Mineral - Hydrocarbon Database and Bibliography of the Geology of East Timor

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July 2002
Figure 1. The Lavai village chief (Lautem District) shows samples of pure manganese ore (pyrolusite) collected a few kilometers south of the village from a large outcrop on the banks of the river. The occurrence is reported to be several hundred metres long and tens of metres thick and was investigated by a Japanese team in the 1970s. Manganese is an essential ingredient of batteries.
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Figure 2. Looking east from Venilale in Baucau District toward a rugged outcrop of Cablac Limestone (Lower Miocene) in G. Urobai (elevation 3038 ft) in foreground and G. Laualiu (elevation 2726 ft). On the skyline the outline of a high peak (G. Matebeanfeto – 7782 ft) can be seen in the clouds.

Figure 3. The children of Ossarua village (Viqueque district) play in a rice field next to the potentially biggest copper and gold occurrence in East Timor (low ridge in background).
Figure 4. Evidence of the hydrocarbon potential of East Timor can be found in Covalima district where a well drilled near Suai on the coast in the 1970s by Timor Oil Ltd. still flows oil when the valve is opened.

Figure 5. A marl deposit in the Baucau Limestone 10 km west of the Baucau airport provides a substantial income to small-scale miners in Baucau District. The marl sells for about US$20/ton and is used to make lime for cement.
Part I.

Overview
A. Geology, Mineral and Hydrocarbon Resources of East Timor: An Overview

1. Geography

The newly independent country of East Timor has an area of approximately 16,000 sq km. It is divided into thirteen administrative districts that are located in the eastern half of Timor Island with the exception of Oecussi district, an enclave in west Timor located on the north coast (Figure 7). East Timor has a maximum length of 275 km and a maximum width of 100 km. The country includes two islands, Atauro and Jaco.

Timor Island is the largest island of the non-volcanic Outer Banda Arc. Timor has attracted the interest of geologists for more than 100 years. Geologically, the island is the largest visible part of a microcontinental fragment, so termed because of its continental crustal makeup in contrast to the adjacent volcanic islands of the Inner Banda Arc. Its geological history is complex and includes a collision with the Eurasian tectonic plate on the north and the Australian plate on the south.

2. Regional geology

The geological setting of East Timor is termed an accreted terrane because parts of the rock sequence were derived from the collision of the Timor microplate with two very large continents, Eurasia and Australia. Accretion may be defined as the structural joining of two or more allochthonous (dislocated) bodies (Figures 8 and 10). Accretion includes the process of scraping sediment off a subducting (sinking) crustal slab and incorporating it into an accretionary prism (American Geological Institute, 1966).

Figure 6. A very early interpretation of the development of the accretionary sedimentary rocks in Timor showing a subducting (sinking) crustal slab and the overlying sedimentary cover being squeezed into complex folds and thrust sheets.


An indication of continuing tectonic instability is the presence of deep-sea troughs with strong gravity anomalies in adjacent seas both north and south of Timor Island. The post-Permian sedimentary record is mainly limestone with significant amounts of ultramafic and metamorphic rocks. There is probably no pre-Permian record but there is a 10,000 m thick record of younger sediments and plutonic rocks that contains a significant number of economic mineral occurrences.
The rock record shows thick units of basic plutonic rocks, schists and phyllite as well as argillites, cherts, radiolarites and other fine-grained deep-sea sediments (Figure 5). The ophiolite suites are especially important as they are the hosts for such economic minerals as copper, gold, silver and chromite. Ophiolites are generated in plate subduction zones and consist of mafic and ultramafic rock assemblages that are associated with either a transtcurrent or thrust faults. At least two major thrust fault sequences are known in East Timor. These are tectonically emplaced having been derived from distant locations and, consequently, are allochthonous tectonic units.

Figure 8. A modern geologic cross-section of Timor (modified from Harris et al., 1998) showing underthrust and tectonically stacked blocks of the Australian continental margin overlain by a sequence of nearly horizontal thrust sheets (Aileu-Maubisse), the Bobonaro mélangé and the Banda terrane. The volcanic rocks in Oecussi District (left margin of cross-section) have good potential for copper. Source: Harris and Long, 2000.
The petrology and tectonic setting of these sequences is still not well understood although they play a key role in the location of metallic mineral occurrences and exploration strategies for oil and gas. The unraveling of the history of the thrust belts will focus the search for economic mineral deposits and increase the number of known occurrences in East Timor.

Timor, once linked to the Australian continent, was separated from it by rifting of Australian continental crust followed by evolution of new oceanic crust in the rift zone followed by lateral tectonic displacement, which began in the Cretaceous - early Tertiary.

The continental fragment broken from the edge of the Australian mainland drifted northward until it collided with the southern edge of the Eurasian plate. This collision produced volcanic activity that resulted in the volcanic rock assemblages found in the Oligocene-Eocene rock record of East Timor and also created the Inner Banda Arc, which is characterized by numerous active volcanoes. Tectonic movement of the Timor microplate slowed in the Quaternary. The Timor Trough south of Timor Island is somewhat of an enigma but may be a subduction zone. Fumaroles, hot springs and mud volcanoes are common in both West and East Timor, especially in the island of Atauro immediately to the north. This indicates that the crust beneath Timor is still hot. One mud volcano located 30 km north of Soe in West Timor erupted steam, smoke and toxic gas in 1982, frightening the local people.
3. Mineral occurrences in East Timor

The orogenic history of Timor plays a critical role in defining the location of its metallic minerals occurrences, notably copper, gold, silver, chromite, manganese and a number of important non-metallic minerals such as limestone, marble, bentonite and phosphate. The northern edge of Timor Island was subducted beneath the complex southern margin of a mixed oceanic and continental Eurasian plate in the Eocene. Consequently, the northern edge of Timor Island is host to a number of important mineral occurrences, e.g. copper, chromite, gold, silver and manganese. One of the potentially richest copper zones is the north edge of Oecussi district, which was explored by a multinational company in the 1980s. The base metals are concentrated in ultramafic rocks, which are parts of an ophiolite suite.

Precious metals such as gold and silver were also deposited in and adjacent to volcanic centers as a result of epithermal activity. Some important copper occurrences are also located in southern Baucau and north central Viqueque districts. Less significant deposits of chromite, manganese and iron sand deposits occur in Manatuto, Baucau and Lautern districts and on Atauro Island of Dili district.

The widespread occurrences of limestone and marl, especially in the eastern and western coastal areas of East Timor, are important and are amongst the few minerals that have been exploited for many years. House foundation materials almost always consist of rock walls made of local rocks cemented with lime made from marl. Important phosphate and bentonite occurrences are located in central Baucau district although these have not yet been exploited. There is a potential for the development of ornamental stones from the numerous good quality marble occurrences in Manatuto district east of Dili. Argillie alteration has resulted in the development of a red to white clay complex in the Aileu Formation. The alteration has changed phyllites and schists to kaolin in a number of places near Aileu town.
The alteration zone occurs over a wide belt beginning a few kilometers east of Dili and extending eastward to include much of Aileu district. This belt contains an almost unlimited amount of clay, including some possibly high-grade kaolin deposits. Moreover, the argillic alteration may be a guide to the occurrence of base and precious metals beneath the cover. River valleys throughout the country include a wide range of sand and gravel deposits some of which have already been used to make concrete blocks. Every major town exploits its own local sand and gravel deposits creating a rather lucrative small-scale mining industry for a large number of entrepreneurs. None of these non-metallic mineral deposits have been evaluated for their technical characteristics.

![Figure 11. Cross-section of sinking oceanic crust in a typical subduction zone of Indonesia. Note development of non-volcanic outer arc (similar to the arc which includes Timor Island) and the volcanic inner arc. Source: Katili, 1989.](image)

Building stones such as granite, andesite, basalt, and gabbro are also present and could provide valuable sources of rock fill, aggregate and road metal. The proximity of outcrops of andesite and basalt to north coastal waters makes them less costly to exploit and ship to points of need. Andesites are especially well suited for use in breakwaters for harbour protection and for stabilizing seabed pipelines. They also make ideal material for railway ballast, road metal and high strength concrete.

4. Marginal basins and hydrocarbons

The complex geological structure that developed as a result of the collision of the Outer Banda Arc (including Timor Island) with Eurasia was further complicated by a collision with the leading edge of the Australian continental plate in the Miocene-Pliocene. The second collision resulted in the accretion of both shelf and deep-sea sediments as well as continental crustal material of the Australian plate. The second event created parts of the geologically complex, faulted and discontinuous mountainous belt, which runs the length of the middle of the island. The faulting and metamorphism that accompanied the second event has also resulted in the further development of metallic mineral deposits.
The development of several large basins occurred after the orogeny. These basins, located along the southern edge of the island are the prime targets for exploitation of hydrocarbons onshore. The basins collected coarse debris from the interior, which was being rapidly eroded due to the uplift resulting from the Pliocene orogeny. These basins were explored by Timor Oil Ltd. in their search for hydrocarbons on land and in the near shore areas adjacent to the south coast from 1957 to 1975. Although 21 wells were drilled, only one or two showed any promise. Still, if one or two of these wells had been brought into the production, the ratio of one successful well for every 10 drilled would be enough to encourage further exploration. Indeed, Timor Oil Ltd. has indicated an interest in continuing their search. However, because of the Island’s structural complexity, the need to apply modern 3-D geophysical exploration methods and petroleum assessment techniques, the
search will be costly. Nevertheless, the proximity of East Timor to Australasian refineries and markets will encourage more exploration in the onshore and nearshore areas (Figure 6).

5. Uplift and earthquake activity

Although the Island went through two prominent orogenic events in the Eocene and Miocene-Pliocene, now it has entered a relatively inactive tectonic period, which has lasted two million years although vertical uplift due to gravity compensation of the Timor crustal welt has been profound, exceeding 1,200 m in Quaternary time. Minor compression has
resulted in some gentle folding in the Quaternary. The present stage is characterized by dormant volcanoes and hot springs in Atauro, the only recently volcanic part of East Timor as well as mud volcanoes and a few fumaroles in West and East Timor. Feeble earthquake activity is noted not far north of the coast of East Timor. There is little if any earthquake activity originating from movement on faults in the crust beneath Timor.

6. Geological information

M.G. Audley-Charles’ famous memoir, *The Geology of Portuguese Timor*, is the primary source of basic geological and structural data for East Timor but significant field work and studies by a large number of faculty and graduate students at the University of London, Flinders University, the University of California at Santa Cruz and in West Timor, the University of Amsterdam. The Dutch work mostly took place between 1900 and 1950 and the investigations of British, Australian, Portuguese and American workers as well as other Europeans mostly after 1950, mainly in the period 1965-1985. An extensive bibliography is included in this report (Parts XII, XIII, and XIV), which indicates a surprisingly large amount of research has been focused on the tectonics and geology of Timor Island. Many of the university groups that carried out research in Timor in the past are still interested in the island and continue to investigate its geologic history.
The original work of Audley-Charles was done during the late 1950s and early 1960s and, hence, was carried out in the early stages of the development of the concept of plate tectonics. The resulting report has some data gaps especially with regard to the geology of the hard rocks and the economic geology of the Island’s metallic and non-metallic mineral resources but it is still a remarkable piece of work. The geologic map made by Audley-Charles and published by the Geological Society of London in 1968 is still a primary source of basic geological information for East Timor. This map was revised and supplemented by field studies carried out by
numerous agencies and individuals over the next thirty years. The work of the Geological Research and Development Centre in Bandung has been significant. See the three bibliographies for an exhaustive list of the literature on the geology, mineral and hydrocarbon resources of the Island.

Audley-Charles was the first European to map East Timor after a pause in interest by the Portuguese. His report was based on 28 months of field work and three years of laboratory studies, mainly petrography and geochemistry all supported by Timor Oil Ltd. In the 1980s and 1990s new field work was carried out in both east and west Timor by Indonesian geologists but remote mountainous areas were not able to be inspected in east Timor as a result of an active local insurgency. Geology was compiled from air photos and reconnaissance surveys along the major roads.

The mapping scale used by Audley Charles (1968) was 1:40,000 for two-thirds of the island and the remainder at 1:100,000 but his map of East Timor was published at a scale of 1:250,000.

The Geological Research and Development Centre (GRDC) in Bandung remapped most of west and east Timor in the period 1975-1995 and has published a set of four quadrangle maps at a scale of 1:250,000. All the maps, save one, were published in the 1990s. The Geological Research and Development Centre (GRDC) of Indonesia has revised part of the column and introduced new names. The work in West Timor primarily was done by H.M. Rosidi, S. Tjokrosapoetro and S. Gafoer (Kupang-Atambua quadrangles) among others. In east Timor the geological mapping done by the GRDC was carried out by S. Bachri and R. L. Situmorang (Dili quadrangle) and E. Partoyo, B. Hermanto and S. Bachri (Bacau quadrangle) among others.

7. Mineral database

The mineral database presented herein mostly is based on unpublished Indonesian data (see Mineral Database Bibliography – Part XIII). The geological map data published by the Government of Indonesia are based on field work, air photo interpretation and regional map compilations made by the Geological Research and Development Centre. The original East Timor mineral database was compiled in about 1995-99 and published in 1999 (Lacerda, 1999). Mineral occurrences cited in the Indonesian database lack reference to latitude and longitude and are shown as point locations on a small-scale map of each district. Moreover, the geologic setting of the occurrences is not indicated. In a few instances there are references to chemical analyses (percent copper and gm/ton of gold and silver) and the size of some non-metallic deposits (e.g. cu m of gravel and sand) was reported. However, the exact location of many deposits is probably inaccurate because of the mountainous terrain and the lack of GPS technology at the time of the initial investigations. For example, the sites of the sand and gravel deposits that were examined by Indonesian engineers and geologists is difficult to determine because most of the river valleys are filled with a long train of alluvial material. Moreover, test drilling and laboratory work is required to properly evaluate virtually every occurrence.
Figure 16. A simplified tectonostratigraphic terrane map of Timor showing the four main terranes.

Source: Harris and Long, 2000

8. Mineral potential

The database and maps compiled by the author include some new data collected from published Indonesian sources that did not appear in the 1999 database, mainly on copper, gold and silver and a little data collected in the field in May 2002. Latitude and longitude is indicated but the geologic host of many occurrences has yet to be determined and requires more field work. The database indicates that East Timor has an unusually large number of copper, gold and silver occurrences in a small area (approximately 16,000 sq km). These mineral deposits occur in several settings, which have not been studied in detail in East Timor. Some occurrences found in plutons and volcanic rocks result from concentration of metals (with the movement of magmatic liquids and gases) during the fractionation of the magma. Concentrations
of copper associated with gold and silver in East Timor commonly are related to ultramafic rocks, which were tectonically emplaced and associated with ophiolite suites. Gold deposits are widespread as alluvial or placer deposits which are derived from extensive areas of metamorphic rock (phyllite, schist and quartz veins) spread along the entire north coast and a few volcanic rock localities scattered amongst the central highlands. Originally these metals were deposited in the country rock, which has been altered by increases in heat and pressure during orogenic events accompanied by migration of metal-rich hydrothermal fluids. Although occurrences are numerous the potential is unknown with the possible exception of copper. See the companion paper in this volume by P.J. Bakker.

Figure 17. Outcrop of bentonite in the Bobonaro Scaly Clay. The occurrence is located one km north of Venilale west of the Venilale-Baucau road (Baucau District).

Orogenies were accompanied by the movement of hot acidic brines (magmatic, metamorphic or heated surface waters). The brines have leached metals from the country rock and deposited them in the crust in pods (e.g. chromite in Manatuto district) and veins and along the walls of fractures that have provided flow routes (e.g. gold in Manufahi district). Subsequently, the metamorphic country rock has released the gold and silver either as discrete grains and nuggets or in solution as it was weathered from the country rock. Erosion occurs at a high rate in Timor especially since the profoundly rapid uplift of the Pliocene-Quaternary. Streams have distributed and locally concentrated the gold in river gravels over wide belts of the north and south coasts as well as parts of the interior in the watersheds that drain metamorphic and volcanic terrains. Lead and zinc deposits are rare but are thought to have been deposited by fluids being expelled in front of an advancing tectonic orogen in the Miocene-Pliocene.

East Timor has had two major orogenies, Eocene and Pliocene in age, both resulting in the development of convergent zones. During stable periods both deep-water deposits and shallow water carbonates were deposited over the more complex thrust and fold belts. These younger deposits yield a large number of occurrences that may be suitable for industrial and chemical uses including limestone yielding lime for
cement, clay for bricks, ceramics and tile, sand and gravel for concrete, bentonite for drilling mud, phosphate for fertilizer and manganese for batteries (Figures 17 and 18).

Figure 18. Gypsum crystals scattered over the surface of the Bobonaro Scaly Clay in Baucau District near the town of Laleia.

8. Hydrocarbon potential

Hydrocarbon data mostly are available from unpublished reports of Timor Oil Ltd., but the dearth of such reports in Dili resulted in an inconclusive evaluation of East Timor’s hydrocarbon potential. Only one important report by Timor Oil Ltd. was available to the United Nations consultants in mid-2002 (see Part XIV for a bibliography of unpublished and published reports on hydrocarbons in Timor and adjacent areas). Timor Oil Ltd. had drilled 21 exploration test holes in the marginal basins of the south coast of East Timor in the period 1957-1975. The primary target was the Viqueque sandstone, a sand filled linear marginal basin (Viqueque basin) lying partly onshore and partly offshore of the south coast. The western part of this basin was intensively explored near the town of Suai by Timor Oil Ltd.. The majority of the western test holes were drilled in Covalima district and the eastern wells in the Aliambata area of Viqueque district. Wells in both areas had oil and gas shows and three wells recovered oil albeit Timor Oil Ltd. considered the wells uneconomic.

Some early shallow wells actually produced “gushers” of water and oil, which was released so strongly that tools were blown out of the hole or lost during drilling operations. In general, one can conclude that there is some hydrocarbon potential in East Timor because (i) sedimentary basins with oil windows in the proper maturation range, (ii) the basins contain permeable sand fill, (iii) the basins probably include source beds rich in organic material further seaward from the present coast, (iv) structural traps are known to exist in the form of anticlines and fault traps with appropriate structural closure, (v) the occurrence of numerous oil and gas seeps in several places along both the north and south coasts indicating that migration of hydrocarbons is continuing at present, (vi) the proximity of the Banda Arc basins to the Bonaparte Gulf basin known to have enormous gas potential, and (vii) the
promising shows and flows encountered during the drilling of a few exploration test holes in the period 1957-1975.

In tectonically old fold-and-thrust belts most oil accumulations occur in cool regions or foreland areas far from the heart of the orogeny. Younger gas tends to occur in the hotter regions closer to the main orogenic activity. The Viqueque basin in Viqueque district is an example of the latter. The Bonaparte Gulf basin, on the other hand, occurs some distance from the orogenic belts of the Outer Banda Arc.

Hot springs and mud volcanoes are found on the south coast close to active oil and gas seeps in the Viqueque basin. The sedimentary fill of the Viqueque basin is largely unexplored but sand permeabilities are believed to be high and faulting has created numerous pathways for hydrocarbon migration. The presence of numerous oil and gas fields in the offshore Bonaparte Gulf basin of Australia-East Timor-Indonesia has created renewed interest in the hydrocarbon potential of onshore areas of East Timor (Figure 18).

Figure 18. Oil seep at Matai (Covalima District). This seep was developed by the Japanese Army in World War II by sinking timber lined shafts to a depth of about 3 m. About 100 (?) barrels of crude oil was recovered per day.

Oil gravity is of two types, a high quality paraffin base type ranging from 30° to 40° A.P.I. gravity and a second type of poor quality consisting of an asphaltic base in the 20° to 30° A.P.I. gravity range. Source beds are thought be the quiet water organic rich muds of deep offshore areas in the Viqueque sequence. Areas with the most promising tectonic and sedimentologic characteristics include southern Viqueque, southern Manatuto, and southern Manufahi districts. Most of the hydrocarbons in this sequence occur at a depth of less than 4-5 km.

Because of its complex tectonic setting the hydrocarbon potential of basins in the interior of East Timor is much less attractive. Suites of non-productive metamorphic and ultramafic rocks in folded thrust sheets overlie otherwise attractive sands and limestones of the Mesozoic sequence. Although folds are broad and
upright in parts of the interior, the structure beneath the cover is complex and includes several décollements. The folds tend to be located in fairly rugged areas with difficult access or in belts that may have suffered temperatures that were too high resulting in the vaporization of oil and gas.

Figure 19. Wai Luli Mountain in Bobonaro District showing one of the large tight folds of the sedimentary cover in East Timor. Access is difficult and exploration in this area would be costly.

Some parts of the interior are tectonically less complex consisting of low rolling plateaus and possibly may offer a more favourable geological environment for the accumulation of hydrocarbons. These areas include the easternmost district (Lautem), north-central Baucau district and Bobonaro district southwest of Maliana town.

9. Summary

In summary, the tectonic history of East Timor resulted in a complexly folded and thrust convergent sequence that created a linear pile of thrust sheets and fault bounded tectonic mélanges, locally consisting of low-high grade metamorphics, ultramafics and both deep and shallow water sediments (Figures 20 and 22). By the beginning of the Quaternary lateral movement had almost ceased indicating compression of the island’s orogenically deformed sequence had almost stopped as convergent forces were dissipated, probably in the vicinity of the Timor Trough. However, strong vertical uplift continued, which has set the scene for active erosion and created a central area of high relief.

Sediment derived from the central highlands was deposited mostly in linear marginal basins formed at the south edge of the Island although a few small basins also were filled in the interior. The trend of these basins is parallel to the broad welt of the main orogen or east-west. The marginal basins filled mainly with alluvial sand deposits which grade laterally into continental shelf sands. In marginal basins coarse sands grade into deep water where organically rich muds form source beds for
hydrocarbons migrating updip. This may explain the occurrence of numerous oil and gas seeps along the south coast. Such post-orogenic basins tend to include a gas province near the coast or in shallow nearshore waters. Gas seeps also occur on the north coast (Figure 21).

Figure 20. Excellent view of high angle thrust fault in Bobonaro District with the overthrust block on the right. Note rocks dipping in the opposite direction in lower left.

Figure 21. Burning gas seep southeast of Manatuto. A number of gas seeps are reported throughout the country. The geology of this area has not been mapped in detail but the gas is probably coming from the Bobonaro Scaly Clay. Source: Photo courtesy of Apiporn Israngkul Na Ayudhya
Oil and gas shows and, less commonly, oil flows were reported from a number of horizons of both Mesozoic and Tertiary age in several of the wells drilled by Timor Oil Ltd. in the 1970s. The large number of oil and gas seeps throughout the country indicates migration is still taking place and source beds are present in the sedimentary sequence (Figure 21). More deep tests and additional geophysical work are required to define the petroleum systems.

Figure 22. A mountain in the town of Laleia (Baucau District) consists of a one km long exotic block of limestone sitting like a plum in a pudding of Bobonaro Scaly Clay. The Lalelia block is one of the largest blocks in the Bobonaro mélange. Note the mottled pink and gray clay outcrop of the Bobonaro Scaly Clay in the left foreground.
Part II.

Introduction
A. An introduction to the 2002 UNDP/ESCAP Mineral-Hydrocarbon Mission to East Timor

1. Introduction

In April 2002 the United Nations Development Programme (UNDP) office located in Dili, East Timor and the Economic and Social Commission for Asia and the Pacific (ESCAP) headquartered in Bangkok agreed to send a jointly sponsored mission to East Timor to assist the government in reviewing existing data on mineral and hydrocarbon deposits and occurrences onshore and to evaluate the hydrocarbon and mineral resource potential of the country. The United Nations administered East Timor for almost three years prior to its independence on 20 May 2002. The 2002 United Nations mission was considered a first step in attracting investment to the mineral/hydrocarbon sector.

The Mission consultants were on the ground prior to the establishment of independence and this was in no short measure due to the efficiency of UNDP (Dili) in approving the project document developed by an ESCAP-UNDP team and providing the necessary funding within a very short period of time. ESCAP organized the mission in Bangkok and recruited three international consultants and one national consultant within 1-2 months. East Timorese geologists of the Department of Environment and Natural Resources were prepared to receive the mission when it arrived in Dili and provided a few reports and geologic maps and a photocopied report of a preliminary mineral database of East Timor that had been prepared in the period 1995-97 (Figure 23).

![Figure 23. UNTAET office in Dili, East Timor.](image)

Many, if not all, geologic reports from Timor had been destroyed by fire during the conflict in 1999 when all government buildings and most homes in East Timor
were systematically razed. The documents that were provided were from small private collections of Ministry officials.

2. East Timor mineral-hydrocarbon potential

The work of the mission was viewed as essential and timely in attracting investors to the mineral-hydrocarbon sector, which would be a long term source of revenue for the country. Foreign exchange from the sale of offshore natural gas could be used to rebuild its severely damaged infrastructure and to meet the needs of many other concerns. The economic fortunes of the country have long been recognized as dependent on the development of offshore hydrocarbon resources in the Timor Sea (Figure 24).

![Figure 24. The harbour at Dili located on the Timor Sea.](image)

However, the mineral resources and hydrocarbon potential of the onshore area, though not well known, also were believed to have potential. The geology of East Timor is favorable for the occurrence of a wide variety of minerals as well as hydrocarbons. These onshore and near shore resources have been brought into focus as a potential source of additional future revenue to supplement revenue derived from the sale of its offshore gas, coffee and other resources and to provide raw materials necessary to rebuild the country. An additional incentive to seek investment in the local mineral industry was that the funds that would be derived from the sale of offshore gas and oil would not be forthcoming for at least four years, until 2006. Already a few local raw materials such as sand and gravel as well as marl and reef-rock were being developed at the cottage industry level (Figure 25). These materials were being utilized to make lime, cement and concrete blocks. Virtually every house in rural East Timor utilizes local marl as a source for cement binder in building rock foundations and limestone blocks as wall footings for wooden house frames.

3. Impact of Timor Gap Treaty
The 1989 Timor Gap Treaty had created an area known as the Timor Gap Zone of Co-operation (ZOC). The Treaty was designed for the expeditious development of offshore hydrocarbon resources in the Bonaparte Gulf Basin. The ZOC was established to manage petroleum operations in Area A of the ZOC, located 320 km from the East Timor city of Dili and 460 km from the Northern Territory city of Darwin. In February 2000, the United Nations Transitional Administration agreed with Australia to continue the terms of the Treaty on behalf of the people of East Timor. After East Timor was declared independent on 20 May 2002, the Government agreed to new terms that would greatly increase the revenue derived from the development of offshore oil and gas.

Figure 25. Small-scale miners derive income by mining sand from the river-bed of the Comoro River valley in west Dili. The necessary equipment consists of a shovel and a wood framed screen.

The potential of the Bonaparte Gulf area of the Timor Sea had already been established in 1993 and in 1994 when the Elang and Kakatua oil fields were discovered in Zone A. The first oil was produced on 20 July 1998 and the fields were producing up to 24,000 barrels of oil per day (bopd), exporting more than 15 million barrels through 23 off-takes. Thus the future financial footing of East Timor was assured because of its rich offshore hydrocarbon resources.

These non-metallic minerals have assumed greater importance as a result of the need to reconstruct the country after the devastation of the 1999 disturbance. The Government had noted the need to evaluate the non-metallic mineral resources potential of the country and to identify suitable sources of primary building materials necessary for construction. The location of sand and gravel, lime for cement and clay for bricks has become of prime importance around the population centres. Some of these deposits are already being worked by teams of small-scale miners, especially in the Comoro River valley in west Dili (Figures 25 and 30).

5. Previous geological work
The island of Timor was the focus of excellent geological work by a large number of expatriate geologists in the years before its independence (see Part XII - Bibliography). The initial work of the Dutch in west Timor and surrounding seas, which began before the turn of the century in about 1890 and continued to about 1955 was notable. The work was carried out by a number of famous Dutch geologists (J.H.F. Umbgrove, H.A. Brouwer, G.A.F. Molengraaff, C.W.A.P. ‘t Hoen, R.W. van Bemmelen, L.J.C. Van Es, J.H. van Hinte and D. de Waard among others), as was the work of the Portuguese (J.C. de Azerado Leme, A.V.P. Coelho, and Carlos Teixeira among others), the French (R. Gagennet, and M. Lemoine among others), Belgians (S.F. Wittouck and his colleagues with Allied Mining Co.), Germans (J. Wanner and H.R. Grunau among others) and since 1960 the work of geoscientists from the United Kingdom which included Audley-Charles, D.J. Carter, and A.J. Barber among others. Universities in Australia (mainly the Flinders University team led by F.H. Chamalaun) and a geological research team from the University of California - Santa Cruz group led by E.A. Silver completed a series of important studies on the tectonics and the geophysical properties of the Timor Island area and adjacent sea floor in the 1970s and 1980s.

Perhaps the most extensive work done in East Timor during the middle of the last century was done by a British geologist, M. G. Audley-Charles, who spent 28 months mapping the country in the early 1960s. His field work was followed by more than three years of laboratory work, paleontological examination of field collections made from the various sedimentary units of East Timor (then Portuguese East Timor) and on the petrography of the rock types at the University of London. The work of Audley-Charles and many others in the last 30 years has revealed the complexity of the Island and provoked a debate on its tectonic origin, which is still on-going. His geologic map (scale 1:250,000) and report (Audley-Charles, 1968) is still the basic guide to the geology of East Timor. Audley-Charles joined the faculty at the University of London and supervised the work of numerous graduate students on the geology of east Timor including several Indonesians who later became famous for their work in West Timor (e.g. S. Tjokrospoetro).

The Indonesian work in Timor and adjacent seas was carried out by a number of geologists (J.A. Katili, S. Tjokrospoetro, W.S. Hartono, J. Sopaheluwakan, H. Praseyto, K. Suwitodirjo, H.M.D Rosidi, S. Gafoer, S. Bachri, R.L. Situmorang, E. Partoyo, B. Hermanto among others).

Regional mineral occurrence maps and base metal mineral databases were compiled mainly by Sukimo Djawadi and Djumhani. The first extensive East Timor mineral database was prepared by an east Timorese, Vicente de Paulo A. Lacerda and published in 1999.

Perhaps the most famous regional compilation on the tectonics was done by an American, Warren Hamilton, who spent eight years studying the tectonics of Indonesia as part of a U.S. Geological Survey project. A number of geoscientists carried out outstanding work. Readers are referred to the Bibliographies (Parts XII, XIII, and XIV) for details. Beginning in the 1970s more than one hundred papers were devoted to the study of the tectonics of Timor.

The present United Nations mission began in the field at East Timor on 29 April 2002 and was concluded on 8 June 2002. The follow-up work of building a data base and a ‘Preliminary Note’ would be completed by the author by 15 July 2002, after which the Economic and Social Commission for Asia and the Pacific (ESCAP) would further refine the data, write a final report and publish an Atlas of Mineral Resources of East Timor.

The scope of the work of the three international consultants and one national consultant was set forth in the project document as follows.

(i) Review of existing data;
(ii) Assist Government in planning, design and development of a strategy for the utilization of mineral and hydrocarbon resources;
(iii) Advise the Government on the national legal policy and on regulatory and environment issues in the development of mineral and hydrocarbon resources;
(iv) Provide recommendations for natural and mineral resources licensing arrangements;
(v) Assist in identification of appropriate public and private sector institutions essential for development of natural and mineral resources
(vi) Recommend private and public sector capacity building programs;
(vii) Draft investment profiles for selected commodities so that a portfolio of investment opportunities can be presented to private domestic and foreign investors.

The work of the mission was carried out by three international consultants, Pieter Bakker, Jack Garnett, the author and a national consultant, Laurenzo Pedro. The mission was launched by two of the above, P. J. Bakker, a mineral policy and investment expert and Jon Rau, the database expert, on 29 April who were joined by the national consultant, Laurenzo Pedro on 30 April. They were joined by a mining law expert, Jack Garnett, on 28 May, 2002.

The work of Pieter Bakker and Jon Rau included an assessment and review of the published and unpublished mineral and hydrocarbon data and was followed up by several field trips to fill in gaps and check the geology and mineral prospects with the objective of compiling geological and mineral resources maps of East Timor. Only a part of the country could be visited during these field trips, which were limited by time constraints although the mission was able to make field studies in six northern districts. The field work resulted in a much better understanding of the geology of the country and also confirmed the presence of important minerals such as copper, chromite, manganese, bentonite, phosphate, clay, limestone, sand and gravel. Several mineral occurrences for which very little published data were available were described (see companion consultant’s report by P. J. Bakker). The field work mostly was focused on the north half of country although the author made one field trip to the south coast (Covalima and Bobnaro districts) (Figure 26).
Areas in the Dili area were easily accessible and were visited on a number of half-day field trips (Figure 27).

7. Mineral database

The basic reference for most of the stratigraphic and structural data is the work of Audley-Charles (1968), which provided the framework for this report. The mineral database was built largely on the work of an East Timorese, Vicente de Paulo A. Lacerda who had compiled an extensive collection of mineral data based on Indonesian sources in the mid and late 1990s. The Lacerda database report is entitled *Data Statistik Bahan Galian Tambang Daerah Timor Timur* which is archived as an Open File Report in the Department of Environment and Natural Resources, Ministry of Economic Affairs and Planning. Field locations of a few of the mineral occurrences were based on the field trips but most of the locations in this report are based on points that were plotted on sketch maps of each district by Lourenzo Pedro, National Consultant, Natural and Mineral Resources, Ministry of Economic Affairs and Planning of East Timor Public Administration who reviewed the data presented on the small scale maps in the Lacerda database and spotted the locations of data points on a larger scale map of each district. The author compiled the mineral occurrences on large-scale maps (1:75,000) published by the Government of Indonesia. Topographic maps (scale 1:250,000) published as Joint Operations Graphic (Air) and prepared by the Army Topographic Support Establishment (Australia) in the late 1990s.

The mission had a few technical reports and journal articles at its disposal but lacked a large number of important technical journal articles and Indonesian government reports and maps, which could not be obtained within the time-frame of the report preparation period. Consequently, it was planned that the report would be supplemented with additional data obtained from the Government of Indonesia by the geological staff of the Water and Mineral Section of the Environment and Natural Resources Development Division of the Economic and Social Commission for Asia
and the Pacific. This mission to Indonesia was completed by Anatoly Kadushkin, an ESCAP officer, in June of 2002.

Figure 27. Outcrop of argillite and weakly metamorphosed sediment of the Aileu Formation on the beach in east Dili town.

8. Bibliography

The author has prepared extensive bibliographies (Parts XII, XIII, and XIV) which should be useful to the Government of East Timor in the collection of data and for rebuilding the library in Dili. Follow up work will update the geological note presented in this report and ESCAP will publish an *Atlas of Mineral Resources of East Timor* in 2003. The Government of East Timor does not have a Geological Survey or a library of earth science books and reports. It will be necessary for the Department of Environment and Natural Resources to build an earth science library from scratch and to systematically collect all of the available geological, mineral and hydrocarbon data and reports on East Timor. USAID has provided a substantial grant for this purpose and for funding an international expert working group meeting. Dr. Barid Manna, an UNTAET senior geological advisor to the Department of Natural Resources is organizing an important Expert Working Group Meeting on the Geology, Tectonics, and Economic Geology of East Timor in October 2002. The funding would be provided by USAID and would also provide for the purchase of the initial collection of geological materials for the Ministry library. The Government of East Timor would be grateful if Universities and Geological Surveys worldwide, especially those in the region, would contribute pertinent materials to this new library.

9. GIS database

A decision would be made by ESCAP in mid 2002 as to which data would be suitable for compilation in GIS format and a geologic and mineral resource map would be published to accompany the *Atlas of Mineral Resources of East Timor*. The preparation of a GIS database would be assisted by a GIS expert of the ESCAP Secretariat in mid 2002 and any new data that could be obtained within the time frame of the project would be incorporated in the database by the Secretariat. It is hoped
that the future Geological Survey of East Timor would be able to continue to build the
database and to utilize the GIS format to update the mineral and hydrocarbon
resources map as additional information was collected in the field. Consequently, the
database and map included with this report should be considered as a preliminary step
in the building of a national mineral and hydrocarbon database. Locations of mineral
deposits should be considered as tentative until verified by more field work.

10. Scope of the report

The report is based on a very brief literature survey, six weeks of office and
field work in East Timor and a follow-up reporting period of about two months. The
report does not include the latest data on the geology and tectonics of Timor. The
identification and the dating of geologic terrains requires more study of primary
geologic reports and much more field work. The stability of the new East Timor
government should ensure renewed efforts to study the island’s geology which will,
no doubt, result in new discoveries of important minerals and, possibly, hydrocarbon
deposits.

Hamilton (1979) noted the following with regard to his eight year study of the
tectonics of Indonesia “Secondary sources – national geologic maps, review papers,
and compendia such as the valuable one by van Bemmelen (1949) – on the one hand
do not repeat enough description for thorough analysis and on the other hand
generally accept the traditional assumptions without adequate discussion. Only by
reading the original reports can one be sure that he has seen all available descriptions
and that he knows the basis, or lack of it, for conclusions that have become
entrenched in the literature.” Much of the Dutch work, for example, is unpublished
even though Open File Reports are present in the archives of the Geological Research
and Development Center in Bandung.

11. Database constraints

The original locations for the mineral occurrences in a report, *Data Statistik
Bahan Galian Tambang Daerah Timor Timur* by Vicente de Paulo A. Lacerda in the
late 1990s and was published in 1999. The locations of mineral occurrences are
indicated on a small-scale scale sketch map of each district and did not include
latitude-longitude data, UTM data or topographic data. Most of the data come from
records and publications (in Bahasa Indonesia) of the Department of Defence and
other agencies in Indonesia. The Lacerda report was the basis for the database
presented in this report and as such the map locations must be used with caution with
regard to mineral occurrence locations. Where possible, the author plotted the data on
large scale topographic maps (both 1:75,000 district maps and 1:250,000 topographic
maps) from which latitude and longitude of each occurrence were determined and
entered into the database tables presented in this report. Latitudes and longitudes were
confirmed by the United Nations mission for a small percentage of the occurrences
noted in the Lacerda database. The details of the geologic relationships and mapping
of each occurrence were not provided in the Lacerda report.

The 2002 United Nations Mineral – Hydrocarbon mission did not have
adequate time nor funding for detailed field work, petrography, age determinations
etc. Very few of the mineral occurrences were visited. The analysis of the
metallogenic relations and a metallogenic map is not possible at the present time. Likewise, data from the 21 test wells that have been drilled in East Timor, mostly onland, has not been archived in Dili, although oil companies that have done work in East Timor are probably willing to give copies of their data to the Government. Finally, the devastation that struck East Timor in 1999 resulted in the loss of most of the meagre Government geological materials on the geology of East Timor. There is no library in the Ministry of Environment and Natural Resources. However, it was reported that the President was given a complete set of geological and other maps by the Portuguese government in mid 2002.

The University of East Timor does not teach geology and is just now getting back on its feet. There is no Geological Survey of East Timor. The country has 2-3 geologists although several more are in training in Australia and Indonesia. My hope is that in future these young geologists will be able to systematically go through the extensive literature on East Timor, and through working with those geologists that have spent years in the study of the geology of the country, begin to build on the previous work.

The primary purpose of this report is to build an initial and preliminary archive of mineral and hydrocarbon resource information in East Timor. The mineral and hydrocarbon data presented herein could be used to support exploration efforts and provide an initial database for the use of investors in the natural resource sector. This work should not be studied in isolation but should be supplemented by close examination of field data and geologic mapping on the ground in East Timor. The reports of the other United Nations consultants attached to the United Nations 2002 Mineral – Hydrocarbon mission should be read. These are archived in Bangkok (Economic and Social Commission for Asia and the Pacific – Environment and Sustainable Development Division, UNDP (Dili) and the Ministry of Environment and Natural Resources (Dili).

12. Acknowledgements

Mr. Egidio de Jeses, Secretary of State, Department of Natural and Mineral Resources and more recently, Secretary of State, Department of Electricity and Water Resources, welcomed the mission and provided encouragement and support throughout its duration (Figure 28).
Figure 28. Secretary of State Egidio DeJesus at work in his office in the Fortento Building. Note the geologic map of East Timor mounted on the wall.

The author would like to express his appreciation to Mr. Finn Riske-Nielsen, UNDP Representative and especially to Ms. Vibeke Risa, UNDP Programme Officer who were responsible for assisting the mission in many ways. Without Ms. Risa’s resourcefulness, the mission would have encountered more than a few problems in route to its conclusion on 8 June 2002 (Figure 29).

Figure 29. UN mission meets with senior UNDP staff in Dili. From left to right, Finn-Riske-Neilsen, P.J. Bakker, Vibeke Risa, Deidre Boyd, Anatoly Kadushkin, Jon Rau and Naoki Takyo.

Other senior officers of UNDP and UNTAET were helpful and provided assistance in many ways. They included Ms. Deirdre Boyd (UNDP) and Mr. Naoki Takyo (UNDP) for providing essential administrative assistance to the mission. Mr.
Ludovic Hood is thanked for his expert leadership in chairing the Workshop on Mineral-Hydrocarbon-Legislation and Policy organized at the conclusion of the mission in Dili.

Mr. Barid Manna (UNTAET mineral advisor) and Mr. Sher Shah Khan (UNTAET mineral policy advisor) are thanked for their support and encouragement to the mission and for courtesies rendered throughout. Mr. Larry Hunt (Agriculture and Land Use Mapping and Team Leader, GIS Training Project) provided useful documents that had been compiled in GIS format.

Mr. Vincente Lacerda, Timor Gap Joint Authority provided helpful information on the methods used in his original database compilation and provided a useful insight into the state of mineral resources development in East Timor and sources of research materials in Indonesia.

Mr. Alfredo Pires of Victoria, Australia, an East Timorese geologist who was present in Timor for a long period as a government geologist in the 1990s, was helpful in summarizing the state of work on East Timor in Portugal.

Mr. Laurenzo Pedro is thanked for his assistance in the preparation of the database and for his good nature and fellowship in the field.

Messrs Pieter Bakker and Jack Garnett were members of the consultant UNDP/ESCAP team and provided useful views, the former on the field geology and the latter on the mineral policy. Both of my fellow consultants are thanked for their good humour and friendship, which made the mission a very enjoyable one for me.

ESCAP provided essential administrative backstopping and officers of the Natural Resource and Environment Development Division, Messers Dulip Jayawardena and Anatoly Kadushkin, are thanked for their kind assistance and support prior, during and after the mission.

Mr. James C. Dowell, Director, Torney Dowell & Associates Pty Ltd. Perth and Mosman Park, WA is thanked for a wonderful cross country day trip to Matai on the south coast where the author saw one of the original test holes of Timor Oil Co. drilled in the 1970s with its “Christmas tree” still in place as well as a famous oil seep at Matai village.
Part III.
Recommendations
A. Recommendations

1. Geological Survey

(i) Create a small but active Geological Survey with expertise mainly in geological mapping, map preparation and report writing, yet understanding the role they must play in linking their work to other disciplines. If possible the Survey should include some limited expertise in geophysical, geochemical and geotechnical disciplines that would be applicable to mineral and hydrocarbon resource exploration and infrastructure development though most of this work could be carried out by consultants. The geologists should be willing to undertake fieldwork throughout the country which consists partly of rugged mountains. In summary, the geological team must be able to communicate with a broad spectrum of specialists representing the vast array of disciplines that will play a role in any thorough field study. A particularly vexing problem of Timor’s geology is its complex tectonic history. Therefore, field mapping teams must have a strong background in structural geology and tectonics and be able to utilize paleontologic and stratigraphic data to unravel tectonic complexities. They should be able to provide data that is necessary to solve the many significant problems surrounding the geologic history of Timor. This will eventually lead to the discovery of new economic mineral deposits, and possibly, hydrocarbons, in areas previously ignored.

(ii) The new Geological Survey should concentrate first on building strength in those areas which are considered essential for the rebuilding of the country. As such it should include some non-metallic mineral specialists that would be able to map and assess the non-metallic mineral resources near the main towns, e.g. sand and gravel, limestone/marl and brick clay, utilizing private sector assistance where possible. A small laboratory for assessment of non-metallic mineral properties would be useful.

(iii) The Geological Survey should make certain that it has environmental geological expertise that is able to provide useful data for urban planning and village development, e.g. locate areas of available ground water and assess the yield of aquifers, provide maps that would be useful for country-wide planning by indicating the areas susceptible to flooding, landslides, mudflows, rock falls and other destructive natural processes. The Survey should also emphasize its role in providing geological data to environmental agencies. The people of East Timor have made known their concerns for preserving the high quality of their present environment, which consists of hundreds of miles of pristine beaches, undisturbed coral reefs and unscarred mountain sides. Geologists, by virtue of their broad training in all of the basic sciences, have strong backgrounds that enable them to understand natural and man-made processes that affect these environments. Consequently, the Geological Survey has an important role in environmental management and should integrate physical data that needs to be utilized in local and regional environmental studies for planning purposes.
2. Geological mapping

The geology of most of the mineral occurrences is poorly known. Therefore it is necessary to immediately undertake geological mapping in areas where the most strategic minerals (e.g. copper, gold, silver, chromite, managanese, phosphate, limestone, bentonite and clay) are located. Preliminary work of the 2002 United Nations Mission indicates that some of these areas may be able to attract international interest and investment from the private sector. The mineral database can be used as a guide in focusing on the areas that need to be further investigated. The mapping should be supplemented, if possible, by basic petrographical and other laboratory work and chemical analyses to assess the quality of the occurrences especially of the widely used non-metallic minerals (Figure 30).

3. Database

(i) The map location data of mineral occurrences must be improved to make the database more reliable by confirming locations of those occurrences and deposits that are considered strategic by using GPS and field mapping. Then these data should be incorporated into the GIS system that ESCAP is assisting the Government of East Timor to build.

(ii) Once locations are confirmed, the geological mapping teams should begin to revise the geological maps using the new coordinates provided by the field checks and make detailed maps of the areas surrounding the occurrences at proper scales.

(iii) Assist the government by providing mineral and hydrocarbon databases in GIS format to a wide variety of potential international investors. Periodically release updated information on strategic deposits including a revised database whenever possible.

4. Document library (books, reprints, and maps)

(i) Build a proper Geological Survey library by using the bibliography in this report to acquire copies of as much of the relevant literature that is possible. One easy way to do this would be to send someone to copy the relevant material at either the U.S. Geological Survey library in Reston, Virginia or to the University of London. Much material can be obtained on-line by using international geological databases such as GEOREF.

(ii) Approach the private sector, especially Timor Oil Co. Ltd., for copies of all reports that are relative to oil and gas exploration in East Timor both onshore and offshore and for copies of their drilling and well completion reports.

(iii) Request copies of books and reports from regional geological surveys and universities on an exchange basis. Many retired geologists that have worked in the region would probably be happy to send their libraries to East Timor if shipping expenses were paid.
5. Assessment of total petroleum systems

Identify and assess the total petroleum systems of the Banda Arc marginal basins lying onshore and in nearshore coastal waters of East Timor.

Figure 30. The valley of the Comoro River located in west Dili town showing its wide alluvial sand and gravel fill. Note the numerous small pits dug by local sand and gravel miners. The Comoro valley deposit is the main source of construction material for the cement block industry in Dili and surrounding areas.
Part IV.

Geology and Mineral Occurrences in East Timor

A. Geology and mineral occurrences in East Timor

1. Introduction

The orogenic history of Timor plays a critical role in defining the location of its metallic minerals occurrences, notably copper, gold, silver, chromite and a number of important non-metallic minerals. The northern edge of Timor Island was subducted
beneath the complex southern margin of a partly oceanic, partly continental Eurasian plate on the north in the Eocene. This collision resulted in magmatic activity and thrusting, which was accompanied by the development of important metallic mineral deposits such as copper, chromite and manganese (Figure 31). Precious metals such as gold and silver were also deposited in and adjacent to volcanic centers as a result of epithermal activity. The result is that East Timor has numerous, possibly large and widely distributed, copper, gold and silver occurrences located along its north coast with some located in the interior, notably the enclave of Ocussi, as well as Baucau and Viqueque districts. Less significant deposits of chromite, manganese and iron sand deposits also occur in Manatuto, Baucau and Lautern districts.

Figure 31. Copper staining (green) in float from a quartz vein in the Bobonaro Scaly Clay near the town of Laleia in Baucau District.

The widespread occurrences of limestone, especially in eastern and western East Timor are sources of lime for cement. Important phosphate and bentonite occurrences are located in central Baucau district and clay in Lautem district (Figure 34). There is a potential for the development of ornamental stones from the numerous good quality marble occurrences in Manatuto district east of Dili. Argillic alteration has resulted in a red to white clay complex in the Aileu Formation, which occurs over a wide belt between Dili and Aileu. This belt contains an almost unlimited amount of clay, including some high-grade kaolin deposits. The clay quality must be studied.
River valleys throughout the country include a wide range of sand and gravel deposits some of which have already been used to make concrete blocks (Figure 32). Most towns exploit their local sand and gravel.

Building stones such as granite, andesite, basalt, and gabbro are also present and could provide valuable sources of rock fill, aggregate and road metal. The proximity of outcrops of andesite and basalt to north coastal waters makes them less costly to exploit and ship to points of need. Andesites are especially well suited for use in breakwaters and for harbour protection (Figure 33). They also make ideal aggregates for railway ballast and road metal.
2. Geological field mapping

M.G. Audley-Charles’ famous memoir, *The Geology of Portuguese Timor*, is the primary source of basic geological and structural data for East Timor but field work and studies by a large number of faculty and graduate students at the University of London, Flinders University, the University of California at Santa Cruz and in West Timor, the work of geologists from the University of Amsterdam has been significant, the Dutch work taking place between 1890 and 1950 and the investigations of British, Australian, Portuguese and American workers as well as other Europeans mostly after 1950.

![Figure 34. Laurenzo Pedro, East Timor national mineral consultant, examines an outcrop of white clay that covers an extensive hill area about two km south of Lautem village (on the sea) and about 1 km east of the Malaida River.](image)

The original work of Audley-Charles was done during the late 1950s and early 1960s during the early stages of the development of the concept of plate tectonics. The resulting report has some data gaps especially with regard to the geology of the hard rocks and the economic geology of the Island’s metallic and non-metallic mineral resources but it is still a remarkable piece of work. The geologic map made by Audley-Charles and published by the Geological Society of London in 1968 is still a primary source of basic geological information for East Timor. This map was revised and supplemented by field studies carried out by numerous individuals over the next thirty years (Bibliography - Part XII).

Audley-Charles was the first European to map East Timor after a pause in interest by the Portuguese. His report was based on 28 months of field work and three years of laboratory studies, mainly petrography and geochemistry all supported by Timor Oil Ltd.. In the 1980s and 1990s new field work was carried out in both east and west Timor by Indonesian geologists but remote mountainous areas were not able to be inspected in east Timor as a result of an active local insurgency. The mapping scale used by Audley Charles (1968) was 1:40,000 for two-thirds of the island and the remainder at 1:100,000 but his map of East Timor was published at a scale of 1:250,000.
The Geological Research and Development Centre (Bandung) remapped east Timor, mostly in the 1980s, and has published a set of four quadrangle maps at a scale of 1:250,000 that cover both West and East Timor. All the maps were published in the 1990s. The Geological Research and Development Center of Indonesia has revised part of the column and introduced new names. The geological mapping in West Timor was done by H.M. Rosidi, S. Tjokrosapoetro and S. Gafoer (Kupang-Atambua quadrangles), East Timor by S. Bachri and R. L. Situmorang (Dili quadrangle) and E. Partoyo, B. Hermanto and S. Bachri (Bacau quadrangle).

3. Mineral – hydrocarbon exploration

East Timor has had a long history of attempts to find oil on land and in nearshore areas. Developments in the Timor Sea stimulated exploration for minerals and hydrocarbons in the onshore area and several international companies have expressed an interest in exploration of the onshore and nearshore areas of East Timor. The potential for metallic mineral deposits had already been established by the work of Allied Mining Company, a Hong Kong based company, in 1937, which had fielded a large exploration party that mapped copper, chromite, gold and silver occurrences in several areas. A number of multi-national companies have acknowledged that there is copper and gold in West Timor and Allied Mining Company confirmed that these minerals also occur in East Timor. In addition, the base metals of chromium, mangesium and iron (sands) were known to be present and minor amounts of silver, lead and zinc had been discovered. East Timor has an abundance of clay, limestone and marl as well as unlimited quantities of alluvial sand and gravel (Figure 35). A number of igneous rocks crop out near the coast and probably would be suitable for aggregate in construction and road building projects. High quality marble occurs in several places Dili and several old quarries are known. One has over 100 large block of marble that has been cut into appropriate sizes for further processing. One quarry close to Dili could provide a source of ornamental stone suitable for local use and for export (see companion report by P.J. Bakker).

Figure 35. Typical red argillic alteration in the Aileu Formation. The alteration zone covers a belt 10-20 km wide along the Dili-Aileu road.
Figure 36. Detail of gneissic structure in the Aileu Formation. Outcrop is located about 13 km west of Manatuto on the Dili-Manatuto coast highway.
Part V.
Maps of the Mineral Distribution in East Timor
Part VII.

Maps of Mineral Occurrences in the Districts of East Timor
Figure 37. A cobble beach located at Laca (Baucau District). Cobbles were selectively screened and sorted for use in the construction industry and in road building during Indonesian times. Most of the cobbles and pebbles selected were white limestone. Note the abandoned screen sorter on the left.

Figure 38. The beach pavement of cobbles at Laca (Baucau District) shows the pebble and cobble sizes that occur as a result of natural beach wash and storm activity.
Mineral Occurrences in Viqueque District, East Timor

Plate 29

Mineral Occurrences in Viqueque District, East Timor

Compiled by
Jan L. Zhu
2007

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Figure 29. P.J. Bakker examines an outcrop of the Bobonaro Scaly Clay about 3 km southwest of Luro (Lautem District). The locality was reported to have a gold occurrence but the mission only discovered abundant pyrite.

Figure 30. The Bobonaro Scaly Clay shows a high degree of fissility, which gives the clay a “scaly” appearance. A large variety of rock types occur as exotic blocks in this terane, which is spread over most of East Timor.
Part VIII.

Mineral Database Tables
Figure 40a. Marble blocks quarried from an outcrop above this point are strewn over a hillside in Manatuto District. The marble is good quality and was probably quarried in the early to mid-1990s. The abandoned quarry is located just off the north coast highway about half way between Dili and Manatuto. The Timor Sea is in the background.
### Table 1. Copper-gold database in East Timor.

<table>
<thead>
<tr>
<th>Map reference number</th>
<th>Latitude E</th>
<th>Longitude S</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB-2.2.1</td>
<td>9 15' 57&quot;</td>
<td>124 13’ 55&quot;</td>
<td>Copper</td>
<td>Pante</td>
<td>Bihala</td>
<td>Bobokase</td>
<td>Bauknanan</td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nitibe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC-2.3.1</td>
<td>8 36’ 25&quot;</td>
<td>126 19’ 06&quot;</td>
<td>Copper and Gold</td>
<td>Vemasse</td>
<td>Ossuala</td>
<td></td>
<td></td>
<td></td>
<td>0.7-11.4 gr/ton</td>
</tr>
<tr>
<td>BC-2.4.1</td>
<td>8 35’36&quot;</td>
<td>126 19’ 06&quot;</td>
<td>Copper and Gold</td>
<td>Fatu Lulic</td>
<td>Ossuala</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>CV-2.1.3</td>
<td>9 14’ 25&quot;</td>
<td>125 10’ 55&quot;</td>
<td>Copper, Gold and Silver</td>
<td>Fatu Lulic</td>
<td>Maubui</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>CV-2.2</td>
<td>9 18’ 25&quot;</td>
<td>125 05’ 52&quot;</td>
<td>Copper, Iron and Gold</td>
<td>Fatu Mean</td>
<td>Maubui</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>EM-2.2</td>
<td>8 49’ 06&quot;</td>
<td>125 26’ 28&quot;</td>
<td>Copper and Gold</td>
<td>Lete Foho</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>MT-2.5.1</td>
<td>8 30’ 00&quot;</td>
<td>126 26’ 02&quot;</td>
<td>Copper</td>
<td></td>
<td>Laleia</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>VQ-2.2.1</td>
<td>8 45’ 40&quot;</td>
<td>126 21’ 49&quot;</td>
<td>Copper and Gold</td>
<td>Ossu</td>
<td>Eastern Ext of Ossu Mtn. ultramafics</td>
<td>Massive sulfide in large ultramafic boulders at base of Hillside on E. side of village near river</td>
<td>10 per cent Cu with Au up to 10 gr/ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VQ-2.2.2</td>
<td>8 48’ 00&quot;</td>
<td>126 16’ 30&quot;</td>
<td></td>
<td>Lacluta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VQ-2.2.3</td>
<td>8 55’ 05&quot;</td>
<td>126 17’ 03&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Table 2. Gold database for East Timor.

<table>
<thead>
<tr>
<th>Map reference number</th>
<th>Latitude East</th>
<th>Longitude South</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Potential (g/t)</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB-2.1.1.</td>
<td>9 10’ 33”</td>
<td>124 24’ 57”</td>
<td>Gold</td>
<td></td>
<td></td>
<td>Noemeto, Tanjung Luban Batu, Nifane</td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>AB-2.1.2</td>
<td>9 13’ 06”</td>
<td>124 26’ 19”</td>
<td>Gold</td>
<td></td>
<td></td>
<td>Mumbal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC-2.1.1</td>
<td>8 35’ 36”</td>
<td>126 19’ 38”</td>
<td>Gold, Vermasse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.85-3 gr/ton</td>
<td></td>
</tr>
<tr>
<td>CV-2.1.1</td>
<td>9 14’ 28”</td>
<td>125 10’ 58”</td>
<td>Gold, Fatu Lulic</td>
<td>Dato Tolu</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>CV-2.1.2</td>
<td>9 26’ 11”</td>
<td>125 05’ 44”</td>
<td>Gold, Tilomar</td>
<td>Foho Lulic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>CV-2.1.3</td>
<td>9 14’ 36”</td>
<td>125 10’ 55”</td>
<td>Gold, Copper and Silver</td>
<td>Fatu Lulic</td>
<td>Fatu Lulic</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>DL-2.2.1</td>
<td>8 13’ 08”</td>
<td>124 36’ 25”</td>
<td>Gold</td>
<td>Atauro</td>
<td>Tanjung Eranmuco</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>DL-2.2.2</td>
<td>8 17’ 02”</td>
<td>125 35’ 03”</td>
<td>Gold</td>
<td>Atauro</td>
<td>Beach (?)</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>DL-2.2.3</td>
<td>8 19’ 11”</td>
<td>125 36’ 28”</td>
<td>Gold</td>
<td>Atauro</td>
<td>Beach (?)</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>EM-2.1</td>
<td>8 47’ 52”</td>
<td>125 26’ 36”</td>
<td>Gold and Copper</td>
<td>Letefoho</td>
<td>Gulolo</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LQ-2.1.1</td>
<td>8 41’ 44”</td>
<td>125 18’ 57”</td>
<td>Gold, Lead and Zinc</td>
<td>Liquica</td>
<td>Lectela</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LQ-2.1.2</td>
<td>8 19’ 14”</td>
<td>125 28’ 47”</td>
<td>Gold, Lead and Zinc</td>
<td>Bazartete</td>
<td>Pantul Tidar</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LQ-2.1.3</td>
<td>8 38’ 03”</td>
<td>125 28’ 55”</td>
<td>Gold</td>
<td>Liquica</td>
<td>Kialeulema</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LT-2.2.</td>
<td>8 33’ 25”</td>
<td>126 49’ 30”</td>
<td>Gold</td>
<td>Luro</td>
<td>Ossalio</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LQ-2.1</td>
<td>8 38’ 03”</td>
<td>125 19’ 55”</td>
<td>Gold</td>
<td>Liquisa</td>
<td>Bazartele</td>
<td>Aeotele Pantal Tvar</td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>Location</td>
<td>Latitude</td>
<td>Longitude</td>
<td>Precious Metals</td>
<td>Place</td>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>-------</td>
<td>--------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT-2.1.1</td>
<td>8° 46' 14&quot;</td>
<td>125° 59' 36&quot;</td>
<td>Gold</td>
<td>Soibada</td>
<td>Diatuto</td>
<td>0.5 gr/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT-2.1.2</td>
<td>8° 37' 55&quot;</td>
<td>125° 58' 38&quot;</td>
<td>Gold</td>
<td>Laclo</td>
<td>Daerah</td>
<td>0.5 gr/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT-2.1.3</td>
<td>8° 46' 14&quot;</td>
<td>125° 59' 36&quot;</td>
<td>Gold</td>
<td>Soibada</td>
<td>Diatuto</td>
<td>0.5 gr/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT-2.1.4</td>
<td>8° 34' 14&quot;</td>
<td>125° 54' 00&quot;</td>
<td>Gold</td>
<td>Laclo</td>
<td>Ue Bairac</td>
<td>0.5 gr/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF-2.1.1</td>
<td>8° 50' 44&quot;</td>
<td>125° 42' 17&quot;</td>
<td>Gold/Turiscia Daerah Manufahi</td>
<td>Manufahi</td>
<td></td>
<td>107 gr/ton 75 gr/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VQ-2.1.1</td>
<td>8° 45' 57&quot;</td>
<td>126° 24' 33&quot;</td>
<td>Gold/Silver</td>
<td>Ossu</td>
<td></td>
<td>Ag 3,968 gr/ton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VQ-2.1.2</td>
<td>8° 46' 38&quot;</td>
<td>126° 00' 00&quot;</td>
<td>Gold</td>
<td>Lacluta</td>
<td></td>
<td>Indication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VQ-2.1.3</td>
<td>8° 53' 44&quot;</td>
<td>126° 17' 52&quot;</td>
<td>Gold</td>
<td>UeTuco</td>
<td></td>
<td>Indication</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Silver database for East Timor.

<table>
<thead>
<tr>
<th>Map reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River or Beach</th>
<th>Potential (g/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-2.2.1</td>
<td>8 35° 03’”</td>
<td>126 18’ 11”</td>
<td>Silver and Gold</td>
<td>Vemasse</td>
<td></td>
<td></td>
<td></td>
<td>490-560 g/ton</td>
</tr>
<tr>
<td>CV-2.3</td>
<td>9 14° 28’”</td>
<td>125 10’ 58”</td>
<td>Silver, Gold and Copper</td>
<td>Fatu Lulic</td>
<td>Fatu Lulic</td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>DL-2.3.1</td>
<td>8 14° 28’”</td>
<td>125 32’ 03”</td>
<td>Silver</td>
<td>Atauro</td>
<td></td>
<td></td>
<td>Conifasi beach</td>
<td>Indication</td>
</tr>
<tr>
<td>VQ-2.3.1</td>
<td>8 44 28</td>
<td>126 26 52</td>
<td>Silver</td>
<td>Ossu</td>
<td></td>
<td></td>
<td></td>
<td>73,025 gr/ton</td>
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### Table 4. Chromite database for East Timor

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<th>Map reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (per cent) and Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-2.7.1</td>
<td>8 35 44</td>
<td>125 33 08</td>
<td>Chromite</td>
<td>Quelicai</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cr₂O₃ – 36.4% and 51.3 %</td>
</tr>
<tr>
<td>MT-2.4.1</td>
<td>8 29 55</td>
<td>125 56 30</td>
<td>Chromite</td>
<td>Laclu</td>
<td>Hilimanu Umakaduaq</td>
<td>Ossu</td>
<td></td>
<td>Ultramafics - Serpentinite</td>
<td>Cr₂O₃ – 36.4% and 49.6 %</td>
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Table 5. Iron sand database for East Timor.

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<th>Map reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River or Beach</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB-2.3.1</td>
<td>9 17' 52&quot;</td>
<td>124 07' 55&quot;</td>
<td>Iron sand</td>
<td>Nitibe</td>
<td></td>
<td></td>
<td></td>
<td>Ambeno beach Quaternary mineral sand</td>
<td>Indication</td>
</tr>
<tr>
<td>DL-2.3.1</td>
<td>8 13’ 38&quot;</td>
<td>125 36’ 25&quot;</td>
<td>Iron sand</td>
<td>Atauro</td>
<td>Biqueli</td>
<td>Maqili</td>
<td>Tanjung Eraumoco beach Quaternary mineral sand</td>
<td>Indication</td>
<td></td>
</tr>
<tr>
<td>DL-2.3.2</td>
<td>8 13’ 38&quot;</td>
<td>125 35’ 11&quot;</td>
<td>Iron sand</td>
<td>Atauro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DL-2.3.3</td>
<td>8 16’ 22&quot;</td>
<td>125 33’ 00&quot;</td>
<td>Iron sand</td>
<td>Atauro</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</table>
Table 6. Manganese database for East Timor.

<table>
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<tr>
<th>Map reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC-2.6.1</td>
<td>8° 33' 25&quot;</td>
<td>126° 10' 14&quot;</td>
<td>Manganese</td>
<td>Vemasse</td>
<td>1 km south of Vemasse</td>
<td></td>
<td></td>
<td></td>
<td>Large deposit of pyrolusite; assessed by Japanese in 1980s; 100m (?) x 10 m x 500 m (?)</td>
</tr>
<tr>
<td>BC-2.6.2</td>
<td>8° 29' 19&quot;</td>
<td>126° 27' 58&quot;</td>
<td>Manganese</td>
<td>Baucau</td>
<td>Bulbau</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>BC-2.6.3</td>
<td>8° 32' 44&quot;</td>
<td>126° 27' 58&quot;</td>
<td>Manganese</td>
<td>Baucau</td>
<td>Samalari</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>DL-2.4</td>
<td>8° 16' 22&quot;</td>
<td>125° 33' 00&quot;</td>
<td>Manganese</td>
<td>Atauro</td>
<td>Maqueli</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LT-2.2.1</td>
<td>8° 34' 05&quot;</td>
<td>126° 49' 30&quot;</td>
<td>Manganese</td>
<td>Luro</td>
<td>Daudere</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LT-2.2.2</td>
<td>8° 27' 17&quot;</td>
<td>126° 49' 22&quot;</td>
<td>Manganese</td>
<td>Luro</td>
<td>Baihoman Puno</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LT-2.2.3</td>
<td>8° 26' 11&quot;</td>
<td>126° 00' 00&quot;</td>
<td>Manganese</td>
<td>Luro</td>
<td>Laivai, Halai</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>VQ-2.4</td>
<td>8° 45' 40&quot;</td>
<td>126° 25' 47&quot;</td>
<td>Manganese</td>
<td>Uatacarbau</td>
<td></td>
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<td></td>
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<td>Indication</td>
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</table>
Table 7. Limestone database for East Timor.

<table>
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<tr>
<th>Map reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN-3.3.1</td>
<td>9 08 52</td>
<td>125 33 41</td>
<td>Ls</td>
<td>Hato Udo</td>
<td>Fahoailako</td>
<td>Pmu</td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>AN-3.3.2</td>
<td>8 48 16</td>
<td>125 38 53</td>
<td>Ls</td>
<td>Hatubulico</td>
<td>Manutaci</td>
<td>Pmu</td>
<td></td>
<td></td>
<td>15 000 000</td>
</tr>
<tr>
<td>AN-3.3.3</td>
<td>8 48 41</td>
<td>125 36 00</td>
<td>Ls</td>
<td>Maubisse</td>
<td>Daeraeh Mabuno Mau Fatubesi</td>
<td>Pmu</td>
<td></td>
<td>1 650 520 432</td>
<td></td>
</tr>
<tr>
<td>AN-3.3.4</td>
<td>8 51 41</td>
<td>125 33 25</td>
<td>Ls</td>
<td>Hato Udo</td>
<td>Maubissi Utara</td>
<td></td>
<td>Balibo</td>
<td>Pmu</td>
<td>1 884 193 668</td>
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- **SiO₂ = 0.4 – 3.77%**
- **CaO = 51.21 – 54.68%**
- **Mg₂O = 0.46 – 2.84%**
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<td>Gypsum</td>
<td></td>
<td>Utara</td>
<td>Gueno</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB-3.6.2</td>
<td>9 23 19</td>
<td>124 20 00</td>
<td>Gypsum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MT-3.11.1</td>
<td>8 30 08</td>
<td>125 59 44</td>
<td>Gypsum</td>
<td>Manatuto</td>
<td>Laleia</td>
<td></td>
<td></td>
<td></td>
<td>39,2 93 tons</td>
</tr>
</tbody>
</table>

### Table 19. Kaolin database for East Timor.

<table>
<thead>
<tr>
<th>Database reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL-3.2.8</td>
<td>8 45 17</td>
<td>125 33 01</td>
<td>Kaolin</td>
<td>Remixio</td>
<td>Maumeta</td>
<td>Aileu hill</td>
<td></td>
<td></td>
<td>2 500 000</td>
</tr>
<tr>
<td>DL-3.12.1</td>
<td>8 16 38</td>
<td>125 34 55</td>
<td>Kaolin</td>
<td>Atauro</td>
<td>Maqueli</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LQ-3.8.1</td>
<td>8 35 11</td>
<td>125 13 30</td>
<td>Kaolin</td>
<td>Bazartete</td>
<td>Ulmera</td>
<td>Lebollua</td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
</tbody>
</table>
### Table 20. Salt database for East Timor.

<table>
<thead>
<tr>
<th>ET Database Reference Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB-3.13.1</td>
<td>9 12 00</td>
<td>124 20 44</td>
<td>Halite</td>
<td>Pante Makassar</td>
<td>Masin</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>BC-3.10.1</td>
<td>8 27 25</td>
<td>126 38 19</td>
<td>Halite</td>
<td>Laga</td>
<td>Nunira</td>
<td></td>
<td></td>
<td></td>
<td>Cl = 10.830 gr/ton Area of 10 250 sq m pH = 6 – 7</td>
</tr>
<tr>
<td>DL-3.6.1</td>
<td>8 33 57</td>
<td>125 29 11</td>
<td>Halite</td>
<td>West Dili</td>
<td>Tasitollu</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
</tbody>
</table>

### Table 21. Manganese database for East Timor.

<table>
<thead>
<tr>
<th>Database reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL-2.5.1</td>
<td>8 16 22</td>
<td>125 33 00</td>
<td>Manganese</td>
<td>Atauro</td>
<td>Maqueli</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LT-2.2.1</td>
<td>n.d.</td>
<td>n.d.</td>
<td>Manganese</td>
<td>Moro</td>
<td>Daudere</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>LT-2.2.2</td>
<td>8 27 17</td>
<td>126 49 22</td>
<td>Manganese</td>
<td>Buihoman</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LT-2.2.3</td>
<td>8 26 11</td>
<td>126 00 00</td>
<td>Manganese</td>
<td>Banura</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LT-2.2.4</td>
<td>8 34 05.</td>
<td>126 49 30</td>
<td>Manganese</td>
<td>Puno</td>
<td>Laivai</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VQ-2.4.1</td>
<td>8 45 40</td>
<td>126 25 47</td>
<td>Manganese</td>
<td>Uatacarbau</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
</tbody>
</table>
Table 22. Silica database for East Timor.

<table>
<thead>
<tr>
<th>Map Reference Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB-3.11.1</td>
<td>9 17 44</td>
<td>124 27 49</td>
<td>Silica sd</td>
<td>Pante Makassar</td>
<td>Pante</td>
<td></td>
<td></td>
<td></td>
<td>320</td>
</tr>
<tr>
<td>AB-3.11.2</td>
<td>9 14 44</td>
<td>124 13 38</td>
<td>Silica sd</td>
<td>Pante Makassar</td>
<td></td>
<td>Tono</td>
<td></td>
<td></td>
<td>3 000</td>
</tr>
<tr>
<td>AB-3.11.3</td>
<td>9 20 03</td>
<td>124 09 08</td>
<td>Silica sd</td>
<td>Nitibe</td>
<td></td>
<td></td>
<td>Oenamu</td>
<td></td>
<td>675</td>
</tr>
<tr>
<td>AB-3.11.4</td>
<td>9 20 03</td>
<td>124 09 08</td>
<td>Silica sd</td>
<td>Nitibe</td>
<td></td>
<td></td>
<td></td>
<td>Pantai Suniufe</td>
<td>108</td>
</tr>
<tr>
<td>DL-3.8.1</td>
<td>8 18 00</td>
<td>125 34 30</td>
<td>Silica Sd</td>
<td>Atauro Lourba Bobonaro</td>
<td></td>
<td></td>
<td></td>
<td>Maqueli</td>
<td>Indication</td>
</tr>
</tbody>
</table>

Table 23. Wollastonite database for East Timor

<table>
<thead>
<tr>
<th>Map Reference Number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Potential (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB-2.1.1</td>
<td>9 00 57</td>
<td>125 23 27</td>
<td>Wollastonite</td>
<td>Bobonaro</td>
<td>Carabau</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 24. Talc database for East Timor.

<table>
<thead>
<tr>
<th>Database reference number</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Resource</th>
<th>Subdistrict.</th>
<th>Village</th>
<th>Mountain</th>
<th>River</th>
<th>Geology</th>
<th>Potential (cu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL-3.9.1</td>
<td>8 43 55</td>
<td>125 35 27</td>
<td>Talc</td>
<td>Aileu</td>
<td>Aisirimou</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
<tr>
<td>MT-3.14.1</td>
<td>8 30 16</td>
<td>125 55 38</td>
<td>Talc</td>
<td>Laclo</td>
<td>Hilimanu</td>
<td></td>
<td></td>
<td></td>
<td>Indication</td>
</tr>
</tbody>
</table>
Part IX.

Hydrocarbon Database
A. East Timor mineral-hydrocarbon potential

We have already noted that the geology of East Timor is favorable for the occurrence of a wide variety of minerals. The hydrocarbon potential is not as well known. Based on current data it is possible to state that, unquestionably, hydrocarbons do occur onland in East Timor. These onshore and near shore resources have been brought into focus as a potential source of additional future revenue to supplement revenue to be derived from the sale of offshore gas and to provide raw materials necessary to rebuild the country. However, the funds that would be derived from the sale of offshore gas and oil would not be forthcoming for at least four years (2006). Therefore, the development of the present minerals and hydrocarbon database is essential to support the development of East Timor’s economy and to attract investment in the mineral and hydrocarbon sectors. The building materials industry is especially dependent on the availability of low cost local materials. Even small local oil seeps provide a source of energy in some rural areas. This section reviews the status of hydrocarbon development in East Timor.

B. Impact of Timor Gap Treaty

The 1989 Timor Gap Treaty had created an area known as the Timor Gap Zone of Co-operation (ZOC). The Treaty was designed for the expeditious development of offshore hydrocarbon resources in the Bonaparte Gulf Basin. The ZOC was established to manage petroleum operations in Area A of the ZOC, located 320 km from the city of Dili and 460 km from the Northern Territory city of Darwin. In February 2000, the United Nations Transitional Administration agreed with Australia to continue the terms of the Treaty on behalf of the people of East Timor. After East Timor was declared independent on 20 May 2002, the Government agreed to new terms that would greatly increase the revenue derived from the development of offshore oil and gas.

The potential of the Bonaparte Gulf area of the Timor Sea had already been established in 1993 and in 1994 when the Elang and Kakatua oil fields were discovered in Zone A. The first oil was produced on 20 July 1998 and the fields were producing up to 24,000 barrels of oil per day (bopd), exporting more than 15 million barrels through 23 off-takes. Thus the future financial footing of the new nation was assured because of its rich offshore hydrocarbon resources.

C. Marginal basins and hydrocarbons

As noted earlier, Timor has developed a complex geological structure as a result of the collision of the Outer Banda Arc (including Timor Island) with Eurasia and Australia. These collisions resulted in the accretion of both shelf and deep sea sediments as well as continental crustal material (including rocks of medium to high metamorphic grade. The latter would have little potential as hydrocarbon reservoirs and no potential as source rocks for oil and gas. In addition, the faulted and discontinuous mountainous belt, which runs the length of the middle of the island, is difficult to explore for hydrocarbons. Although the faulting and metamorphism that accompanied the second event has resulted in the further development of metallic
mineral deposits, it has lessened the opportunities for the accumulation of oil in the center of the island because of the high temperatures and pressure which accompanied the mountain building. But a fortuitous event occurred along the south coast resulting in the development of several large marginal basins after the mountain building. These basins collected coarse debris from the interior, which was being rapidly eroded due to the uplift resulting from the Pliocene orogeny. These marginal basins are prominent targets in the search for hydrocarbons on land and in the near shore areas adjacent to the south coast. However, because of its structural complexity, there was a need to apply modern 3-D geophysical exploration methods and petroleum assessment techniques.

So far as the author knows, the application of the petroleum system approach as used by the U.S. Geological Survey in the Bonaparte Gulf and adjacent basins has not yet been applied to the Banda Arc area of Timor Island. The islands of the Outer Banda Arc Complex should receive the same careful attention that has been given to the Timor Gap Area by multinational companies. The stratigraphy should be reviewed (Figure 41).

The basins on the south coast were explored by Timor Oil Ltd. in their search for hydrocarbons on land and in the near shore areas off the south coast mostly from 1957 to 1975. Although 21 wells were drilled, only one or two showed any promise. Still, if one or two of these wells had been brought into the production, the ratio of one successful well for every 10 drilled would have been enough to encourage further exploration (Table 25). Indeed, Timor Oil Ltd. officially has indicated an interest in continuing their search for hydrocarbons onshore and in nearshore waters of East Timor. However, because of the Island’s structural complexity, the need to apply modern 3-D geophysical exploration methods and petroleum assessment techniques, the search will be costly.
D. Hydrocarbon potential

Hydrocarbon data are available from unpublished reports of Timor Oil Ltd., but the dearth of such reports in Dili resulted in an inconclusive evaluation of East Timor’s hydrocarbon potential. Only one important report by Timor Oil Ltd. was available to the consultants. The primary exploration target of Timor Oil Ltd. was a sand filled linear marginal basin (Viqueque basin) lying partly onshore and partly offshore of the south coast. The western part of this basin was intensively explored near the town of Suai by Timor Oil Ltd. The majority of the western test holes were drilled in Covalima district and the eastern wells in the Aliambata area of Viqueque district. Data regarding the relation of the two areas of interest were not available at the time of this writing.

Wells in both areas had oil and gas shows and three wells recovered oil. Some early shallow wells in the Aliambata area actually produced “gushers” of water and oil which was released so strongly that tools were blown out of the hole or lost during drilling operations. In some general respects, one can conclude that there is some potential because (i) sedimentary basins with permeable sand fills are present along the south coast, (ii) these basins probably include source beds rich in organic material further seaward from the present coast, (iii) structural traps are known to exist in the form of anticlines and fault traps with appropriate structural closure, (iv) the occurrence of numerous oil and gas seeps occur in several places along both the north
and south coasts indicating that migration of hydrocarbons is continuing at present, (v) the proximity of the Banda Arc basins to the Bonaparte Gulf basin known to have enormous gas potential, and (vi) the promising shows and flows encountered during the drilling of a few exploration test holes in the 1950s-1970s.

In tectonically old fold-and-thrust belts, most oil accumulations occur in cool regions or foreland areas far from the heart of the orogeny. Younger gas tends to occur in the hotter regions closer to the main orogenic activity. The Viqueque basin in Viqueque district is an example of the latter, and the Bonaparte Gulf basin of the former. Hot springs and mud volcanoes are found on the south coast close to active oil and gas seeps in the Viqueque basin. The sedimentary fill of the Viqueque basin is largely unexplored but sand permeabilities are believed to be high and faulting has created numerous pathways for hydrocarbon migration. The presence of numerous oil and gas fields in the offshore Bonaparte Gulf basin of Australia-East Timor-Indonesia located to the south has created renewed interest in the Timor onshore potential.

Oil gravity is of two types, a high quality paraffin base type ranging from 30° to 40° A.P.I. gravity and a second type of poor quality consisting of an asphaltic base in the 20° to 30° A.P.I. gravity range. Source beds are thought be the quiet water organic rich muds of deep offshore areas in the Viqueque sequence. Areas with the most promising tectonic and sedimentologic characteristics include southern Viqueque, southern Manatuto, and southern Manufahi districts, Most of the hydrocarbons in this sequence occur at a depth of less than 4-5 km.

Because of its complex tectonic setting the hydrocarbon potential of basins in the interior of East Timor is much less attractive. Suites of non-productive metamorphic and ultramafic rocks in folded thrust sheets overlie otherwise attractive sands and limestones of the Mesozoic sequence. Although folds are broad and upright in parts of the interior, they tend to be located in fairly rugged areas with difficult access or in belts that may have suffered temperatures that were too high which resulted in the loss of oil and gas. However, some parts of the interior are tectonically less complex consisting of low rolling plateaus such as in the far east (Lautern district), north-central Baucau district and Bobonaro southwest of Maliana town.

E. South coast and the Aliambata area

1. Introduction

The southeast coast was the first area of East Timor explored for oil and gas (Table 25). The first test hole was drilled in the Aliambata area of Viqueque district to the shallow depth of 140 feet by a local operator, Elliott and Co., in 1900. Other holes were drilled in the area a few years later by an Australian company, Timor Oil, Ltd. The Australian rig reached a depth of 170 m in the Mete-Hou area but no log or samples are available to determine the stratigraphy. Another well was drilled to a depth of about 800 feet, in the period 1914-1916. The data for a test hole drilled in 1914 are included below. The driller’s log of that well is included below but Audley-Charles (1968) did not accept its geological validity.
2. Oil exploration history

In 1900 Elliott and Co. drilled a well in the Aliambata district to 140 m. The section penetrated was entirely in the Mesozoic.

In the period 1957-1975 the Timor Oil Ltd., an Australian company, drilled eight wells in Mesozoic rocks in various locations on the south coast (Table 25). All of the wells drilled by Timor Oil Ltd. were in Mesozoic rocks which were considered the zone with the best potential by companies operating in Southeast Asian waters. The Aliambata No. 1 well was drilled to 1,355 m. The Ossulari No. 1 was drilled to 2,249 m and the No. 1A to 1,533 m. The Matai No. 1 was drilled to 673 m, No. 2 to 845 m, and No. 3 to 320 m. Matai No. 4 was drilled to 567 m and No. 5 to 1,529 m. Locations are shown on Pl. 13 of Audley-Charles (1968). Sections of the Tertiary stratigraphy were plotted for these eight wells. Core drilling was carried out in the Viqueque and Matai anticlines. A number of wells also were drilled in the 1970s.

Table 25. Exploration oil/gas well database for East Timor.

<table>
<thead>
<tr>
<th>Latitude N</th>
<th>Longitude E</th>
<th>Name</th>
<th>Company</th>
<th>Oil produced (bopd)</th>
<th>District</th>
<th>Date drilled</th>
<th>Structure</th>
<th>Total depth (feet)</th>
<th>Oil/gas shows or API of oil in well</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 48 00</td>
<td>126 36 30</td>
<td>Aliambata – 1</td>
<td>Timor Oil Ltd.</td>
<td>37 bopd</td>
<td>Viqueque</td>
<td>1914</td>
<td>E-W trending, west plunging anticline</td>
<td>4 617</td>
<td>Yes</td>
</tr>
<tr>
<td>n.d.</td>
<td>n.d.</td>
<td>Ossularia – 1/1A</td>
<td>Timor Oil Ltd.</td>
<td>None</td>
<td>Manatuto</td>
<td>1959</td>
<td>Symmetrical – almost a dome but indicated as south plunging anticline</td>
<td>8 746</td>
<td>None</td>
</tr>
<tr>
<td>9 10 46</td>
<td>125 34 10</td>
<td>Betano - 1</td>
<td>Timor Oil Ltd.</td>
<td>None</td>
<td>Covalima</td>
<td>1972</td>
<td>E-W trending anticline; well drilled on south flank of doubly plunging anticline</td>
<td>2 568</td>
<td>None</td>
</tr>
<tr>
<td>9 11 11</td>
<td>125 34 46</td>
<td>Betano - 2</td>
<td>Timor Oil Ltd.</td>
<td>None</td>
<td>Covalima</td>
<td>1972</td>
<td>E-W trending anticline; well drilled on south flank of doubly plunging anticline</td>
<td>4 411</td>
<td>Yes</td>
</tr>
<tr>
<td>9 18</td>
<td>125 16</td>
<td>Matai - 1</td>
<td>Timor Oil Ltd.</td>
<td>120 bopd</td>
<td>Covalima</td>
<td>1961</td>
<td>NE-SW trending doubly plunging anticline</td>
<td>760 - 825</td>
<td>Yes 34.1° API</td>
</tr>
<tr>
<td>Latitude</td>
<td>Longitude</td>
<td>Name</td>
<td>Company</td>
<td>Oil produced (bopd)</td>
<td>District</td>
<td>Date drilled</td>
<td>Structure</td>
<td>Total depth (feet)</td>
<td>Oil/gas shows or API of oil in well</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>------------------</td>
<td>---------------------</td>
<td>----------</td>
<td>--------------</td>
<td>------------------------------------------------</td>
<td>-------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>9 18</td>
<td>125 16</td>
<td>Matai – 1A</td>
<td>Timor Oil Ltd.</td>
<td>110 bopd</td>
<td>Covalina</td>
<td>1961</td>
<td>SW-NE trending doubly plunging anticline</td>
<td>235-848</td>
<td>Yes 34.1° API</td>
</tr>
<tr>
<td>9 18</td>
<td>125 16</td>
<td>Matai - 3</td>
<td>Timor Oil Ltd.</td>
<td>3 bopd</td>
<td>Covalina</td>
<td>1961</td>
<td>SW-NE trending doubly plunging anticline</td>
<td>863</td>
<td>Yes 34° API</td>
</tr>
<tr>
<td>9 18 30</td>
<td>125 17 45</td>
<td>Matai - 5</td>
<td>Timor Oil Ltd.</td>
<td>None</td>
<td>Covalina</td>
<td>1962</td>
<td>East flank of SW-NE trending doubly plunging anticline</td>
<td>4 588</td>
<td>None</td>
</tr>
<tr>
<td>9 16 10</td>
<td>125 17 30</td>
<td>Matai - 6</td>
<td>Timor Oil Ltd.</td>
<td>None</td>
<td>Covalina</td>
<td>1962</td>
<td>Axis of SW-NE trending doubly plunging anticline</td>
<td>1 230</td>
<td>None</td>
</tr>
<tr>
<td>9 18</td>
<td>125 16</td>
<td>Matai - 4</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Covalina</td>
<td>1962</td>
<td>Axis of SW-NE trending doubly plunging anticline</td>
<td>n.d.</td>
<td>None</td>
</tr>
<tr>
<td>9 18 30</td>
<td>125 14 30</td>
<td>RANUC</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Covalina</td>
<td>n.d.</td>
<td>Axis of SW-a NE trending doubly plunging anticline</td>
<td>640</td>
<td>None</td>
</tr>
<tr>
<td>9 21 48</td>
<td>125 16 42</td>
<td>Suai Loro 1</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Covalina</td>
<td>n.d.</td>
<td>South flank of east-west trending, doubly plunging anticline</td>
<td>n.d.</td>
<td>None</td>
</tr>
<tr>
<td>9 22 00</td>
<td>125 16 12</td>
<td>Suai Loro 2</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Covalina</td>
<td>n.d.</td>
<td>South flank of east-west trending, doubly plunging anticline</td>
<td>n.d.</td>
<td>Yes</td>
</tr>
<tr>
<td>9 19 00</td>
<td>124 14 44</td>
<td>Suai 2</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Covalina</td>
<td>n.d.</td>
<td>South flank of east-west trending, doubly plunging anticline</td>
<td>n.d.</td>
<td>None</td>
</tr>
<tr>
<td>Latitude E</td>
<td>Longitude S</td>
<td>Name</td>
<td>Company</td>
<td>Oil produced (bopd)</td>
<td>District</td>
<td>Date drilled</td>
<td>Structure</td>
<td>Total depth (feet)</td>
<td>Oil/gas shows or API of oil in well</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>-----------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----------</td>
<td>--------------</td>
<td>------------------------------------</td>
<td>--------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>9 25 30</td>
<td>125 11.12</td>
<td>Cape Tafari 1</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Ainaro</td>
<td>n.d.</td>
<td>South flank of east-west trending plunging anticline</td>
<td>n.d.</td>
<td>None</td>
</tr>
<tr>
<td>9 25 30</td>
<td>125 12.00</td>
<td>Cape Tafara - E1</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Ainaro</td>
<td>n.d.</td>
<td>South flank of east-west trending plunging anticline</td>
<td>n.d.</td>
<td>None</td>
</tr>
<tr>
<td>9 21 00</td>
<td>125 29.00</td>
<td>Mola - 1</td>
<td>Timor Oil Ltd.</td>
<td>n.d.</td>
<td>Offshore Ainaro</td>
<td>n.d.</td>
<td>n.d.</td>
<td>3,071</td>
<td>None</td>
</tr>
</tbody>
</table>

3. Geological field work and mapping

In the early 1960s field work was being carried out by Audley-Charles (1968) and a geologist from Portugal (Leme, 1963) who investigated part of the area east of Mt. Mata Bia. Leme and Audley-Charles carried out some of the field work together. Audley-Charles initially was working on areas of interest to Timor Oil Ltd. He was retained as a consultant by Timor Oil Ltd. for a number of years and eventually published the results of his research in a memoir of the Geological Society of London (Audley-Charles, 1968). Leme also published a considerable number of reports (see Bibliography).

Leme is reported to be updating his maps of Timor Island, which were compiled at a scale of 1:100,000. According to recent information he continues to work on the geological maps in Portugal (Perez, oral communication, May 2002).

4. Oil seeps and traps

More than 30 oil and gas seeps are known. Approximately 20 exploration holes have been drilled for oil and a number of them have been successful, discovering shallow oil and encountering numerous oil and gas shows. Technical problems have prevented the development of production wells. No wells have been drilled since the 1970s. Geophysical surveys, photogeology and gravity surveys as well as traditional field methods have been employed to discover and map structures, mainly anticlines, that have adequate structural closure and are accessible to the drill. More than a dozen such anticlines are known. Several offshore Tertiary basins show...
promise and have been surveyed by marine geophysical surveys employing seismic methods.

The oil and gas seeps of East Timor occur in three distinct structural elements: (i) the Permian and Mesozoic strata of the autochthon/para-autochthon, (ii) the Bobonaro Scaly Clay mid-Miocene olistostrome which has gas seepages only, and (iii) the Viqueque Group of Neogene molasse (Audley-Charles and Carter, 1974).

The presence of oil seeps on the beach near the site of the Aliambata test holes as well as favourable local structure were factors that encouraged the original operators. A number of anticlines had been mapped along the south coast (Figure 42). Most of the early targets for oil and gas structures throughout the world were based on the presence of anticlinal structures or salt domes in the early and mid-1900s. The anticlinal structure drilled by the Timor Oil Ltd. was termed the Aliambata anticline by Audley-Charles (1968). Such structures commonly provide closure in hinge areas, which trapped oil and gas if reservoir and source beds were present. Fault traps on the limbs of anticlines were also favourable targets.

Figure 42. Map of anticlines in the Viqueque basin of East Timor.
Table 26. History of oil and gas exploration at Aliambata area in the early 1900s.

<table>
<thead>
<tr>
<th>Company</th>
<th>Area</th>
<th>Date of test</th>
<th>Depth of hole (feet)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliot and Company</td>
<td>Southeast coast north of oil seep on the beach near Aliambata</td>
<td>1900 or 1904</td>
<td>140</td>
<td>Unknown; gas leaking from the casing;</td>
</tr>
<tr>
<td>Timor Oil Co., Ltd.</td>
<td>Meta Hou District</td>
<td>1914-1916</td>
<td>800</td>
<td>Oil and gas at 400 ft (?) had sufficient pressure to blow the drilling tools, oil and water over the top of the rig</td>
</tr>
<tr>
<td>Timor Oil Co., Ltd.</td>
<td>Near Aliambata</td>
<td>1926-1927</td>
<td>530</td>
<td>Hole junked because of loss of bit and absence of fishing tools</td>
</tr>
<tr>
<td>Local Timorese company</td>
<td>Irabin</td>
<td>1920s</td>
<td>100</td>
<td>Hole drilled by hand</td>
</tr>
</tbody>
</table>

*Source: Allied Mining Company (1937)*
F. Hydrocarbon potential of the Aliambata area

The geology of the Aliambata area was not well known although some geological mapping had been done in the 1910-1930 period (Table 26). Most outcrops were found in river valleys, which provide good cross sections of the local structure. The area west and northwest of the site could be worked out because of good outcrop data. But areas to the northeast where the relief is stronger were poorly known. The structure is complex including the presence of major overthrusts and metamorphosed rocks in nearby areas. Intrusive rocks and major faults were mapped on the west side of Mara Bia mountain east of the test hole.

The drill site was selected on the axis of an anticline based on geological field data collected in the Aliambata district and the presence of two oil seeps on the beach. The axis of the anticlinal structure trends northeast-southwest. The surface stratigraphy was known based on good exposures in local river valleys. Limestone outcrops of the Cribas Formation occur in Duratay Creek and in the Be Vui River. However, the geology of the flanks of the structure was poorly known at the turn of the century. No regional geological mapping had been carried out in the 19th century.

The age of the folding is probably Late Pliocene to Early Pleistocene (Audley-Charles, 1968)

G. Aliambata anticline

1. Structure

The Aliambata anticline is a complicated structure in which the subsurface geology is virtually unknown below a depth of 800 feet. The fold limbs are characterized by minor folds and the faults are major features that have considerable throw. Field work in the 1960s by Audley-Charles (1968) indicated that the east limb is exposed but the northwest limb is covered by Tertiary sediments and a thrust sheet of the Lolotoi Complex and Maubisse Formation (Audley-Charles, 1968).

2. Stratigraphy

The stratigraphic section along the southeast coast is regarded as autochthonous Permian and Mesozoic rocks (undifferentiated) and as such would be similar to the cratonic sequence found on the north coast of Australia. However, there are large parts of the south coast of East Timor where it is impossible to see the structure beneath the Viqueque Formation and other younger rocks (post-Triassic). There are also klippe of molasse that have been thrust from the south coming to their final location in Viqueque district.

The Ira Bere River cuts across the core of the Aliambata anticline exposing the Cribas Formation. North of Aliambata the hills consist of sediments that probably are the same units that make up the northwest limb of the fold. They include the Aitutu Formation, Wai Luli Formation and Borolalo Limestone. The section penetrated by
the test hole drilled in 1914 was the Cribas Formation, a sequence of limestone, sandstone and shale, which is more than 800 feet thick (Table 27).

The Aliambata area is covered by younger sediments toward the southwest and the section beneath this part of the coast is unknown. It must be regarded that insufficient data are present to properly evaluate the potential at depths deeper than 1000 feet in the Aliambata area. The oil and gas in surface horizons indicate source beds are present in the subsurface whether to the north or south.

3. Oil and gas shows in test holes

Oil and gas was recovered at a number of depths as indicated below (Table 27). Hydrostatic and oil and gas fluid pressures were strong enough to blow the tools out of the hole. The exact depth at which this occurred is unknown but probably was within 300 feet of the surface. Data on the gravity and chemical characteristics were collected (Tables 28-29).

The most active exploration company, Timor Oil Ltd., concluded that they had proved the existence of oil and gas at a number of horizons, two of which were within 90 feet of the surface. They regarded the area as still having potential and that their test was based on insufficient field structural and stratigraphic data. The lack of proper fishing tools to recover a lost drilling bit was critical and led to the junking of two holes one in 1914 and another in 1927.

The area was covered with a dense jungle in 1914-1916. The company noted that a “good anchorage” existed near the coast and that the roads were serviceable and maintained by the Government.

H. Oil potential of Viqueque District

Oil seeps are found quite far inland in East Timor, as far as 23 kilometres from the south coast in southeast Manatuto district, not far west of the western boundary of Viqueque district (Lat 8° 44’ 22”; Long 126° 02’19”), on the north coast of Los Palos as well as on the south coast at Aliambata. The seeps at Aliambata were one of the reasons for drilling a number of exploratory wells beginning in 1910. The resulting shows were reasonably good but the lack of adequate technology resulted in the loss of drilling tools forcing the abandonment of the holes drilled by Timor Oil in 1912-1914. However, the results were good enough to encourage further exploration drilling and the expenditure of large sums for deep tests and geophysical work offshore in southwest East Timor by Timor Oil in the 1950s-70s.

Viqueque district has already been drilled several times. These data have been useful for the interpretation of the subsurface geology of the district (refer to the cross sections of Audley-Charles, 1968). A slim hole core-drill also provided additional information about the Viqueque anticline near the coast. Two test holes, Ossulari-1 and 1A were drilled in 1959 by the Timor Oil Co., Ltd. These two test holes are located close to the coast. The test wells penetrated most of the Viqueque Formation and bottomed near the top of the Wai Luli Formation, a flysch sequence of Upper Triassic-Middle Jurassic age.
Audley-Charles (1968) constructed a number of cross sections that show major structures trending through the central part of East Timor (Audley-Charles, 1968; Sections 1 and 2). The Ossulari anticline was the most important fold which could be tested with less difficulty than other folds farther inland. The Ossulari anticline has been folded into two smaller and less prominent anticlines (Audley-Charles, 1968). The two test holes drilled by Timor Oil Co., Ltd. appear to have been located in a syncline between the two minor anticlines about 17 kilometres north of the south coast. The Ossulari test holes were spudded in an outcrop of a thin scab of the Baucau Limestone. Up to now these two tests are the deepest test holes drilled in East Timor. One was drilled to a depth of 8,746 feet but had no oil and gas shows. The Ossulari test site was selected by a team led by Dr. W. F. Schneeberger who had begun field mapping in East Timor in 1958. An important consideration for the location of the test in this place was the structural interpretation of Mr. I.B. Fretag (unpublished report, 1959) who had carried out important field work beginning in eastern Timor in early 1959. Freytag focussed his work on the central and southern parts of Portuguese Timor and proposed a revised Tertiary stratigraphy. He did not accept the ideas of earlier geologists that included the concept of major overthrust faulting in Portuguese Timor. Overthrusting was an integral part of the structural history of Grunau (1957), Gageonnet and Lemoine (1957A, 1957B, 1958) and Lemoine (1959). Their work required the superposition of several fragmented overthrust blocks to build the island. Freytag considered that the structure seen at the surface continued at depth to the top of the basement and that overthrusting, if present, was not a significant deterrent to the Island’s hydrocarbon potential.

A third test the, Aliambata No. 1, was drilled on the coast immediately north of the beach by Timor Oil Ltd. in 1957. Its total depth was 1,355 m and it was entirely in Mesozoic rocks. However, numerous technical difficulties were encountered and there is no reliable record of the stratigraphy or paleontology (Audley-Charles, 1968). The Chief Geologist, Dr. W.F. Schneeberger (unpublished, 1961) suggested that the test hole was entirely in the Borolalo Limestone which was highly fractured and repeated by faulting. Consequently, the Borolalo thickness is almost seven times its normal thickness in the test hole.

Timor Oil Co. Ltd., also drilled several shallow wells in the far southwest corner of Portuguese Timor, Matai No. 1 (673 m), Matai No. 2 (845 m), Matai No. 3 (320 m), Matai No. 4 (567 m) and Matai No. 5 (1,529 m). None of these wells was able to produce significant amounts of hydrocarbons but some had oil and gas shows.

Table 27. Stratigraphy, oil, gas and water data for Aliambata test hole (1914).

<table>
<thead>
<tr>
<th>Fluids</th>
<th>Flow data</th>
<th>Depth (feet)</th>
<th>Lithology</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh water</td>
<td>Small</td>
<td>55</td>
<td>Top of bedrock; base of 55 feet of alluvium</td>
<td>Quaternary aquifer</td>
</tr>
<tr>
<td>Sulphur water</td>
<td>Strong</td>
<td>95</td>
<td>Limestone</td>
<td></td>
</tr>
<tr>
<td>Oil and gas</td>
<td>15 barrels of oil per day (bopd)</td>
<td>155</td>
<td>Shale, sandstone and limestone</td>
<td></td>
</tr>
<tr>
<td>Oil and gas</td>
<td>36 bopd</td>
<td>255</td>
<td>Limestone</td>
<td>Pressure of gas and oil blew the drilling tools out of the hole</td>
</tr>
<tr>
<td>Source: Allied Mining Company</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 28. Analysis of Aliambata crude oil.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>Aromatic or benzene hydro-carbon; asphaltic</td>
</tr>
<tr>
<td>Colour</td>
<td>Brownish dark straw</td>
</tr>
<tr>
<td>Bottom sediment and water</td>
<td>0.6 degrees</td>
</tr>
<tr>
<td>Density</td>
<td>0.969 at 15.5 °C.</td>
</tr>
<tr>
<td>Sulphur</td>
<td>1.16°</td>
</tr>
<tr>
<td>Flash point</td>
<td>145°C</td>
</tr>
<tr>
<td>Carbon residue</td>
<td>6.4°</td>
</tr>
<tr>
<td>Pour point</td>
<td>-5°C</td>
</tr>
<tr>
<td>Gravity A.P.I.</td>
<td>14.5</td>
</tr>
<tr>
<td>Fire point</td>
<td>168°C</td>
</tr>
<tr>
<td>Ash</td>
<td>0.3°</td>
</tr>
<tr>
<td>Solidifying point</td>
<td>-12° C.</td>
</tr>
</tbody>
</table>

Source: Allied Mining Company.
Table 29. Distillation phases of Aliambata crude oil from the 1914 test hole.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline and kerosene</td>
<td>6.00</td>
</tr>
<tr>
<td>Light cutting oil</td>
<td>18.00</td>
</tr>
<tr>
<td>Lubricating oil</td>
<td>61.00</td>
</tr>
<tr>
<td>Tarry substances</td>
<td>14.3</td>
</tr>
<tr>
<td>Distillation losses</td>
<td>0.70</td>
</tr>
</tbody>
</table>

*Source:* Allied Mining Company
Table 30. Gas seep database for East Timor.

<table>
<thead>
<tr>
<th>Name of gas seep</th>
<th>Latitude S</th>
<th>Longitude E</th>
<th>District</th>
<th>Description of location</th>
<th>Outcrop</th>
<th>Source</th>
<th>Description of gas seep</th>
<th>Structure</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gari Wai¹</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aliambata¹</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loiba</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
<td>Hillside west of the confluence of the Lacuzol and the Bazol rivers</td>
<td>n.d.</td>
<td>Probably Aitutu Fm.</td>
<td>Burning gas</td>
<td>N. limb of Bazol anticline</td>
<td>Small depression. Cultivated area; area of 10 sq m of burnt soil over which a flame dances; Smells strongly oil.</td>
</tr>
</tbody>
</table>

¹ See oil seep database
Part X.

Stratigraphy
A. Stratigraphic column

The summary of the stratigraphy presented below consists mainly of excerpts from Audley-Charles (1968) supplemented by notes from the literature that was available in East Timor at the time of this writing as well as very limited field reconnaissance of several areas along the north coast and in middle and southern Baucau district (Figures 43-44).

Figure 43. Stratigraphy of West Timor showing the Indonesian nomenclature. The same rocks occur in East Timor but with different formation and terrane nomenclature.

1. Indonesian stratigraphic revisions

At the outset it should be noted that the stratigraphy of East Timor is poorly known in spite of the mapping by Audley-Charles (1968) and others. The sequence is still in question. The Indonesian work that followed has revised some of the stratigraphic names but has accepted the general sequence worked out by Audley-Charles (1968). The Indonesian work follows some of his mapping in areas where detailed field mapping work could not be carried out because of the insurgency. Indonesian revisions that appeared in the maps of East Timor published in the 1990s are not reviewed herein.

Some workers questioned the sequence on the basis that it did not recognize the structural complexity of the island or misinterpreted the origin and distribution of thrust sheets and their interrelationship. For example, the Aileu and Maubisse formations were considered allochthonous units by Audley-Charles (1968) but are interpreted as paraautochthonous Australian units by Bachri (1995). The extensive distribution and internal geologic characteristics of the mélange sequence need more
study. Audley-Charles (1968) may have mistakenly mapped some of the largest exotic blocks in the mélange as separate units. Hamilton (1979) described the whole island as “tectonic chaos.” His summary statement of the geology is as follows. “The island consists of….widely different rocks – deep and shallow-water sediments of all ages from Permian to Quaternary, metamorphic rocks including high-pressure types, ophiolites, continental crystalline rocks, and others – are jumbled together in mélange and imbricated terrain. This chaos is a product of the collision of the Banda Arc with the Australian shelf.” In other words it is an “incoherent sheared complex” (Hamilton, 1979). If true, his analysis would render most of the stratigraphy described below as incorrect. The lithologic descriptions and ages should be valid but the sequence may be wrong. In a sense, the “units” that are described below represent a kind of rock catalogue of the different rock types of Timor. The descriptions are still valid but the sequence may be wrong. The history that has been reconstructed by Audley-Charles (1968) from this sequence probably is inaccurate, especially with regard to the thrusting and orogenic history.

B. Stratigraphy of East Timor as Interpreted by Audley-Charles (1968)

1. Permian

Atahoc Formation

The oldest rock unit is a 600 m thick shale of Permian age, the Atahoc Formation with its type locality at Atahoc village. The formation is considered to be an autochtonous unit, a unit formed in place by sedimentation in Permian time. The unit is exposed in only a few places in East Timor such as in the Loi Quero anticline in Los Palos district.

The dominant lithology is hard black pyritic shale with a basal member of hard, unfossiliferous pink and grey massive quartz sandstone with minor intercalated black shale is exposed in Cribas village. The environment is that of a flysch or deep quiet water deposit deposited mainly as turbidity current sediments although graded bedding is not present. Sedimentary structures include current ripple-laminations. Sediments of this type may occur on steep slopes rom coastal environments to great depths. The formation is overlain conformably by the Cribas Formation. A sparse fauna indicates Lower Permian age.

Cribas Formation

Rocks of this unit are exposed in the Cribas and Loi Quero inliers and in four other inliers. The type locality is in the valley of the Sumasse River where it cuts the Cribas anticline in north central East Timor. The unit is also exposed in the Bazol anticline, the Viqueque inlier, the Aliambata anticline, the Loi Quero anticline and the Veru anticline.

The lithology is silty shale with calcareous and clay-ironstone nodules. The base consists of pyritic black and blue-grey shales, micaceous siltstones and greenish fine quartz-sandstones with red and green shales occurring in the middle. Limestone
occurs commonly at the top of the unit. Lavas and tuffs are rare and commonly deeply weathered. Its thickness is about 500 m. The unit overlies the Atahoc Formation conformably in the Loi Quero inlier but its base is rarely seen in other places. Its contact with the overlying Aitutu is not clear and may be tectonic in some places and unconformable in others. *Halobia* occurs in the overlying beds indicating they are of Triassic age. The Cribas contains crinoids, brachiopods, gastropods and bryozoa. The environment was shallow marine but the shales were deposited not far from shore as indicated by the presence of lignite and plant remains as well as the marine fossils.

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 arenites may be to the south in the area now occupied by the Sahul shelf because they are fresh indicating first-cycle deposits.

### 2. Triassic

**Aitutu Formation**

The type section is the Aitutu anticline between Maubisse and Same in Aileu District along the Wai Luli River. This formation is about half of a 2000 m thick sequence of what was once termed “autochthonous Triassic” and “Complexe Trasico-Jurassique” by Grunau (1953). These shales and sandstones are a flysch sequence bearing a basal radiolarian limestone with *Halobia* and *Monotis* indicating an Upper Triassic age. Stratigraphic columns of this unit are extremely generalized. The lower unit, the Tallibelis Member, is the most conspicuous unit and rests unconformably on the underlying Aitutu Formation. It is commonly represented by 50 m of dense, very fine-grained radiolarian calcilutite with well-developed burrowing structures. The lowermost unit forms a rugged, lightly vegetated escarpment. The top of the Aitutu Formation is conformable with the Wai Luli Formation.

Large parts of the Triassic-Jurassic terrain mapped by earlier workers are a Miocene gravity-slide deposit containing huge exotic blocks of Mesozoic and other rocks. The gravity slide unit is the Bobonaro Scaly Clay, a ‘wildflysch” deposit. Audley-Charles (1968) noted that many workers had confused the Triassic-Jurassic shales with the Bobonaro Scaly Clay. Fossils are rare. Following individual units of the formation in the field is impossible because of minor folding and faulting, a characteristic of all of the rocks of East Timor.

The environment is marine as indicated by the microfauna and macrofauna. The calcilutites and interbedded shales, 95 percent of the formation, suggests the absence of strong currents. About 80 percent of the 1000 m thickness of the unit consists of calcilutite that was probably inorganically precipitated from seawater by plankton as calcium carbonate. The macrofauna is impoverished. Conditions were unfavourable for benthonic organisms. Regional paleogeographic studies indicate that Timor occupied a central position in a closed anaerobic basin like the Black Sea (Audley-Charles, 1968). But interbedded calocarenites containing oolites and calcareous algae indicate a Persian Gulf or Bahama type environment.
3. Jurassic

Wai Luli Formation

The unit is predominantly clay consisting of marine shale, marl and fine-grained limestone with a sparse fauna ranging from 600 to 1,000 m in thickness. The unit was termed the “autochthonous Mesozoic”. Later it was shown that much of the so-called “Mesozoic” consisted of the Bobonaro Scaly Clay, a Miocene melange sequence (Audley-Charles, 1968).

The type locality is in the valley of the Wai Luli River where it flows along the axis of the Aitutu anticline. Most of the unit is shale. Basal units are blue-grey marls and calcilutite bearing worm burrows and ammonites. The middle part consists of micaceous shales and calcilutite. The upper part is dominated by marls, shales and quartz arenites. The uppermost unit is a coarse conglomerate containing pebbles of the Aitutu Formation up to 25 cm in diameter.

The unit rests conformable on the underlying Aitutu Formation and is overlain unconformably by rocks of Cretaceous or younger age (Audley-Charles, 1968). Its environment is shallow marine as indicated by the presence of algal pisoliths, oolites and skeletal sand. Locally the environment may have been highly saline as indicated by the presence of pyrite, bituminous horizons and gypsum.

4. Cretaceous

Wai Bua Formation

The type locality is near the village of Wai Bua, 5 km north of Betano. Exotic blocks of this unit are found in the Bobonaro Scaly Clay (Audley-Charles, 1968).

The unit is made of radiolarian marls and phosphatic shales with interbedded colored cherts of Lower Cretaceous age as indicated by the radiolarians. The shales contain manganese nodules and pyrolusite-rich mud suggesting a bathyal environment far from land. Structure has obscured its true thickness and no more than 20 m can be seen in any one locality but its true thickness may be about 500 m.

The fauna indicates open sea conditions but depth of water is estimated to be about 200 m. The absence of burrows suggests a thick pelagic deposit.

Borolalo Limestone

The type locality is in a hill north of the beach at Aliambata. The unit consists of massive to thick-bedded pink calcilutites with abundant brown stylolites and large foraminifera. The thickness of the unit ranges up to 200 m in the type section. Red and black chert nodules and veins cut the bedding.

The unit rests unconformable on the Middle Jurassic shale of the Wai Luli Formation. The contact with the overlying unit, either the Lower Miocene Aliambata Limestone or the Bobonaro Scaly Clay of Middle Miocene age is also an
unconformity. The environment is pelagic. Consequently, Audley-Charles (1968) concluded that Timor was distant from any land during the Upper Cretaceous.

**Seical Formation**

The type locality is at the mouth of the Seical River. Its lithology consists of radiolarites, shales, cherts and marls. 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 is bathyal as indicated by ferromanganeseiferous foraminiferal limestones and graded arenites that suggest turbidity currents were active.

5. Eocene

**Dartollu Limestone**

The type locality is a 100 m thick limestone in Dartollu village in southwestern Timor. The Dartollu rests unconformably on the Aitutu and Wai Luli formations without any intervening tectonic slices. The Dartollu Limestone is part of a sequence that was lumped with the overlying Barique Formation (Oligocene) by Gageonnet and Lemoine (1958). The two formations, collectively termed by them the “Série de Samé”, were considered to be shallow-water marine limestones and eruptive rocks that had been thrust to their present position. Later work showed that in the type locality, Gageonnet and Lemoine had confused the Barique Formation volcanics with the Lolotoi Complex eruptives (Audley-Charles, 1968). The Dartollu lithology consists of thick bedded, brown biocalcareites containing calcareous algae, foraminifera and, locally, echinoderm fragments. The environment of the unit is considered to be a shallow marine reef.

6. Lower Eocene Tectonic Event

In the Lower Eocene a major period of thrusting occurred and great tectonic slices of the Lolotoi Complex were emplaced on the island. These blocks were broken from the upper crust as the leading edge of the Timor Island continental fragment was subducted below the southern edge of the Eurasian plate (Audley Charles and Carter, 1974). The emplacement of these thrust sheets in the Eocene resulted in intense folding and uplift creating both the Inner Banda Arc and the island of Timor. Erosion followed and much of the pre-Eocene and older record was removed.

The Lolotoi Formation is pre-Permian in age and consists of weakly to moderately metamorphosed rocks ranging from sedimentary rock to gabbro and dolerite eruptive rocks. The common metamorphic rocks are phyllites, schists and gneisses that are strongly fractured and range up to 1,000 m in thickness.

7. Oligocene

**Barique Formation**
The type locality is the Quique River valley south of Barique village. The thickness of the unit is estimated to be about 300 m (Audley-Charles, 1968). Early workers (Grunau, 1953; Gageonnet and Lemoiné, 1958) had lumped this unit was the Dartollu Limestone and with thrust sheets of the Lolotoi Complex (Maubisse Formation of Audley-Charles, 1968) and part with the Bobonaro Scaly Clay. Later work by Freytag showed that the Barique Formation was an in situ unit.

Nine km east of Aliambata the Barique Formation crops out in the Cai Dilla Laly River where it consists of a basal tuffaceous boulder-conglomerate overlain by tuffs and lava. The tuffs consist of fragments of basalts and serpentinites. Feldspathic dacitic tuffs are composed of feldspar laths with quartz, pumice and glass. Minor interbedded foraminiferal quartz-sandstones occur. The sandstones are well developed south of Mt. Cablac. The basalt chloritic and carbonate alteration. Andesites with zoned feldspars are common. Pillow structures can be seen locally.

Serpentinites occur in the type-locality and also near Mts. Bibiliu and Cablac. They are massive, tough and dark to greenish-black. Pyroclastics are dominant in other areas.

Around Lacluta village the Barique Formation rests unconformable on the Lolotoi Complex, which was thrust to its present position in the Lower Eocene. The unit rests unconformably on the Dartollu Limestone, the Lolotoi Complex, the Aitutu or the Wai Luli formations.

The unit is overlain unconformably by the Cablac Limestone of Lower Miocene age or the Barique Formation. Stratigraphic relations indicate the Barique Formation must have been erupted between the Upper Eocene and Loswer Miocene.

The basal conglomerate contains boulders of Dartollu Limestone with foraminifera of Upper Eocene age suggesting the Barique is Oligocene in age. Consequently, a period of erosion followed the deposition of the Dartollu Limestone before the deposition of the Barique volcanics.

The environment is marine as indicated by the conglomerates, tuffs and sandstones with foraminifera. Also, the presence of pillow structures in some of the lavas indicate a submarine eruptive. Audley-Charles (1968) suggests that the lavas and tuffs of the Barique Formation were derived from the present site of the volcanic Inner Arc (Wetar and Alor, among others). The active volcanic arc was close to the north coast of Timor.

8. Lower Miocene

Cablac Limestone

The type locality is located at Mt. Cablac in the central range, Viqueque district. The formation forms the mountainous spine of East Timor trending ENE-WSW. Several peaks of the central range rise to elevations between 1500 m and 2400 m (Figure 44a).
Figure 44a. Looking south from near Baucau. The flat surface is a raised coastal plain made of the Baucau Limestone (Pleistocene). The rugged mountains in the distance are capped by the Cablac Limestone (Lower Miocene).

The unit consists of grey, hard, massive limestones of several types: calcilutites, oolitic limestone, calcarenite and intraformational conglomerate ranging up to 400-600 m in thickness. Dolomitization and silicification are common. The unit makes a precipitous escarpment. The unit rests unconformably on the Oligocene Barique or Lolotoi formations. An overlying unit is rarely present because the Cablac usually occupies the top of a mountain but in a few places it is unconformably overlain by the Bobonaro Scaly Clay.

A very shallow marine environment is indicated by calcareous algae, coral fragments etc. Audley-Charles (1968) compares its environment to the present Bahama Banks.

Aliambata Limestone

The type locality is the top of Borolalo hill called north of Aliambata. The hill is also the type-locality for the Upper Cretaceous Borolalo Limestone.

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

9. Upper Miocene

Viqueque Formation

The type locality for the Viqueque Formation is the hill area behind Viqueque village and the Cua River valley where the lower part of the unit is about 130 m thick
and the upper part 370 m (Audley-Charles, 1968). The Viqueque anticline is cut by the Cua exposing the Viqueque Formation in the axial area of the structure.

The rocks are distinctive. They consist of 130 m of massive white marl and grey claystone interbedded with a few chalky limestones and rare vitric tuff. The colour is distinctive and it is readily identifiable on air photos because the rocks weather white and form a white clayey soil (Figure 45). The lower part is formed of claystones and white soil with sandstones becoming increasingly important upwards. The lower part contains two or more 3 m thick vitric tuffs.

Figure 45. Outcrop of white clay in Lautem District. This unit is characteristic of the clays in the Viqueque Formation.

The base of the unit is an unconformity. Generally, the unit rests on the Middle Miocene Bobonaro Scaly Clay but locally it rests with angular unconformity on other units. The unit is overlain conformably by the Seketo Block Clay and the Dilor Conglomerate. These two units together with the Viqueque Formation are overlain unconformably by the Baucau Limestone and the Suain Formation of Pleistocene to Holocene age. The age of the formation is Upper Miocene to Pliocene; on the basis of its microfauna. The unit is marine.

An orogeny preceded the deposition of the Viqueque Formation resulting in the placement of large thrust sheets of Permian rocks and the plastering of a huge gravity-slide deposit, the Bobonaro Scaly Clay, over most of the island of Timor. The Viqueque is a typical molasse deposit deposited following the Miocene orogenic episode.

When Viqueque deposition began Timor had been submerged and covered with the Bobonaro Scaly Clay. As the island began to emerge the Bobonaro Scaly Clay provided the muds of the lower Viqueque Formation. The coarsening of the grain size of the Viqueque upwards indicates the beginning of the regressive cycle and the shallowing of the marine basin followed by the gradual emergence of the island.
After significant uplift the rocks below the Bobonaro Scaly Clay emerged and began to be eroded. These were eruptive and metamorphic rocks that provided the coarse detritus of the upper Viqueque siltstones and sandstones. Local slumping accompanied emergence and slide deposits are also found in the upper Viqueque. In the Miocene – Pliocene the elevation of the island continued and it reached a height of 2500 m above mean sea level in about six million years.

**Lari Guti Limestone**

9. **Pliocene**

The type locality is a cliff sequence on the west side of the Lari Guti Pass between Lari Guti and Wai Neti mountains. The unit is a sequence of yellow calcarenites and thin coral reef rocks ranging up to 75 m. The unit is dated as Middle Miocene based on abundant foraminera. The environment represents a shore facies of beach material or a coral reef similar to the north of coast of modern East Timor.

**Dilor Conglomerate**

The type section of the Dilor Conglomerate is located along the axis of the Dilor syncline south-east of Dilor village where it is about 300 m thick.

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

**Seketo Block Clay**

The type locality occurs in the valley of the Sketo River south of the Builo Range. Good outcrops also are found in the axis of the Bibiliu syncline where it is about 20 m thick.

The lithology 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 overlies the Viqueque Formation everywhere and, locally, may overlie the Dilor Conglomerate.

10. **Late Pliocene Folding**

The Viqueque Formation was folded in the Late Pliocene 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
10. Late Pliocene Folding

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11. Post-Pliocene

Baucau Limestone

The Baucau Limestone consists of grey, hard, cavernous, massive white coral-reef limestone well developed around Baucau town.

The flat lying Baucau Limestone controls the topography in the Baucau and Lautem plateaus. A continuous outcrop occurs along the north coast (Figure 46). In the southern foothills, the Baucau Limestone also crops out in scattered hills. The limestone occurs in four aspects: coral-reef, calcirudite, calcarenite and greywacke-pebbly sandstone facies.

Figure 46. Outcrop of Baucau Limestone two km east of Cum (Lautem District).

The Baucau rests unconformable on older units everywhere. It overlies the Viqueque Formation but locally is found on older formations.

The thickness of the unit varies but is estimated to be about 100 m. Its elevation is reported to range from sea-level (Figure 47) to about 500 m on the
plateaus. Umbgrove (1938) reported an elevation of 600 m and Gageonnet and Lemoine (1958) about 1,000 m. Leme (1963) noted a reef of Baucau Limestone on Atauro island at an elevation of 1,300 m above msl. The highest and oldest terraces are regarded as Pleistocene. The younger terraces occur at progressively lower elevations toward the coast. The Holocene reefs occur also at the present shoreline.

Along the north coast of Baucau District there is a series of raised beaches (Figure 47). The various terrace levels reflect the stages of Timor’s uplift history, the highest terraces being the oldest.

Poros Limestone

The type locality of the Poros Limestone is near the village of Poros, the centre of the Lautem plateau where it is about 20 m thick.

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

Suai Formation

The type locality of the Suai Formation is located around Suai village on the south coast where test well data indicate it has a rudite and arenite section of about 600 m in thickness. The unit can be seen along the coast from Aliambata in the east to the boundary with West Timor.

The unit is poorly exposed and not well known. It is accessible only by drilling. In the Matai No. 5 test hole, north of Suai village, the sediments are rudites
and arenites ranging to gravels. Foraminifera are common in this 600 m thick unit but they represent a death assemblage and were derived from elsewhere.

It may reach 1,000 m in thickness on the coastal plain between Betano and Aliambata.

**Ainaro Gravels**

The type locality of the Ainaro Gravels occurs in a river terrace about 800 m above 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 of Timor (van Bemmelen, 1949; Audley-Charles, 1968).

**C. Stratigraphy of the Eocene Thrust Complex**

**1. Lolotoi Complex**

The Lolotoi Complex is one of the most famous rock units in East Timor. It has been referred to as follows: North Coast Schists, Manufai Diabase, Crystalline Schists and Ophiolites (Figures 48-49). Some workers lumped the unit with the Barique Formation (Grunau, 1953; Gageonnet and Lemoine, 1958). The type locality of the Lolotoi Complex is the valley of the Foho Ra River south of Lolotoi village.

In East Timor there are four thrust sheets. The thrusting post-date 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, one of the major structures that Timor Oil Ltd., drilled in the 1950s. A single sheet may reach 1,300 m in thickness, which is not the maximum thickness because of isoclinal folding.

![Figure 48, Outcrop of schist showing thin bands of argillitic sediment in east Dili town on beach road.](image-url)
The unit consists of sedimentary and eruptive rocks that have a low grade of regional metamorphism. The unit is mainly phyllite but schist, metagabbro, dolerite and gneiss are also present. Eruptive rocks such as gabbro and dolerite are present.

The Lolotoi Complex is a displaced or allochthonous unit. The unit rests on autochthonous pre-Eocene rocks in the Mac Fahic Antcline and the Pualaca Syncline in the western part of East Timor. The units in the thrust include: Aitutu and Wai Luli formations (Mac Fahic anticline), Cribas and Aitutu formations (7 km east of Lolotoi).

The metamorphosed Lolotoi sequence rests on unmetamorphosed sedimentary rock and the only explanation for this is overthrusting (Figure 50).

Figure 49. Drag folds in the Ailue Formation, east Dili.

Figure 40. Melange below the Lolotoi thrust sheet west of Manatuto.
The level of metamorphism and isoclinal folding in the unit indicate that it is the product of a major orogeny, assumed to be Pre-Permian. The Lolotoi Complex could be as old as Precambrian and include major copper occurrences (Figure 51).

2. Dating the Emplacement of the Lolotoi Thrusts

The youngest rocks overlain by the Lolotoi Complex are the Middle Jurassic shales of the Wai Luli Formation as can be seen in the Aitutu anticline 5 km west of Pualaca (Audley-Charles, 1968).

Folds that are overlying the Lolotoi Complex are as young as the Wai Bua Formation (Betano region) dating the Lolotoi as post-Wai Bua Formation or post Senonian. The rocks found resting on the Lolotoi Complex are (i) Middle and Upper Eocene Dartollu Limestone (near Dartollu village), (ii) the Barique Formation (Oligocene eruptives) and (iii) the Cablac Limestone (Lower Miocene massive and oolitic limestones). The age limits of underlying and overlying units indicate the Lolotoi Complex was thrust into its present position within a time range extending from post Senonian to Middle Eocene.

Figure 51. Outcrop of serpentinite in the Lolotoi thrust sheet. This unit is mineralized with a Cyprus type massive sulfide type deposit at this locality in Viqueque District (Ossarua village).

However, before the thrusting the autochthonous units were folded and deeply eroded during the Timorean Orogeny, which began during the same time interval but before the thrusts arrived. Audley-Charles (1968) suggests that the thrusting probably occurred during the end of the limiting time frame or in the Middle Eocene.

D. Stratigraphy of the Miocene Thrust Complex

1. Aileu Formation
The distribution of the Aileu Formation is restricted to a 80 km by 30 km belt on the north coast both east and west of Dili to the Indonesian border.

Van Bemmelen (1949) had lumped these rocks with the Lolotoi Complex.

The type locality is the area around Aileu town. The lithology there includes low grade metamorphosed eruptive rocks but an altered schist is also common. The eruptives also are well developed around Emera town. The Ailue is well exposed west of Manatuto on the coast highway where it appear as weakly foliated dark green ultrabasic rock, probably part of an ophiolite sequence.

Some of the Aileu units are serpentinites which appear to be parts of thrust sheets or blocks inserted amidst a variety of thick volcanics, melange and at least one diorite intrusion (Figure 52). The serpentinites invariably are sheared and bounded by mélange units.

Figure 52. Outcrop of white diroite in a mélange sequence of the Aileu Formation (Permian) on the Dili-Manatuto Road about 13 km west of Manatuto.

Around Aileu they tend to be light-coloured shales that weather red due to argillic alteration (Figure 53). Slate and argillite also are common near Dili (Figure 50). Quartz-phyllites are interbedded.
Figure 53. Redbeds of the Aileu Formation are common in outcrops along the winding mountain road between Dili and Aileu. The red color is the result of argillie alteration of low-grade metamorphic rocks. Locally, the unit consists of red or white clay, which might be suitable for ceramic ware.

The United Nations Mineral and Hydrocarbon Mission to East Timor in May-June 2002 examined the base of the Aileu thrust sheet about 12-14 km west of Manatuto on the coast highway and discovered a sequence of ultrabasic rocks very similar to the Mutis Zone of West Timor (Wiryosujono and Tjokrosapoetro, 1978) (Figures 54-56).

Figure 54. Coast road exposures showing a range of lithologies in the Aileu Formation in Manatuto District about 13-15 km west of Manatuto town. The red weathering unit is typical Aileu schist and the white unit is a volcanic sequence of pyroclastics. Slivers of bouldery mélangé are present. Serpentinites are abundant one km further east.
Figure 55. Outcrop of boulder mélange of the Aileu Formation. Note ultramafic boulder in centre of the photo. The outcrop is located about 13 km west of Manatuto.

Figure 56. This ultramafic inclusion bears a close similarity to a volcanic bomb surrounded by evenly bedded quiet water sediments. It occurs in a sequence of weakly metamorphosed phyllite and schist of the Ailue Formation on the Dili-Manatuto Road.

The base of the overthrust Aileu klippe is characterized by sheared and serpentinized ultramafics and mélange (Figure 57). Serpentinite occurs as slickensided blocks with calcite coatings on the shear zones. The rocks were dominantly serpentinite. This sequence could be traced from near sea level to a height of almost 300 m above mean sea level.
Allied Mining Company, a Hong Kong based company led by Dutch entrepreneurs, prospected for and discovered chromite in the serpentinite part of this block in 1936 (Whittock, 1937). The thickness of the serpentinite unit ranges from 1-3 km. Overlying (?) the serpentinite zone was a sequence of weakly foliated greenstone and gabbro which in turn was overlain by extrusive rocks (tuffs and agglomerate), basaltic pillow lava, diabase and amphibolite schist locally intruded with diorite.
About 3-4 km west of the serpentinite locality, the volcanic sequence grades into a thick marble belt, which had been quarried in the early 1990s. The marble was exceedingly pure, a striking snow white. More than 100 quarry blocks, of about 8 cu m each, were scattered over the hillside of the abandoned quarry. Farther west the sequence became less metamorphosed and grades into sediments and weakly metamorphosed phyllite, slate and massive siltstone and meta-mudstone in Dili along the coast road at the east edge of town. The entire sequence is about 25 km thick. The sequence appears to include layers 1 and 2 of the three layered sequence typical of oceanic crust and upper mantle, only lacking the pelagic sediment cover of radiolarian chert and calcilutite to make it a complete ophiolite suite (Penrose Field Conference, 1972; Shor and Raitt, 1969; Le Pichon, 1965). The sequence approaches the criteria for an ophiolite.

The age of the Aileu Formation near Maubisse is based on pelecypods similar to those of the Permian Cribas. More work needs to be done to confirm this age assignment.

The original environment probably was a thick sequence of shale and sandstone.

2. Maubisse Formation

The type locality is southwest of Maubisse village (Figure 59). The unit is widespread in East Timor. The limestones are well-bedded and consist of dense beds and massive reefs (Figure 60). 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 m of basalt is found on Mt. Ramelau.

Figure 59. 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.
The signature of this unit between Dili and Aileu is its deep red appearance due to significant argillic alteration. Many of the exotic blocks in the Bobonaro are made of Mauabisse Limestone.

The environment of deposition was shallow marine. Reefs indicate warm clear water. The intraformational conglomerates indicate currents were active in the depositional area. The contrast of Permian reef limestones so close to Permian glacial deposits in northern Australia 1,000 km distant have served to emphasis Audley-Charles concept that the Maubisse reef limestones were derived from a distant location to the north because the thrust planes dip north.

Audley-Charles (1968) insists that the Maubisse was thrust from the north onto Timor but this concept has been challenged by Hamilton (1979) due to lack of structural and stratigraphic evidence. Paleomagnetic data collected by Chamalaun and others indicates these rocks were originally part of the Australian continent. Recent work suggests that the Ailue and Maubisse may be facies of on another.

Figure 61. Outcrop of highly fractured Maubisse limestone 6 km north of Maubisse.
Figure 52. Recrystallized reef-rock of the Maubisse Limestone 6 km north of Maubisse town.
Part XI.

Tectonic History of the Timor Area
A. Summary

1. Breakup of Gondwana

The Australian Continental Plate including the present Sahul Shelf drifted northward as a single block beginning in the Permian when Australia was rifted away from Gondwanaland, the primordial southern continent. The movement was due to plate tectonic displacement probably related to convection currents in the mantle. A second stage of rifting occurred under the margin of the northward drifting plate in the Late Cretaceous. A fragment or sliver continental crust containing the basement of Timor Island broke away from the Australian plate as a new rift developed in the Wharton basin. The micro-continental fragment continued to move northward. It was preceded by a deep forearc basin of oceanic crust and was characterized by passive margin sediments on its trailing edge which was also underlain by oceanic sediments and, presumably, oceanic crust. The movement of the “Timor microplate” is unobstructed until it meets the edge of Eurasia in the Eocene when it collides with a mixed oceanic-continental crust. The resulting orogeny creates the volcanic Inner Banda Arc Islands, a sequence of microplates containing a mixture of continental and oceanic floored crust.

2. Eocene orogeny and creation of Inner Banda Arc

Collision occurred in the Eocene between the outer edge of Timor microplate (represented by Timor Island and other islands of the non-volcanic Outer Banda Arc). The islands of the Inner Banda Arc were geologically more closely related to the edge of the Eurasian Plate and were primarily volcanic. The orogeny resulting from this collision is called the Timorean orogeny. The Inner Arc is the eastward continuation of the volcanic Sunda Arc (Sumatra, Java and the Lesser Sunda Island) and consists primarily of volcanic rocks.

3. Accretion and creation of Outer Banda Arc

The outer edge of the Timor microplate included Timor Island and other islands of the Outer Banda Arc such as Savu, Roti, Leti, Moa, Babar, Tanimbar, Kai and possibly Seram and Buru. The Outer Banda Arc is separated from the present edge of the Australian continental shelf by the narrow Timor Trough and a little over 100 km of shallow sea before reaching the edge of the Sahul Shelf. The Outer Arc islands consist primarily of islands made of mostly carbonate sediment with some pelagic mud and deep water terrigenous material. This sequence can be seen to extend round the north side of the Banda Sea. The Timor Trough is Mesozoic in age. Some seismic evidence indicates that the cratonic sequence of the Australian mainland passes beneath the trough as an uninterrupted sequence with marker beds that are not highly deformed but some seismic records show considerable disturbance of the sediments on the slope of the south side of the Trough. The trough was affected by the collision of the Outer and Inner Banda Arcs and may have migrated and narrowed at this time.

4. Role of the Timor Trough subduction zone
Some parts of the rock record of the Outer Banda Arc islands, especially in Sumba and in the Sahul Shelf of Australia (e.g. northern Bonaparte Basin) have not been altered significantly since the beginning of the Permian indicating that no subduction occurred between Australia and the Timor Trough. However there is an ongoing debate as to whether subduction is taking place in the Timor Trough today or whether it ever did in the past. Seismic evidence (Beck and Lehner, 1974) indicate that the principal seismic reflectors encountered in seismic profiling across the Timor Trough can be traced northward beneath it below water depths of 600-2,000 m. Evidence of compressional folding and imbrication is seen on the north side of the Trough (Beck and Lehner, 1974 in Audley-Charles and Carter, 1974). But high angle thrust faulting is also seen there. Seismic evidence (Beck and Lehner, 1974; CCOP-IOC, 1974) indicate that Mesozoic and Permian strata underlying the Australian shelf extend northwards beneath the trough continuing toward the Outer Arc islands. This is of interest if the Bonaparte stratigraphic sequence can be traced into the island of Timor.

5. Relation of Timor geology to the Bonaparte Basin

Recent work in the Bonaparte Basin shows a number of major grabens trending northward toward the Outer Arc. These grabens have thickened Devonian and Carboniferous sections indicating that they originated in the Middle Paleozoic. Structural highs within the grabens are important gas production centres in the East Timor Gap area. The presence of such grabens beneath the Permian thrust sheets in East Timor cannot be ruled out. A number of geoscientists such as Fitch (1972), Hamilton (1973), Katili (1973) and Warris (1973) interpret the Timor Trough as a subduction zone. If their interpretation is correct, it would be impossible for the hydrocarbons to migrate toward Timor unless such migration occurred before the development of the Trough, i.e. in the Devonian or earlier.

6. Collision of Australian plate with Outer Banda Arc

The Outer Banda Arc islands located at the leading edge of the northward drifting fragment or sliver of the Australian plate were the first to collide and deform as a result of the collision. Consequently, northernmost elements of the Outer Banda Arc islands should contain evidence of strong deformation and rocks that are not typical of the Australian cratonic sequence. Some of the rocks of the Island should come from the Outer Banda Arc creating a melange or chaotic mixture of sediments, metamorphic rocks and volcanics. There should be a noticeable difference between the Inner Banda Arc islands rock suites and the northernmost parts of Outer Banda Arc islands unless these areas were overridged by later low angle overthrust sheets.

7. Orogenic processes leading to mineralization in the Outer Banda Arc

The collision of the Australian plate with the Outer Banda Arc has resulted in metamorphism and volcanism. East Timor contains economic minerals that are generated by these processes. Examples of such minerals include precious and base metals as well as minerals resulting from the alteration caused by volcanic activity. Deep seated mantle derived rocks would be likely to contain gemstones such as diamonds, rubies and sapphires which might possibly be present in East Timor.
streams and nearshore waters because such rocks are now exposed in parts of the thrust belt. High, medium and low temperature metamorphic minerals have been developed as the temperatures and pressures dropped (retrograde metamorphism) after mountain building episodes. Wherever these rocks are uplifted and thrust toward East Timor, it is conceivable that these economic minerals exist within the rocks of the island. Some workers argue that the northernmost thrust sheets found on Timor Island show profound close relationships to the rocks of the Australian mainland although they have been metamorphosed, highly deformed and thrust over sheets of mélangé and pelagic material to their present positions. These workers would argue that Timor is an accretional mélangé of most Australian rocks that have been metamorphosed to medium and high grades of metamorphism although they are mixed with deep sea floor sediments that were thrust up with them.

8. The on-going debate

One school of thought, perhaps originally lead by Hamilton (1979) would argue that the collision of the two Arcs results in underthrusting of the Australian plate and associated foredeep sediments beneath the Banda Arc with slices of the the older cratonic sequence resting on the north edge of the down-going Australian plate being thrust northward and over the original younger, mostly shallow water oceanic sediments of Timor. Inasmuch as the thrust sheets were lubricated with mélanges under high hydrostatic head, some of the compressional stress would be released. The sediment pile on Timor Island is compressed but the folds in the Neogene sediments found in the mountainous spine of the island appear not to be overturned in the sense of nappes. The characteristic structure there is broad, upright anticlines and synclines originating from Timorian or later orogenies. The Neogene orogeny have caused basement blocks to move upward. Deformed and uplifted basement blocks affected the overlying carbonates and pelagic sediments draped over them. The result is the breakup of the axial areas of many structures into complexly faulted zones of high angle thrusts, as well as horst and graben block faulting that apparently followed relaxation of stresses in the Pleistocene-Recent.

9. Miocene thrusting of Australian cratonic rocks onto the Outer Banda Arc

The Miocene collision resulted in strong metamorphism and the Permian sediments of the Australian cratonic sequence were converted to schists and other high grade metamorphic rocks as the fragments of the Australian plate collided with the Timor complex. Up-thrusting of these metamorphic rocks toward the north resulted where the Australian plate met the Timor micro-plate. According to traditional subduction theory, the sediments that are converted to metamorphic rocks are scraped off the down-going (subducted) edge of the Australian plate and piled up before the colliding mass but the main cratonic rocks of Australia are either obducted or collide head-on with Timor rocks because of their lower gravity and compressive forces have thrust them upwards and northwards to cap the highest mountains in Timor. On the north side of Timor microplate in the Inner Banda Arc subduction zone, the metamorphic rocks that were generated in the subduction zone are displaced upwards and placed above unmetamorphosed Permian and Mesozoic strata of Australian cratonic and oceanic shelf facies. These cratonic schists and phyllites can be seen lying inter-slivered with tectonic mélanges and ultramafic rocks of
serpentinite, dunite and peridotite along the coast highway eastwards from Dili to Manatuto and within Dili district itself.

10. Origin of the metamorphic rocks on Timor

The similarity of the metamorphic rocks throughout the islands of the Outer Banda Arc suggests they are all allochtonous (derived from the distant indigenous rocks of the Australian plate) like those of Timor. That is, they were derived from the metamorphism of Australian cratonic (stable shelf) facies rocks, probably of Permian age. They were underthrust, at least initially, beneath the Inner Banda Arc complex along the entire meeting points of the two Arcs. Consequently, the economic base and precious metals and minerals that are found in Timor should also be present in the other islands of the Outer Arc.

The pressure-temperature conditions of the high grade meta-anorthosites in Timor suggest that they were formed near the crust-mantle boundary beneath a continent (Audley Charles and Carter, 1974). The coast highway east of Manatuto shows outcrops of ultrabasic rocks (serpentinites) which appear to lie in several stratigraphic positions with respect to the Aileu and Maubisse thrust sheets. The ultrabasic materials may intrude or be thrust over these allochthonous sheets in local areas suggesting a close spatial relationship with the development of metamorphism in the anorthosites and the Miocene overthrusting. It would also suggest that the metamorphics and ultramafics represent the true basement of Timor Island perhaps representing even Precambrian rocks that were at the base of the Australian sediment sequence.
Part XII.

Geological investigations, cruises, hydrocarbon and mineral exploration in Timor and adjacent seas – a chronology of events
A. Chronology of geological work done in the Timor area

Figure 63. Map of major crustal blocks of the Timor area. Source: Hamilton, 1979

1. 1900-1920

Early geologic mapping and exploration

The first map traverses in eastern Timor were carried out by Hirschi (1907) as a preamble to the drilling of several bore holes for oil in the 1910-1920s.

F. Weber investigated the oil potential in 1910-11. The results of his work were referred to by Umbgrove (1935) and Wanner (1956). Brouwer led a number of Dutch expeditions to the Indonesian islands and the Netherlands East Indies (Oost Indië) (the so-called Geological Expedition(s) to the Lesser Sunda Islands) beginning in about 1910. He published numerous papers including several monographs on the islands of the Banda arcs over the next 37 years in a Dutch publication series entitled Jaarboek Mijnwezen Nederlandsch Oost-Indië. Brouwer recognized six tectonic units. Many Dutch geologists contributed important papers to this series including a number by Dirk de Waard (1954-57) in the middle and late 1950s.
The concept of Alpine type overthrusts in Timor was first referred to by Wanner (1913) who published a monograph entitled *Geologic von West Timor* in 1913. Molengraaf (1913, 1914, 1915), a Dutch expert on the East Indies, agreed with Wanner with regard to overthrust tectonics in Timor and recognized four tectonic units.

**First wells drilled in search of oil**

Exploratory drilling for oil began in the first two decades of the 20th century. This was the beginning of long standing interest in the oil and gas seeps of Timor which encouraged investors to risk capital in test drilling projects. The first well was 140 m deep and was drilled in the Aliambata area, a place which was the focus of several more wells in the 1920s and more sophisticated drilling in the 1950s. A 170 metre well was drilled at Mata Hai in 1914. The Aliambata area was a popular exploration target because of the presence of oil and gas seeps and a mud volcano near the beach. Moreover, the nearshore area there was suitable as a boat anchorage and a logistical centre could be set up without too much difficulty.

**2. 1920-1940**

**More exploration wells for oil and gas**

In 1926-28 another well was drilled at Aliambata but went a little deeper to 220 metres. Again, the well was prompted by the proximity of nearby oil seeps.

**Mineral exploration**

The Allied Mining Corporation (AMC) carried out a fairly detailed geological reconnaissance of several areas along the north coast of eastern Timor and central-east Timor (Baucau-Viqueque districts). These areas were considered to have some economic mineral potential in 1936 (Whittouck, 1937). AMC completed an interesting and highly professional assessment of the metallic mineral occurrences they discovered. They reported the presence of precious metals, gold and silver, as well as copper and chromite but considered the occurrences unsuitable for further development.

**Paleontology**

A singularly important piece of work was Wanner’s synthesis (1914-1929) of the paleontological faunas of Timor published in a monograph entitled *Paleontologie von Timor*. This monograph attracted world-wide interest with its description and illustrations of an exciting and exotic Permian brachiopod fauna in Timor among other interesting faunas. The brachiopod fauna was considered to be similar to one known from Australia (Teichert, 1939). Wanner’s collections were probably from thrust sheets of Permian strata (Maubisse Limestone) now believed to be derived from Australia. This was the beginning of a major controversy because Audley-Charles and D. Carter (1974), Carter et al. (1976) and Barber et al. (1977), all considered the Permian faunas to have Asiatic affinities rather than Australian due to their presumed allochthonous origin and similarities to Asian faunal and floral assemblages.
Hamilton thought they were an Australian fauna after corresponding with a number of Australian paleontologists (Hamilton, 1979). On the other hand Runnegar (in a personal communication to Audley-Charles in 1976) insisted that the Permian brachiopod fauna had a close affinity to one known from Western Australia (Audley-Charles, 1978). Audley-Charles (1978) rejected his argument on the basis that the total aspect of the fauna and flora was closer to Asian families even though the brachiopods were similar to those in Western Australia. Later, Teichert changed his opinion and indicated that he believed the Timor Permian fauna was different from that of Western Australia and closer to faunas known from Sumatra, Kalimantan, Malay Peninsula and the Philippines (Teichert, 1941; Stauffer and Gobbett, 1972; Audley-Charles, 1978).

**Paleogeography**

Umbgrove (1938) and Teichert (1939) were the first to show that the presumed autochthonous rocks in Timor had been deposited in a Mesozoic geosyncline (the Westralia-Timor-East Celebes geosyncline) that contained facies and faunas uniquely different from those of western Indonesia and the Philippines (Audley-Charles, 1978). It was noted that the Mesozoic faunas were local in contrast to the Permian faunas presumed to have been derived from a distant location to the north and emplaced tectonically on Timor as a series of allochthonous imbricate thrust sheets (Audley-Charles, 1978). Prior to the work of Umbgrove and Teichert and after it as well (Smith et al., 1973) most workers had located the Tethys Ocean of Mesozoic age between the Outer Banda Arc and Australia suggesting that Timor and related islands of the arc were fixed to Asia.

3. **1940-1950**

**R.W. van Bemmelen’s work**

In 1949 a three volume synthesis and geological monograph entitled *The Geology of Indonesia* was completed by van Bemmelen (1949). Van Bemmelen had worked on the geology of Indonesia for more than 20 years and this publication pulls together most of the significant work done by the Dutch in Indonesia. This magnum opus will stand as the first compilation of the diverse and complex geology of the Indonesia archipelago and considered everything from volcanoes and earthquakes to mineral deposits. Timor is shown in cross-section as a complex sequence of folded thrust sheets piled one above the other and thrust to the north. Subduction is indicated by descending crustal slabs, the Outer Banda crust being subducted beneath the north edge of Timor.

**Companhia Ultramarine do Petroleo**

The Companhia Ultramarine carried out geological reconnaissance work in eastern Timor in 1947-48. The summaries of the geological mapping of H.R. Grunau, a distinguished Swiss geologist, and his colleague, F. Escher, were presented in a series of papers by Grunau (1953, 1956, 1957A, 1957B) including the important report entitled *Geologie von Portugiesisch Osttimor* that was published in the Swiss journal, Ecolgae Geologic Helvetiae in 1953.
Texeira (1952) carried out geophysical research for the Companhia Ultramarine do Petroleo which included a review and assessment of the significance of the gravity work of G. de Snoo who had carried out the first regional gravity survey in 1947-48.

Geological results of the gravity survey were published by Granau (1953, 1956, 1957a, 1957b). Gravity data were discussed by Teixera (1952).

Shell Oil Company

A regional gravity survey of Portuguese Timor was carried out by Shell in 1947/48 (Crostella and Powell, 1975). Several years of field mapping was also undertaken in Portuguese Timor by Shell Oil Company geologists but results were apparently not encouraging to the Company as no drilling was carried out.

4. 1950-1960

Timor Oil Ltd. (TO)

Timor Oil began operations in eastern Timor in 1956. The Company employed Audley-Charles as a consultant to map Portuguese Timor and supported his research work at the University of London. When they concluded their work in 1972, the company had drilled 21 wells many of them discovering modest amounts of oil and dozens of oil and gas shows (Crostella and Powell, 1975). See the period 1960-1970 below in the chronology of geological work compiled for this report.

Hydrocarbon exploration and more geologic mapping of Portuguese Timor by Gageonnet and Lemaîne

Robert Gageonnet and Marcel Lemoine published an important paper which summarized the results of their field work in the early 1950s. The paper Contribution à la Connaissance de la Géologie de la Province Portugaise de Timor: (Portugal) presented new stratigraphic and structural interpretations based on their geological mapping in eastern Timor in 1955. This work was followed by several other publications on east Timor by the same authors (Gageonnet and Lemoine, 1957B, 1957C, 1958).

Important field work was carried out to provide a basis for hydrocarbon potential by I.B. Freytage (unpublished, 1959). The work focused on central-southern East Timor (Portuguese Timor at that time). He revised the Tertiary stratigraphy and challenged earlier concepts of large scale overthrusting.

First geological map of Indonesia – scale 1:5,000,000

Klompé (1954) compiled a geologic map of Indonesia at a scale of 1:500,000,000 for the Geological Survey of Indonesia.

Heat flow in the Banda Sea floor
Bowin (Bowin and others, 1977) measured heat flow in the Banda Sea and found values that were typical of most Indonesian marginal basins. Heat flow values mostly were less than 1.5 microcal/sq cm/sec.

5. 1960-1970

**Timor Oil Company**

Twenty-one wells were drilled by Timor Oil Ltd. from 1957-1975. Some of the wells discovered hydrocarbons but the company said these were uneconomic. Many oil and gas shows were reported. One of the wells (Matai 1) yielded a “considerable” amount of oil and, today, when the valve on the well-head is opened, a fountain of oil and water is sprayed about 13 m, according to local villagers. As recently as May 2002 it was noted that trails stained with oil lead away into the bush indicating that local people are still collecting oil from this well for cooking or lighting purposes.

Exploration methods employed by Timor Oil Company were better than those carried out by companies in the early and mid-1900s. The early exploration methods by Timor Oil mainly relied on surface mapping in the mid 1950s (e.g. Alimabata No. 1). Detailed field mapping was carried out by a field party that was led by M. G. Audley-Charles who compiled the data further refining it for submission as a Ph.D. dissertation at the University of London (Audley-Charles, 1968). Gravity surveys, stratigraphic tests and coring were employed prior to the selection of drill sites for a number of wells during the late 1950s: Ossulari 1 and 1A, six Matai wells, Caro Ulo 1, and Ranuc 1. Field mapping and regional studies using air photos were employed prior to the drilling of Betano 1 and 2 (Crostella and Powell, 1975).

The Timor Oil Ltd. drilling programme was focused near the sea at Suai (Covalima district) because reflection seismic surveys indicated suitable structural and sedimentary settings were present. They carried out 248 km of single fold coverage in 1968 and 174 km of expanded coverage in 1970. As a result of favourable seismic data another eight wells were drilled; Cape Tafara 1, Cape Tafara East 1, Suai 1, 2 and 2A, Suai Loro 1 and 2, and Cota Taci 1 (Crostella and Powell, 1975).

Matai 1 was reported to yield 160 bopd and the company reported that Cota Taci 1 yielded 200 bopd. TOC regarded their interpretation of the local structure as tenuous and noted that previous unsuccessful drilling might have been due to improper interpretation of the field and geophysical data (Crostella and Powell, 1975).

Offshore geophysical work commenced in 1967. A total of 365 km of marine sparker survey was shot along the south coast for Timor Oil.

**International Oil Company (IOC)**

International Oil Company (IOC) began exploration of the Indonesian West Timor area in 1968. The IOC block covered an area of 5,047.91 sq km of Timor and adjacent waters off the south coast. The company committed to spend USD 2.45
million in 6 years (CCOP, 1976). The participant’s interest was 35 percent and B.O.C. (Australia) had a 65 percent interest and focused on both Timor and the Timor Sea. Their work included a 1,429 km offshore seismic survey from Kolbano to Kupang. The survey also covered the area between the Indonesian islands of Semau, Roti, Savu, Raidjua and Dana (Crostella and Powell, 1975). In 1970 International Oil Company carried out a seismic survey of six areas of Portuguese Timor: Aliambata (132 km), Beaco (323 km), Belu (208 km), Bena (291 km) and Savu (254 km). The 1970 work also included a seismic survey line of an additional 87 km in Indonesian Timor (Crostella and Powell, 1975). In 1972 IOC returned to West Timor, offshore Kolbano, and surveyed an additional 360 km. In spite of the considerable effort to obtain offshore data, the results apparently did not justify an offshore test and no drilling followed on behalf of either Timor Oil Ltd. or IOC.

**Woodside-Burmah Oil N.L.**

In 1974 Woodside-Burmah Oil N.L. joined International Oil Ltd. and Timor Oil Ltd. to carry out offshore geophysical exploration in the Timor Sea near the south coast of east Timor.

**B.O.C. of Australia Ltd. (BOCAL) - subsidiary of Woodside-Burmah Oil (N.L.)**

BOCAL was the operator of the joint venture of TO, IOC and Woodside-Burma beginning in late 1974 (Crostella and Powell). A number of reflection seismic surveys were carried out in offshore areas. Field surveys were used to map onshore areas in more detail. The work resulted in one deep offshore test, the Mola 1, which was drilled in early 1975. The test reached a depth of 3077 metres and was reported to be a dry hole. This test was the last onshore and offshore exploration activity in the east Timor area up to the present.

**University of London**

Audley-Charles (1968) carried out field work in East Timor as part of his Ph. D. thesis completed in 1965 at the University of London. The work was funded by Timor Oil Ltd., an Australian oil and gas company. The field work began in 1959 and continued until the end of 1961.

Audley-Charles spent 28 months in the field (approximately 18-20 sq km day on average) and was supported by the results of paleontological investigations by numerous scientists in the United Kingdom that were essential in determining the ages of the various units. Inasmuch as the terrain is rugged in much of the island, it was only possible to carry out this work at a semi-reconnaissance level in order to cover the ground.

Audley-Charles carried out petrographic work on 3,000 rock samples from the whole column in the 1960s.

Geochemical analyses of major and trace elements were carried out on Cretaceous rocks to support the assessment of their potential for oil and gas source rocks and interpretation of the sedimentary environment.
Audley-Charles had access to aerial photographs and topographic base maps (1:40,000 and 1:100,000) for part of the area. The field maps were compiled at a map scale of 1:100,000 but his geologic map was published at a scale of 1:250,000.

**Woods Hole Oceanographic Institution; Institute of Geological Science, London; and the Indonesian Naval Hydrographic Office**

In 1969-1971 Woods Hole Oceanographic Institution and other agencies noted above carried out a study of the geological structure of the Java Sea and adjacent continental shelf running 7,400 line km of geographical traverses that included 6,000 geophysical traverses that included seismic, magnetic and gravity measurements. Most of these studies focused on the northern Sunda Shelf, Gulf of Thailand and adjacent deepsea floor but parts of the traverses crossed waters of Indonesia, Cambodia, Malaysia, Philippines and Viet Nam.


**Oil Companies**

There were numerous oil companies carrying out work in the Sunda Shelf and adjacent areas of Indonesia and adjacent areas (including a little work in the Timor sea) in the 1960s and 1970s. Most of the work of international companies was carried out in Indonesian waters where operating companies had offshore concessions that covered 1,652,105.35 sq km (CCOP, 1976). The geophysical data these companies collected was later utilized to interpret the tectonics of Timor and adjacent areas (Hamilton, 1979). The list of companies that were interested in Indonesian oil is long. A partial list includes AGIP Società per Azioni, Amoco Production, Amoseas Indonesia, Atlantic Richfield and Atlantic Richfield Indonesia, Australian Aquitaine, British Petroleum Co. and BP Petroleum Development Ltd., Caltex, Chevron Exploration Co., Cities Service Oil Co., Continental Oil Co., Exxon Corp., Gulf and Western Indonesia, Gulf Oil Corp., Mobil Oil Corp., Natomas and Independent Indonesiaan American Petroleum Co., Oceanic Exploration Co., Phillips Petroleum Co., Shell International Petroleum, Stanvac Indonesia, Superior Oil Co., Tenneco Oil Co., Tesoro Petroleum Corp., Texaco, Inco. Total Indonesie, Trend Exploration, Union Carbide Petroleum Co., Union Oil Co., Woodside-Burmah Oil and Burmah Oil Co. of Australia. These data are still useful for interpreting the geology and tectonics of the Banda and Timor Sea area and the islands of the Outer Banda Arc.

**Mining Companies.**

Mining companies were also interested in Indonesia in the 1960-1980s. However, eastern Timor was generally ignored aexcept for the work of Allied Mining Company in 1936. Only a few Dutch companies searched for copper and gold in the 1920s in west Timor (Netherlands East Timor) and these exploration efforts are discussed briefly in Hoen (1930). In the 1980s there was some interest by international companies in the possibility of finding copper in the ophiolite sequences thrust into northern Timor. Only a few companies received concessions (COW) in Timor. These included CRA (probably in the 1980s - Ocussi district of western Timor). The only work in Portuguese Timor was carried out by Allied Mining Co. in 1936 but this exploration discovered significant copper, gold, silver and other
occurrences. Many companies were more interested in other areas such as Sulawesi (e.g. P.T. Internatinal Nickel Indonesia – east arms of Sulawesi; Nikko Exploration and Development Co., Ltd - west-central Sulawesi. Conzine Riotinto Malaysia focused on central Sumatra.

**Imperial College, London and others**

In 1971 Imperial College, London and other institutions from the U.K., U.S.A. and Indonesia carried out geophysical research and training in the Banda Arcs. The work included refraction shooting, seismic reflection, magnetic profiling, bottom sampling of the continental and oceanic crust (CCOP, 1976).

**Regional Sea Floor Geology of the Banda Arc**

Hamilton (1979) summarized the regional geology of eastern Indonesia noting that the crust on the inside of the Banda Arc is almost entirely oceanic crust while that on the outside (south facing) is continental crust, even around the tight loop of the arc that includes the eastern islands of Seram, the Watubela Islands, Kai Islands and Tanimbar Islands. The subduction zone and trench (Timor Trough) separating these islands from the continental crust of New Guinea is also underlain by continental crust. The oceanic character of the crust inside the Arc was reported by Curray and others, 1977; Purdy and Detrick, 1978; Purdy and others, 1977, and Raitt, 1967, all cited by Chamalaun and others (1976) and Hamilton (1979). Later Praseyto in a series of papers (Praseyto, 1988-1999) showed that some of the ridges in the Banda Sea were of continental origin and consisted of microcontinents or continental slivers that could have come from as far away as Papua New Guinea.

**Continental Crust extends from the Outer Banda Arc through the Timor Trough to Australia**

From Sumba to Seram, including Timor and the other islands of the Banda Arc east of Timor, the crust from the Outer Banda Arc to the Australian mainland including the crust beneath the Timor Trough is made up of continental rocks based on seismic structure and magnetic anomalies (Bowin and others, 1977; Shor and Jacobson, 1977, Hamilton, 1979).

**Timor Trough**

The Timor Trough is a present-day subduction zone according to Hamilton (1972, 1979). It can be traced around the outside of the Banda Arc, separating the arc from the Sahul Shelf. The trough is less than 3,000 m deep and is not in continuity with the Java Trench. Seismic profiles (Beck and Lehner, 1974) show that Timor is underthrust by the Australian craton although Mesozoic and Tertiary formations can be traced beneath the trough. Seismic evidence collected by the Australian Bureau of Mineral Resources shows that the overthrust block (on the Sahul shelf side of the

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2 Continental crust was defined by Hamilton (1979) as crust that reached continental thickness as a result of either tectonic accretion in subduction systems or by silicic magmatism. In the Timor area most Tertiary and Mesozoic continental crust reached crustal thickness by being accreted in subduction systems or by thrusting. Timor crust was not created autochthonously by silicic magmatization but reached Timor by drifting away from a spreading centre in the Wharton Basin.
trough) is imbricated and folded. Extensive gravity slides characterize the slopes of the south side of the trough. Many workers have suggested that collision rather than subduction is occurring in the area of the trough. The resulting compression has created the late Tertiary-Quaternary structures seen in Timor.

Australian Bureau of Mineral Resources, Geology and Geophysics – Discovery of a Sea Floor Spreading Centre in the Wharton Basin and the Rifting of Timor from the Australian Plate

Falvey (1972) carried out the first work that indicated rifting had occurred in the Wharton Basin west and northwest of the Australian continent. The rifting was dated as Late Jurassic-Cretaceous based on sea floor magnetic stripes. His discovery of magnetic anomalies on the floor of the basin opened up a whole new perspective on the structural history of the Banda Arc. It indicated a spreading system had created new sea floor in areas that had previously been part of the Australian continental craton beginning in mid Mesozoic time. The new Jurassic rift system split away a block of Australian crust which would become the Indonesian islands of the Outer and Inner Banda arcs after their collision with the Eurasian plate. Timor and associated islands of the Banda Arc are thought to have been generated when this block collided with Eurasia in the Late Cretaceous. Microcontinental slivers or fragments of the continental sea floor of the northwest Australian shelf area drifted northward towards Asia as submerged platforms or marine shelves. The stratigraphy of these blocks commenced with the pre-rift Permian sediments that had been deposited on an unconformity above the Precambrian basement of the Australian craton. The Permian age sediments on the microcontinents were covered by younger, post-rift, Jurassic and Triassic marine sediments deposited during the long journey across the eastern Indian Ocean (referred to as the Tethys sea in the literature) finally colliding with the Asian continent in the early Tertiary.

Geological Survey of Indonesia (GSI) – Geological Mapping of the Banda Arc

Geologic mapping of the Timor area by the Geological Survey of Indonesia (GSI) began in the mid-1970s but most of this work was not published until the mid- and late 1990s. The Geological Survey of Indonesia carried out intensive geological mapping work on the Banda Outer Arc ridge and the northern Banda islands.

GSI – Geological Mapping of Timor Island

Mapping of Timor was completed by the GSI at a scale of 1:250,000 by the end the 1980s. West Timor was mapped first (Rosidi et al., 1979); maps were published later of east Timor including the Baucau Quadrangle (Partoyo, Hermanto and Bachri, 1995; the Dili Quadrangle (Bachri and Situmorang, 1994); and the rest of west Timor - the Kupang-Atambua Quadrangles (Suwitodirjo and Tjokrosapoetro, 1996). Geologic maps also were completed of Sumba, Tanimbar, Kai, Seram, Buru, Sula, Obi and Misool. Some of these now have been published and some are still in files of the Geological Research and Development Center as Open File Reports.

GSI – Banda Sea Floor Mapping
An expedition to the Banda Sea was carried out using the vessel R/I Jalanidhi with H.M.S. Hartono as chief scientist in October and November of 1975.

**Lamont-Doherty Geological Observatory Sea Floor Mapping**

A few of the ten cruises of the Research Vessels Robert Conrad and Vema, of the Lamont-Doherty Geological Observatory of Columbia University surveyed Timor and Banda sea waters and adjacent seas and yielded high quality seismic reflection profiles of many critical areas. Many of the profiles were utilized by Warren Hamilton (1979) in his magnum opus on the tectonic history of Indonesia and adjacent areas.

**Australia Bureau of Mineral Resources, Geology and Geophysics – Timor Sea Floor Mapping**

The BMR sent its research vessels to the Timor Sea on numerous occasions during this period. The important work of Falvey (1972) has already been noted above.

**U.S. Geological Survey and Warren Hamilton’s work**

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 U.S. Geological Survey (1979) 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. He constructed numerous cross sections across subduction zones and published more than one hundred seismic reflection profiles gathered over the years by many state and private organizations operating in the region (Hamilton, 1974A, 1974B, 1978). Hamilton drew heavily on his background as one of the early workers on the Franciscan mélange in California. He discussed the tectonics and development of the Outer Banda Arc which includes Timor relying heavily on unpublished maps and reports of numerous Indonesian agencies (mainly the Direktorate Jenderal Minyak dan Gas Bumi and the Direktorat Jenderal Pertambangan. Data from Lemigas and Pertamina, the latter releasing many reflection profiles, were used to illustrate much of the report and to support his conclusions. Maps and other data were provided by numerous oil companies operating in the region.

Hamilton’s work was compiled on a bathymetric map produced by Scripps Institution of Oceanography that had a 500 m contour interval. Much of this work has withstood the test of time and the work will remain as a watershed amongst the many tectonic studies of eastern Indonesia. Hamilton’s field work in Timor consisted of a the field trip led by S. Tjokrosapoetro. The trip was restricted to the west half of the island and appears to have been through a belt of mélange. Consequently, perhaps partly due to this field trip, his view of the island’s geology encompasses the structural concept of a tectonic mélange. He did not accept stratigraphic sequences presented by Audley-Charles (1968) nor those compiled by the Dutch in west Timor concluding that Timor and adjacent islands in the Outer Banda Arc consist of a Tertiary subduction mélange and imbricated complex (Warren, 1979).
Hamilton concluded that the Banda Arc, from Timor to Seram, consisted of a ramp of continental crust pushed in front of an advancing island arc (Inner Banda Arc). He suggested that the “subcrop of the primary plate boundary, beneath the surficial debris wedge, is approximately along the inner edge of the outer-arc ridge.” The Banda Outer Arc ridge, including Timor Island is the top of a wedge of mélangé and imbricated rocks, and the part exposed in the island was mostly late Neogene in age. He believes that subduction continues at the toe of the wedge beneath the Timor Trough. Seismic evidence indicates that Australian sediments can be traced in reflection profiles from the present shelf into the Timor trench. The Timor mélangé contains deep water sediments as young as early Pleistocene and shelf sediments as young as early Miocene. Of particular importance in this study was the effort made to distinguish facts from perception and inference.

**Benioff Zone beneath Timor**

Hamilton (1974) indicated on an earthquake map of the Indonesian area that the Benioff zone beneath the Banda Sea is “spoon shaped” and dips 40° down to a depth of 200 km increasing sharply thereafter to 75° (Hamilton, 1979). The zone dips “inward from the south, east, and probably north” to more than 600 km beneath the western Banda Sea. Active volcanoes are 125 km above the seismic zone which is fairly typical for the Indonesian area.

**SEATAR I– Studies of East Asian Tectonics and Resources**

Detailed regional studies of the metallogenesis and tectonic patterns in East and Southeast Asia and crustal transects were organized as part of the International Decade of Ocean Exploration (IDOE) held in Bangkok in September 1973 under the auspices of a new working group that was referred to as SEATAR. SEATAR is an acronym for Studies in East Asian Tectonics and Resources (CCOP/IOC, 1980). A workshop was jointly sponsored by the Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP) and the Intergovernmental Oceanographic Commission (IOC) and attracted the interest of an impressive group of world famous oceanographers and geologists. This Workshop became known as SEATAR I. This workshop was followed by the equally famous SEATAR II workshop held in Bangkok in 17-21 October 1978. The papers of the second Workshop were published by the Geological Research and Development Centre in 1981 as Special Publication No. 2. A review of SEATAR work since the first workshop and a technical summary of the second Workshop was compiled and published by CCOP in 1980.

**SEATAR studies of the mineral potential in Timor - J.A. Katili assessment**

In his address to SEATAR II Workshop in 1979, J.A. Katili, then Director General of Mines of the Department of Mines and Energy, noted that five years of geological and marine geophysical studies had been carried out in connection with the review and research of the Banda Crustal Transect proposed by the SEATAR I Workshop. The Banda Transect is especially important for this mineral resources assessment because it includes Timor. Katili (1980) noted that geologic data were inadequate and that there were many different interpretations of the data. There were also complexities and perplexities. For example, the presence of ophiolites in some
outer arcs was associated with nickel and chromite deposits (Sulawesi) whereas other island arcs had no base metal deposits but showed indications of hydrocarbons. The work of the Allied Mining Company (1937) and Timor Oil Ltd. already had revealed that Timor had both base metals and hydrocarbons.

Kitili (1980) also recognized that porphyry copper deposits were associated with volcanic activity and subvolcanic plutonism at deeper levels in many countries. Yet, at the time of his writing (1979) no significant porphyry copper deposits had been reported in Indonesia’s arc systems. These were to be discovered later.

One of the important SEATAR II programmes that evolved from this meeting was known as the Crustal Transect Project. Crustal transects were planned as part of the tectonic studies and included transects through the Banda Sea, one of which passed through Timor. The Banda Sea Transect (Crustal Transect IV) was published by CCOP in 1991 after a long delay and organizational problems.

**SEATAR cruises and other expeditions of the 1970s**

A number of cruises were organized in support of the SEATAR research. Bowin and others (1980) compiled the data derived from the SEATAR expeditions of 1976 and 1977 and made a bathymetric map of the entire Banda Sea using a 250 m contour interval. Another expedition, SINTA, derived data from a SeaMARC II sidescan mosaic, 3.5 kHz echo characters and the dredging and coring of surface sediments in the Banda Sea. These cruises shed new light on the origin of the Banda Sea and its ridges. The petrology of the Banda Ridge volcanics and its relation to the Inner Volcanic Arc volcanics north of Timor was studied by Silver and others (1985) and Schwartz (1985).

**SEATAR Crustal Transect of Banda Arcs**

The Transect IV publication focused on the Australian continental shelf, the Timor Trough, the Banda Outer Arc Ridge, the Banda Volcanic Arc, the Banda Sea, Seram, the Seram Trough and the Australian continental shelf north of Seram (CCOP, 1991).

The purpose of the SEATAR transect compilation was to show the substantial cross-arc variations, both geological and geophysical, but also demonstrated general continuity of geology along the strike of the arc. The transects also showed free-air gravity anomalies; structural features; and geology with surficial sedimentary isopachs; together with data on magnetic lineations, paleomagnetism and heatflow. A correlation table for the geological units, subsurface data and cross sections of free-air gravity, geology, crustal structure and seismicity.

**Banda Sea an Timor structure**

Work was carried out by Silver and others (1985) who outlined the structure and origin of the central Banda Sea region. A significant discovery was that the Banda Ridges were composed of displaced and submerged continental fragments.
confirming previous speculation. The marine geology and geophysical data were compiled in Atlas format by Prasetyo (1984).

**Hydrocarbon potential**

The hydrocarbon potential of underformed Plio-Pleistocene sediments of Seram was studied by Zillman and Paten (1975). The geologic section of Timor is very similar to Seram. Both islands contain important deposits of bathyal mudstone and siltstone, littoral sands and reefs. Timor has a thick molasse sandstone sequence in forearc basins on its south coast. Oil seeps are numerous on Seram as they are on Timor. Commercial oil was thought to originate from Neogene source beds in Bula (Zilliman and Paten, 1975). The discovery of commercial oil in Seram in the early 1970s led to detailed studies by O’Sullivan et al. (1985) and indicated the promise of the Pleistocene sands and the Mesozoic formations (e.g. Triassic Kanikeh Formation). These discoveries rekindled interest in potential for onshore and nearshore discoveries in Timor.

**University of London geological field research**

Many studies of Timor and adjacent areas were carried out by graduate students working under Audley-Charles and A.J. Barber. In the 1980s a number of studies of the islands stratigraphy and sedimentology were undertaken (Bird et al., 1989; Cook et al., 1989). This group focused its work on Timor’s structure and showed that overthrust features were the primary elements of the tectonic style.

**Flinders University geological field research**

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. Their work has emphasized the importance of steeply dipping and normal faulting as opposed to the overthrust school which was led by Audley-Charles and Barber of the University of London. Chamalaun’s research resulted in paleomagnetic evidence for the relative positions of Timor and Australia in the Permian (Chamalaun, 1977). He also obtained palaeomagnetic data from the Maubisse Formation of East Timor (Chamalaun, 1977).

The Bouguer gravity field of East Timor was measured by Chamalaun and others in the mid 1970s (Chamalaun, Lockwood and White, 1976).

**University of California at Santa Cruz geological field research**

The work at UC Santa Cruz was led by E.A. Silver and his students. They noted that the relationships discovered in Buton were very similar to the geology seen in Timor (Smith, 1983) and Sulawesi (Silver et al., 1983).

Prasetyo (1989) studied the marine geology and tectonic development of the Banda Sea, which was modeled as a sedimentary basin. The work of Santa Cruz
students and others showed the Permo-Triassic formations had a provenance in Gondwanaland.

**INDOPAC cruises 7 and 10**

These expeditions were made in 1976 and 1977 and collected geophysical and geological data on the Banda Sea.

**MARA 9 and Rama 12 cruises**

The cruises were made to the Banda Sea by the Scripps Institution of Oceanography in 1979 and 1981.

**CCOP-IOC SEATAR Working Group Meeting of 9-14 July, 1979**

The papers presented at the meeting make an especially strong contribution to the geology and tectonics of Timor. The Proceedings were edited by A.J. Barber and S. Wryosujono and published by the Ministry of Mines and Energy, Geological Research and Development Centre of Indonesia (GSI, 1980).

7. 1980-1990

**Pertamina/Beicip**

Pertamina/Beicip (1982) published a geological map of eastern Indonesia at a scale of 1:2,000,000. Overthrust features were mapped on Timor and Seram and both islands were shown to have a similar structural style (Rosidi et al., 1979). Tanimbar, east of Timor, also was shown to be characterized by overthrust structures; the Molu Complex was the over-riding tectonic unit (Sukardi and Sutrisno, 1981).

**Metallogenesis**

Metallogenesis along the Sunda Arc was largely ignored by most workers although it was noted that gold and silver mineralization occurred in Lomblen, east of Flores and north of Timor (e.g. Atauro island located in the Inner Banda Arc a few kilometers north of Dili in East Timor has occurrences of both gold and silver). Gold and silver were associated with ring and polygonal structures (old calderas) observed on SPOT images in the Atanila area (Soemarto, 1989). Epithermal mineralization was indicated on Flores by the type of alteration and mineralization. The base and precious metal mineralization deposit model closest to the alteration, texture and mineralogy at Atanila was the Creede type epithermal vein deposit (Soemarto, 1989). SEATAR reported in 1980 that a vein copper prospect occurred near Bone in West Timor. Alluvial gold derived from crystalline schists is also found in both East and West Timor. Manganese deposits are small and uneconomic on East Timor. Chromite deposits have been established on the north coast of Timor not far from Dili but in 1937 geologists that mapped the deposit indicated it was also uneconomic.
Hydrocarbons

The SEATAR II workshop noted that hydrocarbons occurred onshore in Viqueque district of south-central East Timor (CCOP, 1980). The Viqueque Basin of East Timor is a thick molasses-type basin filled with several thousand meters of coarse sand, quartzose greywacke. The basin had one of four oil occurrences that were reported in the Outer Banda Arc in 1980. High gravity oil and some low gravity oil and asphalt occurs in sediments of Neogene age. The oil is considered to be immature with regards to oil generation timing. Oil is thought to have migrated from Mesozoic source rocks into Neogene sands following Recent faults and older Tertiary thrusts. The SEATAR II report recommended the continuation of onshore work and further exploration.

Snellius II expedition

The Netherlands Council of Oceanographic Research and the Indonesia Institute of Science (LIP I) used two vessels, the Tryo and the R/I Jalanidhi to carry out an expedition to the Banda Sea in 1984.

Joint cruises of University of California at Santa Cruz, University of Hawaii (Hawaii Institute of Geophysics) and the Marine Geological Institute of Indonesia were carried out. These cruises were made to the Banda Sea in 1983 used the R/V Kana Keoki collected Sea MARC 11 side-scan mosaics, single channel seismic reflection data and geological grab and dredge as well as piston core samples.

Banda Sea ridges, Timor and many other islands – continental slivers

The ridges in the Banda Sea, north of Timor, were shown to consist of both continental and volcanic basement rocks (Silver et al., 1985) and Hamilton (1979). They showed that some of these microcontinents had been displaced more than 600 km (e.g. Sula Platform). Likewise, Timor had been displaced as a sliver of the Australian continent, first colliding with the Inner Banda Arc resulting in the development of a volcanic island arc in the Eocene followed by a second collision with the Australian craton in the Miocene resulting in a narrow and highly complex collision zone primarily affecting the north coast and mid-section of the country. Both collisions were characterized by overthrusting preceded and followed by deposition of mélange. The second collision resulted in a narrow zone of severe thrusting and metamorphism recorded in mappable thrust sheets and faults along the high mountainous spine of the mid-section of the country as well as the north coast both east and west of Dili. The orogeny resulted in the accretion of several slices of continental rocks and seafloor sediments forming a complex mélange of ultramafics, and low to medium grade metamorphics of continental origin. Thrust sheets are frequently bounded by soft mélange sequences containing exotic blocks of many types of sedimentary and metamorphic rock that were deposited over most of the country.

Mineral Resource assessment of Timor

J.P. Dorian, A.L. Clark and Djumhani completed a somewhat controversial mineral resources assessment of Indonesia in the mid-1980s (Dorian et al., 1985).
They assessed the mineral potential of Indonesia using a method referred to as the Unit Regional Production Value (URPV) technique first introduced by Griffiths (1969). The technique is based on the assumption that geologically similar regions contain equal values of mineral resources and that comparable production will be achieved under similar levels of exploration and production. They concluded that data from historical mineral production and economic reserve amounts from “well-explored” areas could be used by the URPV technique to estimate the inventory of mineral resources in “less-explored” or underdeveloped regions. One of their axioms was based on a complex geology and suggested that “the more geologically complex and diverse an area is, the greater the likelihood of mineral resources.”

Timor was considered to be amongst the most complex of Indonesia’s many islands and was composed of a variety of rock types ranging in age from Permian to Quaternary. Important rock types include claystones and limestones (24%) with extensive areas of massive crystalline metasediments (19.6%), mafic extrusives (35.3%) and ultramafic intrusives (3.8%). These data were compiled by Djumhani from an unpublished map of the mineral resources of Indonesia. Djumhani used a point count technique and the data from the soon to be published Metallogenic Map of Indonesia (Djumhani, 1986) compiled on a geologic-tectonic base map. This analysis resulted in a correlation of Timor with Arizona, which had an estimated unit regional production value of US$510,000/sq km. Assuming an area of 16,000 sq km for East Timor, the value of East Timor’s potential mineral production would be US$8,160 million. Arizona had little historical production of petroleum but has had a significant production of copper, coal, molybdenum, gold and silver. It should be noted that East Timor has no coal deposits. In 1985, Timor was ranked as the second richest province amongst all of the provinces of Indonesia in the value of its potential mineral production based on this method.

8. 1990-2000

Banda Sea ridges studies using Baruna Jaya II and III

The R/V Baruna Jaya III cruises collected single channel seismic geophysical and dredged rock samples from the Banda Sea in 1994-95. These cruises resulted in new data on the structure and bathymetry of the Banda Ridge structural elements and their relationship to the island of Timor (Rehault and others, 1993). The Banda Ridges are interpreted as having the composition of a continental borderland in the same sense that most of Timor originated as part of the Australian continental borderland. Likewise, both were continental fragments (microcontinents or slivers of continents) that were transported as a result of plate movement over long distances. In the case of the Banda Ridge, the geology indicates that they were transported hundreds of kilometers from Irian Jaya and ended up in their present position in the Late Miocene, coinciding with the final collision of the Australian continental plate with the island of Timor. The mechanism by which these continental fragments are slivered, displaced and accreted is still a subject of research. Some slivers are displaced along strike-slip faults similar to the southern borderland of California (Crough, 1981; Crowell, 1987, Howell and Vedder, 1987).
Part XIII.

Notes on the Geology and Mineral Potential of Selected Districts
A. Geology of Aileu District

1. Topography

Aileu is a hilly and mountainous district located south of Dili in the north-central part of East Timor. Several mountains are more than 1,000 m above mean sea level (amsl). It is characterized by high hills in the west, north and central parts. The mountains range above 1,000 m amsl in about 50 percent of the District. Lower topography ranging from 500 to 1000 m above sea level occurs in the river valleys, which are about 2 km wide, narrowing in their headwaters.

The elevation of the eastern third of the district is mostly 500-1000 m amsl dropping to 100 to 500 m above msl along the two main rivers, the Naru and Lado rivers, which flow eastward. The two rivers drain a wide low agricultural area near the eastern margin of the district but have their headwaters in high mountains located east of Aileu town in the center of the district.

The district is divided into four subdistricts: Kecamatan Aileu, Kecamatan Liquidoe, Kecamatan Remexio, and K. Laulara.

The topography drops off toward the north and a strip about 4 km wide ranges in elevation from 500 to 1,000 m amsl near the border with Dili district on the north.

2. Aileu town

The district town of Aileu is located in the southwest part of the district on a south-flowing tributary of the Manotani River which flows generally eastward. The valley occupied by Aileu town is about 2 km in width. The lowland around Aileu widens toward the north becoming 4-5 km wide where two south-flowing tributaries join about one km northeast of the town.

There are number of high peaks in the central mountain belt. The highest peak, Baqar Hoholau, is 1,394 m amsl and is located in the northwest corner of the district, about nine km north of Aileu.

3. Aileu Formation Stratigraphy

The district terrain is made up mostly of the Aileu Formation of Permian age. The terrain south of the Manotani Hun river is made up of the Maubisse Formation also of Permian age. Both units are allochthonous units, which have been thrust south over younger sediments (Figure 64).
Audley Charles (1968) described this formation as equivalent to the Lolotoi Complex or North Coast Schists of Van Bemmelen (1949). Gageonnet and Lemoine (1958) made detailed investigations of the formation.

The type locality of the formation is located in the mountains surrounding Aileu town. Exposures are good in bluffs and creeks. The formation is found throughout northeast East Timor. The south border of the unit is more or less parallel to the trace of the Manotani Hun River which may be structurally controlled by the contact between the two allochthonous Permian units, the Aileu and Maubisse formations. Audley-Charles noted that its southern extent reached Emera.

The Aileu Formation consists of shales, phyllites, slates and less commonly metamorphosed volcanics. The shales are light colored and weather a deep red. Slates are blue-grey and light purple colored with excellent cleavage. Quartz-phyllites are interbedded with the slates. The phyllites are lustrous.

4. Structure

The Aileu Formation is a nappe or thrust sheet derived from the north. The thrust plane underlying the formation dips north. The Aileu Formation is metamorphosed but rests on unmetamorphosed Wai Luli shales in the western side of the valley of the Laclo, west of Manatutu. The stratigraphic relationships confirm that the Aileu Formation is an allochthonous unit. There is a lowering of the grade of metamorphism from north to south suggesting that the overthrusting was from the north to south.

The formation contains conglomerates with abundant clasts of volcanic rocks as well as tuff and minor grey shale. Five-hundred metres of basalt occurs in the upper part of the unit in Mt. Ramelau.
The outcrop is easily recognized because it weathers to a deep red and is rich in fossils, mainly crinoids and bryozoans. The volcanic rocks are also red and orange and tend to be porphyritic or vesicular.

Large exotic blocks up to 0-5 km in length are characteristic of this unit. The blocks are made of the Bobonaro Scaly Clay. These were derived from a different terrain probably located to the north.

5. Maubisse Formation

The unit is allochthonous. It rests tectonically on the authochthonous Aitutu and Wai Luli formations. The unit rests on Triassic and Jurassic strata of autochthonous origin indicating that it is allochthonous.

The fact that the thrust planes dip north suggests that this formation was derived from the north. The Bobonaro Scaly Clay, a closely related unit, was also derived from the north (Audley-Charles, 1965a).

A-C suggested that the unit was deposited originally in the region of the Celebes and southern Kalimantan (Audley-Charles, 1965a).

7. Economic Mineral Deposits

Sand and gravel

Sand and gravel occurs along all of the major valley floors and is an excellent source of local sand for cement block and concrete. It is extracted from valley deposits near Aileu town.

Andesite

Andesite is recorded in the Aileu formation in the north central part of the district. It would be a possible source of road and railway aggregate.

Marble

Marble occurs in the Aileu formation in the northeast corner of the district. It could be used as a building stone or possibly an ornamental stone.
Figure 67. Typical outcrop of the Aileu Formation in the hills west of Aileu town. Note the reddish cast. Locally, the rocks have been altered to kaolin, a potentially valuable non-metallic mineral.

**Kaolin**

Kaolin is reported to occur in both formations. The East Timor mineral database (de Paulo and Lacerda, 1999) indicates the presence of kaolin both north and south of the town of Aileu in the Aileu Formation.

Kaolin was reported to occur at one locality on the east-flowing Manotani Hun River.

**Limestone**

Limestone is an abundant resource throughout a narrow strip bordering the southern edge of the district. The Maubisse Formation crops out in many places along the east-west trending belt.

**Talc**

Talc occurs in the northeast corner of the district near the Dili district boundary. It occurs in the Aileu Formation within the schists. The presence of hot springs throughout this area indicates that the talc may be of hydrothermal origin and probably developed as an alteration product of micaceous argillaceous units in the schist. Talc has numerous uses and could become an important economic minerals depending on the size of the deposit.

8. **Accessibility**

The Aileu area is connected by road to both Dili and Maubisse. The potential market for the rich limestone resources of Aileu district is the Dili capital area.
9. Summary

The geology of Aileu district should be mapped in greater detail as there are a number of important minerals, which occur there including talc, marble and limestone. Of these limestone is by far the most important as a source of lime, building stone and ornamental stone. More data should be obtained about the mineralogy and engineering properties of the rocks in Aileu district. The abundant sand and gravel deposits are useful for construction and road-building purposes.

B. Dili District Geology

1. Introduction

Dili District is the most important district in East Timor (see chapter on Dili economic and social situation). However the area of the district is smaller than most. It stretches along the Timor sea and benefits from a good location for trade as well as a number of extensive sandy coastal tracts which might prove interesting for tourism and infrastructure development in the future.

The district is blessed with an abundance of sand and gravel resulting from the deposition of sand where stream gradients change abruptly near the sea or are terminated by the coastline resulting in the deposition of a delta (Figure 68). A minor amount of coral reef-rock has accumulated on beach berms and this is collected by local people and used as a source of lime. Brick clay occurrences have not yet been reported in the mineral statistical data for Dili district (Lucerda, 1999). Other than these important non-metallic resources there are few minerals of economic interest in the district on the main island. Atauro, a coastal island located a few kilometers north of the coast, has prospects for several base metals and precious metals: gold, silver, mineral sands (magnetite), kaolinite, coral reef-rock, sand and gravel and hot springs.
2. Dili town

Location

Dili is located on the north coast of East Timor at Latitude 8°33’00”S, Longitude 125°34’00”E. in the northwest corner of the coastal tract in Dili district.

Setting

The town is built on a narrow, low-lying, sand covered coastal enclave, a sloping bench ranging in elevation from only a few metres to perhaps 20 metres above sea level (estimated 2-20 m above mean sea level). The coastal tract is surrounded by highlands on three sides. The topography constrains the limits of the town and has forced it to develop along the coast. The town occupies all of the available flat land in the coastal area, which is confined by a ring of horseshoe-shaped highlands and hills. These rise sharply on the north, east and west beginning about 1-2 kilometers from the beach.

Roads

The main road near the sea extends east-west along the coast but branches in the heart of the town to make a beach road which continues east and northeast parallel to the beach. The eastern beach road hugs the base of a steep cliff before ending about 3 km east of the centre of the town where a peninsula of hard rock prevents further access to the east. About five north-south main roads that from the main east-west thoroughfare, the coastal highway. The main highway turns inland and trends southeast toward Dili Timur located about 3 km from the main junction with the beach road in the center of Dili town.
City plan

The city is laid on a longitudinal grid plan that is designed to conform to the local topography, a long and narrow plain or enclave. The topography only provides room for a few east-west roads and a series of north-south roads that divide the town into rectangular blocks. Traffic circles occur in a few places. The main business center and government buildings are located just one or two hundred metres from the beach along the main beach road in the center of town. Small houses, shops and schools dot the area between the beach road and about one-half km inland of the beach. Fortunately, the beach area has been kept open and the port development has been minimal so that the coastal view is excellent.

![Figure 60. Typical beach scene showing bold-embayed headlands typical of the Dili District.](image)

Dili is reported to have a good harbor and the water is probably at least 7-8 m deep near the container loading point. There is a park and promenade along the beach a Maritime Hotel and many restaurants. Hotels and beach resorts are spread eastward on the south side of the beach road in the eastern half of the beach area but these are interspersed with many damaged and gutted buildings and institutions dating from the 1999 violence. Hotels and restaurants are liberally sprinkled throughout the town. The beach front homes west of the city center house Embassies and the center of town is marked by a magnificent complex of white arched European styled buildings that house the Government. Nearby is the 400 year-old fort of the Portuguese which was restored for Independence day celebrations.

3. Coastal geology

The enclave appears to have developed in a zone of weaker rocks, primarily slates and shales (Figure 71). In the east end of the beach road where the coastal plain narrows to a few tens to hundreds of metres, the rocks are much more quartz rich and tend to be hard meta-siltstone and sandstone (graywacke), schist and phyllite. Harder quartz-rich rock zones form hogbacks east and west of the town center, forming steep
slopes, which drop to within one-hundred metres of the beach. These hills have dip slopes to the south.

Figure 71. Sands in the foreground consist of quartz, amphibole and feldspars eroded from the headlands of schist and gneiss in the background. The rocks in the immediate area are softer argillite and slate.

Exposures of the metasediments described above are assigned to the Ailue Formation (Audley-Charles, 1968) can be seen in most coastal road-cuts. The dip in the metamorphic foliation is towards the south. The hills locally weather red in the zones of oxidation and incipient laterization. Fresh rock is gray or dark colored.

4. Topography

The topography is picturesque and the hills surrounding the town are rounded and almost barren. Hillsides are green and grass covered with outcrops appearing in roadcuts at the base of the steep slopes. Hilltops have a few shrubs and trees that provide a little shade for the hilltop villages that abound in the area (Figure 72). The lowland area is covered with mostly one-story houses and shops with a few two-story and more rarely, three-story buildings along the main streets. Larger trees are present everywhere in this area. Gardens are common and banana and coconut trees are everywhere. Orange trees are grown in surrounding small gardens and plantations where water is adequate. During May and June, the dry period, the streams are in their low flow stage and water levels are very low.
5. Urban geology

The western suburb of the Dili coastal enclave consists of a large delta formed by the Camoro River. The river valley is floored with coarse sand and gravel, which grades laterally into cobbly and bouldery lenses. The sand and gravel deposit in the delta is estimated to be at least 5-10 m thick. The alluvium of the Camoro River is the main source of sand and gravel for construction material in the city. The eastward edge of the city is sharply constricted by a bold headland, Fatocama point, made of hard rock, schist, phyllite and slate. The point extends northwesterly about 1-2 km into the Wetar Strait. The point lies northeast of the main part of the city but causes waves to refract sharply into the eastern part of Dili harbour sweeping black sands weathered from the Aileu Formation onto the eastern beaches of the town.

There is a small local surf breaking over the reef located about 50-200 metres offshore when a south wind blows. The surf may range up to about one-half to one metre in height in these places but the reef is discontinuous and the main harbour entrance has no reef offshore. The reefs are located mostly in the eastern part of Dili bay. The surf develops in shallow water where bedrock is near the surface but just below water level on the northeast edge of the city parallel to the beach. A few small islands of schist and meta-sediments occur nearshore. In this area the berm, a ridge of coarse debris rising about one to two metres above mean seal level, consists of coarse rounded pebbles made of quartz vein material, slate, schist, slate and shale. The lower parts of the beach that are exposed at low tide are made of black sand with pebbles appearing again near the water line. The berm is covered with very coarse debris and is the location of the main coastal road. The material here consists of large pebbles ranging up to cobble and boulder size, which forms a firm base for road construction. Coral reef debris is common in the northeastern beaches.
The highlands behind the city on its west, south and east sides rise to elevations of a few hundred metres, in the highest parts. The hills are covered with foot trails and small houses and farms dot the hilltops. The hillsides are far too steep to be settled. Here and there a small bench harbors a house. Goats and chickens are the main livestock raised in the hilly tracts. The coastal road to Dili is hit by frequent rockfalls.

**Figure 74. Rockfalls are frequent on the coastal road leading into Dili**

Comoro River and about a dozen smaller streams have their headwaters in highlands to the south made of the Aileu Formation. The Dili drainage has built a coalescing coastal sand and gravel deposit that is present everywhere beneath the town. A belt of beach sand and gravel extends inland for a distance of 2 km and east-west for a distance of about 11 km.

**Figure 77. A view of the small-scale mining operation along the floor of the Comoro River valley, west Dili.**
The elevation of the coastal tract ranges from 0 to 20 m above msl. The slope increases sharply from the coastal sand covered enclave into the surrounding hills of bedrock. The coastal tract is very flat but the contact with the base of the hills is abrupt. All of the small mountain streams that flow toward the sea through the city are confined to narrow trenches by stone retaining walls probably built by the Portuguese. The valley floor of a typical stream is only about 20-50 metres wide.

6. District geology

The geology of the mainland (Timor Island) part of Dili district is not complex. It consists of two primary units: (i) a sequence of meta-sediments and metamorphic rocks and (ii) beach sands and gravels as well as river sands and gravels grading into deltaic sands near the sea. The offshore part of Dili district, Atauro Island, lies about 10 kilometres north of Dili and can be seen from the Dili town. The geology of Atauro Island (Palau Atauro), a recently extinct area of volcanic activity, is quite different from the main part of the Island and will be discussed separately.

7. Stratigraphy

Aileu Formation

The main unit of the Dili district is the Aileu Formation of probable Permian age. The geologic data presented below are from Audley-Charles (1968) supplemented by information obtained by the United Nations mission. The unit consists of shales, phyllites, slates, and meta-eruptive rocks. The Aileu Formation is considered to be 1,000+ m thick by Audley-Charles (1968). The Aileu was deposited at the deep water end of the neritic zone or in the bathyal zone. The minerals of the Aileu Formation are variable depending on the rock type. The schists and phyllites are green to black and contain abundant chlorite, biotite, hornblende, quartz and muscovite. Quartz veining is abundant in all lithologies along the east beach road, best observed in roadcuts 2 km east of the Dili town center (Figure 78). The quartz veins 1-20 cm thick, folded, locally crenulated and generally white. The veins vary in width pinching and swelling in the minor fold axes as a result of shear. The veining is inserted parallel to the foliation in the schists. Typical ptiigmatic folding is visible in some areas.
8. Tectonic history

The Aileu is considered to be an allochthonous unit by Audley-Charles (1968), a thrust sheet or nappe, thrust northward toward the Australian plate during the collision of that plate with a micro-plate of the Eurasian plate. The sense of thrusting was from the north to south resulting in the displacement of Aileu rocks onto younger rocks. The thrust planes dip north. Although the foliation planes in the unit are complex and show at least three stages of deformation. The main ledge-forming stratigraphic units dip north toward Wetar Island according to Audley-Charles (1968). In the capital region, there foliation planes of the local rocks in the headlands dip south and along the coast east of Dili, the hard units clearly dip south or southeast. Dip slopes to the south are clearly seen in the hills of Pt. Fatocama visible from the beach road at the east end of the town of Dili. The structure of the Ailue is complex because it has been deformed at least three times.

The slates and shales are black. Siltstones and fine-grained sandstone appear to show graded bedding. Massive bedding is locally common is the meta-sediments of this unit.

9. Economic minerals

Sand and gravel

The most important economic minerals are the sand and gravel being exploited near the main coast road, the Liquica-Dili road, and its continuation eastward, the Dili Metinaro road. In many places in the Dili area, small-scale miners are selectively collecting quartz pebbles of various size grades. Coral reef rock ,which has been
thrown up on the beach by storm waves is also collected to be crushed to make lime. The sand is hand screened. It is derived from either river or beach material.

(i) S. Comoro valley and delta

Many artisanal miners are working the valley floor deposits in the stream valley of the Comoro River, which is perhaps the largest deposit in Dili district. The workers sort out sediment of different size grades using a screen. The conical shaped piles are later manually loaded into trucks, which take the sand to local cement block factories. The sand and gravel is used in the construction industry, primarily as a source of sand for concrete, cement blocks and the pebbles are probably crushed and used for aggregate. However, the quality of the sand is not good as it contains a variety of mafic minerals as well as iron oxides and clay.

The Comoro River has built a deltaic plain about 3 km wide from east to west and at least two kilometers up-stream from its seaward margin. This delta could be a source of rich construction material for the Dili area as it is quite extensive and has adequate reserves, which should last for many years. The delta ends in a prominent peninsula, Pt. Maudukai Motael, located about 4 km west of the town centre.

(ii) Deposits west of Dili

Other sand and gravel deposits are located at Dili Barat, two km east of the town center, and at De Tacitol, 6 km west of the Dili town center.

(iii) Deposits east of Dili

East of Dili the best sources of sand and gravel are located in the valleys of the Erscic River, the Erscic Coastal Plain, and the Metinaro Coastal Plain.

C. Atauro Island Geology

1. Introduction

The Island is located about 10 km north of the Dili district coast line. Its area is 144 sq km. Its size ranges from 20 km in length (north to south) and 10 km in width at the maximum. Its highest peak, Mano Coco, has an elevation of 999 m above msl (Figure 80).

The soils of Atauro Island were studied by Portuguese soils scientists (Leme and Pissarra, 1962). They were associated with the Geólogos da Missão de Estudos Agronomicos do Ultramar. In the introduction to their work they indicated that earlier work had been done on the soil of Timor by the Grupo de Trabalho de Pedologia (Brigada de Timor) da Missao de Estudos Agronomicos do Ultramar.
They came to important conclusions that have a bearing on the geology of the island, which is very poorly known. However, because of the possible presence of minerals such as gold, silver and kaolin, it is important to review what is known.

2. Topography

There are 11 different terrace levels on Atauro, each of which is accompanied by the development of coral reef limestone. The terraces occur at the following levels above msl:

1. 2-3 m
2. 60-65 m
3. 75-80 m
4. 90-115 m
5. 170-180 m
6. 200-210 m
7. 250-300 m
8. 420-450 m
9. 555-580 m
10. 600-620 m
11. 650-700 m

The presence of so many terrace intervals for relatively young coral reef material indicates the rapid rate of uplift of the island. The terrace levels are also important exploration marker horizons as the reef rock is relatively thin and caps bedrock, mostly of volcanic origin.

The topography of the island is variable. From north to south the land surface rises through a number of terraces consisting of reef rock until a relatively flat surface is encountered at an elevation of about 555 m above mean sea level. This surface is referred to as Planalto de Ainartuto by the Portuguese.
An east west profile shows high mountains along the sea coast attaining a maximum elevation of 999 m above msl (Mt. Manocôco). The surface drops and flattens out across the middle of the island, which is covered with a crust of reef rock ranging from an elevation of 555 m above msl up to 700 m above msl. Another range of mountains lies adjacent to the west coast, referred to as the Mt. Marupos range. Its highest peak is Mt. Marupos at 750 m above msl. A cross section from southwest to northeast shows an extensive dissected flat surface lying at an elevation of 620-650 m above msl. Some lower levels at 550 and 605 are also found. Upon reaching within a few kilometers of the coast the topography reveals a low ridge of volcanics rising to 620-700 m above msl. Then the surface drops off into three terraces at elevations of 580, 460 and 420 m above msl. These terraces are all covered with reef rock.

3. Economic minerals

Gold

Gold is reported to occur in the magnetite sands in several places on the east side of the island.

Limestone

The abundance of fossiliferous limestone might indicate a potential for ornamental stone or building stone. Moreover, depending on the quality, the rock might be suitable for lime.

Silver

Silver is reported to occur about two km inland from the coast on the southwest side of the island.

Andesite

Volcanic rocks are found over about two-thirds of the island. They are variable and include andesite on the southwest coast.

Other volcanic rocks

Leme and Pissarra (1962) such as basalt, dacite, rhyolite and tuff also occur. Basalt is the predominant rock type.

Magnetite sand

Atauro island has concentrations of magnetite sand in black sand deposits which also contain pyroxene and olivine.
The minerals are believed to be derived from minerals of volcanic rocks through weathering and transport to the beaches by streams and slope wash.

The location of the most important deposits is Pala and Beloi.

Pyroxene rich sands what are associated with magnetite are encountered at points and sand spits near Nu Haló.

4. Petrography of volcanics

Several early workers studied the petrography of the eruptive rocks (Brouwer, n.d.). He noted the presence of andesite. The andesite was characterized by abundant phenocrysts of pyroxene and amphibole. J. Brak-Lamy studied the escarpment near Mau Meta (Atauro village) and reported pyroxenitic andesite and vitric glass. He analyzed the chemistry of these rocks.

5. Thermal springs

Thermal springs are important as possible sources of hot water for tourism and cooking purposes. Such springs are found at Nu Haló and the outer parts of the district of de Palo. They were also observed at Mau Meta and Fato Lela.

The temperature of the water is reported to be 80°C.

It was reported that the water has therapeutic value.

D. Viqueque district geology

1. Introduction

Timor Island has been an attractive exploration target for oil and gas for more than 100 years and Viqueque District has attracted considerable interest. This probably stems from its numerous oil and gas seeps as well as the sedimentary nature of the rock sequence and several large anticlines. Inasmuch as Timor is the largest island of the non-volcanic Outer Banda Arc, also comprising the islands of Roti, Leti, Tanimbar, Kai, Ceram, Buru and Buton, it was considered to have good prospects compared to the volcanic Inner Banda Arc. Moreover, numerous large folds were obvious in the sedimentary cover both in the center of the Island as well as along the south coast. Although, it was recognized that the island also had considerable crustal instability and major overthrusting since the end of the Cretaceous, this was not considered to be a drawback in view of the numerous oil and gas seeps which showed the presence of hydrocarbons.

The stratigraphy is dominated by limestone and shale. A central mountain belt is made of Miocene and younger rocks. The range has been elevated since the Middle Miocene.

2. Early work
The earliest reconnaissance geological work was done by Hirschi (1907). The island attracted the interests of an oil explorationist, F. Weber, in 1910-11 and local operators had already drilled in coastal Viqueque district in 1900-1904. Allied Mining Corporation geologists made important mineral surveys in Viqueque district in the 1930s. Their maps and cross-sections have been published (Wittouck, 1937).

The Royal Dutch Shell carried out field surveys led by H.R. Grunau. They mapped parts of East Timor in 1947-48. Gravity work was also carried out in the late 1940s and early 1950s (Grunau, 1953, 1956, 1957A, 1957B). This was followed by the work of Timor Oil Ltd. in 1958-1959 which resulted in the drilling of two deep wells in Viqueque district. The most important work was done by Audley-Charles in the period 1958-1964 who submitted his thesis on Portuguese Timor to the University of London in 1965. This work was published by the Geological Society of London in its Memoir series.

Viqueque district is dominated by three large east-west trending anticlines, the Ossu Anticline on the north and the Musam and Ossulari anticlines in the south which make it attractive for oil exploration. The coastal area was drilled first but later interest shifted into the interior. The area of interest to explorationists of the 1950s extended southward from the southeast flank of the broad Ossulari anticline to the coast and is underlain primarily by the Viqueque formation of Upper Miocene age. Inland from the coastal plain area the geology is dominated by the Bobonaro Scaly Clay of Miocene age. The highest mountains, Mt. Laritame and Mt. Builo are made up of the Cablac Limestone of Miocene age.

In the east central and west central parts of the district are large and important outcrops of the Barique formation of Oligocene age, a unit that has economic potential for base and precious metals. This unit consists of agglomerate, basaltic tuff, lavas and contains limestone fragments derived from the Dartola Formation. It was deposited in an epimeritic environment and has a thickness of more than 300 m (Partoyo and others, 1995).

3. Stratigraphy

Cribas Formation

Rocks of this unit are exposed in both the Cribas and Loi Quero inliers as well as four other inliers where they consist of silty and clay shale. The formation is widely exposed in East Timor and forms the top of high mountains in Viqueque district. The type locality is in the banks of the Sumasse River where it cuts the Cribas anticline in north central East Timor. The unit is also exposed in the Bazol anticline, the Viqueque inlier, the Aliambata anticline, the Loi Quero anticline and the Veru anticline.

The base consists of pyritic black and blue-grey shales, micaceous siltstones and greenish fine quartz-sandstones. Units in the middle are red and green shales. Limestone occurs commonly at the top of the unit. Lavas and tuffs are rare and commonly deeply weathered. Its thickness is about 500 m. The unit contains crinoids, brachiopods, gastropods and bryozoa. The environment was shallow marine, not far from shore as indicated by lignite and plant remains as well as the marine fossils.
Large scale sedimentary slump structures are common and indicate slumping in shallow water perhaps where the steep submarine slope is near shore. The unit may be a pro-delta deposit.

**Triassic**

**Aitutu Formation**

The type section is the Aitutu anticline between Maubisse and Same in Aileu District. The formation is exposed in the drainage of the Waï Luli River. This formation is about half of a 2000 m thick sequence of what has been termed ‘autochthonous Triassic’ and ‘Complexe Trasico-Jurassique’ by Grunau (1953). The shales and sandstones are a flysch sequence bearing a basal radiolarian limestone.

Large parts of the Triassic-Jurassic terrain mapped by earlier workers is in reality a Miocene gravity-slide deposit containing huge exotic blocks of Mesozoic and other rocks. The gravity slide unit is the Bobonaro Scaly Clay, a ‘wildflysch’ deposit. Audley-Charles (1968) noted that many workers had confused the Triassic-Jurassic shales with the Bobonaro Scaly Clay. Fossils are rare. The environment is marine as indicated by the microfauna and macrofauna.

**Jurassic**

**Waï Luli Formation**

The unit is predominantly clay consisting of marine shale, marl and fine-grained limestone ranging from 600 to 1,000 m in thickness. Its fauna is sparse. Early workers lumped the Jurassic and Triassic sediments as one unit. The unit was termed the “autochthonous Mesozoic”. Later it was shown that much of the so-called “Mesozoic” consisted of the Bobonaro Scaly Clay, a Miocene rock sequence (Audley-Charles, 1968). The type locality is in the valley of the Waï Luli River. Basal units are blue-grey marls and calcilutite bearing abundant worm burrows and ammonites. The middle part consists of micaceous shales and calcilutite. The upper part is dominated by marls, shales and quartz arenites. The unit is conformable on the underlying Aitutu Formation and is overlain unconformably by rocks of Cretaceous or younger age (Audley-Charles, 1968). Its environment is shallow marine as indicated by the presence of calcarenites with algal pisolites, oolites and skeletal sand.

**Cretaceous**

**Waï Bua Formation**

The type locality is near the village of Waï Bua, 5 km north of Betano. Exotic blocks of this unit are found in the Bobonaro Scaly Clay (Audley-Charles, 1968). The unit is made of radiolarian marls and phosphatic shale with interbedded colored cherts of Lower Cretaceous age as indicated by the radiolaria. The fauna indicates open sea conditions but depth of water is unknown, but is estimated to be about 200 m. The absence of burrows suggests a thick pelagic deposit.
Borolalo Limestone

The type locality is in a hill north of the beach at Aliambata. The unit consists of massive to thick bedded pink calcilutites with abundant brown stylolites and visible foraminifera. The thickness of the unit ranges up to 200 m in the type section. Red and black chert nodules and veins are common. The unit is unconformable on the underlying Middle Jurassic shales of the Wai Luli Formation. The overlying unit, either the Lower Miocene Aliambata Limestone or the Bobonaro Scaly Clay of Middle Miocene age, also rests unconformable on the Borolalo Limestone. The environment is pelagic.

Seical Formation

The type locality is at the mouth of the Seical River. Its lithology consists of radiolarites, shales, cherts and marls. 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 is bathyal.

Eocene

Dartollu Limestone

The type locality is the village of Darollu in southwestern Timor. The Dartollu Limestone is part of a sequence that was lumped by Gageonnet and Lemoine (1958) with the overlying Barique Formation of Oligocene age as one unit. They considered the two formations, collectively termed by them the “Série de Samé”, to be shallow-water marine limestones and eruptive rocks that had been overthrust to their present position. Later work showed that in the type locality the Barique Formation consists of in situ volcanic rocks that had been confused with the Lolotoi Complex eruptives by Gageonnet and Lemoine (Audley-Charles, 1968).

Lower Eocene Tectonic Event

In the Lower Eocene a major period of thrusting occurred and the great tectonic slices of the Lolotoi Complex were emplaced. These blocks were broken from the upper crust as the leading edge of Timor Island was subducted below the Outer Banda Arc (Audley Charles and Carter, 1974). The emplacement of these thrust sheets in the Eocene resulted in folding and uplift. The deformation was intense and the soft cover of sedimentary rocks was thrown into folds and faulted.

The Lolotoi Formation is pre-Permian in age and consists of weakly to moderately metamorphosed rocks ranging from sedimentary rock to gabbro and dolerite eruptive rocks.

Oligocene

Barique Formation

The type locality is the banks of the Quique River south of Barique village. The thickness of the unit is estimated to be about 300 m (Audley-Charles, 1968).
Early workers (Grunau, 1953; Gageonnet and Lemoine, 1958) had lumped this unit was the Dartollu Limestone and with overthrust sheets of the Lolotoi Complex (Maubisse Formation of Audley-Charles, 1968) and part with the Bobonaro Scaly Clay. Later work by Freytag showed that the Barique Formation was an in situ unit.

Serpentinites occur in the type-locality and also north of Mt. Bibiliu and near Mt. Cablac. They are massive, tough, dark, greenish-black, and veined. Pyroclastics are dominant outside of the type locality. Massive sulphides are reported to occur in serpentinites of Ossu subdistrict of Viqueque district.

The unit is overlain unconformably by the Cablac Limestone of Lower Miocene age. However, locally, younger formations may rest on the Barique Formation. Stratigraphic relations indicate the Barique Formation must have been erupted and deposited between the Upper Eocene and Lower Miocene. The basal conglomerate contains boulders of Dartollu Limestone with foraminifera of Upper Eocene age. These data suggest the Barique is Oligocene in age.

Lower Miocene

**Cablac Limestone**

The type locality is located at Mt. Cablac in the central range, Viqueque district. The formation forms high peak along the mountainous spine of middle East Timor trending ENE-WSW. Several peaks of the central range rise to elevations between 1500 m and 2400 m. The unit consists of grey, hard, massive limestones of several types: calcilutites, oolitic limestone, calcarenite and intraformational conglomerate ranging up to 400-600 m in thickness. The unit makes a precipitous escarpment.

**Aliambata Limestone**

The type locality is the top of the hill called Borolalo north of Aliambata. The hill is also the type-locality for the Upper Cretaceous Borolalo Limestone. The lithology of the unit consists of yellow limestone with numerous large foraminifera. Its thickness is 50 m and it rests unconformably on the Upper Cretaceous Borolalo Limestone.

Upper Miocene

**Viqueque Formation**

The type locality for the Viqueque Formation is the hill area behind Viqueque village and the banks of the Cua River where the lower part of the unit is about 130 m thick and the upper part 370 m (Audley-Charles, 1968). The Viqueque anticline is cut by the Cua and the sequence is well exposed in the axial area of the structure.
The rocks are distinctive. They consist of 130 m of massive white marl and grey claystone interbedded with a few chalky limestones and rare vitric tuff. Upwards they become more silty and sandy. The tone is distinctive and it is readily identifiable on air photos.

The base of the unit is an unconformity. Generally, the unit rests on the Middle Miocene Bobonaro Scaly Clay, but locally it rests with angular unconformity on other units. The unit is overlain conformably by the Seketo Block Clay and the Dilor Conglomerate. The age of the formation is Upper Miocene to Pliocene; on the basis of its microfauna. The unit is marine.

An orogeny preceded the deposition of the Viqueque Formation that resulted in the placement of large thrust sheets of Permian rocks on the island of Timor and the emplacement of a huge gravity-slide deposit called the Bobonaro Scaly Clay. Therefore, the Viqueque is a molasse deposit that follows an orogenic episode.

When Viqueque deposition began Timor had been submerged and covered with the Bobonaro Scaly Clay. As the island began to emerge the Bobonaro Scaly Clay provided the muds of the lower Viqueque Formation. The coarsening of the grain size of the Viqueque upwards indicates the beginning of the regressive cycle and the shallowing of the marine basin followed by the gradual emergence of the island.

After significant emergence the rocks below the Bobonaro Scaly Clay emerged. These were eruptive and metamorphic rocks that provided the coarse detritus of the upper Viqueque silstones and sandstones. Local slumping accompanied emergence and slide deposits are also found in the upper Viqueque. Elevation of the island continued and it reached a height of 2500 m above mean sea level in about six million years (Upper Miocene to the Upper Pliocene).

Pliocene

Late Pliocene Fold Event

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

Post-Pliocene

Baucau Limestone

The type locality of the Baucau Limestone is a grey, hard, cavernous, massive white coral-reef limestone located in the series of terraced reef limestones that crop
out about the town of Baucau and it is a typical north coast reef limestone that can occur at various elevations from sea level to above 1,000 m.

Topographic expressions of the Baucau Limestone are seen in two plateaus, the Baucau plateau and the Lautem plateau. A continuous outcrop occurs along the north coast. In the southern foothills, the Baucau Limestone also crops out in scattered hills.

The Baucau is unconformable on older units everywhere. It overlies the Viqueque Formation but locally is found on older formations and occurs in scattered outcrops in south Viqueque district.

The thickness of the unit varies but is estimated to be about 100 m. Its elevation is reported to range from sea-level to about 500 m on the plateaus. But along the north coast the Baucau is a series of raised beaches. The terraces are the stages of Timor’s uplift history.

**Suai Formation**

Although this unit was mapped in southwest East Timor it may occur in the subsurface of coastal Viqueque or offshore.

The type locality of the Suai Formation is located around Suai village on the south coast where test well data indicate a rudite and arenite section of about 600 m in thickness. The unit can be seen along the coast from Aliambata in the east to the boundary with West Timor.

The unit is poorly exposed and not well known. It is accessible only by drilling. It may reach 1,000 m in thickness on the coastal plain between Betano and Aliambata.

**4. Structure**

The Timorean orogeny resulted in a major fold belt parallel to the coast. The narrowest structures are near the coast but broad anticlines of large amplitude with significant closure occur inland (Audley-Chrales, 1968). One of these large structures, the Ossulari Anticline has been drilled twice. The large anticlines have been broken into a number of horsts and grabens in their axial areas, which appear to have been the sites of thrusting as well as normal faulting. Some cross sections of Partoyo and others (1995) show a major overthrust fault at the base of the Borolalo Formation, a thick-bedded massive limestone with intercalated chert and calcareous shale of Cretaceous age. The Borolalo is more than 200 m thick.

The deformation of the sedimentary cover in Viqueque district may be primarily the result of movement of the basement resulting in compressive stress being exerted from north to south. The thrusting that culminated the Eocene orogeny dislocated stiff blocks of the Lolotoi Formation, which is considered to be a part of the upper crust and has been laterally displaced for a significant distance. A large overthrust sheet of the Lolotoi Complex is found in central Viqueque district.
The Lolotoi Formation consists of weakly metamorphosed rocks ranging from sedimentary rock to gabbroic to doleritic eruptive rocks. A large block of the Lolotoi Formation is indicated to be present within a few hundred metres of the surface in northern Viqueque district (Partoyo and others, 1995). Blocks of the Lolotoi are also very near or at the surface in the eastern and western parts of the district. It consists of phyllites, schists and gneisses, which have been strongly fractured. The Lolotoi Formation is considered to be of pre-Permian age and to have a thickness of more than 1,000 m.

Pre-Permian Overthrust Units

Lolotoi Complex

This is one of the most famous rock units in East Timor. It has been referred to by a number of names as follows: North Coast Schists, Manufai Diabase, Crystalline Schists and Ophiolites. Some workers lumped the unit with the Barique Formation (Grunau, 1953; Gageonnet and Lemoine, 1958).

The Lolotoi thrust sheet has been termed a klippe, a German word meaning sheet. Americans would refer to the unit as an overthrust or thrust sheet.

The type locality is the bank of the Foho Ra River south of Lolotoi village.

In East Timor there are four thrust sheets, the thrusting post-dating folds of the Timor orogeny (Figure 1). 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 Antcline, one of the major structures that Timor Oil Ltd., drilled in the 1950s.

The unit consists of sedimentary and eruptive rocks that have a low grade of regional metamorphism. In the type section the rock is mainly phyllite but schist, metagabbro, dolerite and gneiss are also present. The entire sequence shows isoclinal folding. Eruptive rocks are described as metamorphosed and mainly gabbro and dolerite types.

A single sheet may reach 1,300 m in thickness, which is not the maximum thickness because of isoclinal folding.

The Lolotoi Complex is a displaced or allochthonous unit and the evidence for this is presented below. The evidence for thrusting of the Lolotoi sheet has been collected in a number of places. For example, the unit rests on autochthonous pre-Eocene rocks in the Mac Fahic Antcline and the Pualaca Syncline in the western part of East Timor. Some of the various units which are cut by the thrust sheet include the following: Aitutu and Wai Luli formations (Mac Fahic anticline), Cribas and Aitutu formations (7 km east of Lolotoi village and 4 km north of Lolotoi village).

The metamorphosed Lolotoi is shown to rest on unmetamorphosed sedimentary rock and the only explanation for this is overthrusting.
The units are assumed to have been thrust from the north. This was the direction of thrusting of Permian strata during a later orogeny (Audley-Charles, 1968).

The level of metamorphism and isoclinal folding in the unit indicate that it is the product of a major orogeny, assumed to be Pre-Permian. The unit could be as old as Precambrian.

**Emplacement of Lolotoi Complex**

The youngest rocks overlain by the Lolotoi Complex are the Middle Jurassic shales of the Wai Luli Formation as can be seen in the Aitutu anticline 5 km west of Pualaca (Audley-Charles, 1968). The rock sequence above the Lolotoi Complex is important in Viqueque district as it has been drilled for oil and gas with mixed results.

Folds that are overlain by the Lolotoi Complex have rocks as young as the Wai Bua Formation (Betano region) and this dates the Lolotoi as post-Wai Bua Formation or post Senonian. The oldest rocks found resting on the Lolotoi Complex are the Middle and Upper Eocene Dartollu Limestone (near Dartollu village). In many places the Barique Formation (Oligocene eruptives) and the Cablac Limestone (Lower Miocene massive and oolitic limestones). The age limits of underlying and overlying units indicate the Lolotoi Complex was thrust into its present position within a time range extending from Senonian to Middle Eocene.

However, before the thrusting the autochthonous units were folded and deeply eroded during the Timorean Orogeny which occurred during the same time interval but before the thrusts arrived. Audley-Charles (1968) suggests that the thrusting probably occurred during the end of the time frame indicated or Lower to Middle Eocene.

It is characteristic of block overthrusting of units such as the Lolotoi to create folds as a result of the movement of such blocks while overlain by a soft cover. Although the original emplacement of the block may have been through gravity sliding on a lubricated basal shale or clay and lateral dislocation over some distance, later deformation would result in the movement of the blocks, creating deformation in overlying sediments and sequences in direct contact with them.

The structural interpretation of the Island's deformation has been the subject of debate for more than 50 years. The role of the basement in thrusting is important. The Lolotoi unit either has been thrust southward as part of the basement at the time of the collision of Australia with the Banda arc in the latter stages of the Timorean orogeny, perhaps creating a compressive force that caused the deformation of softer sediments into east-west trending folds in Viqueque district. Locally, thrust sheets of the Lolotoi may have acted as an unyielding buttress while overlying softer sediments of Mesozoic and Cenozoic age were thrust southward against and over it. The compression of the cover has resulted in both broad folding inland as well as sharp narrow folds near the coast. One of these folds, the Viqueque anticline has been tested by both shallow and moderate depth drilling near the coast at Aliambata.
Part XIV.

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Part XV.

Mineral Database Bibliography of East Timor
A. Mineral Database Bibliography


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Part XVI.

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XVII.

Annexes
Annex A

Selected National and District Social and Economic Data

I. Economic and social situation

A. Overview

Most of the following data are from the Suco Survey Report of the Asian Development Bank and the World Bank (2001); ADB (2000). Some data and conclusions are based on personal observations of the consultant in May and June 2002.

The GDP data indicated fair growth in East Timor prior to the Asian financial collapse of 1997. Real GDP and real GDP per capita had increased 6-9 percent per year. In 1997 the Rupiah collapsed and GDP per capita fell to US$246 per year in East Timor.

Growth following the violence of 1999 was next to nil.

East Timor is considered to be a low-income region with respect to the economies of adjacent countries and has a narrow economic base.

The most important sectors are agriculture, forestry and fishing in 1997 (35% of GDP).

Table 1.1. Income by sector (percent of GDP in 1997).

<table>
<thead>
<tr>
<th>Agriculture</th>
<th>Forestry</th>
<th>Fishing</th>
<th>Public Administration</th>
<th>Construction</th>
<th>Wholesale and retail trade, transport</th>
<th>Non-food crops</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td>18</td>
<td>17</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>


Government expenditure was US$116 million in 1997-98, which was considered low by regional standards.

Growth had stalled completely by September of 1999 as a result of the violence.

Many people had already fled East Timor by early and mid-1999. The data indicate that about 90,000 people left in 1998-1999.

Up to 50 percent of GDP was lost in 1999.

B. Population
The population of East Timor grew from 799,000 to 868,000 people in 1997. In 1999 the population had been reduced to 779,567 but climbed again to 794,298 in 2001 (Suco Survey, 2001; ADB, 2000).

C. Poverty

Rural areas represent 76 percent of the population but include 85 percent of the population living in poverty. A total of 41 percent of the total population of East Timor is living below the poverty line (UNDP, unpublished). About 325,000 people are living in poverty in East Timor.

1. Urban poverty

Only 14 percent of Dili’s residents are below the poverty line but many are only slightly above it. In other urban areas the situation is much worse, 40 percent of the populations are in poverty and living at bare subsistence levels. The rural west and center areas have the highest level of poverty, 51 percent.

D. Education

Forty-six percent of the population has no education and 52 percent of the poor people cannot read. Two percent of the population has attended university.

E. Employment

Table 1.3 Breakdown of occupation by sector.

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer</td>
<td>42</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
</tr>
<tr>
<td>Student</td>
<td>12</td>
</tr>
<tr>
<td>Housewife</td>
<td>27</td>
</tr>
<tr>
<td>Teacher</td>
<td>2</td>
</tr>
<tr>
<td>Civil servant</td>
<td>1</td>
</tr>
<tr>
<td>Skilled worker</td>
<td>1</td>
</tr>
<tr>
<td>Trader</td>
<td>2</td>
</tr>
<tr>
<td>Fisherman</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Non-farm labourer</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: UNDP, unpublished.


G. Economic activity

Economic activity was weak from 1997 to mid-2000. Trade within the country was insignificant during this period. Agricultural areas deteriorated to the point of
subsistence level farming. Manufacturing had almost ceased after 1999. However, construction activity had picked up considerably after mid-2001.

A major humanitarian effort was put in place by the United Nations and NGOs beginning in 2000.

The construction industry was weak even during the initial support phase of the United Nations development activities but by 2002 was indicating moderate growth.

Transport and trade sectors were weak.

Finance was non-existent.

The weakness in the economy in 2000 stemmed many factors as reported by ADB (2000):

- Disruption of agricultural production;
- Weak local demand for fresh produce;
- Stagnant cash economy;
- Departure of non-East Timorese business;
- Destruction of transport equipment, buildings etc.;
- Increase in prices of goods and services;
- Loss of capital or access to capital;
- Insecurity affecting business confidence.

H. Impact of the United Nations, NGOs and the Peace-keeping Forces

Some resources that are required by the United Nations agencies are contracted from foreign firms established in East Timor. These firms need local resources including labour. The hotel and restaurant sectors, a few of which are owned by the East Timorese, have benefited the most from the activities within the enclave. A boom in public administration and construction has resulted in a weak ‘trickle down’ effect. But repatriation of profits and wages of United Nations staff and consultants does not add much to the slowly growing economy of East Timor. Dili is the urban area that benefits the most.

I. Rural economy

This sector is still considered weak because of the poor recovery and the breakdown of the farm activity within the agricultural sector, which began in 1997 and its total collapse in 1999. As noted, this sector had been reduced to the subsistence level in 1999.

Income levels are low throughout the country.

A few East Timorese in Dili are benefiting from the United Nations activities but most are still living at or slightly above the poverty level.
J. Drivers of economic activity

1. Food crop production

The exchange and sale of food crops between regions traditionally has been the major economic activity in East Timor and was recovering in 2001-2002 from its absence in 1999-2000. Food is channeled to Dili, which is the major demand center.

Trade in agricultural commodities is focused in Dili.

The main crops, rice and maize, are most in demand in the districts of Bobnaro, Cova Lima, Manufahi, Viqueque, Manuatuto, Baucau and Oecussi.

Coffee

The export of coffee is a key activity. This accounts for 10 percent of the country’s economic activity. The main coffee production centers are located in Ermera (the most important coffee growing center), Ainaro, Manufahi and Líquica districts. Most of the coffee is exported to Indonesian provinces or overseas. Coffee is the main source of income for residents of Ermera, Ainaro and Líquica who are required to purchase food from other areas. There are attempts being made to improve the quality of the coffee and to enlarge its export potential.

K. Public sector

Public administration results in significant incomes for civil service and military personnel, mostly living in Dili. There were 30,000 civil servants and 12,000 military personnel in East Timor. The public works budget was large prior to the violence of 1999, Rupiah 60 billion in 1998-90, and would probably be at about the same level after independence.

Funding for the public sector was from outside the region.

L. Recent developments (FAO and WFP, 2000)

Maize crops were expected to recover in 2000 and yields were expected to be normal.

Rainfall has been more than normal as a result of La Nina storm activity.

Planting activity was almost normal in 2001 and 2002.

Displaced farmers and the lack of animals and mechanized farm equipment was notable.

Overall production was expected to be better than that of 1997/98 when the crops were severely damaged by a drought.

Trade was severely disrupted in 1999-2000.
There is still a shortage of cash for food purchases.

Transport and distribution problems are still present.

Widespread theft of vehicles caused problems in 1999 but this was much reduced after the arrival of United Nations civilian police in 2000. Roads were damaged by high rainfall and no funds were available to maintain farm and transport equipment.

Transport costs are high in line with high fuel costs.

Coffee distribution and marketing was almost back to normal in 2002.

The unrest of 1999 resulted in the destruction of 75-80 percent of social infrastructure. This has resulted in a booming construction industry but this has been focused mainly in Dili.

UNTAET, donor and NGO expenditures to the year 2000 were high.

Table 1.2 UNTAET, donor and NGO expenditure (to the year 2000)

<table>
<thead>
<tr>
<th>United Nations staff salaries</th>
<th>Reconstruction and development expenditures</th>
<th>Peacekeeping Forces</th>
<th>NGO</th>
<th>Donors</th>
</tr>
</thead>
<tbody>
<tr>
<td>US$50-100 million (per year)</td>
<td>US$134 million (2000/01)</td>
<td>US$50-100 million (per year estimated)</td>
<td>US$10-20 million (per year estimated)</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td>US$ 103 million (2002/03)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: ADB, 2000 and consultant’s analysis.

L. Major constraints to economic development after May 2002

- Reduction in United Nations staff after May 2002;
- Some reduction in United Nations reconstruction and development activity after May 2002;
- Weak demand outside the United Nations enclave;
- Weak sales revenues from the goods and services sector;
- Low scale of business activity and excessive costs of purchasing basic materials such as local timber, sheets of zinc roof, cement, freight transport, truck hire and rice;
- Large increases in prices;
- Security concerns outside of Dili will result in a slower business recovery in rural areas;
- Poor opportunities for income throughout the country;
- Low level of health and educational services;
- Increased competition in fruit and vegetable retailing has resulted in lower incomes and profit levels in most rural areas;
- Lack of capital;
- Funding of most businesses was from savings;
• Dearth of banks and other financial institutions;
• Shortage of equipment and transport;
• Problems with government;
• Anticipated weak police system after CivPol leave;
• Difficulty in establishing a growth friendly environment for economic activity.

M. Positive aspects of economic activity in 2002

• Departure of many of the larger traders has created opportunities for East Timorese businesses;
• Businesses that have access to the enclave will benefit most;
• Markets are re-emerging throughout the country (FAO/WFP, 2000);
• Strong construction industry in Dili (but weak elsewhere);
• Good potential for normal crop production and resumption of coffee exports;
• Commencement of operation of more commercial banks in future with assistance from the World Bank, e.g. the Banco Nacional Ultramario (BNU) had established a small loan facility with access to US$4 million;
• Reappearance of trade links with Indonesia and other countries in the region;
• Optimism amongst East Timorese business people that sales will increase in the future;
• Recomencement of the operation of many small shops;
• Opportunities for East Timorese to develop management skills;
• Improving infrastructure, especially roads: many new roads have been built;
• Apparent willingness of the East Timorese people to develop the health and educational sectors, a high priority of the new government;

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II. Aileu District

A. Social Conditions
In 1997 food production in Aileu was the second highest in East Timor after Bobonaro district.

The main food crops produced were maize (323 kg p.a.) and cassava (204 kg p.a.). Minor production of rice and sweet potato was reported. The district also produces the second highest amount of vegetables (80 kg p.a.). This was exceeded by only one district, Manufahi.

B. Income

The average monthly income per household member was about 80,000 Rupiah which was in the middle income bracket for East Timor. (ADB, 2002).

C. Population

The population of Aileu was about 31,827 in 2001 (Suco Survey, 2001). This was 110 percent of its population in 1997.

About 44 percent of its population is under the age of 15. (ADB, 2001).

D. Health

East Timor people suffer from a wide variety of diseases of which malaria was by far the most important in the year 2000 (126,606 cases reported). Other diseases were simple diarrhea, bloody diarrhea/dysentery, lower respiratory tract infections, clinically compatible measles and clinically suspected meningitis.

Aileu has a relatively good health record having reported only 1-4 cases of each of the above diseases during a 33 week period in 2000. This record was one of the best for East Timor and was bettered only by Manufahi.

Aileu households reported a very low deterioration in their attitude towards health services in 2000 (3 percent of households were unhappy with health services).

E. Education

Of the 13 districts in East Timor, Aileu has a very good attitude towards the provision of educational services. Most schools were operating about 3 hours per day and the curriculum was limited to English and Portuguese. These services had improved since 1997.

Only about 17 percent of households reported a deterioration in educational services in 2000.

F. Food vulnerability

There was only moderate vulnerability to food shortages but there were groups of poor people lacking sufficient volume and/or variety of food.

G. Cash expenditures
Cash expenditures per capita were rising very slowly in Aileu, having risen from almost zero in 1997 to about 110,000 Rupiah in 2000.

H. Hardship

Aileu district had recorded low social and economic hardship in 2000 compared to high hardship in Ainaro (social sector), Baucau (economic), Bobonaro (social), Cova Lima (social and economic), Lautem (economic) and Liquica (social).

References


World Bank, 1999a, *Poverty and Social conditions in East Timor: Summary*.


III. Dili District

A. Introduction

Only a small sample of the Dili district was sampled in the ADB survey (ADB, 2000). The data summarized here are mostly from the ADB survey and personal observations during the period 31 May – 8 June, 2002.

Dili is the main demand area of East Timor. In the past most of the trade from food producing areas that resulted in cash income for farmers came from selling produce to the people of Dili and for coffee export. Consequently, Dili was the source of cash income for most farmers in the surrounding rural areas well as the coffee growing areas. Since the early 1990s there was a decline in demand for food in Dili but this changed dramatically with the arrival of the United Nations Transitional Authority of East Timor (UNTAET), NGOs and Peacekeeping Forces. However, the availability of transport and the road conditions have still limited the extent of the rural area that has been able to benefit from this development.

However, it has been noted that the availability of government funds resulting from the United Nations infusion of cash has been slow to ‘trickle down’ to poor rural people (ADB, 2000). The help provided by the international community has eased
the problems of education and health services. There are still resource constraints but the absence of government charges, availability of medicine and trained health personnel, and teachers have been significant.

Most Dili residents are still cash poor and housing conditions are not good. Poverty has increased and more than half of the population of East Timor lives below the poverty line (ADB, 2000). In Dili fewer households are living in poverty than any other urban area in East Timor.

Dili residents have fewer health problems now and also have benefited from better health care than is provided to most rural people. Family displacement was not as significant in Dili as it was in the rest of East Timor.

Economic activity is expected to increase as time goes on and social conditions should improve. Much is dependent on the coffee crops and local products such as fish, vegetables, and the demand for household goods. It was noted that there are about 50-100 vendors selling fish carried on bamboo poles walking throughout the city of Dili. There are many small mini-marts and restaurants as well as more than two dozen appliance stores.

Businesses that were established during the United Nations period of assistance may have difficulty surviving after the United Nations personnel leave and this development would impact most severely on hotels and restaurants. However most of the larger of these establishments are foreign owned.

The delivery of government services is expected to be most important during the first few years after the United Nations agencies leave.

B. GDP

GDP data of the recent past had indicate good growth prior to the violence. Real GDP and real GDP per capita increased by 6-9 percent per year between 1990-1999.

GDP per capita was only US$246 in 1997.

Agriculture, forestry and fishing accounted for about 35 percent of GDP in 1997.

Other important sectors were public administration and construction, which amounted to 20 percent of GDP.

Wholesale and retail trade and transport amounted to about 35 percent of GDP.

C. Population

In 2000 the population of Dili was almost 100 percent of its population in 1997. There was a reduction in population in most other areas.
The population of Dili district was 120,474 according to the Suco Survey (2000).

D. Income

Sixty percent of households interviewed reported a monthly income of less than 200,000 Rupiah in 1999-2000. This amounts to a per capital cash income of less than US 15 cents per person for a family of 7 people.

About 40 percent of households reported a cash income of less than R100,000 per month.

Today East Timor is generating only 15 percent of the government expenditure of US$116 million in 1997-98.

E. Food production

An urban area has a low per capita food production and Dili’s is no exception. The breakdown is as follows: 1 kg p.a. of rice, 11 kg p.a. of maize, 16 kg p.a. of cassava and 16 kg p.a. of sweet potato. All of these numbers are lower than any other district. Obviously, they indicate a high demand for food produce in the capital district.

Other important vegetables important in other regions that are scanty in Dili are as follows: green peaks (0-1 kg p.a.) and other vegetables (3 kg p.a.).

F. Food production facilities

Dili is the center of the coffee industry production. Coffee passes to exporters via local buyers. There are a large number of small growers in the hills. The transport sector is weak and some farmers cannot get their coffee crop to Dili. At the present time many local buyers also do not have enough capital to buy coffee. The coffee industry is weak.

Facilities are available for storing the coffee bean in Dili and some other urban centers. Coffee production was fair to good in 2000. The crop is picked from June to November and the main processing facilities are in rural areas and Dili.

G. Retail situation

Obviously, sales revenues were not good in Dili in the year following the violence. In 2001 and 2002 retailing was very brisk in those sectors benefiting from the presence of the United Nations forces and administrative staff. Those sectors which benefited most were related to the hotel and restaurant industry.

Many large traders departed but some returned in late 2001 and early 2002.

Grocery retailing and wholesaling were suffered.

Many of the pre-violence traders have tried to recommence operations.
H. Mining sector

A number of local companies provide clay; sand, gravel and lime (crushed coral reef rock) some of which is transported to Dili from neighboring districts and some of which is mined from local river valleys and collected from beaches.

The demand for construction materials, on the other hand, has resulted in a small local cottage industry operated by East Timorese in Dili. There is a high demand for sand, gravel and lime. A small number of local Dili people, commonly older people, were earning their living by hand picking construction material of various sizes from the Dili beaches. These people sort sand, gravel, pebbles, and cobbles into separate piles, which are picked up each night by a local dealer in construction materials who uses a pickup truck to move these commodities to his warehouse and storage area.

I. Average monthly income

In 2000 the average monthly income in Dili was only 100,000 Rupiah which was the second highest per household income in East Timor, exceeded only by Emera.

J. occupation by household

In 2002, the largest employer was UNTAET and NGOs also hired a significant number of Dili residents.

The three most important occupations by household in East Timor were fruit and vegetable farming (8 %), labouring (7 %), and rental/kiosk (6 %). There were a number of occupations (12 %) that were not subdivided and individually recognized in the survey. In Dili the most important occupations are related to the hotel and restaurant sectors and their related labor services. Street vendors, shop owners and government workers comprise a large percentage of the community.

Taxi drivers number between 100 and 200. Bus drivers probably range in number from 100 to 200. Construction workers probably represent the highest percent of the labour sector.

K. Expenditures per household

The average expenditure per household member in 1999 was R50 by the poorest 10 percent compared to R406 by the top 10 percent of the income group. This was reduced to R12 per household member in 2000 for the poorest 20 percent and R337 for the top 10 percent of the income group.

L. Health conditions

Conditions were poor throughout the country prior to the 1999 violence. Infant mortality rates were 85 deaths per 1,000. Under-5 mortality rate was 124 deaths per 1,000.
In a 33 week period during the year 2000 the following treatment numbers were recorded for selected diseases: simple diarrhea (35), bloody diarrhea/dysentery (42), lower respiratory tract infections (43), malaria (25), clinically compatible measles (19) and clinically suspected meningitis (0).

Tuberculosis was a major cause of morbidity. Malaria was the second main cause of mortality and the cause of between 10-36 percent of health care visits. Only 25 percent of the villages had a health clinic. The average distance to a hospital was 75 km.

M. Malnutrition

No estimates were available for the rate of malnutrition in Dili. Poor nutrition results in malnutrition and pre-2000 data indicate 38 percent of children aged between 12 and 59 months in East Timor suffer from malnutrition. A survey by FAO and the WFP indicated that malnutrition was not a serious problem.

N. Health Services

About 32 percent of the households interviewed in Dili reported a deterioration in health services.

O. Educational Services

Educational indicators were not good. About 46 percent of the households interviewed in Dili reported a deterioration in educational services. The national illiteracy rate in 1998 was 59 percent. Primary enrolment in 1998 was 70 percent. However several of the large secondary schools were open in Dili and the University of Timor was offering courses in business administration.

P. Household composition

The average household size in East Timor is 7 people.

Ninety percent of households had sons and daughters and 20 percent had a grandmother or grandfather.

Q. Gender

Data were poor. The household survey indicates that 25 percent of households were headed by women. Seventy-six percent of households reported the father was the main source of income.

R. Housing

Many households had been forced to move as a result of the violence.

In Dili ex-military compounds were being used. Family units had moved into houses. Land ownership was a major problem. Many houses were being refurbished
in May of 2002. Most of the better houses were occupied by family units. Many of the large government buildings were gutted but had been cleaned up.

S. Food vulnerability

Widespread starvation was avoided as a result of food support from WFP and other donors.

Some people were able to use savings to buy food.

Relatives provided food.

T. Alternative staples

In Dili former civil servants and spouses sold food after the violence. Households shifted consumption from rice to cassava, sweet potatoes, yams and taro throughout 1998-2002. Fruit is for sale in Dili, e.g. numerous vendors scour the city with plastic string nets consisting of 8 oranges which was sold for US1 dollar in mid-2002.

The forest provided additional food immediately after the violence. Today it is still an important source of food in rural areas. Dili is located in a deforested area but benefits from local coconut, orange and banana plantations. Tubers and fruits were eaten during hard times. Men hunted wild boar, deer, birds, monkeys and tree kangaroos (FAO and WFP, 2000).

U. Occupation by households in Dili

<table>
<thead>
<tr>
<th>Public service</th>
<th>Animal husbandry</th>
<th>Retail/kiosk</th>
<th>Labouring</th>
<th>Coffee growing</th>
<th>Fruit/vegetable farming</th>
<th>Rice farming</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>1</td>
<td>72</td>
</tr>
</tbody>
</table>

V. Food vulnerability

Dili had very low food vulnerability in April 2000. However it was expected to have a higher vulnerability in the early 2000s.

W. Poverty

The incidence of poverty was rising rapidly over the period from 1997 to 2000. The curve was especially steep in Dili but the expenditure of the top 5 percent of income grew rapidly during this period. There was a need to buy grocery items, clothing and enough food to ensure a balanced diet.
X. Hardship indicators

The hardship in Dili was considered to be at the medium level.

References


World Bank, 1999a, *Poverty and Social conditions in East Timor: Summary.*


Annex B

Persons Met

Mr. Finn Riske-Neilsen, UNDP Representative, Dili

Ms Deidre Boyd, Deputy Resident Representative, UNDP, Dili

Ms Vibeke, Programme Officer, UNDP, Dili

Mr. Naoki Takyo, Assistant Representative, Community Development and Rehabilitation Unit, UNDP, Dili

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