and "accreted" material to it or in front of it in the vicinity of the Outer Banda Arc (figure 2.4). For Hamilton's theory to be correct, the bulk of the Timor sequence should consist of mélange built up from the floor of the continental slope to a thickness of over 4,000 metres and overlain by slices of Australian cratonic rocks generated by redistribution of the mélange mass by gravity sliding. The result would be imbrication of the upper part of the pile of Australian crustal material in Timor (Carter and others, 1976; Hamilton, 1979 and 1980; Bowin and others, 1980; von Rad and Exon, 1983; Audley-Charles, 1983; Harris and others, 2000). Indeed, the mélange in Timor is found in about 60 per cent of the island throughout the 6,000 metres thick sequence of imbricated rock of the Miocene and older age.



Source: Harris and others, 2000.

Figure 2.2. Different structural interpretations of the origin of Timor Island.

Development of the accretion wedge proposed by Hamilton would have continued during the Late Miocene and Early Pliocene (Hamilton, 1979 and 1980). As the accretionary prism on the slope thickened, the mass eventually was built above the sea level. The forerunner of Timor and other nearby islands of the Outer Banda Arc began to emerge from the sea as a non-volcanic island arc. The axis of this topographic high became the Outer Banda Arc and consisted of exposed accretionary sediments, which were almost entirely derived from the cratonic sequence of the Australian plate. The accretionary prism continued to be uplifted throughout the Pliocene and Pleistocene time reaching heights of over 3,000 metres above the sea level.

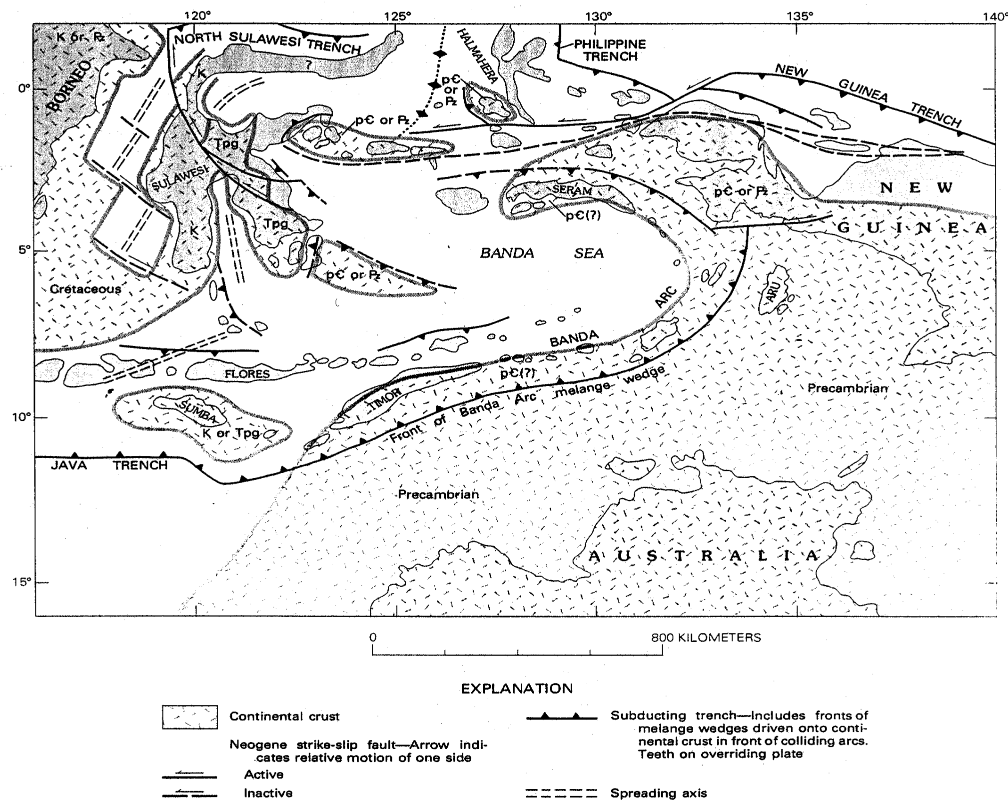


Source: Audley-Charles, 1978.

Figure 2.3. Schematic section through Timor to illustrate the stratigraphy of the allochthonous Asian elements thrust over the para-autochthonous Australian facies (Australian plate) as conceived by early workers.

The down-going slab stripped off pieces of the ophiolite Banda terrane as it descended. These blocks were thrust as sheets of ophiolite and other mafics and ultramafics onto the submerged margin of Timor, which was later exposed during the Late Pliocene - Pleistocene uplift.

The discussion on the origin of Timor and the other islands of the outer Banda arc is by no means over and continues to this day. The references provided will guide the reader through the details of the different interpretations, opinions and positions. The main element in the different theories and on which they are all in agreement and that has a direct bearing on the descriptive geology of Timor-Leste is that the island is built up with contributions from the Australian continental plate, the mélange and the ophiolitic Banda terrane.



Source: Hamilton, 1978.

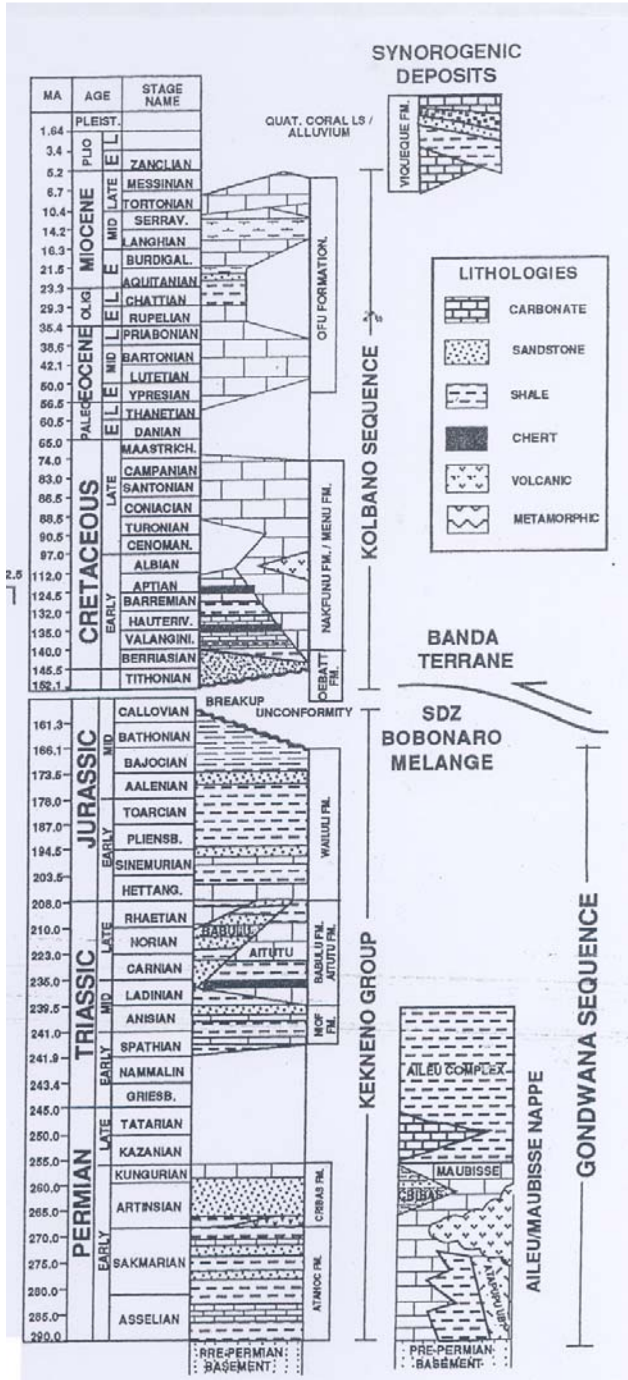
Figure 2.4. Distribution of the two major crustal rock types in the Timor area.

C. Stratigraphy of Timor-Leste

The stratigraphic column presented in figure 2.5 shows a detailed sub-divided sequence for the western part of Timor Island. All the units in the column are also present in Timor-Leste, but a similarly detailed stratigraphic column with the locally prevalent unit names has not been published. The second stratigraphic column for Timor-Leste is shown in figure 2.6. The same units as in figure 2.5 are presented but with less detail and fewer sub-divisions. The following sections describe the individual rock units in some detail.

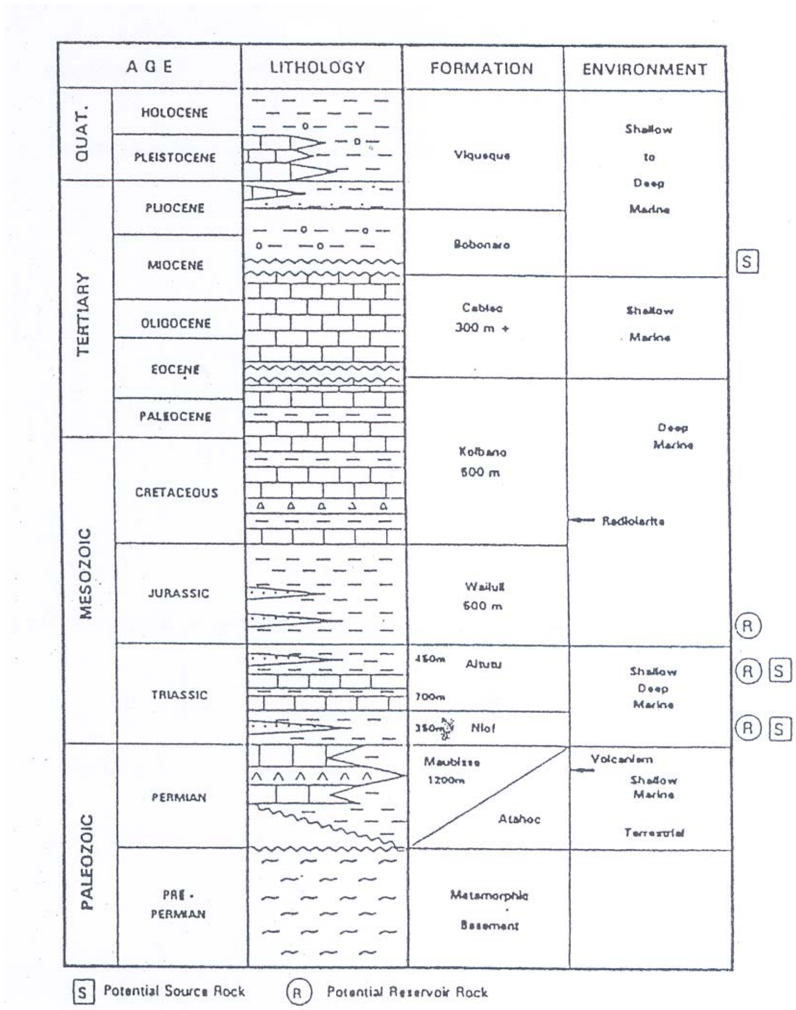
1. Precambrian amphibolites and greenschist facies, unnamed part of the Aileu Complex

The oldest exposed rocks of the Banda Arc are meta-anorthosites of granulitic facies (Barber and Audley-Charles, 1976). These anorthosites are associated with



Source: Harris and others, 2000.

Figure 2.5. Stratigraphy of West Timor showing the Indonesian nomenclature. The same rocks occur in Timor-Leste but some have different formation and terrane names.



Source: Reed, de Smet, Harahap and Sjapawi, 1996.

Figure 2.6. Stratigraphy of Timor-Leste showing reservoir and source rocks for hydrocarbons.

metamorphic rocks of the amphibolite and greenschist facies in Timor and other islands of the Outer Arc.

2. Cambrian-Carboniferous

The concept of Timor riding on the edge of the Australian continent suggests that a Paleozoic section similar to that reported in the thick Devonian-Carboniferous sediments found in the Bonaparte Gulf Basin should be present on Timor Island.

3. Permian

(a) Atahoc Formation

The oldest rock unit found in Timor-Leste is a 600 metres thick shale of the Permian age, the Atahoc Formation, considered to be autochtonous. The unit is exposed in only a few places in Timor-Leste such as in the Loi Quero anticline in Los Palos district. The dominant lithology is black pyritic shale, hard and unfossiliferous at the base deposited as flysch or deep quiet water turbidity current sediments without graded bedding. Sedimentary structures include current ripple-laminations. Sediments of this type may occur on steep slopes in a range of environments from coastal to deep water. The formation is overlain conformably by the Cribas Formation. The sparse fauna indicates the Lower Permian age.

(b) Cribas Formation

The Cribas formation is a silty shale with calcareous and clay-ironstone nodules. The base consists of pyritic black and blue-grey shale, micaceous siltstone and greenish fine quartz-sandstone with red and green shale occurring in the middle. Limestone occurs commonly at the top of the unit. Lava and tuff are rare. The Cribas Limestone has a thickness of about 500 metres. Its contact with the overlying Aitutu Formation is not clear and may be tectonic in some places and unconformable in others. *Halobia* occurs in beds overlying the Cribas Formation. The Cribas Formation contains crinoids, brachiopods, gastropods and bryozoa. The environment of deposition was shallow marine but the muds were deposited not far from the shore as indicated by the presence of lignite and plant remains.

Large scale sedimentary flow structures are common indicating slumping in shallow water on the steep submarine slope near shore. The unit may be a pro-delta deposit. The source for the fresh-looking arenite could be to the south in the area now occupied by the Sahul shelf.

4. Triassic

(a) Aitutu Formation

In Timor-Leste, this unit is regarded as a deep water flysch autochthonous unit. Its age equivalent in western Timor is limestone, reefoid and allochthonous, but in Timor-Leste, it includes a calcilutite, shale and sandstone sequence and contains a basal radiolarian limestone with *Halobia* and *Monotis,* which indicates an Upper Triassic age.

Stratigraphic columns of the Aitutu are extremely generalized. The lower Tallibelis Member is the most conspicuous and rests unconformably on the underlying Aitutu Formation. It is commonly represented by 50 metres of dense, very fine-grained radiolarian calcilutite with well-developed burrowing structures. The lowermost subunit forms a rugged, lightly vegetated escarpment. The top of the Aitutu Formation is conformable with the Wai Luli Formation.

The environment is marine as indicated by the micro- and macrofauna. The calcilutite and interbedded shale units suggest the absence of strong currents. About 80 per cent of the 1,000 metres thickness of the unit consists of calcilutite that was probably inorganically precipitated from seawater by plankton as calcium carbonate. Large parts of the Triassic-Jurassic terrane mapped by earlier workers are a Miocene gravity-slide deposit, the Bobonaro Scaly Clay, containing huge exotic blocks of the Mesozoic and other rocks.

5. Jurassic

(a) Wai Luli Formation

The Wai Luli unit is predominantly clay, marine shale, marl and fine-grained limestone with a sparse fauna and ranging from 600 to 1,000 metres in thickness. Most of the formation is shale. Basal sections are blue-grey marl and calcilutite bearing worm burrows and ammonites. The middle part of the formation consists of micaceous shale and calcilutite. The upper part is dominated by marl, shale and quartz arenite. The uppermost section is a coarse conglomerate containing boulders of the Aitutu Formation.

The Wai Luli rests conformably on the underlying Aitutu Formation and is overlain un-conformably by rocks of the Cretaceous or younger age (Audley-Charles, 1968). Its environment is shallow marine as indicated by the presence of algal pisolites, oölites and skeletal sand. Locally, the environment of deposition may have been highly saline.

6. Upper Cretaceous

(a) Wai Bua Formation

The Wai Bua unit is made up of radiolarian marl and phosphatic shale with inter-bedded colored chert of the Lower Cretaceous age. The shales contain manganese nodules and pyrolusite-rich mud suggesting a bathyal environment. The fauna indicates open sea conditions. Structure has obscured its true thickness and no more than 20 metres can be seen in any one locality but its true thickness may be about 500 metres.

(b) Borolalo Limestone

The Boralo Limestone consists of massive to thick-bedded pink calcilutite with abundant brown stylolites and large foraminifera. The thickness of the unit ranges up to 200 metres in the type section. Red and black chert nodules and veins cut the bedding. The unit rests unconformably on the Middle Jurassic shale of the Wai Luli Formation. The contact with the overlying Lower Miocene Aliambata Limestone or the Bobonaro Scaly Clay of the Middle Miocene age is also an unconformity. The environment of deposition is pelagic.

(c) Seical Formation

The lithology of the Seical Formation consists of radiolarite, shale, chert and marl. Highly disturbed pale cream and black thin-bedded cherts are rich in radiolaria. Arenites are finely cross-laminated. The age of the unit is upper Lower Cretaceous. The environment deposition is bathyal as indicated by ferro-manganiferous foraminiferal limestones and graded arenites suggesting that turbidity currents were active.

7. Eocene

(a) Dartollu Limestone

The Dartollu rests un-conformably on the Aitutu and Wai Luli formations without any intervening tectonic slices. The lithology consists of thick bedded, brown biocalcarenite containing calcareous algae, foraminifera and, locally, echinoderm fragments. The environment of the unit is considered to be a reef.

8. Oligocene

(a) Barique Formation

The Barique Formation crops out nine kilometres east of Aliambata, in the Cai Dilla Laly River where it consists of a basal tuffaceous boulder-conglomerate overlain by tuffs and lava. The basic tuff consists of fragments of basalt and serpentinite. Feldspathic dacitic tuff is composed of feldspar laths with quartz, pumice and glass. Minor interbedded foraminiferal quartz-sandstone also occurs. The sandstone is well developed south of Mt. Cablac. The basalt is chloritic and has undergone carbonate alteration. Pillow structures can be seen locally.

Serpentinite occurs in the type-locality and also near Mts. Bibiliu and Cablac. The ultramafics are massive, tough and dark to greenish-black. Pyroclastics are dominant in other areas. Around Lacluta village, the Barique Formation rests unconformably on the Lolotoi Complex, which was thrust to its present position in the Lower Eocene. Elsewhere, the unit rests unconformably on the Dartollu Limestone, the Aitutu or the Wai Luli Formation.

The unit is overlain unconformably by the Cablac Limestone of the Lower Miocene age or the Barique Formation. Stratigraphic relations indicate that the Barique Formation must be the Upper Eocene to Lower Miocene. The basal conglomerate contains boulders of the Dartollu Limestone with formaminifera of the Upper Eocene age suggesting that the Barique Formation may be of the Oligocene age.

9. Lower Miocene

(a) Cablac Limestone

The Cablac Limestone forms the ENE-WSW trending mountainous spine of Timor-Leste. It consists of grey, hard, massive limestone of several types: calcilutite, oölitic limestone, calcarenite and an intra-formational conglomerate ranging up from 400 to 600 metres in thickness. Dolomitization and silicification are common. The unit makes a precipitous escarpment. The limestone rests unconformably on the Oligocene Barique or Lolotoi formations. An overlying unit is rarely present because the Cablac Limestone usually occupies the top of a mountain but in a few places it is overlain by the Bobonaro Scaly Clay. A very shallow marine environment of deposition is indicated by calcareous algae and coral fragments.

(b) Aliambata Limestone

The Aliambata Limestone consists of yellow limestone with numerous large foraminifera. Its thickness is 50 metres and it rests unconformably on the Upper Cretaceous Borolalo Limestone. The environment of deposition is interpreted as a deep open marine basin.

10. Upper Miocene

(a) Viqueque Formation

The marine Viqueque Formation is a 130 metres thick Upper Miocene to Pliocene unit of massive white marl and grey claystone interbedded with chalky limestone and rare vitric tuff. The Viqueque Formation is a typical molasse formation deposited following the Miocene orogenic episode. The base of the unit is an unconformity. Generally, the unit rests on the Middle Miocene Bobonaro Scaly Clay but locally it may rest with angular unconformity on other units. It is overlain conformably by the Seketo Block Clay and the Dilor Conglomerate. These two units in turn, together with the Viqueque Formation, are overlain unconformably by the Baucau Limestone and the Suain Formation of the Pleistocene to Holocene age.

The orogeny that preceded the deposition of the Viqueque Formation resulted in the placement of large thrust sheets of the Permian rocks and the plastering of a huge gravity-slide deposit, the Bobonaro Scaly Clay, over most of the island of Timor. When Viqueque deposition began, Timor had been submerged and covered with the Bobonaro Scaly Clay. As the island began to emerge, the clay provided a source for the mud of the lower Viqueque Formation. The coarsening of the grain size of the Viqueque Formation upwards indicates the beginning of the regressive cycle and the shallowing of the marine basin followed by the gradual emergence of the island.

11. Miocene

(a) Lari Guti Limestone

The Lari Guti Limestone is a sequence of yellow calcarenites and thin coral reef rocks ranging up to 75 metres. The unit is dated as the Middle Miocene based on abundant foraminera. The depositional environment represents a shore facies of beach material or a coral reef similar to the north coast of modern Timor-Leste.

(b) Dilor Conglomerate

The Dilor unit consists of poorly sorted sandy conglomerate with a dark red lateritic crust. The lower contact is unconformable with the underlying Viqueque Formation, but where this unit is absent, the Dilor conglomerate rests unconformably on the Bobonaro Formation. The poor sorting and boulder-beds associated with strongly cross-bedded sand suggest a marine deltaic environment.

(c) Seketo Block Clay

The lithology of this unit consists of white and pale gray clayey marl or pebbly mudstone containing unsorted, angular blocks of older rocks. It lacks the "scaly" or fissil appearance of the Bobonaro Scaly Clay. The Seketo generally overlies the Viqueque Formation, but locally, it may overlie the Dilor Conglomerate.

12. Post-Pliocene

The Viqueque Formation was folded in the Late Pliocene time and Timor began to emerge as an island. Four post-Pliocene units were deposited (i) the marine Baucau Limestone; (ii) a lacustrine unit, the Poros Limestone, (iii) a near shore marine unit, the Suai Formation and (iv) the Ainaro Gravels, an alluvial terrace gravel. By the end of the period of emergence, Timor was covered with alluvial systems and local basins had developed.

(a) Baucau Limestone

The flat lying Baucau Limestone consists of grey, hard, cavernous, massive white coral-reef limestone well developed around Baucau town. The unit controls the topography in the Baucau and Lautem plateaus. A continuous outcrop occurs along the north coast. In the southern foothills, the Baucau Limestone also crops out in scattered hills. The limestone occurs as coral-reef, calcarenite and a greywacke-pebbly sandstone facies. The Baucau Limestone rests unconformably on older units everywhere. It overlies the Viqueque Formation, but locally, it is found on older formations. Along the north coast of Baucau Distric,t there are a series of raised beaches (photo 2.1). The various terrace levels reflect the stages of Timor's uplift history.

Photo 2.1. Outcrop of Baucau Limestone two km east of Cum,Lautem District.

(b) Poros Limestone

The Poros unit is a pale-brown to cream-colored limestone that weathers grey. Limestone is hard, thin bedded and rich in gastropods and algae of lacustrine origin.

(c) Suai Formation

The Suai Formation is poorly exposed and not well known. In the Matai No. 5 test hole, north of Suai village, the sediments are rudite and arenite ranging to gravels. Foraminifera are common in this 600 metres thick unit but they represent a death assemblage and were derived from elsewhere.

(d) Ainaro Gravels

The Ainaro Gravels occur in a river terrace about 800 metres above the mean sea level at Ainaro village. Similar terraces are found on other rivers such as the Laclubar, Cribas, Samé, Aileu and Railaco. The most famous Ainaro terrace occurs east of the Lois River where it forms the eastern edge of the great Central Basin.

13. Stratigraphy of the Miocene Thrust Complex

(a) Lolotoi Complex (Banda Terrane)

The Lolotoi Complex has been given various names over time, such as the North Coast Schists, Manufai Diabase, Crystalline Schists and Ophiolites and Banda Terrane.

Photo 2.2. Outcrop of the Lolotoi schist showing thin bands of argillic sediment in east Dili town on om beach road.

Photo 2.3. Drag folds in the Aileu Formation, east Dili.

The Lolotoi Complex (Banda Terrane) has been emplaced by thrusting that post-dates folds of the Timor Orogeny. One major thrust sheet occurs in Viqueque district between Aliambata and Baucau. The Viqueque thrust sheet of the Lolotoi Complex covers the middle part of the Betano Anticline. The unit consists of sedimentary and eruptive rocks that have a low grade of regional metamorphism. The unit is mainly phyllite but schists, meta-gabbro, dolerite and gneiss are also present. The Lolotoi Complex (Banda Terrane) is a displaced or allochthonous unit and commonly rests on breccia (photo 2.4). The complex overlies autochthonous pre-Eocene rocks in the Mac Fahic Antcline and the Pualaca Syncline in the western part of Timor-Leste.

Photo 2.4. Tectonic breccia below the Lolotoi thrust sheet west of Manatuto. Note blocks of grey schist.

14. Stratigraphy of the Upper Miocene-Pliocene Thrust Complex

(a) Aileu Formation (Aileu Complex)

The Aileu Formation is composed mostly of weakly metamorphosed pelites and psammites with local occurrences of carbonate and igneous bodies of the Permian to Jurassic (?) age (Barber and Audley-Charles, 1976; Barber and others, 1977; Berry and Grady, 1981; Berry and McDougall, 1986; Harris, 1991; Prasetyadi and Harris, 1996). The unit commonly is slightly metamorphosed to sub-greenschist facies except along the north coast (photo 2.5). There, the grade increases sharply to amphibolite facies (Prasetyadi and Harris, 1996). The distribution of the Aileu Formation is restricted to a

Photo 2.5. Coast road exposures showing a range of lithology in the Aileu Formation in Manatuto District about 13-15 km west of Manatuto. The red weathering unit is Aileu schist and the white unit is a volcanic sequence of pyroclastics.

80 kilometres by 30 kilometres belt on the north coast both east and west of Dili. The Aileu lithology there includes low grade metamorphosed eruptive rocks and altered schist.

(b) Maubisse Formation

This limestone unit is widespread in Timor-Leste (photo 2.6). The limestones are well bedded and consist of dense beds and massive reef. They are colored red, pink, white and grey. The fauna is rich, especially in the reef facies. Conglomerates contain clasts of eruptive rocks and tuff. A sequence of 500 metres of basalt is found on Mt. Ramelau. The environment of deposition was shallow marine in warm clear water.

Photo 2.6. The Maubisse Limestone thrust sheet crops out along the top of the mountain on the skyline. The locality is about 7 km north of Maubisse town.