

ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

**ATLAS OF MINERAL RESOURCES
OF THE ESCAP REGION**

Volume 17

Geology and Mineral Resources of Timor-Leste



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PREFACE

Following the ESCAP reforms process over the last two years and the decisions on realigning the ESCAP work programme on the geoscience and minerals sector towards water resources, volume 17 of the ESCAP Mineral Atlas series completes the work of the ESCAP secretariat in the evaluation of the geological prospects, mineral resource potential and mineral development policy of ESCAP member countries. This publication is devoted to Timor-Leste, a new independent country since 20 May 2002, which was unanimously admitted to membership in ESCAP during the first phase of the fifty-ninth session of the Commission, held on 24 and 25 April 2003 at Bangkok.

This publication aims to assist the Government of Timor-Leste in its current efforts to revitalize and build up its economy so that it can recover in the aftermath of 1999 events and post-independence economic crisis through the promotion of further investments in the accelerated development of the petroleum and mineral sectors of Timor-Leste. The primary purpose of this publication is to build an initial and preliminary archive of mineral and hydrocarbon resource information in Timor-Leste. 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 resources 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 Timor-Leste.

Volume 17 consists of the present book and two accompanying atlas sheets comprising geological and mineral occurrences maps of Timor-Leste on the scale 1:500,000. The book contains an overview of background data and economic outlook for Timor-Leste, geology and tectonic setting, mineral and hydrocarbon resources and their potential, current status of the mining industry and petroleum exploration and development as well as the ESCAP recommendations to the Government and donor community on policy, strategy, regulatory framework and capacity-building in the development of the mineral and petroleum sectors of Timor-Leste. The publication also contains an extensive reference and bibliography on geology, tectonic evolution, petroleum geology and mineral resources to guide professional readers. The database and maps 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 fieldwork.

The most significant conclusion arising from the publication is that Timor-Leste does have mineral potential and that some of that potential will almost certainly attract foreign mining companies. The most attractive potential of Timor-Leste is in base metals, mainly copper, and associated gold and silver. This potential is in the proven occurrence of the so-called Cyprus type volcanogenic massive sulfides related to ophiolite sequences. Chromite and vein-type gold represent other exploration targets in which the private sector will be interested. There might also be interest in the clay mineral potential, in phosphorites as well as in marble and other stone resources. Some of these resources may represent targets for domestic investment. Oil and gas potential in Timor-Leste has long been recognized and investor interest is already apparent. Several applications for the development of these potential resources have been submitted to the Government.

The information contained in this volume is based mainly on a study recently completed by Jon Rau during a consultancy assignment with ESCAP. The study, in turn,

is based on the ESCAP report entitled “Natural and mineral resources inventory, policy and development strategy”, which was prepared by the ESCAP secretariat during 2002 in execution of ESCAP/UNDP Special Services for Policy and Programme Development (SPPD) Project TIM/01/022. The study includes excerpts from the main reports prepared by ESCAP consultants on (a) formulation of national mineral policy, legislation and regulatory framework for the Government of Timor-Leste by Jack Garnett, (b) economic geology, development strategy and capacity building by Pieter J. Bakker and (c) mineral and hydrocarbon database and geological bibliography of Timor-Leste by Jon L. Rau. New information and maps on the history of petroleum exploration and recent developments in the Timor Sea are also included.

The originals of all of the above reports by the ESCAP consultants are in the offices of UNDP (Dili) and the Office of the Secretary of State for Natural and Mineral Resources (Fomento Building, Dili) as well as at the headquarters of the Economic and Social Commission for Asia and the Pacific, Environment and Sustainable Development Division, Bangkok.

The ESCAP secretariat would like to express its appreciation to Jon L. Rau for his enthusiasm and dedication in preparing and designing this study, which aims to generate interest among geoscientists, the international mining and petroleum community and financial institutions in further research on the geology, and mineral and hydrocarbon resources of Timor-Leste and investment promotion in the development of mineral-based and petroleum industries of the country.

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Chapter I

Timor-Leste: Background Data and Socio - Economic Conditions

A. Background data

1. Geography

The newly independent country, Timor-Leste, has an area of approximately 16,000 square kilometers. 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 1.1). Timor-Leste has a maximum length of 275 kilometres and a maximum width of 100 kilometres. The country includes two islands, Atauro and Jaco.

The country is surrounded by sea on three sides: Wetar Strait on the north, the Timor Sea on the south and the Maluku Sea on the east (figures 1.1.-1.3). Timor-Leste has a land border on the west with the Indonesian province of East Nusa Tenggara. The 13 administrative districts are sub-divided into 67 subdistricts, 498 villages and 2,336 sub-villages.

Timor-Leste is mountainous in about one-third of its area, mainly in the west, hilly in about one-third of its territory, which forms a wide belt around the mountains. The central and eastern parts of Timor-Leste contain several low plateaus and coastal lowlands fringed by a narrow coastal plain in the north and a wide coastal plain in the south as well as several scattered arc-shaped and linear low mountain belts. The plateau and lowland areas representing about one third of the territory of Timor-Leste are located mainly in the east (figures 1.2 and 1.3).

The Ramelau Range extends about one-third of the length of the western third of Timor-Leste but because of its ruggedness and the many myths surrounding its history, it has received prominence in the literature. The highest peak in the Ramelau Range is Foho Tamailau which has an elevation of 3,037 metres above mean sea level. The peak is located 11 kilometres east of Atsabe village on the Dili – Gleno road. The topography of the Ramelau Range grades into lower mountains, which are broken up by hills and river valleys to the east and west. To the north, it grades into northeast trending coastal ranges in Dili and Aileu districts, which are lower than the average elevation of the Ramelau Range. Between the Dili coastal range and the Ramelau Range, there is a rough high mountainous area, the Aileu Range that extends from the eastern boundary of Ermera District through Aileu District to southern Manatuto District. The highest peaks in this range are in the west near the boundary with Ermera District, e.g. Foho Olopana (5,876 feet). Summit elevations in the Aileu range gradually decrease in elevation from nearly 6,000 feet in the west to about 3,000-3,800 feet in the east. This range can be described mostly as 'low mountains' broken up by northeast trending valleys occupied by large tributaries to the main north-flowing drainage. In fact, taken as a whole, the western third of the country is a 'washboard' of mountains extending from the north coast to within 2-10 kilometres of the south coast.

A large part of the northern third of the country near the coast, extending from Manatuto to the eastern tip of the island, is a dissected plateau which varies in elevation ranging from 1,000 to 2,000 feet above mean sea level with many low hills rising above this surface. The Manatuto-Baucau Plateau is approaching a mature state



Figure 1.1. Administrative map of Timor-Leste.



Figure 1.2 Physio-geographic map of the Timor Island and adjacent areas.

of dissection and the original surface cannot be easily distinguished as such except south of Baucau where it is very flat and virtually undissected.

The structural arrangement of the various western mountain ranges, including the Ramelau Range, suggests that the western part of the island is made of a number of discrete parallel northeast trending mountain blocks which originated from forces (stress fields) operating within the same structural setting. The mountain ranges east of the Baucau-Viqueque road are more irregular and do not occur in sets of parallel ridges like the western ranges of the Ramelau group. Instead, they are isolated and distributed in both linear and arc-shaped patterns.



Source: Instituto Geografico & Instituto Superior Tecnico (Portugal).
Figure 1.3. Relief and subset maps of districts of Timor-Leste.

The distribution of the eastern mountain ranges seems unrelated to the systematic arrangement of the northeast trending ranges of the western part of the country. The Ramelau and related ranges to the north and south such as the Dili, Aileu, and Cablac ranges all trend in same direction.

The two mountain systems of Timor-Leste are separated by a 20-30 kilometres wide lowland occupied by major rivers that flow mostly to the north coast. This valley is termed herein the Quelicai Lowland.

Fossil coral terraces are found at elevations ranging from a few metres above sea level to almost 1,000 metres (3,281 feet) in some interior plateaus. The most obvious plateaus capped by fossil coral reefs are located along the north coast between Manatuto and the eastern tip of the island. Inland, flat surfaces near the coast are invariably capped by Pleistocene coral reefs that are essentially planation surfaces and could be referred to as marine plains. These are surfaces upon which coral development was temporarily limited to the height of sea level. The two most obvious marine plains underlain by fossil coral reefs are the plain south of Baucau and the gently south sloping surface occupied by a large freshwater lake in the east located in Lautem District. Raised coral reefs are present as beach lines along the north coast and are especially well developed west of Manatuto and east of Baucau.

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The Quaternary and Recent coral terraces on the north coast of Timor and the adjacent island of Atauro extend to 700 metres above sea level indicating rapid but spasmodic uplift in the last 100,000-200,000 years. There are eleven different terrace levels on Atauro, each of which is accompanied by the development of coral reef limestone, but the most significant and best developed surface is at an elevation of 555 metres above mean sea level.

A sequence of shoreline features and fringing reefs resulted from both Quaternary sea level changes and an uplifted land margin. Many of the features have been dated using Th230 and U234 isotopes. A shoreline located about 63 metres above sea level is well developed on Atauro Island and has been dated as 120,000 years before present (Chappell and Veeh, 1978). An uplift rate of 55 metres in 120,000 years indicates that the uplift rate in Atauro Island was 0.0004 m/yr or 0.4 metres per 1,000 years. If this rate had continued for one million years, parts of Timor could have been raised 400 metres (1,323 feet).

2. Climate

Timor-Leste has an ideal climate for geophysical and geochemical exploration. The climate is tropical, warm and humid, but very dry in the most part of the year. The wet season is from December to March in the north and from December to July in the south. Practically, there are no rainfalls during the other months. Hydrocarbon exploration, focused mostly on the south coast, would enjoy hot and moist weather, with an estimated rainfall of 160-270 centimetres, and a mean temperature of 24°C. The months of August through November are dry.

The north and mid-central parts of the country (Ambeno, Baucau and Viqueque districts), have a hot and dry climate with rainfall estimated at 50-110 centimetres and a mean temperature of 26°C. In mountainous areas of the interior above an elevation of 1,350 metres, the climate is cool with rainfall above 320 centimetres evenly distributed. The average temperature on the coast is about 25°C in the wet season. On the northern coast, the rainfall ranges from 500 to 1,000 millimetres per year. The southern coastal plain, receives over 2,000 millimetres and has two wet seasons.

3. Road Network

The country's main arterial roads are located along the north coast. The roads on the south coast are mostly in poor condition and surfaces consist of gravel or dirt requiring 4WD vehicles in the wet season. Good sealed roads are found in and near urban centers. The road network had a total length of 1,400 km when surveyed in 2000. About one-third to one-half of the roads need maintenance to improve banks and prevent landslides.

There are 450 bridges, which are well constructed but in the south a few important bridges are either out or uncompleted. Where bridges are out, the streams are shallow and can be forded most of the year. The central mountain ridge is rugged reaching 3,000 metres in elevation. It can be crossed in several places but the roads are in poor condition and consist of poorly maintained one-two lane tracks with gravel or dirt surfaces. Sealed roads in the northern coastal plain, plateaus and foothills permit average speeds of about 50 km/hr. Potholes are common and most roads are narrow from 3.5 to 5 metres.

4. Population and land use

Timor-Leste had a population of 884,636 people in 1988 with a population growth rate of 2.87 per cent during a period from 1990 to 1997. Parts of central Timor-Leste are sparsely populated but it has about a dozen large towns along the coast in addition to its largest city and capital, Dili, located on Wetar Strait.

The population is scattered over about 442 villages covering 213 square kilometers and primarily located in lowland areas along the north and south coasts and in the foothills. Most of the land area is forest (approximately 11,000 square kilometers) but the trees are small and the bush is not thick. There is a substantial area of vacant land (589 square kilometers), wetlands (419 square kilometers) and plantations (456 square kilometers). Mixed farms occupy 217 square kilometers. Paddy is grown in the lowlands whilst coffee is the most important crop in the west highlands.

5. Language and literacy

The Government has decided to introduce Portuguese progressively as the language of instruction. Most people speak Tetun, the mother tongue and most adults understand Bahasa Indonesia. English is rarely spoken. Few teachers speak Portuguese. There are primary schools in most villages but before independence, 30 per cent of the children were not enrolled at all. Secondary enrolment never reached above 36 per cent at the lower secondary level and 20 per cent at the upper secondary level (UNDP, 2002). The literacy rate was 43 per cent (15 years and over) in 2002. Education is the highest development priority in the country.

6. Religion and ethnicity

Ninety-eight and a half per cent of the population is Roman Catholic. There is no antagonism between Catholics and the other religions, Islam (0.79 per cent), Hinduism (0.68 per cent) and Buddhism (0.06 per cent). There are more than thirteen ethnic groups of which the most important are Timorese, Belu, Tetun, Galoli, Nambi, Tokode, Fataucu, Makasae, Midiki, Idate, Mambae, Bunak and Kemak.

7. Economy and infrastructure

Timor-Leste is in the midst of a period of rapid development. The catastrophic violence of the recent past severely weakened the country and its population was seriously affected by the loss of their homes and food shortages in 1997 and 1998. Now, there is a need to rebuild most of the infrastructure in Dili, especially government and municipal buildings, hospitals, schools, and power stations to generate electricity. Power grids need to be repaired in some areas in order to distribute electricity. There is a need to improve farm-to-market roads as well as mountain crossings, expand ports and also develop the infrastructure necessary to support the country's agricultural and mineral potential. There are two airports, one at Baucau and the other at Dili.

Currently, there are 11 ports in Timor-Leste. Dili Port located in a small open harbor, is the main port of Timor-Leste. The approach is a narrow passage through reefs marked by beacons. The concrete wharf is 180 metres long and 20 metres wide providing for vessels with a maximum length of 140 metres and 7.2 metres of draft to dock. The wharf is being extended by 40 metres. The harbor has a beach-landing site with a rock-concrete ramp. The port has a hard stand and a container yard. Additional infrastructure includes a harbor master building, transshipment warehouse, five warehouses, and an administrative building all in good condition. The port has no

container handling equipment nor is it able to offload cargo from ships (UNDP, ADB and the World Bank Joint Assessment Mission, 1999).

8. Industry and agriculture

In the past, Timor-Leste's industrial development was focused on agricultural products such as coffee, coconuts, cinnamon, areca nuts, paddy and other crops as well as small-scale craft industries such as wood handicrafts and woven cloth. Timor-Leste has an ideal climate and soil for coffee plants and its Arabica beans attract a premium price on world markets (Backman, 1999). Sandalwood vanished from other tropical forests many years ago but can still be harvested in commercial quantities in Timor-Leste. Its wood is a source for expensive oils used to make perfumes, soap and incense sticks.

There is a small-scale cement industry utilizing local materials but a Portland cement plant has been proposed. Fish products could account for a larger percentage of its earnings and could become as important as they are to Iceland. Tourism is expected to be a large earner of revenue in the future.

9. Trade

Timor-Leste has entered a period of modern growth and repopulation with the return of five hundred thousand people that were displaced in 1997. It has begun to trade again with neighboring countries. In 1996, the country's exports were valued at USD\$24,473,510 and it relied on imports worth US\$1,788,100. Potential trade partners include Indonesia, the Southeast Asian countries, Australia, and the countries of the Indian sub-continent as well as China and the rest of Eastern Asia. Timor-Leste is well positioned to exchange goods with these countries and to export natural resources, including minerals, should their potential be realized. Timor-Leste has a good access to both Australian and Indonesian markets. Its location just across the Timor Sea from Darwin and the short distance to the large ports of Java and Sumatra give the country singular benefits. Singapore and ports of Indochina are close enough to provide an incentive for Timor-Leste to develop bulk cargo commodities such as minerals. It is half way between potential Indian and Pacific Ocean markets and very close to a number of import ocean trade routes.

B. Social and economic conditions

1. Social conditions

The Timor-Lesteese people have a strong love of freedom. This was never stifled even though they had to endure colonial rule for hundreds of years. The human potential is excellent. Standards of health are low. Life expectancy is only 57 years due to the impact of preventable diseases such as malaria, dengue fever and respiratory tract illnesses.

One of the strongest thrusts of the new government will be in the education sector because more than half of the population is illiterate. The Government has indicated that the language of instruction will be Portuguese, which is a problem because few teachers speak Portuguese. The language of the people is Tetun. The teaching profession needs more teachers because the current ratio of students to teachers is 60 to one in the primary schools. Curriculum development requires international assistance. One hundred per cent enrollment in primary schools is a major goal of the new Government.

Rural households are engaged in subsistence agriculture. Productivity is low. However, the soils and water situation are good so that with proper land use management and the development of irrigation systems there is promise for a brighter future. Flooding is a problem and soil erosion needs to be controlled. The agricultural sector, the mainstay of the economy, needs to have better equipment and the farm to market roads are poor. The north coast is endowed with reasonably good quality roads but the rugged mountains that divide the country into two coastal plain areas are difficult to cross and all roads in the mountains require improvement.

Incomes are too low. The 41 per cent of the population that are living below the poverty level try to exist on only \$0.55 per person per day. Better incomes are found in the urban areas. The typical situation in rural areas is one of too many households with four or more children and small landholdings with a few livestock.

In spite of the difficulty of living in an atmosphere of weak economic conditions, the people now have a sense of well being due to the fact they feel safer. The crime rate is low. Since the advent of Independence, 43 per cent of the people feel more secure. People feel relatively good about their future chances for a better standard of living for themselves and their children.

The population is growing at about 2.5 per cent annually. The agricultural sector and the 'informal economy' attract about 20,000 young people each year. The legal system is being strengthened, as the courts and judiciary were weak and corrupted in former days.

The most serious environmental problem is polluted water and poor sanitation. These conditions impact most severely on women and children because of the time and care that need to be devoted to sick children.

There is a strong sense of community in Timor-Leste. Community leaders and the local people are vocal and work together. Youth and student movements were active during the country's long struggle against colonialism. They will continue to support their goals of a better way of life for all.

2. Economic conditions

The Government recognizes the immediate needs to chart a new economic path. This requires that the agricultural sector, the main stay of the economy, receive close scrutiny. Over the long term, agricultural productivity needs to be improved. A tremendous job is required to rebuild the country's infrastructure.

The economic and social infrastructure was severely damaged during the devastating violence that was triggered by the massive vote in favour of independence on 30 August 1999. Afterwards, the Timor-Lesteese people found their homes destroyed and the Government returned to face innumerable burned out structures. Institutions were totally wrecked by the savagery of the attacks. Yet, the physical destruction could not dissipate the energy waiting to be used to rebuild the country. Every Timor-Lesteese heart could envision a better future and, some day, a much better way of life for their children. People were prepared to sacrifice today for the prospect of a secure future.

Economic activity was weak before the violence and continued thereafter, from 1997 to mid-2000, but some devastated areas now have been cleaned up and a few rebuilt. 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 and experienced modest growth in 2002. Transport and trade sectors were weak. Finance was non-existent until recently. The weakness in the economy in 2000 stemmed from many factors as reported by ADB (2000):

- Disruption of agricultural production;
- Weak local demand for fresh farm produce;
- Stagnant cash economy;
- Destruction of transport equipment, buildings etc.;
- Increase in prices of goods and services;
- Insecurity affecting business confidence.

Since the ADB report was compiled, agricultural demand is struggling back to normal, the cash economy has picked up and most rural buildings have new roofs. The cost of goods and services is still high. Security has improved markedly with the success of U.N. Peacekeeping operations and people feel safe.

Tourism is a sector that appears to have strong potential. The country is endowed with some of the most pristine beaches and marine conditions in Asia. The countryside is clean and Timor-Leste villages are smart and tidy. The forests are still in reasonable good condition and the hillsides make beautiful vistas in the afternoon sun. The sunsets are spectacular.

One of the strongest opportunities for economic development lies in the hydrocarbon industry. The offshore areas are rich in natural gas and oil. Onshore areas also have some oil and gas potential. Mineral potential is good with the discovery of a few substantial occurrences.

The Government expenditure was US\$116 million in 1997-1998, which was considered low by regional standards. It was anticipated that this level would again be reached in 2006.

Chapter II

Geology of Timor-Leste

A. History of geological work in Timor Leste

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

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

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

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

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

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

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

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

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

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

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

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

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

B. Regional geologic and tectonic setting of Timor-Leste

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

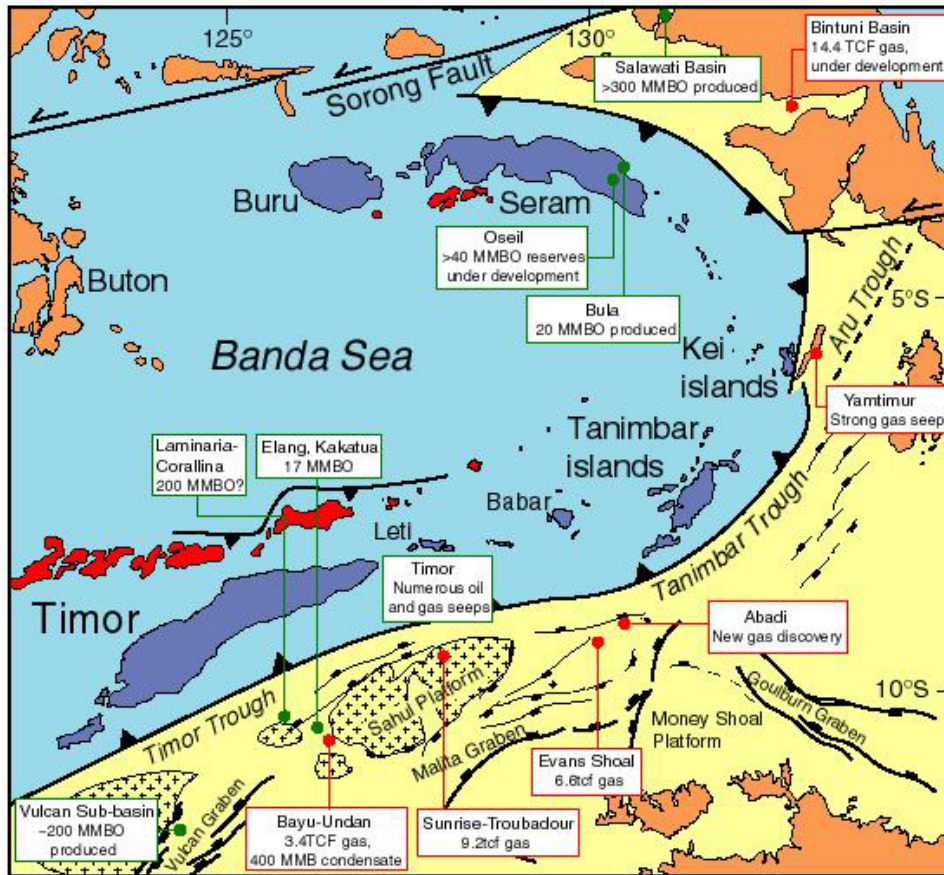


Figure 1: Banda Arc structure and regional hydrocarbon occurrences

Source: Charlton, 2002.

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

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

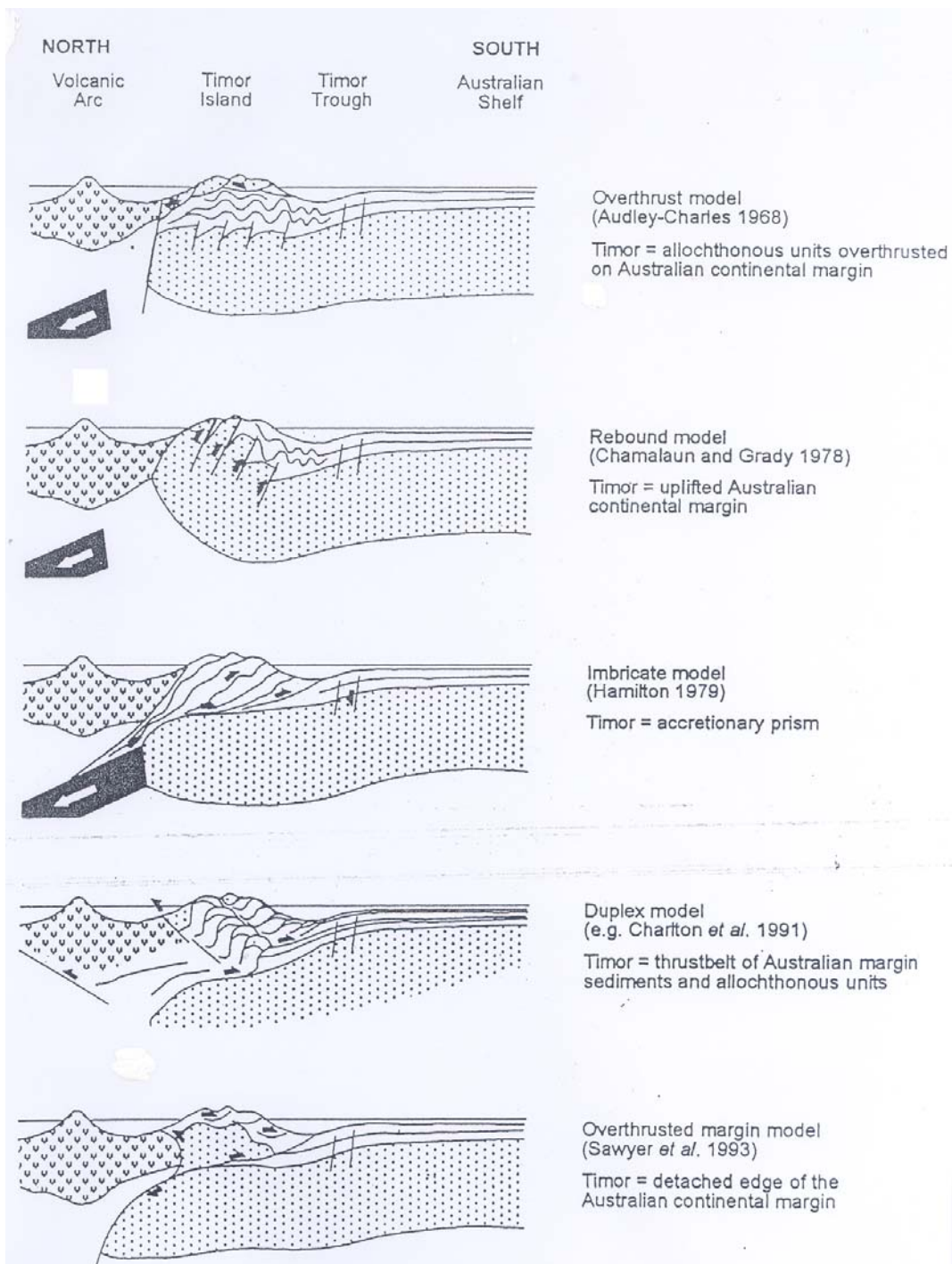
The oldest of these theories proposed in the 1970s suggests that Timor is the leading edge of the Australian continental plate which had ‘stubbed its toe’ against Asia in the Middle-Late Miocene (Audley-Charles, 1968). The relationship (distance) between Australia and the island of Timor remained fixed until the collision because they were part of the same plate (Audley-Charles and others, 1972; Carter and others, 1976; Barber and others, 1977). This theory agrees with the ideas of Wanner (1913) who considered that Timor consisted of two types of formations, para- autochthonous Australian strata and allochthonous Asian strata, with the allochthonous strata thrust onto the autochthonous sequence during the collision (figure 2.3).

Another concept, involving the subduction of the Australian Craton along a nearly flat subduction zone resulting in the underthrusting of the Australian Plate beneath the Eurasian Plate was proposed by Fitch and Hamilton (1974) and Hamilton (1977). This

theory was termed the imbrication model by Chamalaun and Grady (1978). The underthrusting of Australia was to have begun some time before Timor was formed, although ultimately Timor was built as a result of accretion related to subduction (Hamilton 1979 and 1980). The trace of the subduction zone at the surface usually corresponds to the Timor Trough (figure 2.2).

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

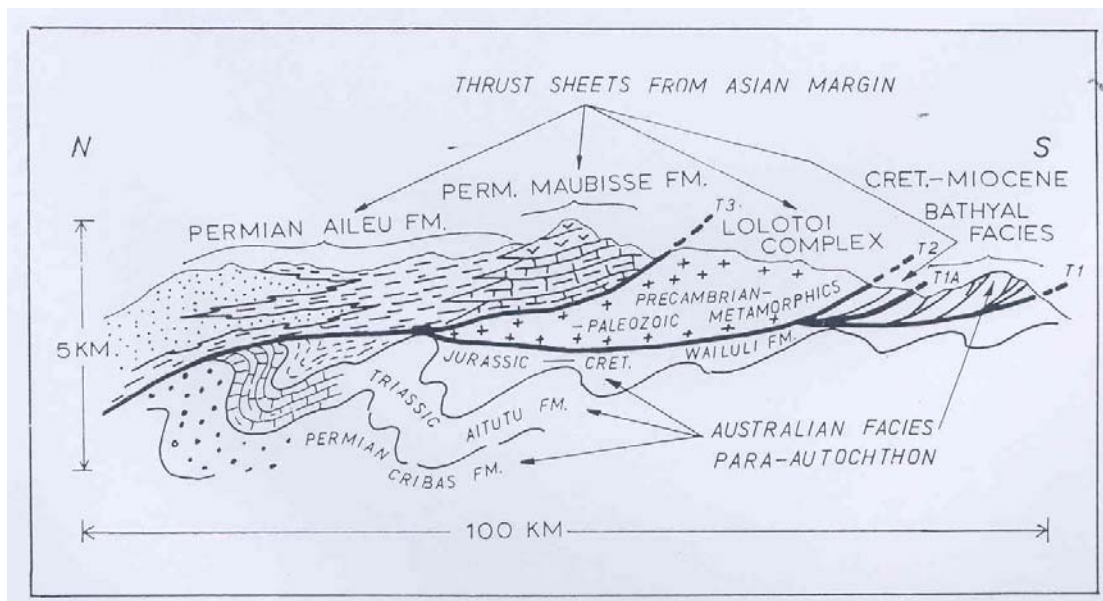
Based on seismic reflection data, Hamilton (1979 and 1980) suggested that a thick accretion prism derived from sediments and slices of old Australian cratonic rocks was built on the surface of the subducting plate, which was at continental slope depths but moving landward at a very gentle angle. This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



Source: Harris and others, 2000.

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

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

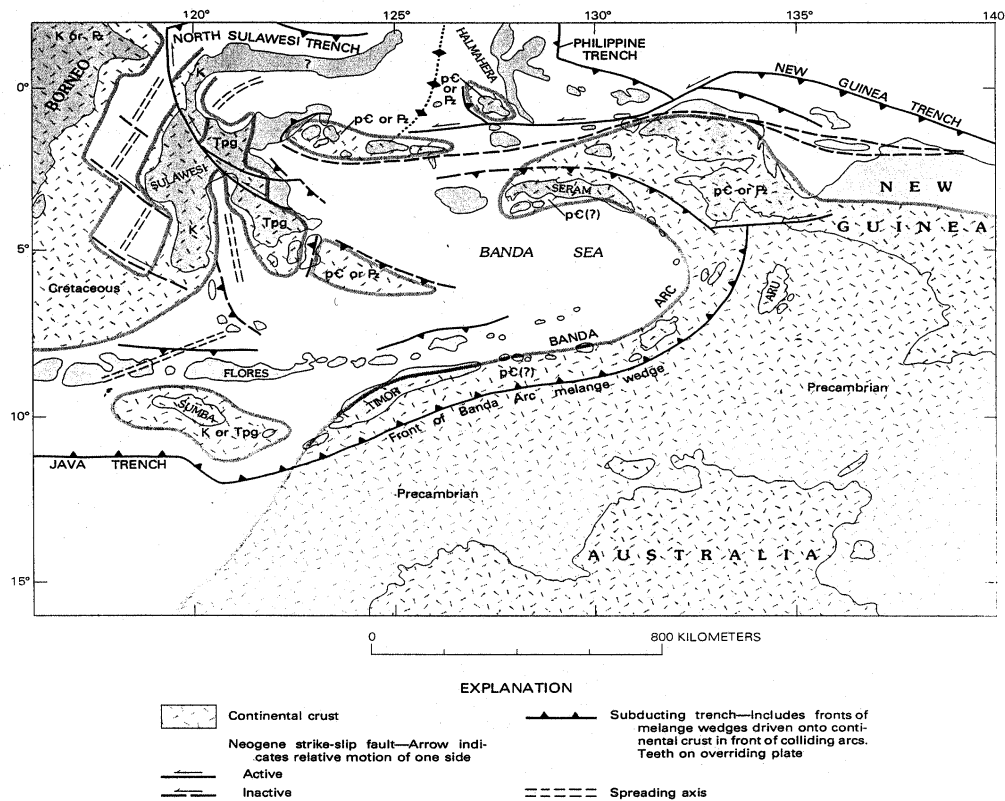


Source: Audley-Charles, 1978.

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

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

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



Source: Hamilton, 1978.

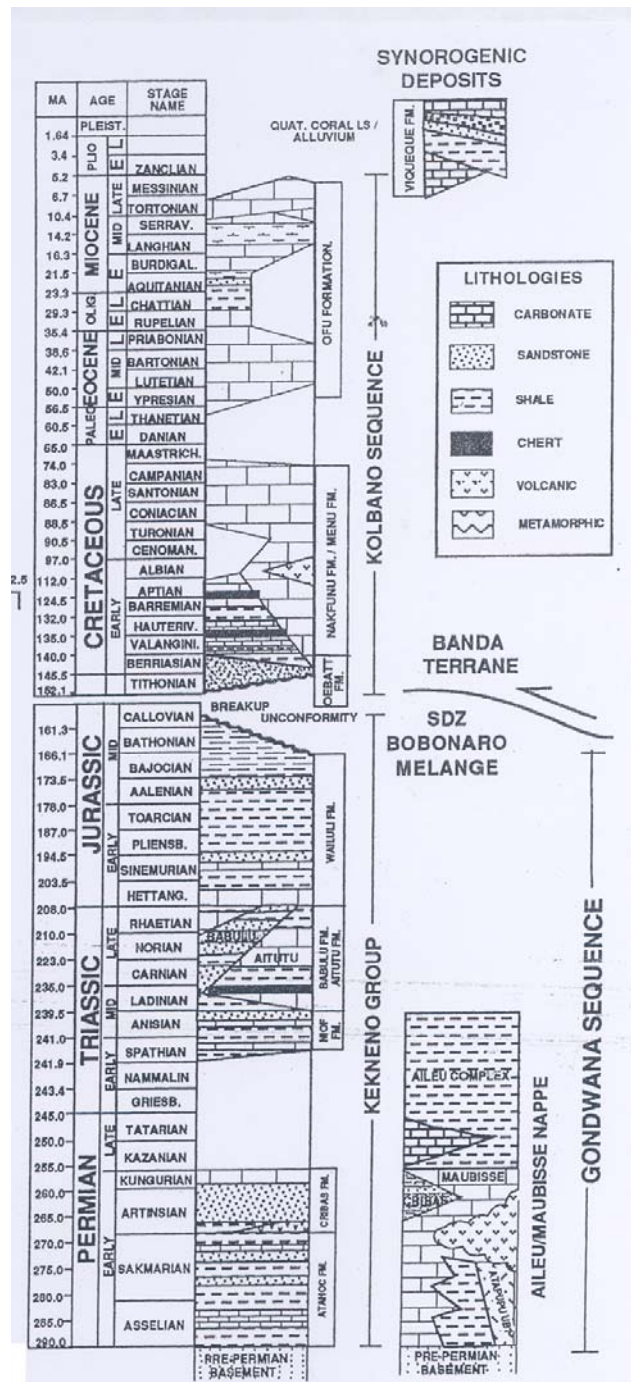
Figure 2.4. Distribution of the two major crustal rock types in the Timor area.

C. Stratigraphy of Timor-Leste

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

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

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



Source: Harris and others, 2000.

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

A G E		LITHOLOGY	FORMATION	ENVIRONMENT
QUAT.	HOLOCENE			
	PLEISTOCENE		Viquesque	Shallow to Deep Marine
TERTIARY	PLIOCENE			
	MIOCENE		Bobonaro	
	OLIGOCENE		Cablec 300 m +	Shallow Marine
	EOCENE			
	PALEOCENE			
			Kobano 500 m	Deep Marine
MESOZOIC	CRETACEOUS			Radolarite
	JURASSIC		Waitul 500 m	
	TRIASSIC		450m Alpu	Shallow
			700m Niof	Deep Marine
PALEOZOIC	PERMIAN		Maubisse 1200m Alahoc	Volcanic Shallow Marine
	PRE - PERMIAN		Metamorphic Basement	Terrestrial

S Potential Source Rock
 R Potential Reservoir Rock

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

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

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

2. Cambrian-Carboniferous

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

3. Permian

(a) *Atahoc Formation*

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

(b) *Cribas Formation*

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

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

4. Triassic

(a) *Aitutu Formation*

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

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

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

5. Jurassic

(a) Wai Luli Formation

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

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

6. Upper Cretaceous

(a) Wai Bua Formation

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

(b) Borolalo Limestone

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

(c) Seical Formation

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

7. Eocene

(a) Dartollu Limestone

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

8. Oligocene

(a) Barique Formation

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

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

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

9. Lower Miocene

(a) Cablac Limestone

The Cablac Limestone forms the ENE-WSW trending mountainous spine of Timor-Leste. It consists of grey, hard, massive limestone of several types: calcilutite,

oolitic limestone, calcarenite and an intra-formational conglomerate ranging up from 400 to 600 metres in thickness. Dolomitization and silicification are common. The unit makes a precipitous escarpment. The limestone rests unconformably on the Oligocene Barique or Lolotoi formations. An overlying unit is rarely present because the Cablac Limestone usually occupies the top of a mountain but in a few places it is overlain by the Bobonaro Scaly Clay. A very shallow marine environment of deposition is indicated by calcareous algae and coral fragments.

(b) Aliambata Limestone

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

10. Upper Miocene

(a) Viqueque Formation

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

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

11. Miocene

(a) Lari Gutu Limestone

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

(b) Dilor Conglomerate

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

(c) Seketo Block Clay

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

12. Post-Pliocene

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

(a) Baucau Limestone

The flat lying Baucau Limestone consists of grey, hard, cavernous, massive white coral-reef limestone well developed around Baucau town. The unit controls the topography in the Baucau and Lautem plateaus. A continuous outcrop occurs along the north coast. In the southern foothills, the Baucau Limestone also crops out in scattered hills. The limestone occurs as coral-reef, calcarenite and a greywacke-pebbly sandstone facies. The Baucau Limestone rests unconformably on older units everywhere. It overlies the Viqueque Formation, but locally, it is found on older formations. Along the north coast of Baucau District there are a series of raised beaches (photo 2.1). The various terrace levels reflect the stages of Timor’s uplift history.



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

(b) Poros Limestone

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

(c) Suai Formation

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

(d) Ainaro Gravels

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

13. Stratigraphy of the Miocene Thrust Complex

(a) Lolotoi Complex (Banda Terrane)

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



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



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

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



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

14. Stratigraphy of the Upper Miocene-Pliocene Thrust Complex

(a) Aileu Formation (Aileu Complex)

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



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

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

(b) Maubisse Formation

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



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

Chapter III

Mineral and Hydrocarbon Resources of Timor-Leste

A. MINERAL RESOURCES OF TIMOR-LESTE

1. History of mining and mineral assessment in Timor-Leste

The Australian National University has carried out preliminary studies of the prehistoric copper industry in Timor Leste (Glover, 1972 and 1986). Analysis of ancient copper mining sites and tools as well as of copper artifacts and ornaments, axes and other grave goods proves the presence of local prehistoric smelting and copper manufacturing operations in Timor-Leste. Portuguese archeologists reported finding copper ore bodies with simple galleries and pits as well as tunnel props in the 1950 - 1960s.

The oldest mineral exploitation activity in Timor in the modern period was probably also copper mining. The earliest reference to copper mining in Timor is found in correspondence of 1849-1850 from the Ministry of Colonial Affairs (Netherlands). The ministerial correspondence refers to "...copper mines on Timor and the gold mines on Celebes." (Schwidder and Vermeij, 2001). 't Hoen and Van Es (1925) were the first to describe the copper mineralization and potential of Timor based on a survey of occurrences in the western part of the island.

The Allied Mining Corporation (AMC), a Belgian company working for Hong Kong interests (Asia-Pacific Investment Co.), carried out a detailed geological reconnaissance of several areas along the north coast of eastern Timor and in the central-east Manatuto, Baucau and Viqueque districts. AMC concluded that these areas had some economic mineral potential based on exploration work in 1936 (Wittouck, 1937). AMC, using a large complement of geologists and engineers, completed a thorough 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, manganese and chromite but considered the occurrences uneconomic and discouraged further development.

Early discoveries by Australian prospectors of gold in Manufahi district were lost in the canons of history and a positive assessment of the mineral potential of Timor did not come until the work of Dorian and his co-workers. J.P. Dorian and others, completed a somewhat controversial mineral resources assessment of Indonesia in the mid-1980s (Dorian and others, 1985). They assessed the mineral potential of the archipelago 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 (e.g. the United States of America) could be used by the URPV technique to estimate the inventory of mineral resources in "less-explored" or underdeveloped regions.

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 Timor-Leste, the value of Timor-Leste'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.

While mining companies were very interested to work in Indonesia in the 1960-1990s, eastern Timor was generally ignored, although in the 1980s there was some interest by international companies in the possibility of finding copper in the ophiolite thrust sequences of northern Timor. A few large companies received concessions (COW) in Timor. CRA/Rio Tinto received a COW in the Oecussi district in the early 1980s. P.T. Dwi Tunggal Inti Sakta was the first company to report that it had discovered gold deposits in Viqueque and Baucau districts of East Timor (Kuo, 1995).

2. Metallogeny and mineral potential of Timor Island and adjacent areas

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-Leste is located near the Inner Banda Arc, the site of a Miocene subduction zone. Oceanic rocks of the Eurasian plate were thrust onto Timor-Leste by tectonic processes, which are poorly understood. 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 was explored by a multinational company in the 1980s. The base metals are concentrated in ultramafic rocks, which are parts of an ophiolite suite. Large parts of Timor-Leste are underlain by cratonic rocks derived from Northwest Australia. These rocks too are notably endowed with a wide variety of economic mineral occurrences.

Precious metals such as gold and silver were also deposited in and adjacent to volcanic centers in the Inner Banda Arc as a result of epithermal activity. One of the islands of this Arc, Atauro, belongs to Timor-Leste. Atauro has a number of gold and silver occurrences. 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 Timor-Leste, 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. Argillic 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.

The most attractive mineral potential of Timor-Leste is in base metals, mainly copper, and associated gold and silver. This potential is in the occurrence of so-called Cyprus type volcanogenic massive sulfides related to ophiolite sequences. This style of mineralization can be observed in outcrop in the Ossu area of the Viqueque District. Geological reasoning and extrapolation allow for the conclusion that similar mineralization will be found in other locations where ophiolite sequences are found in the territory. Chromite, vein gold and certain non-metallic minerals are also found and may have potential.

Timor Island is a part of the non-volcanic outer Banda arc. It occupies a suture or collision zone between the Asian and the Australian plates. Formed by mechanical accretion of underthrust or collided Australian continental margin material, the island is covered by several autochthonous sequences. Ophiolites, the so-called Banda terrane, and a clay mélange are the main overlying sequences. Two other important aspects of the geology and geologic evolution that influence the metallogeny are the Australian northwest shelf and the active tectonics and the continuing uplift of the territory.

Ophiolite is a stratified group of three separate rock types. The lowermost member consist of peridotites and dunites, above which are layered to massive gabbros that in turn are source to and overlain by a volcanic member composed of sheeted dikes and pillow basalts. While the individual basic to ultrabasic rocks of this sequence have been mapped by the Allied Mining Corp. (1937.), the recognition of these rocks as an ophiolite series was first clearly mentioned by van Bemmelen (1947). "Schist-Ophiolite Complex is probably widely distributed.... andit forms the overthrust unit of the North Coast Schist-Manufahi Diabase Complex." Van Bemmelen based his descriptions on the earlier work of Dutch geologists, particularly that of de Roever (1940) and the Allied Mining Corp. (1937). A geological sketch by van Bemmelen clearly shows that large areas in Timor-Leste are underlain by ophiolites.

Possibly the best and most complete description of the ophiolitic rocks, though not under the term ophiolite, is found in the annotation to the geologic map of the Kupang – Atambua Quadrangle in West Timor (Rosidi, 1978). In this annotation, the Manamas Formation (Tmm.) corresponds to the upper section of the accepted ophiolite sequence, while the Ultra Basic Unit (UB) forms the lower part and completes the sequence.

Ore deposits in ophiolites (Coleman, 1977; Cox and Singer, 1986) include massive sulfides as stratabound bodies in the pillow lavas, mainly as copper-bearing massive pyrite lenses with some gold and silver. At times, these lenses also carry lead and zinc values. These Cyprus Type volcanogenic massive sulfides are usually between 500,000 tons and a few million tons in size, though larger deposits exist. They account for significant ancient and modern mining in Cyprus, Oman, Turkey, Greece, the Philippines and elsewhere and, with copper grades between 1 per cent and 10 per cent, are attractive exploration targets.

Manganese and manganese-iron-silica formations overly this type sulfide deposits. They are mostly low grade accumulations of manganese oxides and silicates. Chromite occurs in ophiolites, in podiform chromite deposits and as schlieren. Ophiolite related chromite deposits include some of the most important deposits in the world, such as those in the Islamic Republic of Iran, Greece, Turkey, the Philippines and New Caledonia.

Nickel deposits can form secondary concentrations in laterite weathering profiles on the dunites and peridotites of ophiolitic sequences. Most notable are the examples from New Caledonia where huge lateritic nickel concentrations exist. The ultrabasic rocks of Timor-Leste contain approximately 2000 ppm Ni (Harris, 2000) and could, therefore, in theory also be the source rock for the formation of concentrations of lateritic nickel. Field observations however seem to indicate the absence of deep laterite weathering profiles, probably due to the constant uprising of the island, and, therefore, no evidence exists for the occurrence of this type of mineral concentration.

The occurrence of platinum group minerals (PGMs) related to ophiolites has been reported from Oman where platinum group minerals have been found in the Samail ophiolite (BRGM, 1995) and from the Islamic Republic of Iran. No indication exists that these may also occur in Timor-Leste, but excluding the possibility is, as always in exploration, risky.

The Bobonaro Mélange (Harris, 2000), and the Bobonaro Scaly Clay (Charles, 1968) or the Sonnebait Series by the older Dutch workers, covers large parts of Timor island and about 60 per cent of the territory of Timor-Leste. The unit consists of soft scaly clay with exotic blocks and lenses of rocks of all ages and sizes in it, sometimes dominating the landscape as abrupt outcrops as in Laleia, where a huge knoll of limestone with no apparent roots and surrounded by mélange stands towering over the city.

The clay itself has probably been derived from the sub-marine weathering of volcanic ash material and has been structurally interpreted as marking the collision suture between the Australian lower plate and the Asian upper plate (Harris and others, 2000). Much of the clay in the mélange is bentonitic in nature with a dominance of smectite clay minerals.

Raised beaches, reefs and alluvial terraces including the occurrence of raised reef material at altitudes of 500 metres and more above, clearly indicate that the recent and probably ongoing tectonic movements cause continuous uplift of the island. One of the consequences of this uplift is the likely absence of any thick accumulations of deep tropical weathering, and thus the probable absence of large nickel laterites. The uplift results in aggressive erosion and the possible formation of concentrations of mineral sands. Large concentrations of ordinary sand and gravel will result, though these concentrations may be ‘bouldery’ and unsorted.

3. Metallic mineral occurrences of Timor-Leste

(a) Copper and gold

Several copper, copper-gold and gold occurrences have been reported all associated with a suite of basic to ultrabasic rocks. The geological setting in all areas is dominated by ultrabasic units, with extensive serpentinite alteration, and intrusive diorite/diabase rocks. These basic/ultra basic units are in many places covered by more recent marine sediments and, therefore, their total extent in each individual area is unknown.

The earliest descriptions (Wittouck, 1937) refer to “serpentine plugs and irregularly shaped masses exposed in places through the mantle of chaotic sediments ...” The possibility that there is a connection between the ultrabasic occurrences in some of the districts should be considered, but mapping and geophysical surveying will be needed to supply the evidence. Most of the indications described so far occur in the Baucau and Viqueque districts. Native copper occurs at the Virac area where it has been found in large lumps weighing up to several kilograms. A dense brown breccia of “uncertain character ...” (Wittouck 1937) is cemented by calcite, which in the larger cracks appears as a coarse crystalline, banded and iron stained filling; the native copper mineralization is possibly connected to these vein fillings.



Photo 3.1. Serpentinite rock collected from near the Ossu massive sulfide occurrence.

In the Ossuala area, in a similar setting, stringers filled with complex sulfides occur in the serpentinite. The sulfides are chalcopyrite, pyrite and others. Sampling by the AMC (1937) returned values of 10 per cent of copper, 3g/t gold and 170 g/t silver. The wall rock appears to be mineralized as well, although with much lower grades (photo 3.1).

“In the Ossu area, float and large boulders of pyrite and chalcopyrite are found on a ridge of serpentinite. The area is 15x15 metres wide and the float is in situ. Grades in the pyrite are reported to be 10 per cent of copper, 3-4 g/t gold and 70 g/t silver. Gossanous material was observed encrusting the sulfides...” (Wittouck, 1937). These spectacular large boulders of copper/gold/silver massive sulfide weighing from 5 to 15 tons are located at the bottom of a serpentine ridge along the track from Ossu to Leca, on the east side of the Vei Berek stream about 10 metres above the stream level (photo 3.2).

The occurrence has not been evaluated and explored. The Allied Mining Company describes the occurrence as “...probably small...” without having done sufficient work. With today’s knowledge of this style of mineralization, one must conclude that the outcrop itself is a significant indication and may well be the tip of a much larger ore body. The confirmed occurrence of these boulders in close association with the serpentinitized basic/ultrabasic rock sequence suggests that the other areas underlain by these ophiolites have potential for the same mineralization.



Photo 3.2. Large boulders of massive sulfide occur at the base of a serpentinite ridge in Ossu, Viqueque District.

Some of these areas are already on record as having either copper or copper/gold indications (Vemasse/Ossuala and Virac, both in the Baucau District). Other ophiolite localities are in Covalima, Manufahi, Manatutu and Lautem districts. These other areas have not yet have been explored for metallic sulfides, such as the area near Daudere, about two kilometres south of the coastal road and about ten kilometres before Lautem. Here, extensive clay alteration on two prominent hills marks the landscape over several hundreds of square metres, while in the immediate neighborhood ochres and umber type rocks are found. It is expected that these occurrences are more widespread in the territory than presently known. They warrant close inspection.

In the Manufahi district, there are several showings of chalcopyrite in the ophiolite sequence, none of these has been described in sufficient detail to enable accurate evaluation, but the sum of the indications suggests a great similarity with the ophiolite-related mineralization elsewhere.

In the western part of Timor island, similar occurrences of massive sulfides were reported as early as in the 1920s. 't Hoen and van Es (1925) reported on work done on the Bonè ore body and several other smaller occurrences. While apparently the grade of these mineral occurrences was attractive, the size of the occurrence was almost invariably small. From a review of the investigation work of 't Hoen and van Es (1925), it seems that all the occurrences were embedded in clay-like material, suggesting that the mineralized blocks may have been 'exotic' and occurred in the Bobonaro Scaly Clay. This does not diminish the importance of the outcrop at the Ossu area and the indications elsewhere in Timor-Leste, though it may indicate that exploration programmes for these massive sulfides may be costly and time consuming.

(b) Chromite

Chromite occurrences are reported from Baucau, Manatutu and Manufahi districts. Of these, only the occurrence in the Manatutu district has been evaluated to such an extent that it may be included in the list of possible economic deposits.

The chromite in the Manatutu district is an occurrence of podiform chromite and is similar to chromite mineralization in allochthonous ophiolite bodies found in the Circum Pacific belt in the Philippines, New Caledonia and Kalimantan, Indonesia. Typically these chromite deposits occur in highly deformed dunite and harzburgite units of ophiolite complexes. Chromite occurs in the Hili Manu subdistrict of Manatutu district. The occurrences are located south of the village of Behada at km 53 on the main coastal road (1:25,000 topographic map series, sheets Lacle and Behau.). The best exposures are reported from the Biau Hill at an elevation of 699 metres, three kilometers to the south.

Geologically, the area is characterized by good exposures of a variety of rock types and evidence of extensive contact metamorphism with diorite intrusive in a setting in which serpentine, amphibolite schists, massive limestone and Mesozoic marine sediments are represented. The diorite is schistose and possibly emplaced along the

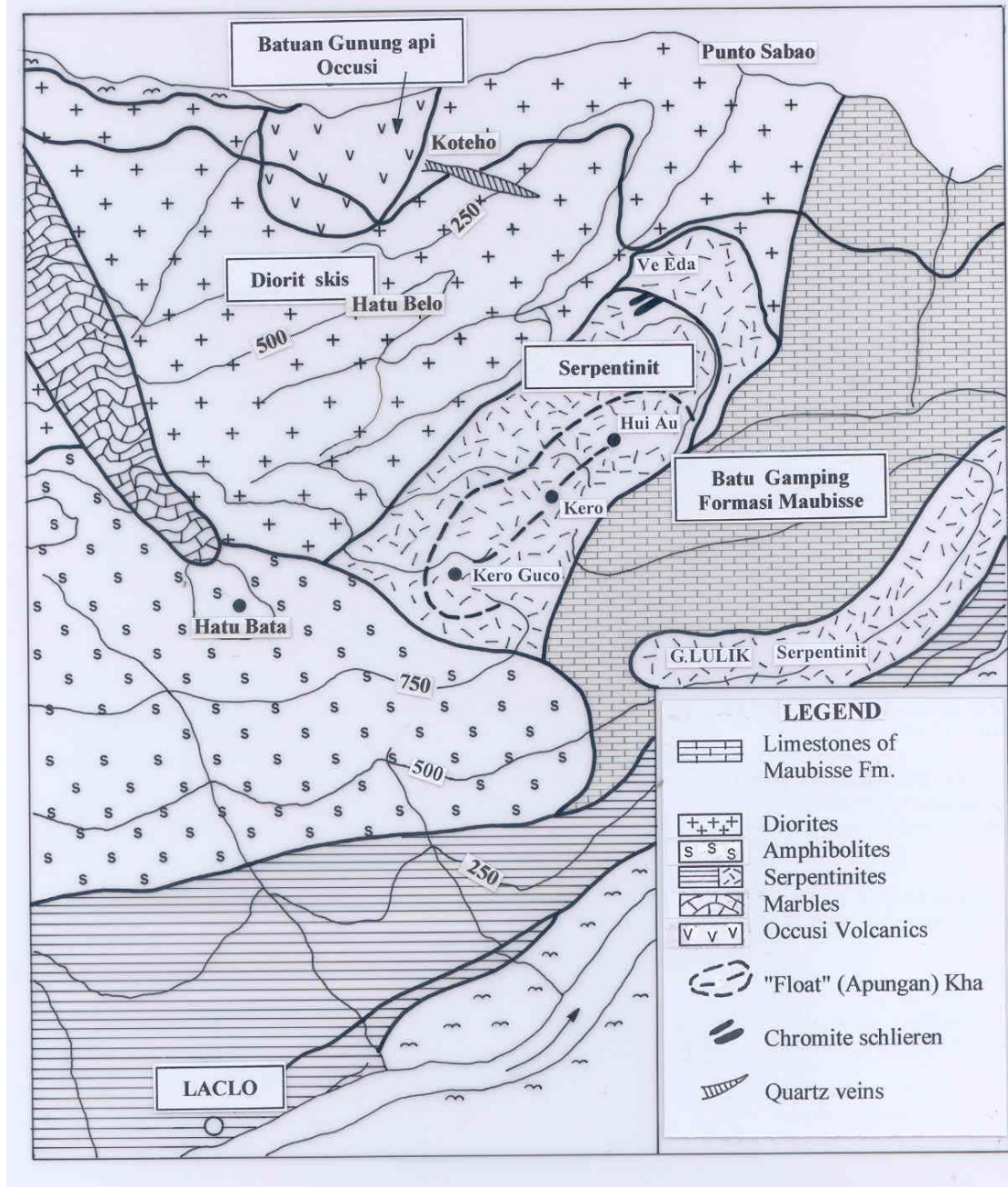
contact of the ultra basic unit. The diorite has an outcropping volcanic equivalent at km 52. The Mesozoic calcareous investigated marine sediments partly cover the ultrabasic unit.

A serpentized ultra basic unit and a deep black coarsely crystalline rock with bronzite phenocrysts and pyroxinite contains chromite segregations and lenses. The serpentine unit forms a NNE-SSW steep ridge running from km 53 on the main coastal road to the Biau Hill over a length of 3,000 metres. Chromite lenses and schlieren occur in several places in the ultrabasic mass in a general direction coinciding with the trend of the massif. Several outcrops of chromite have been observed along a trend of 2,500 metres long, mainly along the crest of the ridge.

Two outcrops are up to 6x6 metres in size and other smaller outcrops exist. These outcrops may be connected and certainly the continuity of the schlieren and the regular intervals between outcropping lenses suggests a possible connection between individual outcrops.

The quality of the chromite is good, with grades between 36% and 51%, while the mineralization has a sharp contact with the rock suggesting the possibility of easy separation.

Background data for chromite shows that 80 per cent of the world's major podiform chromite deposits are between 2,000 and 200,000 tons in size. Few deposits are larger and deposits of one million tons are an exception; 80 per cent of the world's major deposits have a grade between 33 per cent and 52 per cent Cr₂O₃ (Cox and Singer, 1986).



Source: Wittouck, 1937.

Figure 3.1. Allied Mining Company map of chromite occurrence at Heli Manu in the hills above km 53 on the Dili-Manatuto road. Note the occurrence of the chromite schlieren in a band of serpentinite trending northeast-southwest.

The reported grade of the Hili Manu chromite falls well within the norm for an economic deposit. The tonnage remains to be determined, but the several reported outcrops with exposures of up to 36 square metres and an extensive length of 2,500 metres over which the mineralization has been followed, indicates that the potential for an economic size chromite deposit exists at this location.

(c) Gold

The Manufahi district has considerable outcrop of basic and ultrabasic rocks. In the Bubussusu area, small bodies of coarse grained gabbro-diorite rocks crop out. Along the S. Lacro river, a dense dark basaltic rock, that appears to be made up almost entirely of ferromagnesian minerals, is seen to intrude a black shale unit, while near the Ailalec area, north of the Morok Creek, large massive bodies of volcanics are noted. These rocks were earlier described under the collective name of Manufahi diabase. According to this description (AMC 1937), the name covers a collection of different igneous rocks including ultra basic rocks, in places serpentinized, dyke rocks and volcanics. It is again similar to the ophiolite sequences observed in the Manatutu and Viqueque districts.

As elsewhere, limestone and other sedimentary rocks cover these igneous and volcanic rocks in several places. Gravels and older terraces are abundant in the Lower foothills. A very large older gravel deposit occurs along the Sue River. The district has long been known for its gold potential and there are several known occurrences of gold. Some of these have been known and mined since the middle of the 19th century. Hard rock gold occurs and there is widespread evidence of alluvial gold in recent and older gravels.

Gold has been observed in quartz veins that occur as lenticular bodies in shales and schists. These veins and veinlets are fairly constantly mineralized, at times with free and visible gold. Quartz–calcite veins occur in altered diabase and at the contact between diabase and black shales. They are mineralized with disseminated chalcopyrite, pyrite and gold. Calcite in fissure veins and as lenses in shale is mineralized with pyrite. Downstream of these veins intense panning has taken place. There are reportedly large gold nuggets found in the gravels. There is a widespread evidence of placer gold along the sections of the Sue, South Lacro and Cler rivers. Extensive re-working of old terraces has taken place giving rise to the formation of large placers.

(d) Manganese

The environment of massive sulfide deposits in Timor-Leste is also marked by the occurrence of manganese minerals. These may be expected in the form of an exhalative blanket much like iron formation in greenstone style massive sulfide environments. The manganese occurrences will, therefore, be mainly low grade and highly siliceous. One such occurrence is in Lautem district, but overall, the available indications of manganese from the literature are limited, the best indication being described as 1,000 tons large. The literature for the western part of the island (‘t Hoen en van Es, 1925) confirms the absence of large manganese concentrations on Timor Island.

4. Non-metallic minerals of Timor-Leste

(a) *Bentonite clay*

Large accumulations of bentonite clay, all occurring in the Bobonaro Mélange (Audley-Charles, 1968; Hamilton, 1979; Harris 2000.), are known from the Bobonaro, Baucau and Manatuto districts. The clays are also reported in Rosidi (1975) who refers to the typical ‘popcorn’ swelling texture of exposed bentonite, produced during successive periods of wetting and drying out. Geologically, the Bobonaro unit is a tectonic/sedimentary mélange widely spread over the island of Timor. It consists of a clay matrix in which a large and wide variety of exotic blocks are found, all derived from older formations. The clays vary widely in color but are remarkably uniform in character and mainly smectitic.

The Bobonaro Mélange is the most widespread unit on the island, so, there should be no shortage of clay deposits of good size and characteristics in Timor-Leste. However, until now, only the occurrence at Venilale area in Baucau district has been evaluated in some detail. This occurrence contains some 400,000 cubic metres of clay equivalent to 1 million tons reserves.

The Venilale deposit can be seen from the road between Baucau and Viqueque districts. It shows up as a major bed of the Bobonaro scaly clay formation in an incised riverbed. The thickness of the clays is several tens of metres and the extension along the gully is several hundreds of meters. It may be estimated that the width is of several hundreds of metres as well, roughly confirming the available estimate of 400 000 cubic metres. There is no information at hand on the quality of the clays but the typical popcorn texture of dried out bentonite is in evidence.

(b) *Phosphorites*

Phosphorites are known from Baucau district (Badan Koordinasi Penanaman etc., 1987), where they occur as accumulations in the Bobonaro clay unit, in the Deamena area near Abo village. The phosphate ‘pellets’ have the color of dark chocolate and are found as loose, unconsolidated materials from sand to boulder size on ridges and slopes of hills. The location of interest is the Bukit Makalosso area. Early assays of the phosphate rocks show the grades between 9 and 22 per cent of P_2O_5 . In 1975, a Japanese consulting firm reported a grade of 31 per cent of P_2O_5 . The style of mineralization is not known but the presence of the francolite mineral, a fluor-apatite, points to a marine sedimentary setting i.e. a sedimentary phosphorite (Mathers, 1989).

Marine sedimentary phosphate deposits of the so-called upwelling type may be very large in size, ranging between 20 and 400 million tons in size with grades between 15 per cent and 25 per cent of P_2O_5 . If residual weathering and enrichment of such a deposit has taken place, a Tennessee style deposit may have formed with even higher grades. The phosphorites remain to be evaluated. They may represent an interesting resource for a local small-scale fertilizer plant and even medium size fertilizer industry.

(c) Other non-metallic minerals

A variety of other industrial minerals are reported to occur in Timor-Leste. These include the evaporites gypsum and salt, wollastonite, graphite and talc, silica sands, sulfur and ochre.

(i) Gypsum and salt

Gypsum and salt are found in Ambeno, Bobonaro and Manatutu districts. Indications of a small tonnage have been quoted for Manatutu district. The exact setting in which these evaporites occur is unknown. Audley-Charles (1968) notes the occurrence of gypsum in the Wai Lulu Formation of the Jurassic age, but argues that this does not prove that the formation was not marine. He suggests that a highly anaerobic saline deep-sea environment was responsible for the deposition of salts. This would make it unlikely that large, good quality gypsum deposits may be available. Rosidi (1979), puts the gypsum occurrences of West Timor in the Bobonara mélange. This seems to be correct as gypsum does occur in the mélange near the Laleia area.

World-wide, most economic, large and high quality gypsum deposits occur in the Miocene or date back to the Triassic. In the absence of these indications, gypsum might not be a major potential mineral commodity in East-Leste.

(ii) Wollastonite

Wollastonite occurs in Bobonaro and Ermera districts. No details are provided for this high-grade metamorphic mineral.

(iii) Silica sands

Silica sands of uncertain quality are reported from several sites in Ambeno and Manufahi district. In Manufahi district, large volumes of silica sands are indicated, close to one billion cubic metres resources. These concentrations on land would be the product of repeated alluvial concentration and washing of high silica content rocks. Good quality sands do also occur along some of the beaches in Baucau and Lautem districts.

(iv) Graphite, talc, ochre and sulfur

The indication of graphite is known in Liquisa district. Talc is reported from Aileu and Manatutu districts. In both cases, there is only an indication. Ochre is indicated to occur in Lautem district. This may be related to massive sulfide mineralization. This ochre mineralization is seen in an area of significant clay alteration, near the Daudere area, just south of the coastal road some 10 kilometres before the city of Lautem. Sulfur is reported from Aileu, Bobonaro and Dili/Autaro districts. In Autaro and Bobonaro, the sulfur is a hot spring occurrence, while in Aileu district, a volcanic rock association is reported.

(v) *Construction and building materials*

Extensive deposits of industrial rocks and sand and gravel are found all over the territory of Timor-Leste. Gabbro, andesite, basalt, diorite and tuffs are reported from 10 districts. The occurrences are mostly noted without details of reserves being provided, with the notable exception of the Ainaro district that has huge basalt resources with a total volume of well over 2 billion cubic metres. Basalt, andesite or any other igneous or volcanic rocks that can be quarried on or near the southern coast may be exported for use as “armor rock” in the protection of pipelines in shallow waters.

(vi) *Clays*

Clays and mudrocks, including bentonite and kaolin, are reported from 9 districts. Especially large reserves of clays are in the districts of Ainaro, Bobonara and Manufahi where the total indicated resources are close to or well over one billion tons. The largest kaolin deposit is in Ailieu district with indicated resources of 2.5 million cubic metres.

(vii) *Limestone and dolomite*

Limestone and dolomite are widespread and reported from all districts in Timor-Leste. Huge tonnages are found in Manufahi district where billions of cubic metres have been outlined. Large resources also occur in Ainaro and Baucau districts. The unlimited volumes of limestone can be the basic raw material for a cement industry provided that the necessary energy becomes available. Cottage industrial use could be made of the raised coral reefs; these contain a wide variety of coral and other marine animal and plant remnants.

(viii) *Marble*

Marble is reported from 10 districts, while *travertine* is reported to occur in Baucau district. The Manatutu district has the largest indicated volume of marble. A total resource of well over 100 million cubic metres has been indicated in several occurrences and deposits. A marble quarry is located at km. 52 along the Dili – Manatutu coastal road.

(ix) *Sand and gravel*

Sand and gravel occur almost everywhere and is reported from all districts of Timor-Leste (photo 3.3). Practically everywhere, the indicated volumes are huge. The quality of sand and gravel in many different river beds all over the country is, however, low being composed of a variety of mineral constituents.



*Photo 3.3. Looking towards Dili from the mountains on the east side of the city.
Note the long valley trains of sand and gravel extending towards the coast.*

5. Minerals that have not been reported but might occur in Timor-Leste

(a) Lateritic nickel

Based on the widespread occurrence of ultrabasic rock units and on trace element assays of samples of these rocks as presented in the literature (Harris, 2000), one might expect concentrations of laterite nickel. Rosidi (1978) reports garnierite, a nickel silicate typical for laterite deposits, in the explanatory notes on the geology of West Timor, but no significant thickness of any tropical weathering profile has been reported or seen in Timor-Leste.

(b) Platinum Group Elements

Platinum Group Elements might also be expected to exist in connection with the wide occurrence of the above ultrabasic rock suites.

(c) Diamonds

The geological connection of the structure of Timor-Leste with the Australian continental margin crust suggests that it would not be impossible to encounter diamonds on the island, maybe in alluvial or beach deposits.

B. HYDROCARBON RESOURCES OF TIMOR-LESTE

1. History of petroleum exploration in Timor-Leste

The earliest hydrocarbon exploration in Timor was carried out in an area of oil and gas seeps near Laclubar, the so-called Pualaca seeps located in western Timor-Leste, where a small-scale oil recovery operation was undertaken in 1893 (La'o Hamatuk, 2002 cited in Charlton, 2003).

The Aliambata area in Viqueque district of Timor Leste was a popular exploration target from 1910 to 1928 because of the presence of several coastal oil and gas seeps and a mud volcano near the beach (Timor Oil Co., 1976; Wittouck, 1937).

Geological and geophysical work by the Companhia Ultramarina de Petróleo, an agency of Portugal charged with the study of the hydrocarbon potential of its overseas colonies, was organized in 1940 to investigate the company's concession along a strip of territory lying abreast of the longitude of 125°50'00". After the Second World War, Escher and Grunau continued geological mapping and geophysical surveys for the company for several years. The Companhia Superior de Petróleos de Timor held a concession in Oecussi district. The company's geologist, A.E. Feldmeyer, carried out studies of the district's geology which were published in 1948.

A regional gravity survey of Portuguese Timor was carried out by Shell in 1947 and 1948 (Crostell and Powell, 1975). Several years of field mapping were also undertaken in Portuguese Timor by Shell Oil Company geologists but results were apparently not encouraging to the company as no test drilling was carried out.

Texeira (1952) carried out geophysical research for the Companhia Ultramarine de Petróleo (Portugal) which included a review and assessment of the significance of the gravity work of G. de Snoo who was responsible for the first regional gravity survey of Timor in 1947-48. The results of the gravity survey were published by Granau (1953, 1956, 1957a, 1957b).

Gageonnet and Lemoine have summarized the results of their field work for the Insitutut Français du Pétrole in the mid-1950s in *Contribution à la Connaissance de la Géologie de la Province Portugaise de Timor: (Portugal)*. They 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 eastern Timor by the same authors (Gageonnet and Lemoine, 1957B, 1957C, 1958).

Shell Oil Co. has carried out a new hydrocarbon assessment in Portuguese Timor (Freytag, 1959). The work focused on the central-southern part of Timor-Leste. Freytag revised the Tertiary stratigraphy and challenged earlier concepts of large scale overthrusting suggesting the geology was less complex than perceived by earlier workers.

A consortium consisting of Arco Australia Ltd., Australian Aquitaine Pty. Ltd. and Esso Australia Ltd. began geophysical exploration in the Timor Sea and Bonaparte Gulf in 1962 (Laws and Kraus, 1974).

A consortium of Woodside Petroleum, Burmah Oil Company and Anglo-Dutch Shell Oil Company conducted an aeromagnetic survey covering parts of the Timor Sea and Bonaparte Gulf in 1963, followed by seismic surveys in each of the years from 1964 to 1968 (Mollan and others, 1969). Seismic work by Burmah Oil led to an estimate that the 'Kelp Structure' was one of the most petroliferous areas in the Timor Sea and could contain between 500 million and 5 billion barrels of oil and 50,000 billion cubic feet of gas (Westfield, 1984). By the beginning of the 1970s, Burmah Oil considered the entire Timor Sea to be prospective for hydrocarbons.

On land, twenty-one wells were drilled by Timor Oil Ltd. over a period from 1911 to 1975. Some of the wells discovered hydrocarbons and six or seven had gas and oil shows. Two wells produced 160-200 bpd of high gravity, low sulfur oil but the company reported that these production rates were uneconomic. Offshore geophysical work commenced in 1967. A total of 365 km of marine sparker survey was shot along the south coast for Timor Oil Ltd.

In the 1970s, the Timor Oil Ltd. (TOC) drilling programme was focused near the sea at Suai (Covalima district) where reflection seismic surveys indicated suitable structural and sedimentary settings were present and both oil and gas seeps existed in this area (figure 3.2). TOC carried out 248 km of single fold coverage in 1968 and 174 km of expanded coverage in 1970. As a result of the assessment 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. However, 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). However, there are persistent reports that some Matai oil was exported to Australia for refinery tests.

The last well drilled by Timor Oil was the Mola No. 1 drilled off the southwest corner of Portuguese Timor in February 1975. The initial success of this offshore well caused 'frenzied trading in the shares of Timor Oil and its senior partner Woodside Burmah', because it encountered high gas pressures (King, 2002). Subsequent testing showed that the hydrocarbons present were not commercial (Woodside Burmah Oil NL, 1974B). Shortly thereafter, Woodside-Burmah Oil NL drilled the Savu No. 1 well on Savu Island of West Timor in October 1975. This well was also a dry hole. In 1968, Woodside-Burmah Oil NL joined International Oil Ltd., an affiliate of Timor Oil Company, and two other companies to carry out more offshore geophysical exploration in the Timor Sea near the south coast.

Timor Oil Co. entered into a 'farm in' arrangement in 1972 with International Oil Exploration NL and Amalgamated Petroleum. This consortium drilled two exploration wells in the Betano Structure on the south coast of Portuguese Timor. Both were dry holes. In 1973, more 'farm in' arrangements were concluded between Woodside-

NOTES: 1. LITERATURE: KENNEDY, R. (1991) *Using Statistical Methods in Social and Behavioral Sciences*. London: McGraw-Hill. 2. *Practical Statistics* (1992) 2nd edn.



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Burmah, International Oil and Timor Oil. The Woodside consortium comprised Woodside-Burmah Oil NL, 50 per cent, Shell Development (Aust) Pty Ltd. 16.66 per cent, BP Development Australia Pty Ltd, 16.66 per cent, and Cal-Asiatic Oil Co., 16.66 per cent (King, 2002).

The arrangement permitted Woodside-Burmah the right to 65 per cent of a contract that International Oil had with Pertamina to carry out a marine seismic survey and onshore geological survey including the drilling of 2 to 4 wells (Woodside Burmah, 1974; International Oil, 1974 cited in King, 2002). The second part of the arrangement permitted Woodside-Burmah a 30 percent interest in Timor Oil's contract with Portuguese Timor granted in 1973 permitting Timor Oil NL the right to explore for oil and gas in Timor both onshore and offshore for two more years (King, 2002).

BOCAL was the operator of the joint venture of TOC, IOC and Woodside-Burmah beginning in late 1974 and continuing for two years (Crostellla and Powell, 1975). A number of reflection seismic surveys were carried out in offshore areas. Field surveys were carried out to map onshore areas in more detail. The work resulted in one deep offshore test, the Mola 1, a dry hole drilled in early 1975 adjacent to the coast of East Timor opposite Suai. The test reached a depth of 3,077 metres. A second well, Savu-1 was drilled on Savu Island in late 1975 and was also unsuccessful. These tests were the last onshore and offshore exploration activity in East Timor until the 1990s when Mobil Oil Indonesia Inc. (Reed and others, 1996) carried out a reconnaissance of the geology of the province. Further offshore work was undertaken by Pertamina in the early 1990s. They collected geophysical data from a 'widely spaced grid of exploration lines' off the south coast of East Timor (Sitompul and others, 1993; Hardjono and others, 1996 and Charlton, 2003).

Offshore exploration work south of Timor was undertaken by Adobe Oil and Gas (Texas) and Oceanic Exploration (Denver) in 1974 as a result of a permit granted to a Portuguese company, PetroTimor, a subsidiary of Adobe (Charlton, 2003). This work included the collection of seismic reflection data offshore "beyond the 200 metres shelf limit as far as the median line with Australia, in water then (and now) under dispute with Australia" (Charlton, 2003).

2. Onshore hydrocarbon potential

Of the several workers that have addressed the hydrocarbon potential onshore, the reports by Timor Oil Ltd (1976) and Audley-Charles (1962, 1968) remain amongst the more relevant but recent studies by Charlton (2002, <http://www.manson.demon.ac.uk>) present new views and interpretations, notably that the island may not be as structurally complex as many believe.

Overall, the conclusion that there is oil and gas potential onshore is based on: (i) the existence of sedimentary basins with permeable sand fills along the south coast (Audley-Charles, 1968); (ii) these basins probably include source beds rich in organic material further seaward from the present coast and also onland (Charlton, 2000 and

2002; Thurlow, 2000); (iii) structural traps are known to exist in the form of anticlines and fault traps with appropriate structural closure (Audley-Charles, 1968; Charlton 2000, 2002 and 2003); (iv) 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 (Timor Oil Ltd, 1976 and 2000; Audley-Charles, 1968; Charlton, 2000, 2002 and 2003), (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.

The complex geological structure of Timor Island, is the result of the collision of the Australian continental plate with Eurasia and the addition of shelf and deep-sea sediments as well as continental crustal material to the island. After the collision and a period of mountain building, development of several large marginal basins along the south coast took place. 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.

More than 30 oil and gas seeps (figure 3.3) are known to 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 hosts gas seepages only, and (iii) the Viqueque Group of Neogene molasse (Audley-Charles and Carter, 1974). Hot springs and mud volcanoes are found on the south coast close to active oil and gas seeps in the Viqueque Basin (figure 3.4). 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 primary exploration target of Timor Oil Ltd., the main explorer for many years, was the sand-filled linear marginal Viqueque basin complex lying partly onshore and partly offshore of the south coast. The western part of this basin was intensively explored near the town of Suai. Test drilling began as early as in 1911, but the most significant deep wells were drilled from 1957 to 1975. The majority of the western test holes were drilled in Covalima district and the eastern wells in the Aliambata area of Viqueque district. Out of the twenty-one wells that were drilled by Timor Oil Company Ltd., two showed some promise but were judged as uneconomic. Some early shallow wells in the Aliambata area actually produced “gushers” of water and oil.

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 from the surface. They regarded the area as having potential but that their tests might have been based on insufficient field structural and stratigraphic data. In the Viqueque district 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 the Upper Triassic-Middle Jurassic age.

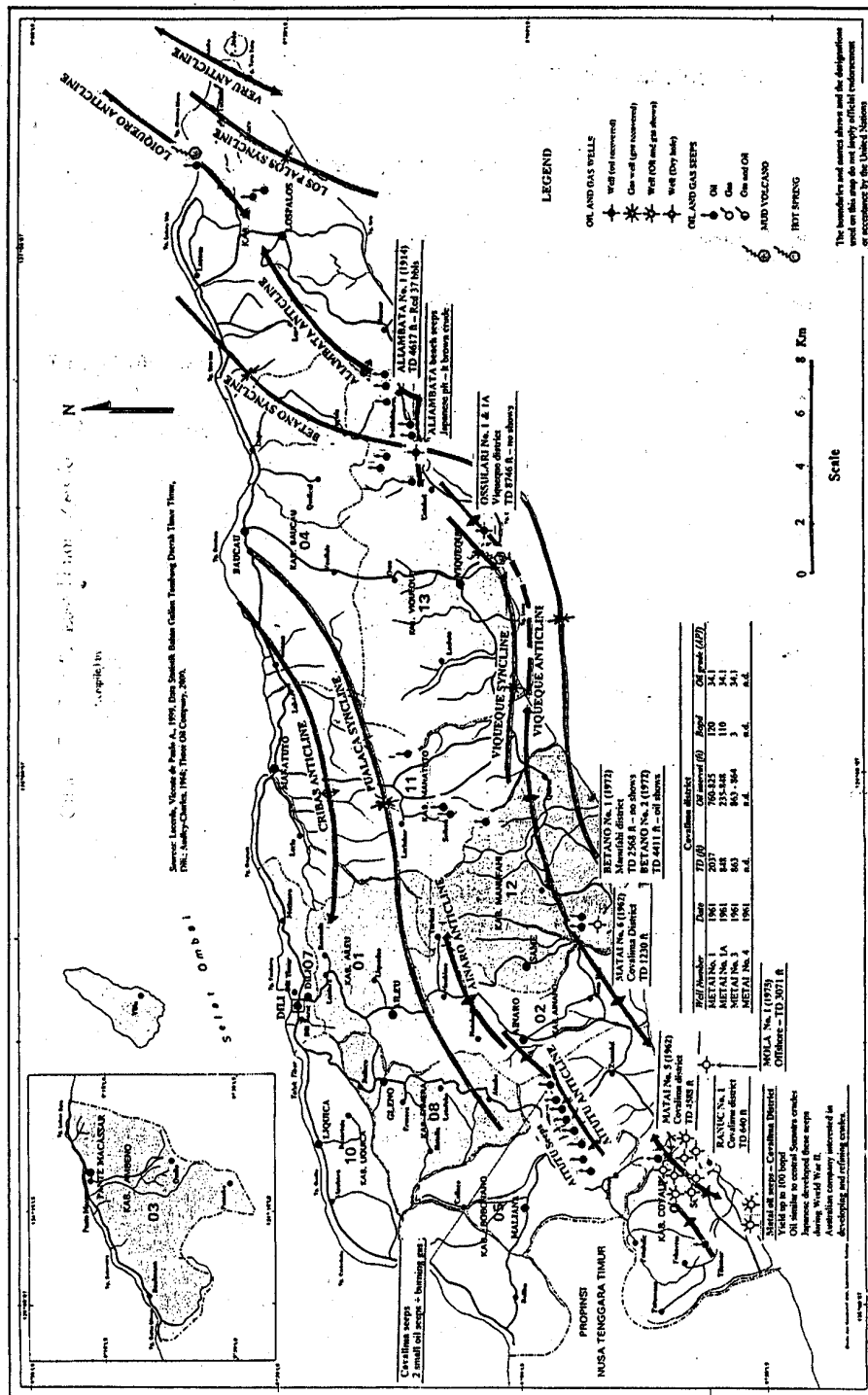
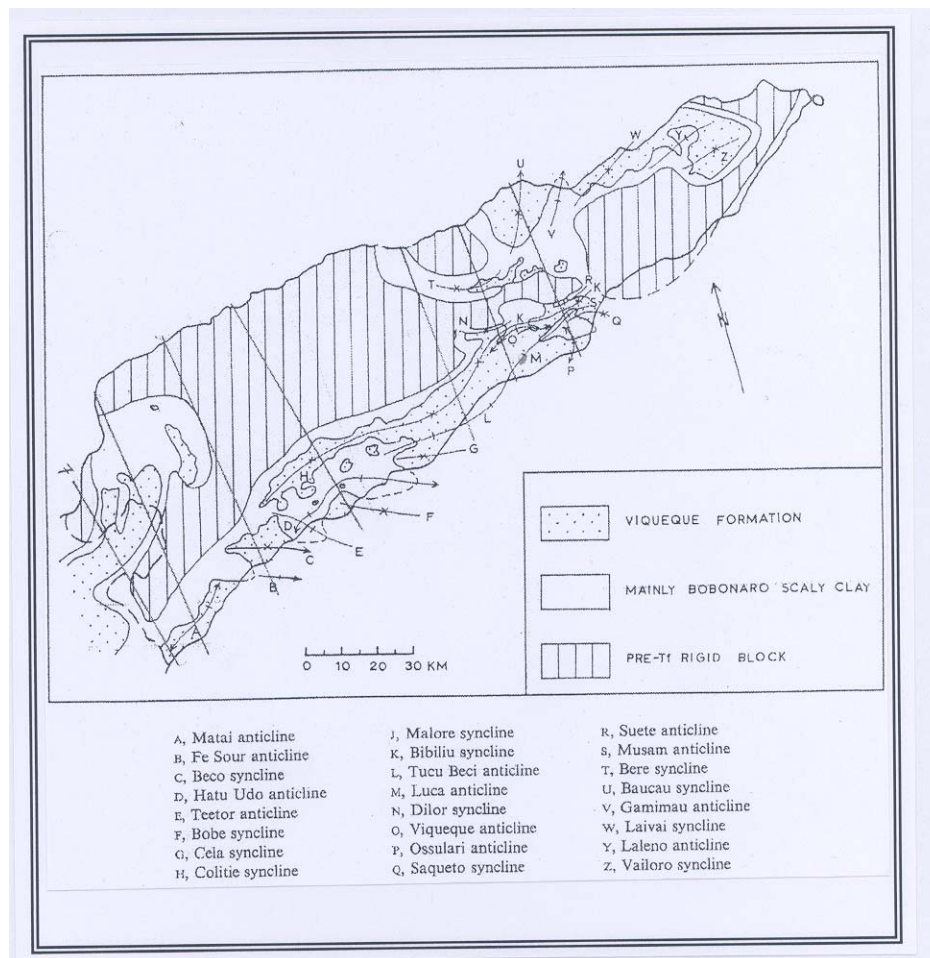


Figure 3.3. Oil and gas data for the onshore part of Timor-Leste.

Audley-Charles (1968) constructed a number of cross-sections that show major structures trending through the central part of Timor-Leste. The Ossulari anticline was the most important fold which could be tested with less difficulty than other folds further inland (figure 3.4). 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. They were spudded in an outcrop of a thin scab of the Baucau Limestone. Up to now, these two tests are the deepest holes drilled in Timor-Leste. One was drilled to a depth of 8,746 feet but had no oil and gas shows.



Source: Audley-Charles, 1968

Figure 3.4. Map of anticlines in the Viqueque basin of Timor-Leste.

An important consideration for the location of the test wells in this place was the structural interpretation by I.B. Freytag (unpublished report, 1959) who had carried out field work in eastern Timor in early 1959. Freytag focused 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 as an integral part of the structural history (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 a depth to the top of the basement and that overthrusting, if present, was not a significant deterrent to the Island's hydrocarbon potential.

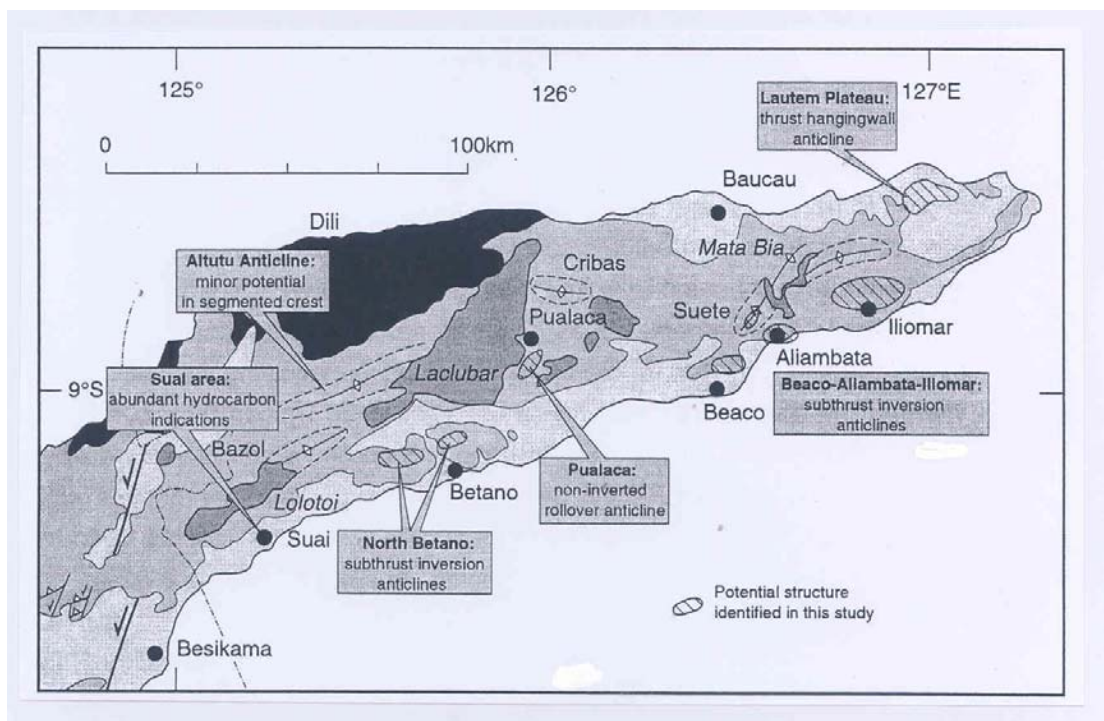
Because of the complex tectonic setting, the hydrocarbon potential of the basins in the interior of Timor-Leste is much less attractive than of those near the coast but this sector should not be excluded from future exploration (Charlton, 2003). Suites of non-productive metamorphic and ultramafic rocks 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, many tend to be located in fairly rugged areas with difficult access or in rocks buried by thrust sheets that are difficult to explore. However, some parts of the interior are tectonically less complex consisting of low rolling plateaus such as in the far east (Lautem district), north-central Baucau district and Bobonaro district, southwest of Maliana town. Any areas that were overthrust with hot mantle or basal oceanic crust are less attractive because the heat front of the thrust sheet would probably vaporize any hydrocarbons that were present in the sediments beneath.

A series of cross-sections showing the consequence of the collision of the northern trailing margin of Australia with the Banda volcanic arc are presented in Howell (1995). Howell has noted that such collisions, i.e. the accretion of one or more terranes to a continental margin, commonly results in a petroleum habitat of fold-and-thrust belts and foreland basins requiring continental shortening. Examples of such collisions are found in the assembly of the late Cenozoic history of eastern Indonesia and the development of prolific petroliferous provinces behind the arcs of Java and Sumatra. Older examples are illustrated by the Appalachian/Ouachita/Marathon trend in North America and Rocky Mountains foothills belt of western Alberta. A series of illustrations showing how a convergent continental margin evolves into a major petroleum province are presented in Howell (1995). The transformation of organic material in the deep crustal setting where elevated temperatures are present takes place. The generation of chains of hydrocarbons results in the movement of liquid petroleum migrating away from the orogen, aided by water escaping from the zone of crustal compression. As the lithosphere bulges up, as Timor did in the late Pliocene and Pleistocene, the liquid petroleum migrates up along the flank of the uplift, "sucked by forces of buoyancy" moving into shallow traps or escaping via oil and gas seeps (Howell, 1995).

In his most recent assessment of the petroleum potential Charlton (2003) recognizes "world class" Late Triassic-Early Jurassic source rocks on Timor-Leste and fluvio-deltaic sandstones that would make excellent reservoir rocks, sealed by Middle

Jurassic shales. Charlton (2003) disagrees with the interpretation of the complex structure presented by some early workers, e.g. Hamilton (1979 and 1980), noting that: “Timor is structurally no more complex than many other hydrocarbon-bearing provinces globally”. Charlton argues that oil and gas seeps are the proof that hydrocarbons exist and that understanding a petroleum system includes tracing the hydrocarbon from its evolution to its final entrapment, if any. The source of the oil throughout one system defines that system.

Charlton (2003) also noted that Timor source rocks are similar to those found on Seram and considers the data provided by Peters and others, (1999) as favoring the potential on Timor as well. Peters and others, (1999) concluded that there were similarities between the Jurassic source rocks in Timor and those on the Australian Northwest Shelf. The most common traps are likely to be inversion anticlines, such as the one tested by the Banli-1 well in East Nusa Tenggara. Anticlines of a similar type have been mapped at the surface in Timor-Leste (e.g. the Cribas, Aitutu and Bazol anticlines, figure 3.5).



Source: Charlton, 2003.

Figure 3.5. Sketch map of prospective areas in the onshore part of Timor-Leste.

The subsurface is reported to have similar inversion anticlines (e.g. Northwest Betano anticline, Northeast Betano anticline, as well as similar structures in a number of other areas such as Aliambata, Iliomar, Suai and Suete (Charlton, 2003). The following

nine traps were suggested by Charlton (2003) as being potential hydrocarbon reservoirs on Timor-Leste: (i) NW Betano inversion anticline; (ii) NE Betano inversion anticline; (iii) Aliambata inversion anticline; (iv) Iliomar inversion anticline; (v) Suai inversion anticline; (vi) Sute inversion anticline; (vii) Pualaca rollover anticline; (viii) Lautem domal culmination; and (ix) South coast stratigraphic traps.

Timor Sea data indicate that source beds of many ages are present but a thermal event related to the collision of Australia with the Inner Banda Arc may have reactivated deep faults releasing hot brines from depth and creating pathways for hydrocarbon migration. In the Outer Banda Arc, migration probably resulted from the faulting that accompanied the collision of the Australian plate with the Banda Arc. In Timor, oil and gas seeps occur in many places suggesting that there are widespread traps spilling hydrocarbons at depth or that hydrocarbons are being generated at the present and are migrating immediately to the surface.

The Mesozoic sediments in Timor may represent a fill that was caught in the foreland basin (“crustal sag”) generated in front of the advancing Australian orogen. This sequence was buried by later thrusts and ophiolite nappes, in places, and the effect of the heat from these ocean floor sediments may result in either the loss of the organic material if the section is too hot or the generation of oil and gas due to thermal loading. The Late Pliocene-Pleistocene uplift has probably reactivated some of the faults causing the main oil seeps that are seen throughout Timor, especially adjacent to major anticlines. However, the sequence throughout the island is suitable for the development of a petroleum province because it contains both source and reservoir rocks, some of which may be “world class” (Charlton, 2002).

3. Offshore hydrocarbon discoveries and potential

The Timor Sea has had a remarkable series of successes following the discovery of the Elang field in 1994. The area, originally thought to be gas prone, also has been shown to be an oil province. New geological concepts and better seismic technology have increased the rate of discovery of new fields and lowered the cost of exploration.

Following the awarding of Production Sharing Contracts to 11 consortia representing more than 20 companies a highly competitive search for oil and gas began. Extensive exploration has included the acquisition of 50,000+ km of 2D seismic and 3,000+ km of 3D seismic surveys.

A total of 45 wells have been drilled in Area A of the Timor Gap Petroleum Development Zone (figure 3.8) over a 10-year period with a discovery ratio of 1:5 (Kyranis, 2003). Discoveries within and adjacent to the Joint Production Area up to 2003 include the Elang and Kakatua oil fields, the Bayu-Undan gas/condensate field, the Jahai oil field, the Kelp Deep gas field, the Chuditch gas field and the Kuda Tasi oil field.

Timor Gap

1. Seabed agreement between Australia and Indonesia

An agreement between Australia and Indonesia was negotiated in 1972 to demarcate the areas that could be explored and developed by each country in offshore areas of the Timor Sea. When this Agreement was negotiated, a 'gap' was left between the eastern and western parts of the Australia-Indonesia seabed boundary in the area south of Portuguese Timor. This area was referred to as the 'Timor Gap.' The Timor Gap Treaty was signed provisionally by Australia and Indonesia in December 1989 to cover the 'gap' in the seabed area between Australia and East Timor. On 30 August 1999, the Timor Sea Treaty, negotiated between Australia and Timor-Leste replaced the Timor Gap (Zone of Cooperation) Treaty.

2. Timor Gap Joint Authority

The Timor Gap Joint Authority was established in 1991 to administer the part of the Zone of Cooperation known as Area A (Kyranis, 2003). Offices of the Authority were located in Darwin until the Dili Office was opened in June 2002. Following the awarding of Production Sharing Contracts to 11 consortia representing more than 20 companies a highly competitive search for oil and gas began. Extensive exploration has included the acquisition of 50,000+ km of 2D seismic and 3,000+ km of 3D seismic surveys. East Timor and Australia signed an agreement in July 2001 that would divide royalties from oil and gas production in the Timor Sea and thereby created an opportunity for Timor-Leste to benefit from these developments. There may be further discussions and negotiations and these may include boundary demarcation and other issues related to the joint development zone.

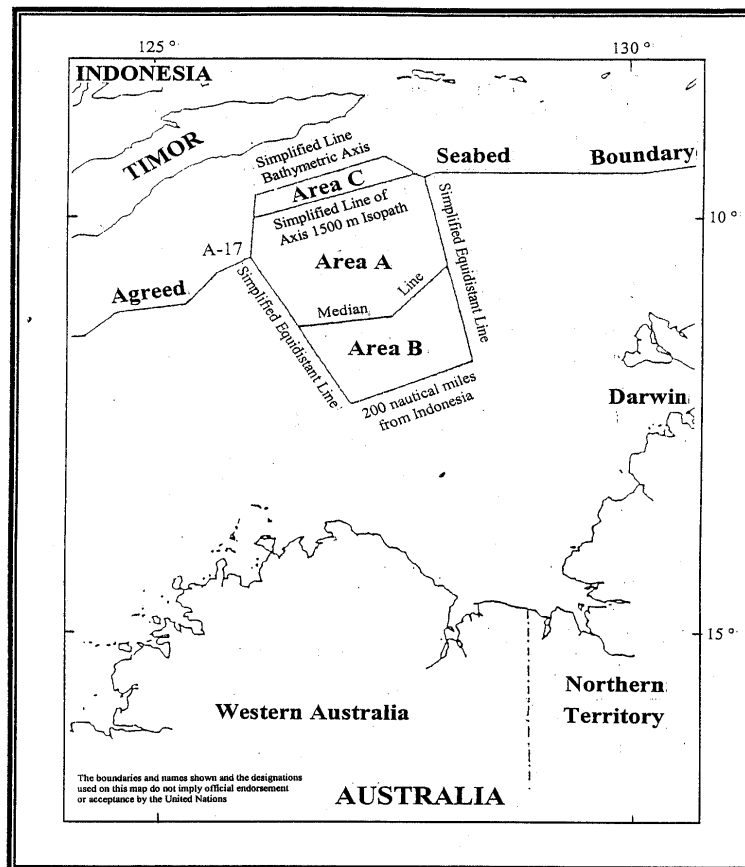
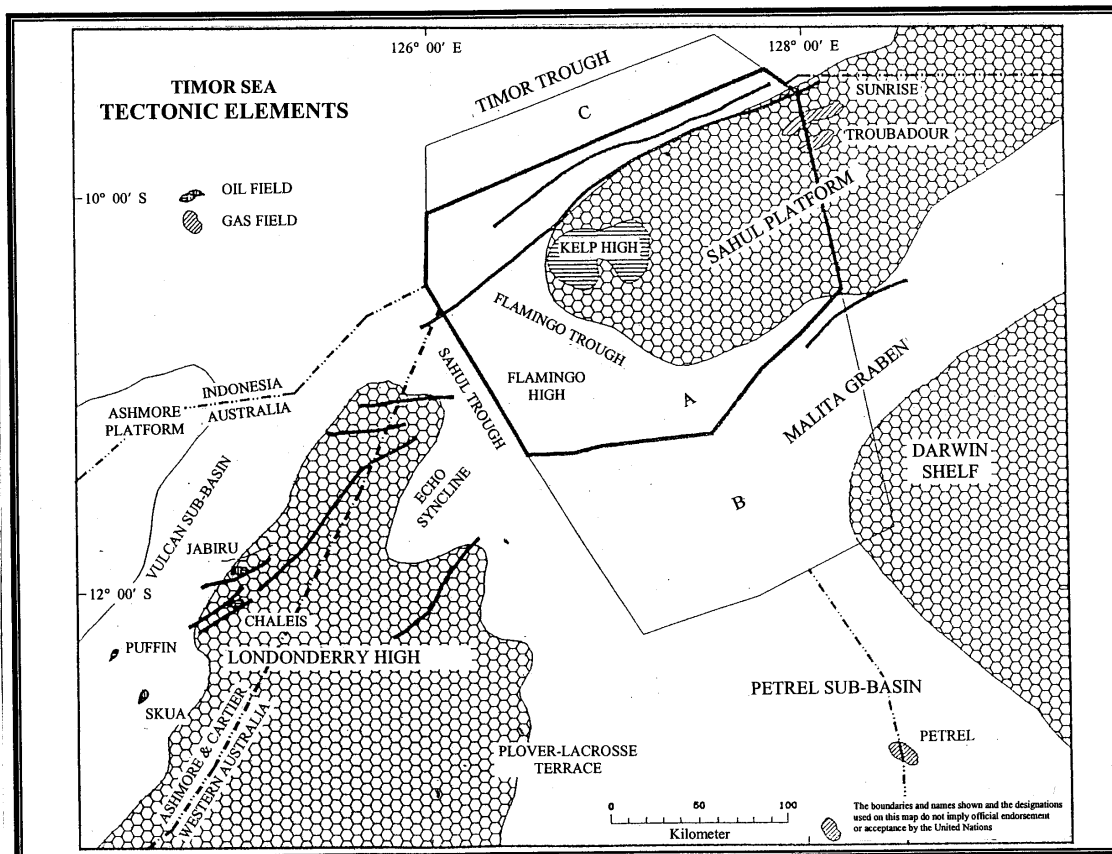


Figure 3.6 Location of the Timor Gap Petroleum Development Zone.



Source: Prasetyo, 1994.

Figure 3.7 Tectonic elements of the Timor Sea.

The Elang/Kakatua oil fields commenced production in July 1998 and produced more than 26.5 million barrels of oil up to 2003 (Kyranis, 2003). The Elang/Kakatua prospect had been originally mapped in the early 1970s but the discovery well was drilled only in 1994. This well, the Petroz Elang 1 was the first to prove the presence of economic oil fields in the eastern Timor Sea. The field trap is a three-way closure of the reservoir rock against a series of faults with a Lower Cretaceous shale seal and an oil column of 76.5 meter. Recoverable reserves are estimated at 29 million barrels making it a medium sized oil accumulation (Maio and Plybon, 1999).

The Bayu-Undan gas/condensate discovery is considered to be a giant field with proven and probable recoverable reserves of 3.4 trillion cubic feet (TCF) gas and 400 million barrels of condensate and liquid petroleum gases (LPGs) (Kyranis, 2003).

The Greater Sunrise Gas Province includes a super-giant gas field with reserves of more than 8 trillion cubic feet (TCF) of gas of which about 1.6 TCF is located in the Joint Production Development Authority (Kyranis, 2003).

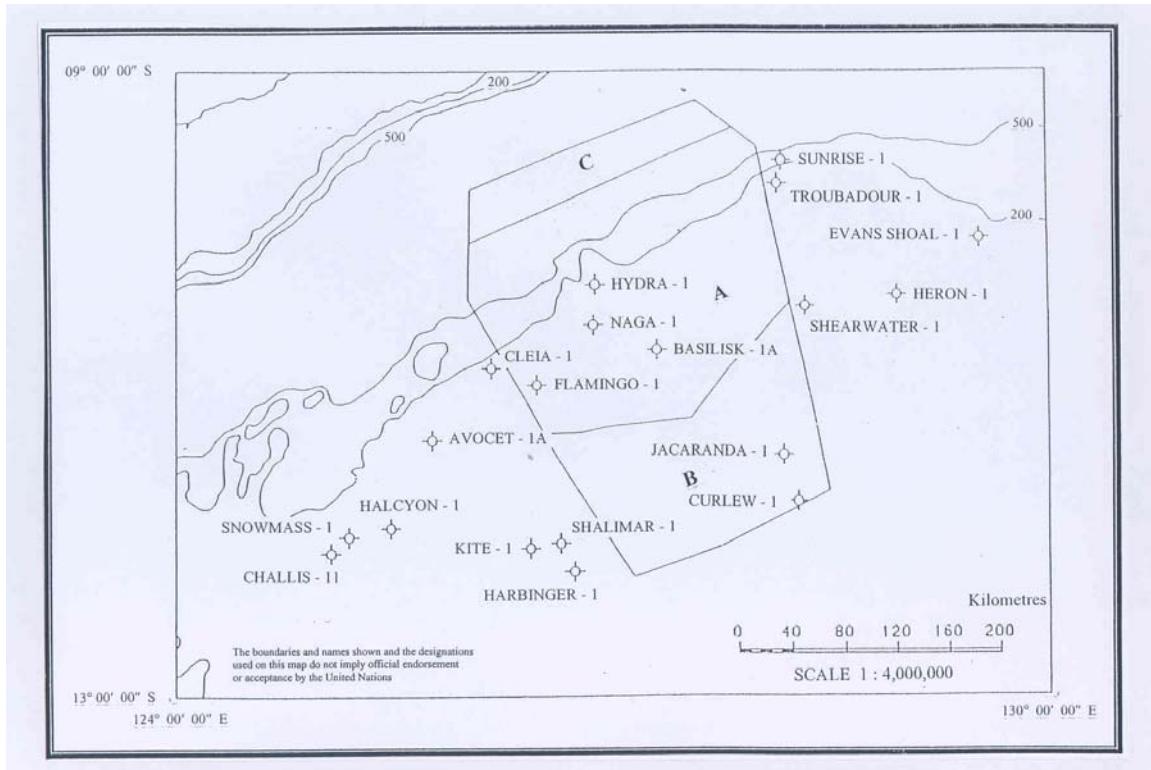
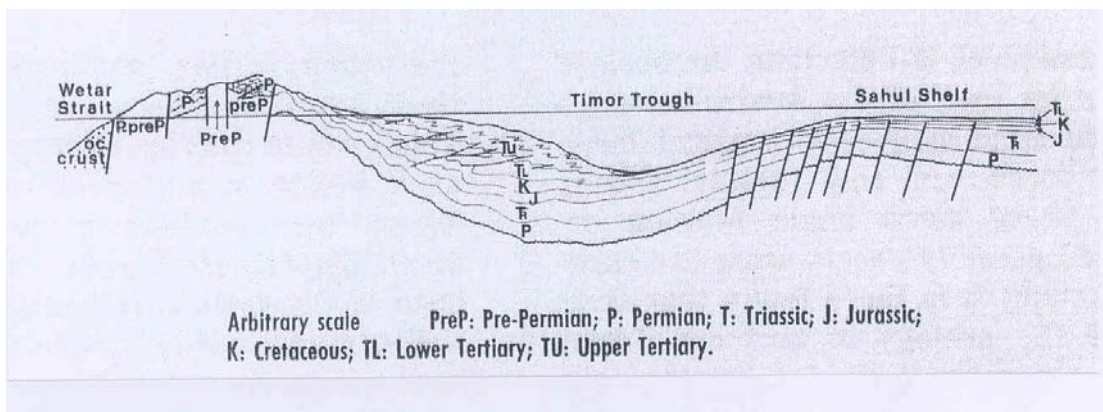


Figure 3.8 Location of wells in the offshore areas of Timor-Leste and Australia.

The Jahal and Kuda Tasi fields contain combined reserves in excess of 15 million barrels of recoverable oil and may be too small to be economic without using infrastructure already in place at nearby fields.



Source: Chamalaun and Grady, 1978.

Figure 3.9 Diagrammatic geological transect of Timor and offshore area.

Considerable additional potential exists in offshore areas, some of that potential may well be within areas over which Timor-Leste has or will have negotiated interests. An extensive discussion with maps and cross-sections of the geology and hydrocarbon potential of the sea areas between Timor-Leste and Australia is available online at the web site of the United States Geological Survey. The ‘Open File Report nr. OF 99-50P, entitled *Total Petroleum Systems of the Bonaparte Basin Area* was authored by Michele G Bishop. (USGS 2000; www.usgs.gov; <http://greenwood.cr.usgs.gov/energy/WorldEnergy/OF99-50P>).

The following section of that report sums up the further offshore potential of the area as follows:

“The Bonaparte Gulf Basin Province contains three proven petroleum systems with numerous styles and ages of exploration targets and considerable under-explored potential. The eastern arm of the Mesozoic petroleum system contains one gas discovery, Evans Shoal-1 and several shows thought to be sourced from this portion of the Malita graben indicating the presence of mature source rocks in the eastern area of the province. Numerous exploration targets may be present within the Malita graben and on the faulted edges north and south. This eastern area also contains potential exploration targets involving Jurassic and Cretaceous sandstones onlapping basement rock along the northern edge of the Darwin shelf. These onlapping stratigraphic and drape anticline type of prospects should be targets around the entire edge of the Darwin shelf. Some of these types of plays have been drilled on the western side of the Bonaparte Gulf, but most of the area of the Darwin shelf and the Moyle platform on the eastern side of the gulf adjacent to the mature Mesozoic system and the mature Paleozoic system remains unexplored (Miyazaki, 1997). On the west side of the Joseph Bonaparte Gulf along the Berkeley platform and the Londonderry high, where drilling has also been sparse, similar onlapping stratigraphic and paleotopographic drape style traps may occur. This play has been successful in the Browse Basin Province on the western edge of the Londonderry high with discoveries at Gwydion and Cornea (Bishop, 1999).

Fault traps on the margins of the Londonderry high, Laminaria high, Flamingo high, Sahul platform and Troubadour high, adjacent to mature source rocks in the synclines, have been successful exploration targets and could be the sites for additional discoveries. Lowstand, shallow-water and highstand, deep-water sandstones in the synclines offer numerous under-explored drilling targets. In the Vulcan graben, possible inversion structures similar to Jabiru, along with lowstand valley-fill clastics are potential targets.

Similar lowstand stratigraphic and paleotopographic traps might be encountered in the Paleozoic systems along both the east and west sides of the gulf. High-quality, mature source rocks are predicted adjacent to the Moyle platform on the east side of the Petrel assessment unit and shows occur to the west on the Plover-Lacrosse terrace and Londonderry high (Edwards and others, 1997).”

C. DEVELOPING TIMOR-LESTE'S MINERAL AND HYDROCARBON RESOURCES: RECOMMENDATIONS AND PRIORITY AREAS FOR FUTURE DONOR SUPPORT

The recommendations in this sub-chapter have been worked out by a team of ESCAP consultants in the course of preparation of the report entitled “Natural and Mineral Resources Inventory, Policy and Development Strategy”, which has been completed by the ESCAP secretariat during 2002 in the execution of UNDP Special Services for Policy and Programme Development Project TIM/01/022. The report, *inter alia*, includes the reports of the ESCAP consultants focused on (i) Formulation of National Mineral Policy, Legislation and Regulatory Framework for the Government of Timor-Leste by Jack Garnett, (ii) Economic Geology, Development Strategy and Capacity Building by Pieter J. Bakker and (iii) Mineral and Hydrocarbon Database and Geological Bibliography of Timor-Leste by Jon L. Rau. The original reports are in the offices of UNDP (Dili) and the Office of the Secretary of State for Natural and Mineral Resources (Fomento Building, Dili) as well as at the headquarters of the Economic and Social Commission for Asia and the Pacific, Environment and Sustainable Development Division in Bangkok.

1. Recommendations on regulatory framework

(a) Mineral Policy

It is recommended that the Government of Timor-Leste adopt a mineral policy that will allow for the responsible and profitable exploration and development of its natural and mineral resources. This policy should allow for private sector involvement and should put the responsibility and the risk for the exploration and development of the resources squarely in the hands of the private sector. In accepting the risk and responsibility, the private sector should be allowed to make profits and be assured of the security of its investments.

(b) Regulatory Framework

It is recommended that immediate attention should be directed to the drafting and discussion in the Parliament of a regulatory framework that will allow investors to apply for the necessary licenses to investigate and, if successful, develop the mineral potential. It is not recommended that any licensing be concluded before this process has been completed.

(c) Oil and Gas Investment Legislation

Oil and gas potential in Timor-Leste has long been recognized and investor interest is already apparent. It may be in the interest of the Government to draft and enact oil and gas investment legislation without delay.

(d) Capacity Building

It is recommended in the interest of capacity building in the natural and mineral resources sector that exploration and development work by the private sector include obligatory training and education in mining and hydrocarbon projects. Successful project should deliver well-trained and educated technical personnel during and at the end of the project's life.

(e) Mining Law

A draft Mines and Minerals Management Law (MMML) has been prepared for the Government of Timor-Leste by a United Nations consultant. This legal framework should be scrutinized by the Government Attorney prior to the presentation to the Parliament. In order to effectively regulate the above law and taking into consideration the core specialized staff currently available, the designation of a "Registrar of Mineral Rights" and that of a "Mineral Advisory Board" has been included in the draft Law. It is expected that the draft law and the key Implementing Rules and Regulations on the management of mines and minerals will be the basis in formulating a National Mineral Policy for Timor-Leste. The key components of the Mines and Mineral Management Law (MMML) and related regulations that are presently being studied by the Government include the following areas:

(i) *Objective*

The objective of the Law is open up the land-based mineral resources of Timor-Leste to credible, properly regulated investigation and sustainable mining activities.

(ii) *One official Registration System for all Mineral Rights Transactions*

A National Mineral Rights Registration System shall be established in the Office of the Registrar of Mineral Rights in Dili. All applications and subsequent mineral license transactions shall be systematically entered in a Registration Book and recorded on License Area Control Maps updated daily and open to the public. Applications will be approved by the Minister in a timely fashion based on receipt of registration and land rental fees and submission of detailed work reports.

(iii) *One Secure Mineral Right*

Only one formal document, a Mining License, is recommended for a successful applicant to secure the right to conduct exploration and mining activities as specified in the Law. Monitoring, control and oversight of such activities shall be accomplished through the annual submission of a progressive work programme, payment of escalating land rental fees, and by inspection and enforcement of specified obligations by authorized officers.

(iv) *Investment Stabilization Agreement*

The provision for this possible attachment to a mining license has become a common element of many internationally competitive mining laws. It has many variations, but its main function in all legislation is to negotiate the “freezing” of certain tax, fiscal and legal provisions over fixed periods of time for large scale mining projects.

It is recommended that this Law provide for the voluntary request by a registered license holder for the Government’s consideration to cap certain prevailing tax rates and legal requirements for projects of “national importance” that will require large capital investment and significant debt financing.

(iv) Local Community Sustainable Mining Partnership

Making the community a partner is an innovative recommendation designed to initially address the critical issues of local awareness, education and decision-making involvement of the rural and traditional communities where mineral license activity is more often directed.

Where exploration activity identifies a commercially viable mining operation, provisions are made for the creation of a formally constituted Sustainable Mining Development Authority (SMDA). This cooperative partnership will be chaired by a Government appointee and made up of representatives of the local community, the district and the mineral license holder’s mine management team. Funding is to be allocated by the Government for the use of the SMDA from the anticipated revenues accruing from the mining operations.

The objective of this partnership is to stimulate and support skills training and educational and entrepreneurial initiatives for long-term sustainable enterprises that reinforce local economic, environmental and cultural concerns that will continue beyond the inevitable closure of the mine.

(v) Mining Regulations

A section of this Law must be drafted to enable the Minister to make regulations for the sustainable management of mines and minerals and for the purpose of giving effect to the provisions of the Law. It is acceptable, and in fact is a common practice in many mining jurisdictions, to prepare Mining Rules and Regulations prescribed by a law subsequent to its enactment. In order to allow for rapid implementation of this legislation, it is recommended that certain administrative framework regulations accompany the final draft law, specifically:

- A regulation prescribing the official procedures for accepting, processing, approving and registering transactions relating to mineral license activities;

- A regulation prescribing the format of work programmes and reports required by applicants and registered holders to document all exploration, mine feasibility and mining activities;
- Additional detailed regulations will be needed in the future. Many of those laws should specify integrated regulatory coordination with other impacted agencies, ministries and jurisdictions, especially where forestry, agriculture, ecological and religious land overlaps and restrictions occur. Similar, landowner negotiation/compensation/appeal, social and cultural impacts, environmental rules and compliance all are best managed through inter-Ministry of inter-jurisdictional protocols and cooperation application of uniform national standards and procedures.

2. Recommendations for capacity building in the mineral and hydrocarbon sectors

It is recommended that to advance the Government planning for department structure and capacity building, the Government designate a new or existing Department to include a Geological Survey and Mines Division and an Oil and Gas Division. These two, initially small divisions would be complemented with an Administrative Section.

(a) 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 field work 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 Timor-Leste 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.

(b) 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, manganese, phosphate, limestone, bentonite and clay) are located. Preliminary work of the 2002 ESCAP 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.

(c) Geological Survey 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 Timor-Leste 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 Timor-Leste if shipping expenses were paid.

(d) 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 Timor-Leste.

(e) Introduction of a geology programme at the University of Timor-Leste

Timor-Leste should build a small group of Geological Survey staff some of which could also teach at the University of Timor-Leste. The University should take steps to introduce a geology programme in its Faculty of Science. This should be a high priority and might be done before programmes in other sciences are introduced although basic chemistry, physics and biology must be included in the geology programme. Graduate work should be undertaken in other countries.

3. Priority areas for future donor support

(a) Mining legislation and regulations

It is recommended that the Government will seek donor support for institutional strengthening and the development of professional capacity building programmes focused on the following priority administrative areas:

- (i) Development of a mining cadastre and mining licence registry office;
- (ii) Provision of assistance in implementing mining regulations;
- (iii) Provision of training for mining regulation officials;
- (iv) Secondments to mining jurisdictions;
- (v) Initiate the preparation of a National Mineral Rights Registration System (NMRRS) and support for its implementation;
- (vi) Institutional strengthening and professional capacity building related to implementation of the Mines and Minerals Management Law (MMML) and related regulatory framework;
- (vii) Preparation of guidelines and materials on sustainable mining principles, rules and procedures for national and district administrations.

(b) Primary geological survey projects for potential donor support

It is recommended that the following projects should be undertaken to ensure the development of Timor-Leste's most promising mineral occurrences. For example, the following governments have geological survey expertise that uniquely qualifies them for providing support to the Government of Timor-Leste for these tasks:

- (i) Setting up a new Geological Survey Department and development capacity in geology, mining and overall resource management. To be potentially financed by USAID and executed by the United States Geological Survey.
- (ii) Construction and/or modernization of an existing building for the purposes of housing a Geological Survey and Oil and Gas Office, including laboratory equipment and associated training. To be potentially financed by the Government of Japan and executed by JICA.
- (iii) "On-the-job" training and scholarships in geology, mining and oil field engineering. To be potentially financed by all licensed exploration and production companies in oil and gas development and in mining.
- (iv) "On-the-job" training in evaluating exploration and development contract proposals from oil and gas and mining companies. To be potentially supported by the United Nations and executed by individual experts.
- (v) Compilation of a new geologic map for Timor-Leste using and interpreting existing data. To be potentially financed by the Government of Australia and executed by Australia's department charged with geological surveying, formerly AGSO.
- (vi) Compilation of a new airborne geophysical survey of Timor-Leste. To be potentially financed by CIDA and executed by the Geological Survey of Canada.
- (vii) Clay mineral survey of Timor-Leste. To be potentially financed by the United Kingdom and executed by the British Geological Survey.
- (viii) Industrial minerals and ornamental stone review and inventory. To be potentially financed by the Government of Finland and executed by the Finnish Geological Survey.

3. Areas of anticipated donor assistance in geological mapping and assessment of minerals and hydrocarbons

- (i) Provide assistance in detailed geological mapping of the most important mineral occurrences and validation of location using GPS and to include revision of the mineral database, if necessary.
- (ii) Formulation of investment profiles on base metals and associated gold, silver, chromite and non-metallic mineral occurrences.
- (iii) Development of a marble and rock-cutting and polishing industry.
- (iv) Development of a limestone processing and cement industry to include consideration of a Portland cement plant.
- (v) Assessment of the Petroleum Systems in Timor-Leste and offshore areas in its Exclusive Economic Zone (EEZ).
- (vi) Assessment of the economic impact of development of specified onshore and offshore mineral and hydrocarbon resources for consideration in the National Development Plan (2003-2007).
- (vii) Establishment of a GIS facility with appropriate hardware, information/data, experts/operators, specialized software and peripherals (digitizer and plotter).

Chapter IV

Mineral and Hydrocarbon Database for Timor-Leste

A. INTRODUCTION TO MINERAL AND HYDROCARBON DATABASE OF TIMOR-LESTE

The recent review of geology and mineral resources of the territory of Timor-Leste was completed in 2002 by a team of three ESCAP consultants working under contract with the United Nations. This work was sponsored by the United Nations Development Programme (UNDP) and executed by the Economic and Social Commission for Asia and the Pacific (ESCAP). The work of the consultants covered the areas of geology, mineral resources and hydrocarbons and included the drafting of a regulatory framework for consideration and promulgation by the Government of Timor-Leste. Also included in the work of the consultants was the preparation of a database on the geology and mineral resources of Timor-Leste. While most of the review of the geology and resources of the country is included and incorporated in the foregoing chapters, the actual maps and tables of the database are presented separately in this chapter.

1. 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 a Timor-Lesteese, 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 under the above ESCAP/UNDP project, Natural and Mineral Resources Unit, Ministry of Economic Affairs and Planning of Timor-Leste 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 ESCAP mission to Timor-Leste in May-June 2002 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 timeframe 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 to collect maps and reports was completed by the ESCAP secretariat in June 2002.

2. Database constraints

The original locations for the mineral occurrences are plotted on small scale maps, without latitude and longitude grids, in a report, *Data Statistik Bahan Galian Tambang Daerah Timor Timur* by Vicente de Paulo A. Lacerda. The report was compiled in the late 1990s and published in 1999. Most of these data come from records and publications (in Bahasa Indonesia) of the Department of Defence and other agencies in Indonesia. The Lacerda's 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, Jon L. Rau 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 Economic and Social Commission for Asia and the Pacific 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's report.

The above 2002 ESCAP Mineral–Hydrocarbon mission did not have adequate time nor funding for detailed field work, petrography, age determinations and other field studies. Very few of the mineral occurrences were visited. The analysis of the metallogenic relations and a compilation of a metallogenic map is not possible at the present time. Likewise, data from the 21 test wells that have been drilled in Timor-Leste, mostly onland, has not been archived in Dili, although oil companies that have done work in Timor-Leste are probably willing to give copies of their data to the Government. Finally, the devastation that struck Timor-Leste in 1999 resulted in the loss of most of the meager Government geological materials on the geology of Timor-Leste. 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 the mid-2002.

The University of Timor-Leste does not teach geology and is just now getting back on its feet. There is no Geological Survey of Timor-Leste. The country has a few geologists although several more are in training in Australia and Indonesia. It is hoped that in future these young geologists will be able to systematically go through the extensive literature on Timor-Leste, 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 database is to build an initial and preliminary archive of mineral and hydrocarbon resource information in Timor-Leste. 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 Timor-Leste.

3. Database recommendations

(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. These data should be incorporated into a GIS system by the Government of Timor-Leste.

(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.

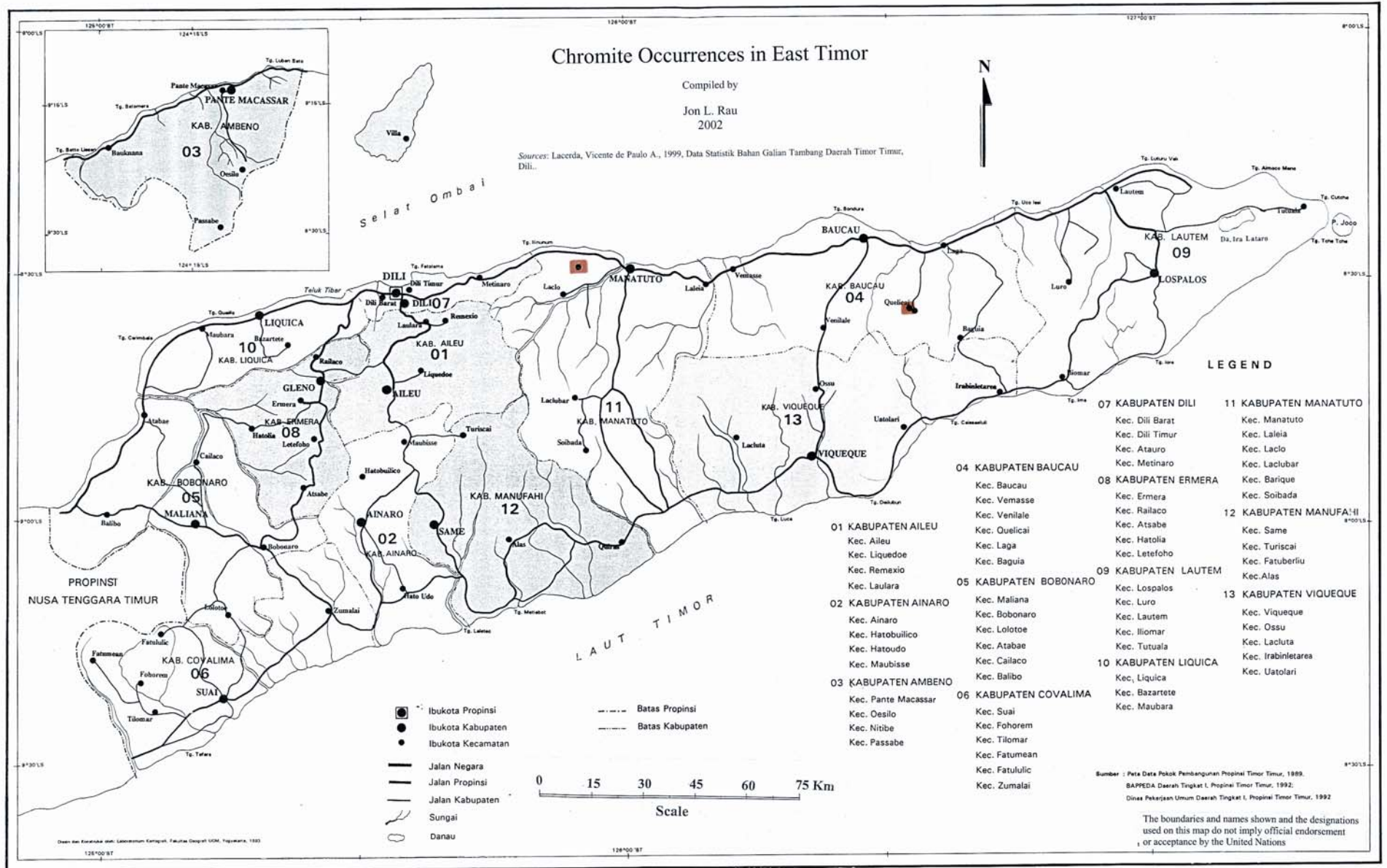
4. GIS Database

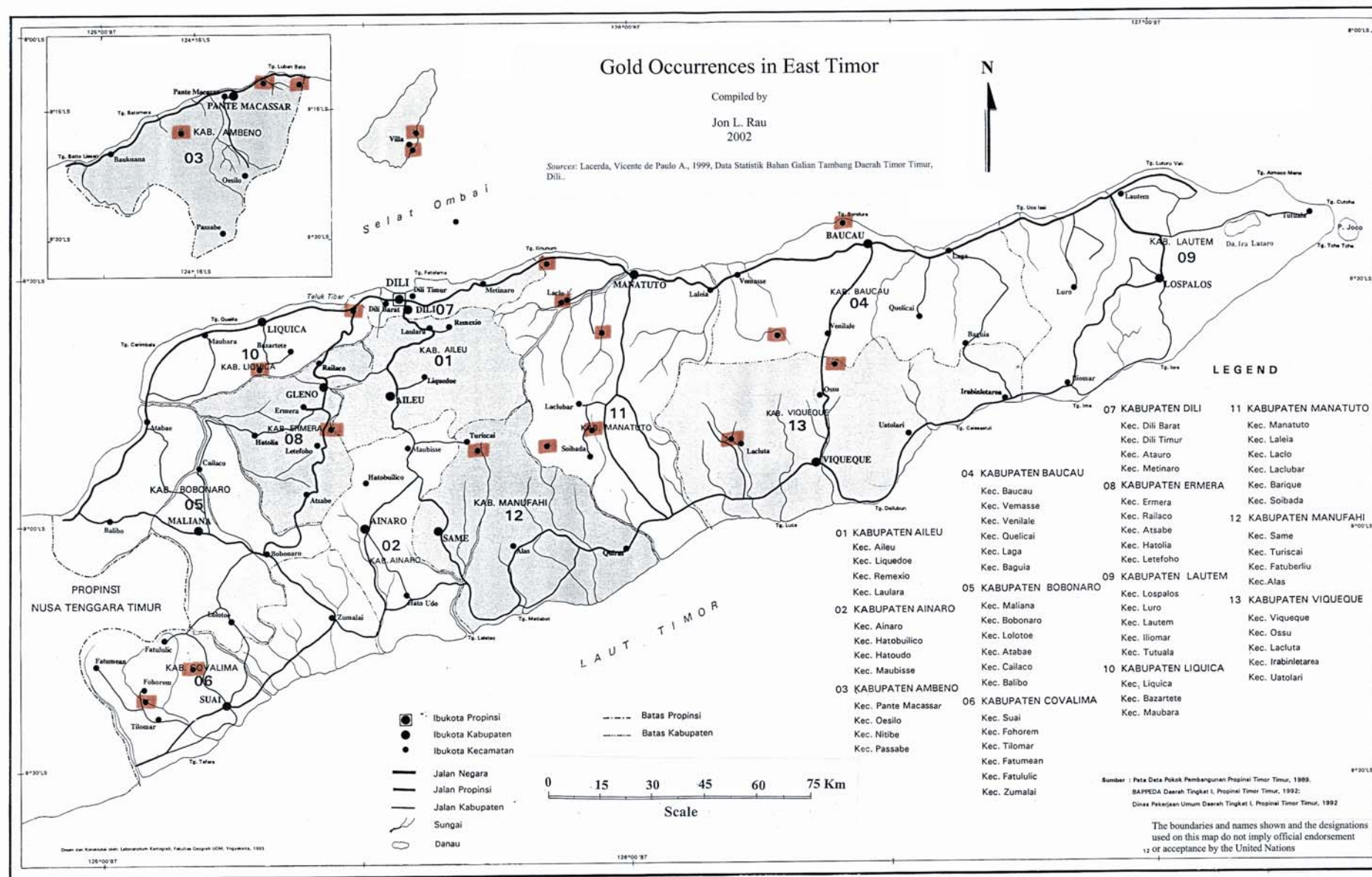
Data suitable for compilation in GIS format located on a geologic and mineral source map should be published by the Government of Timor-Leste and reviewed periodically for follow-up publication at regular intervals. The preparation of a GIS database should be assisted by a GIS expert and any new data that could be obtained within each year should be incorporated in the database. The future Geological Survey Department of Timor-Leste should 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 maps 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.

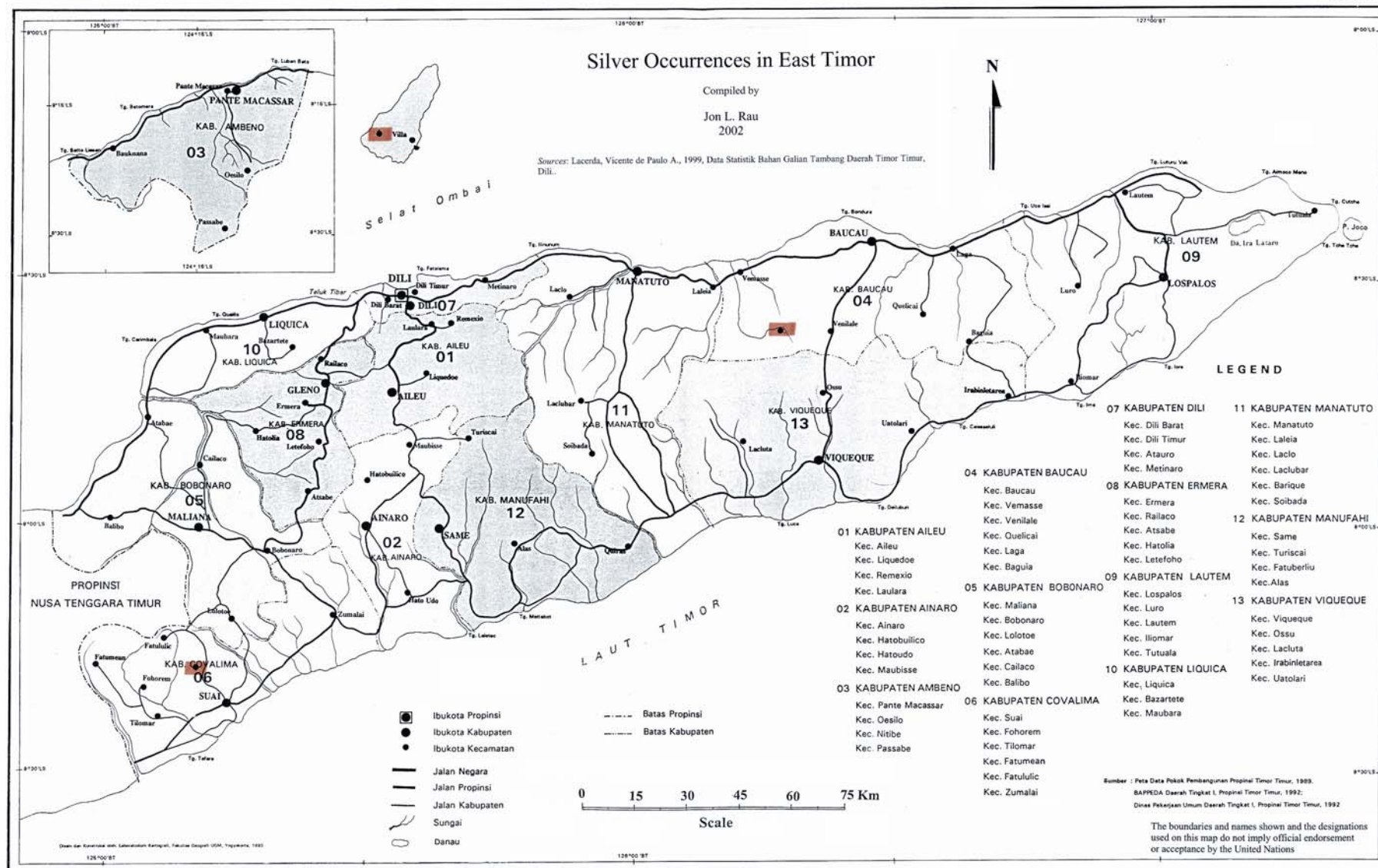
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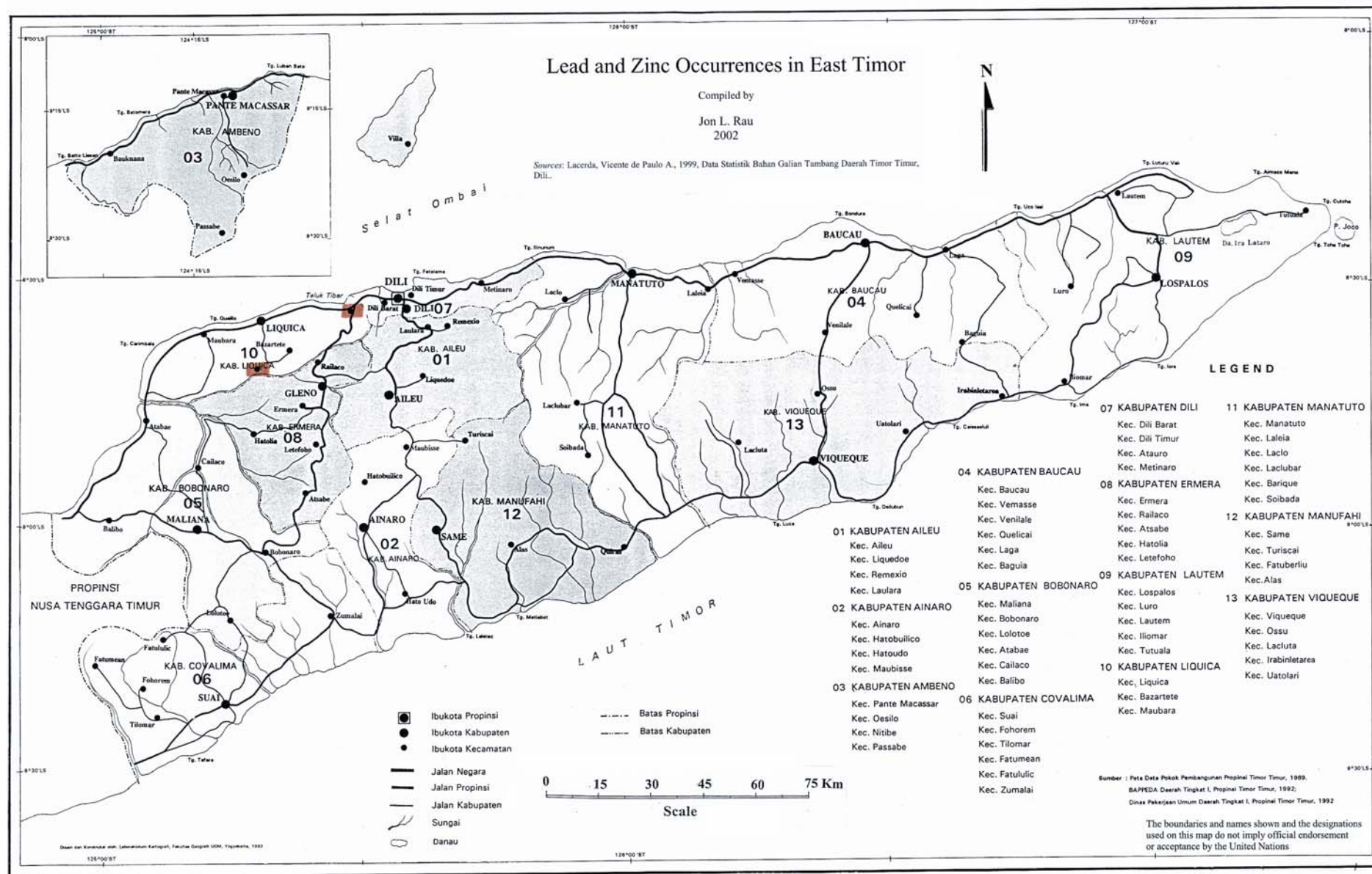
**Maps of the Mineral Distribution in
East Timor**

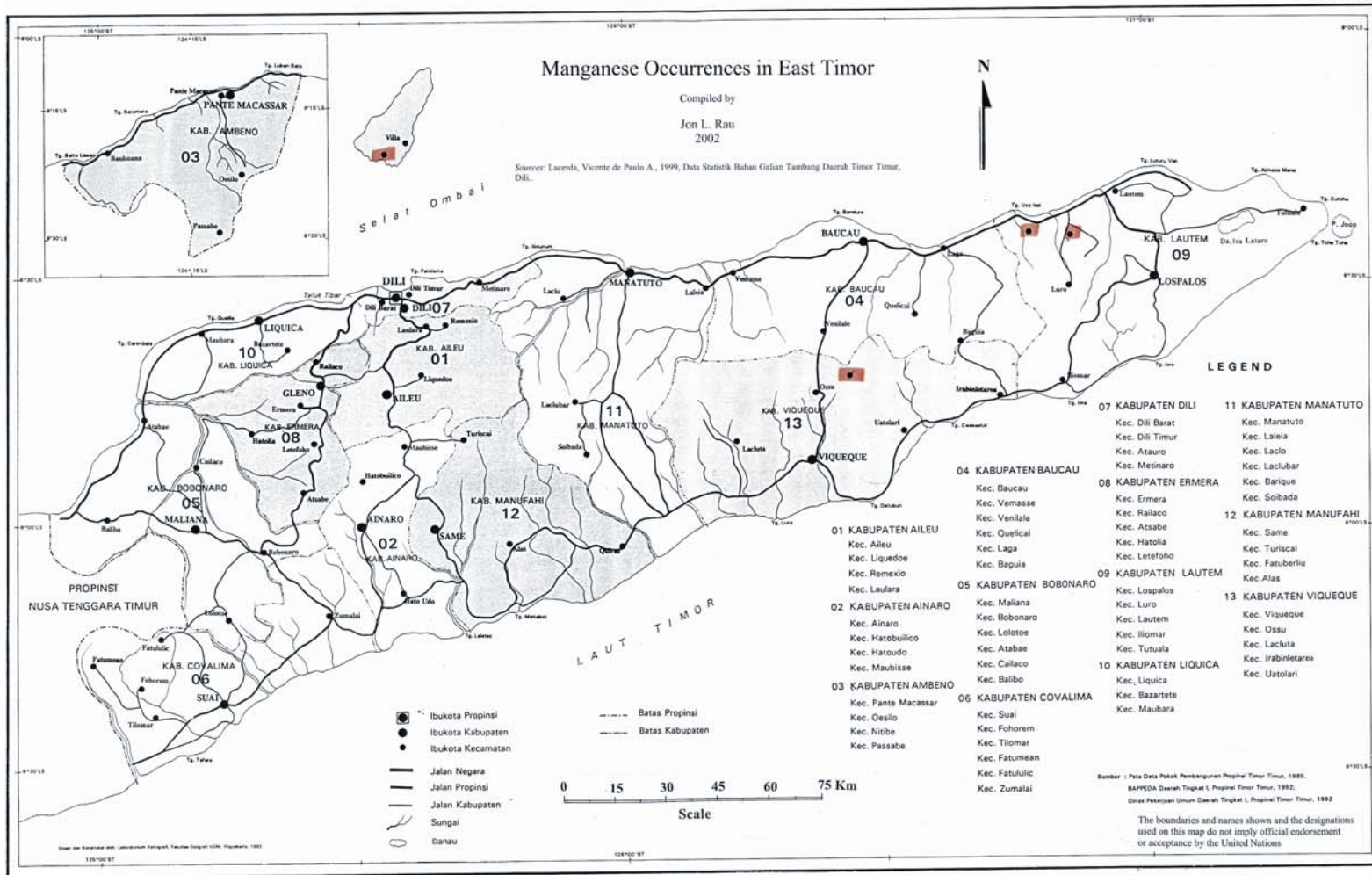


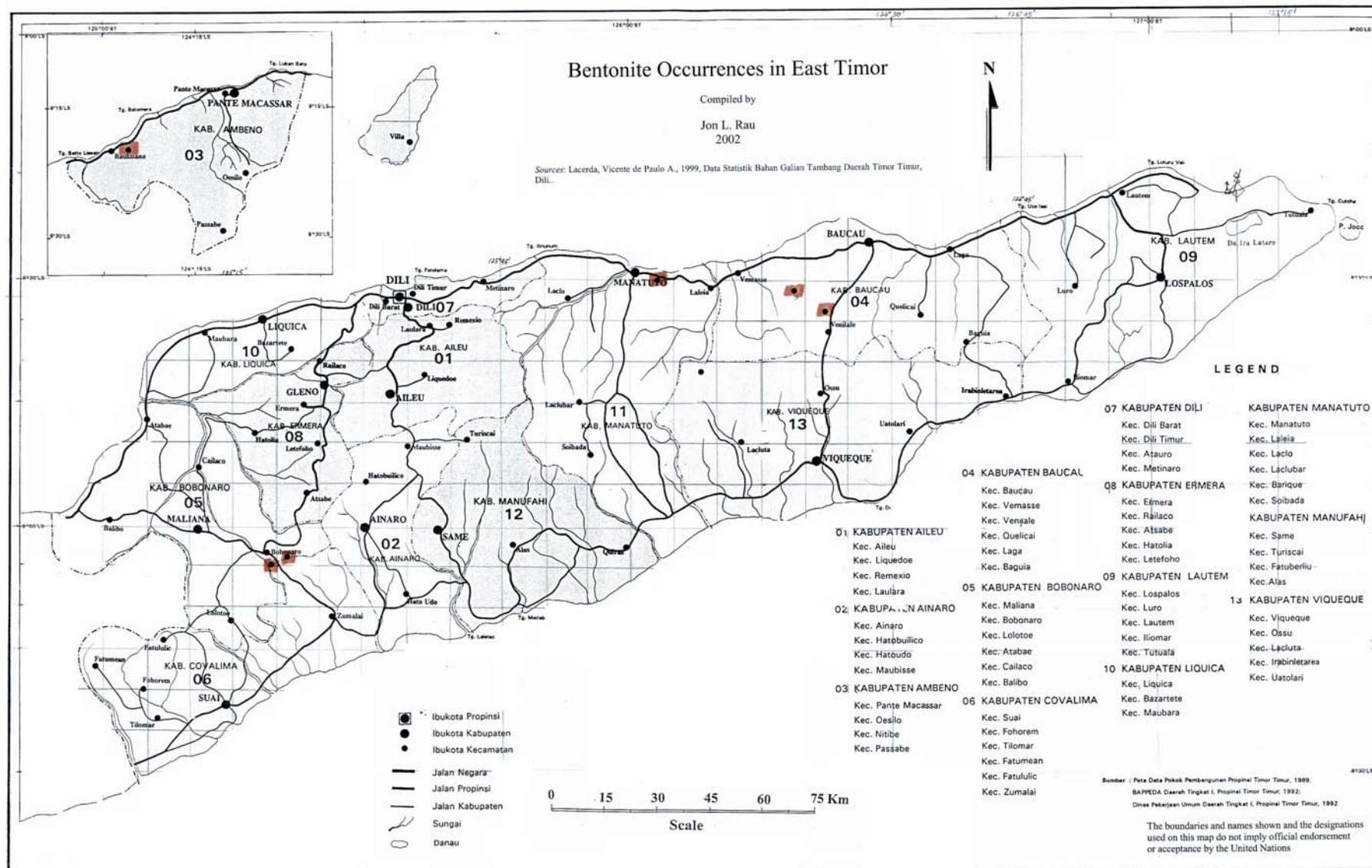


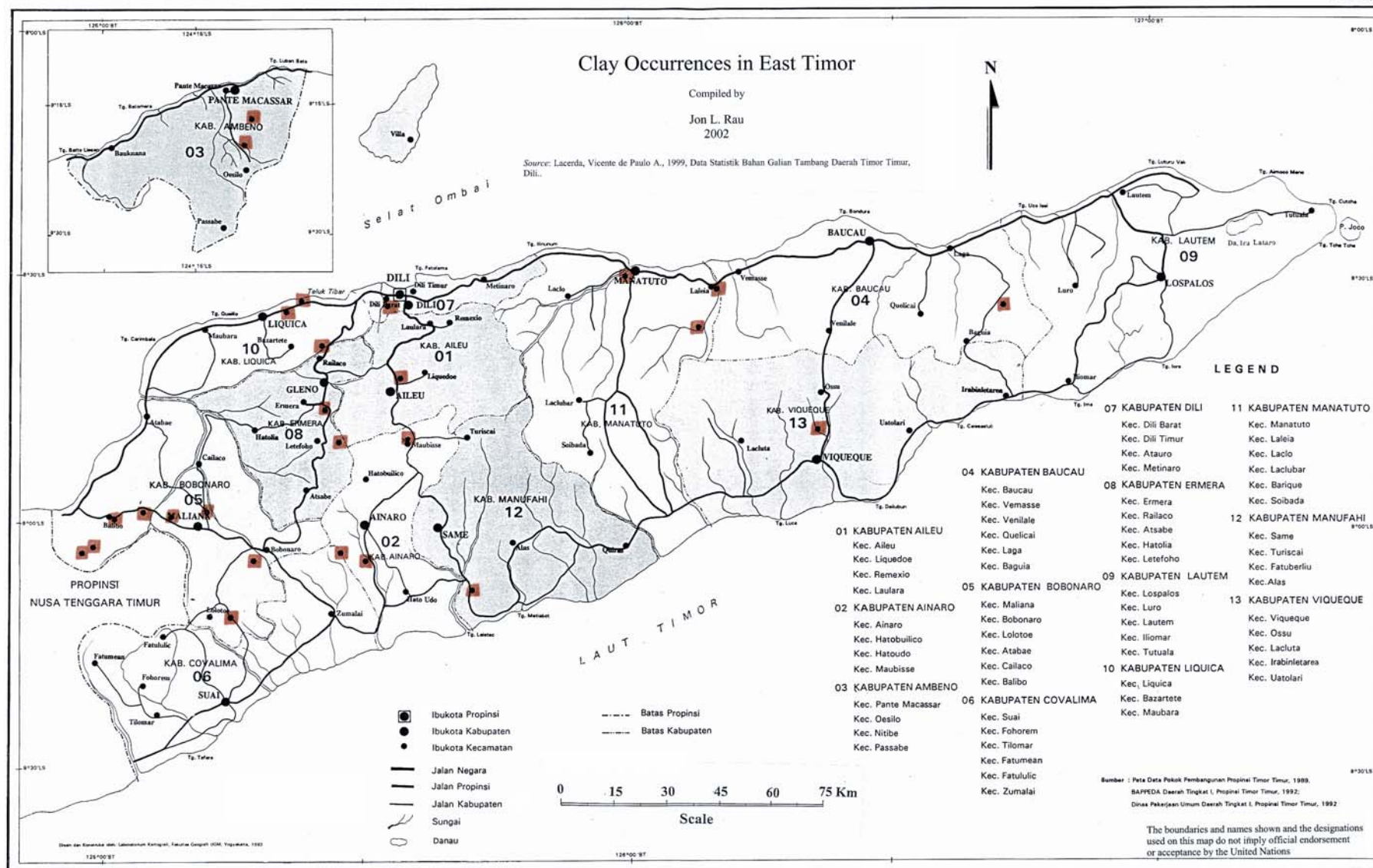




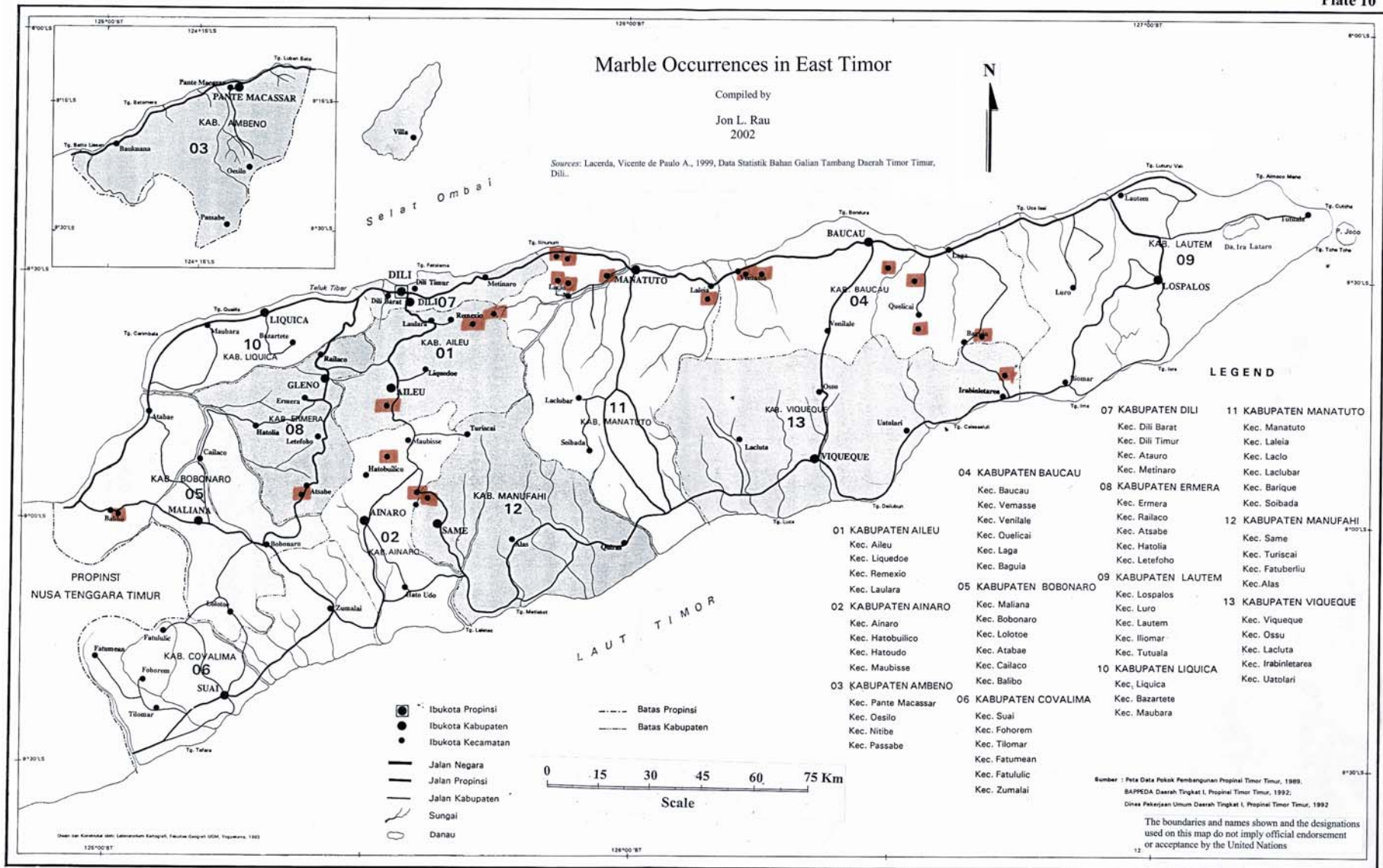


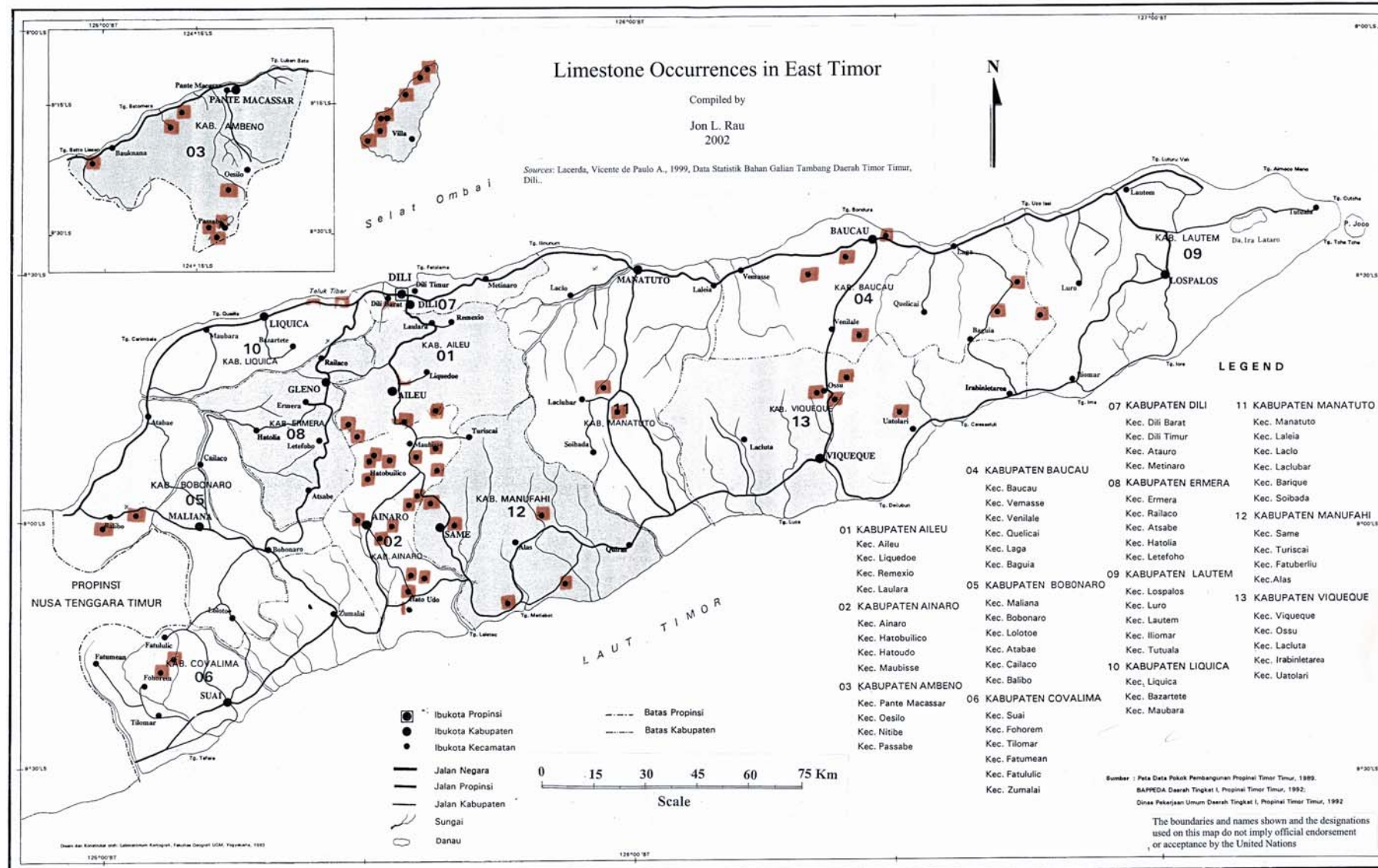


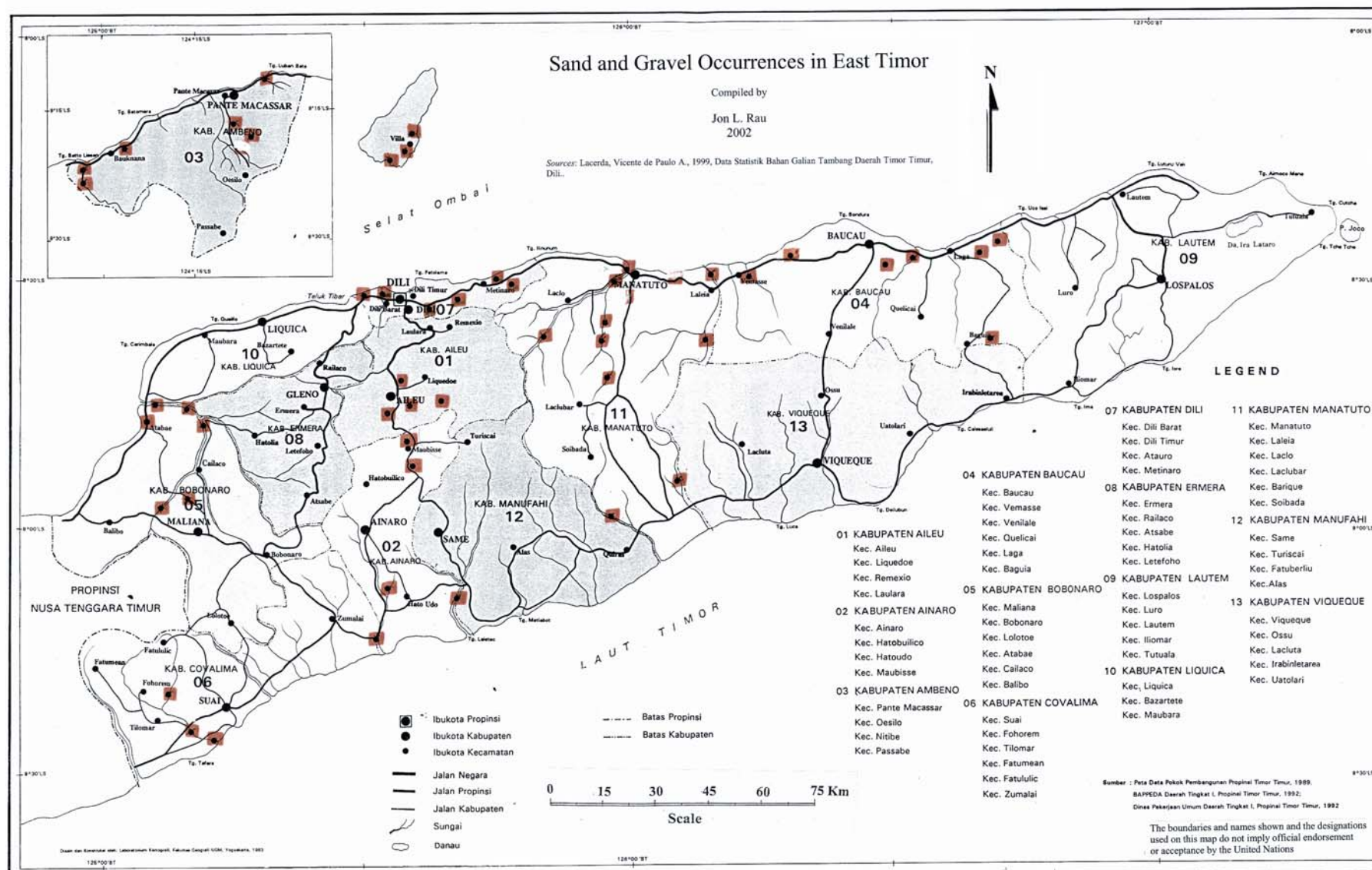












Part VII.

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.

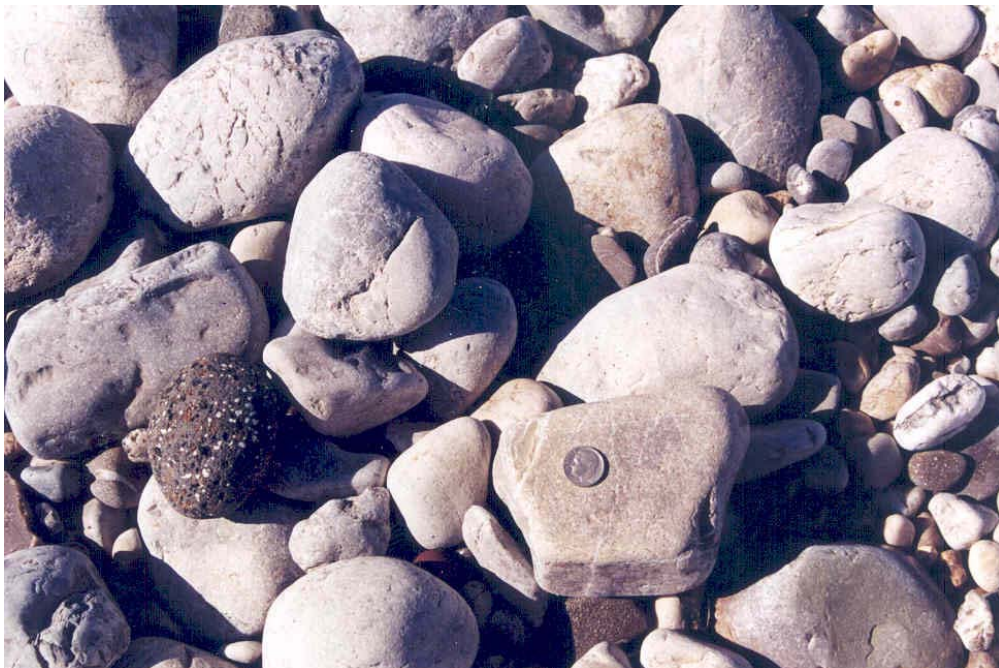
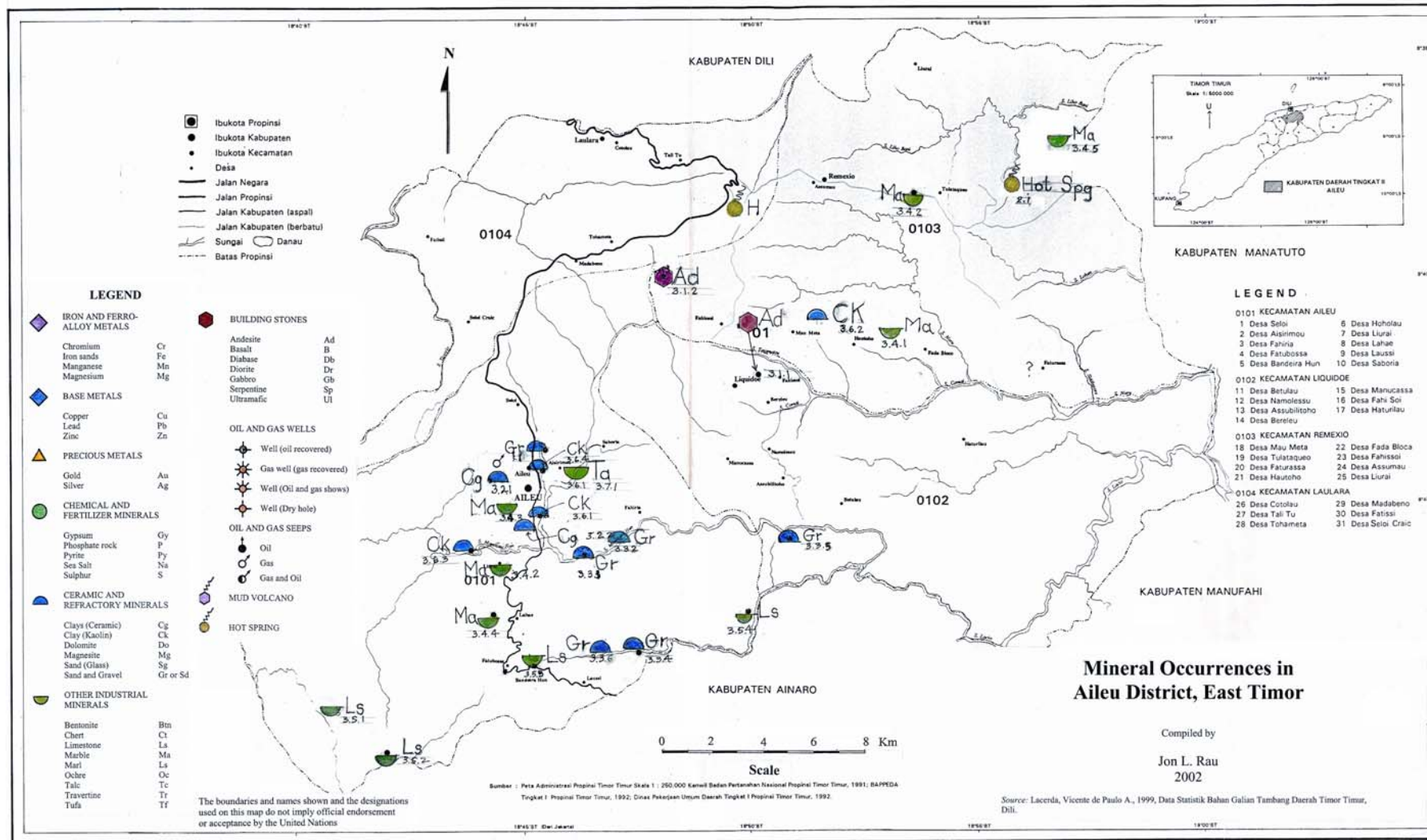
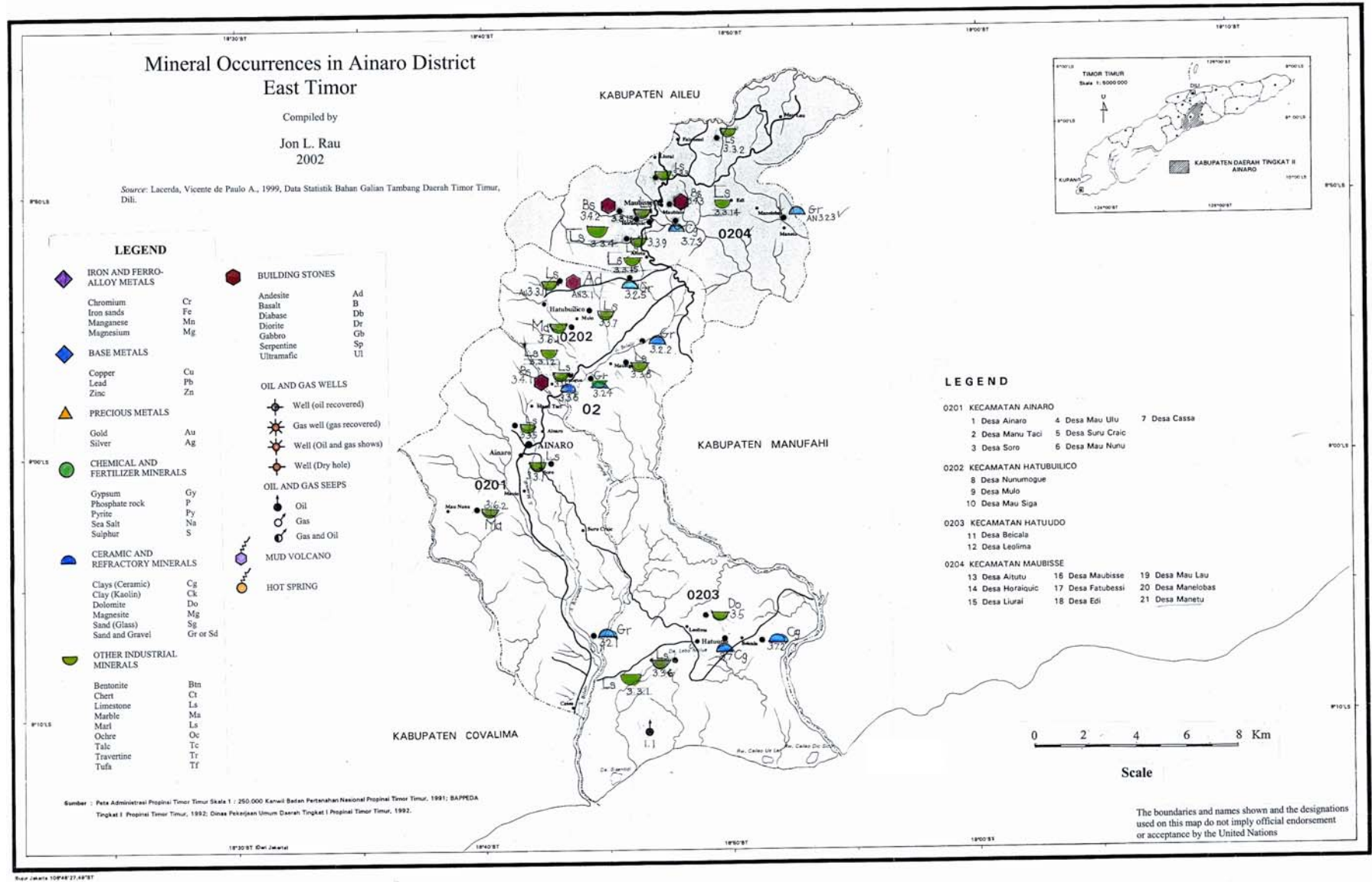
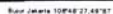


Figure 38. The beach pavement of cobbles at Laca (Baucau District) shows the pebble and cobble sizes that occur as a result of natural beach wash and storm activity.







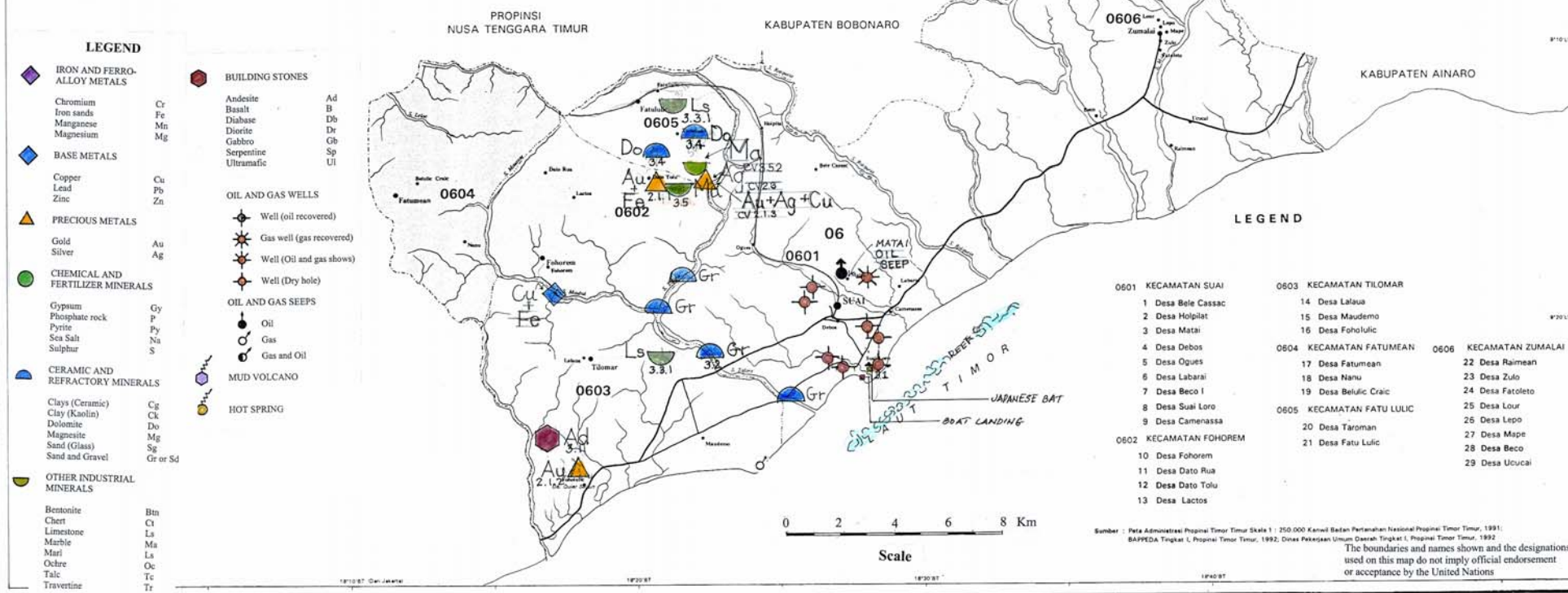


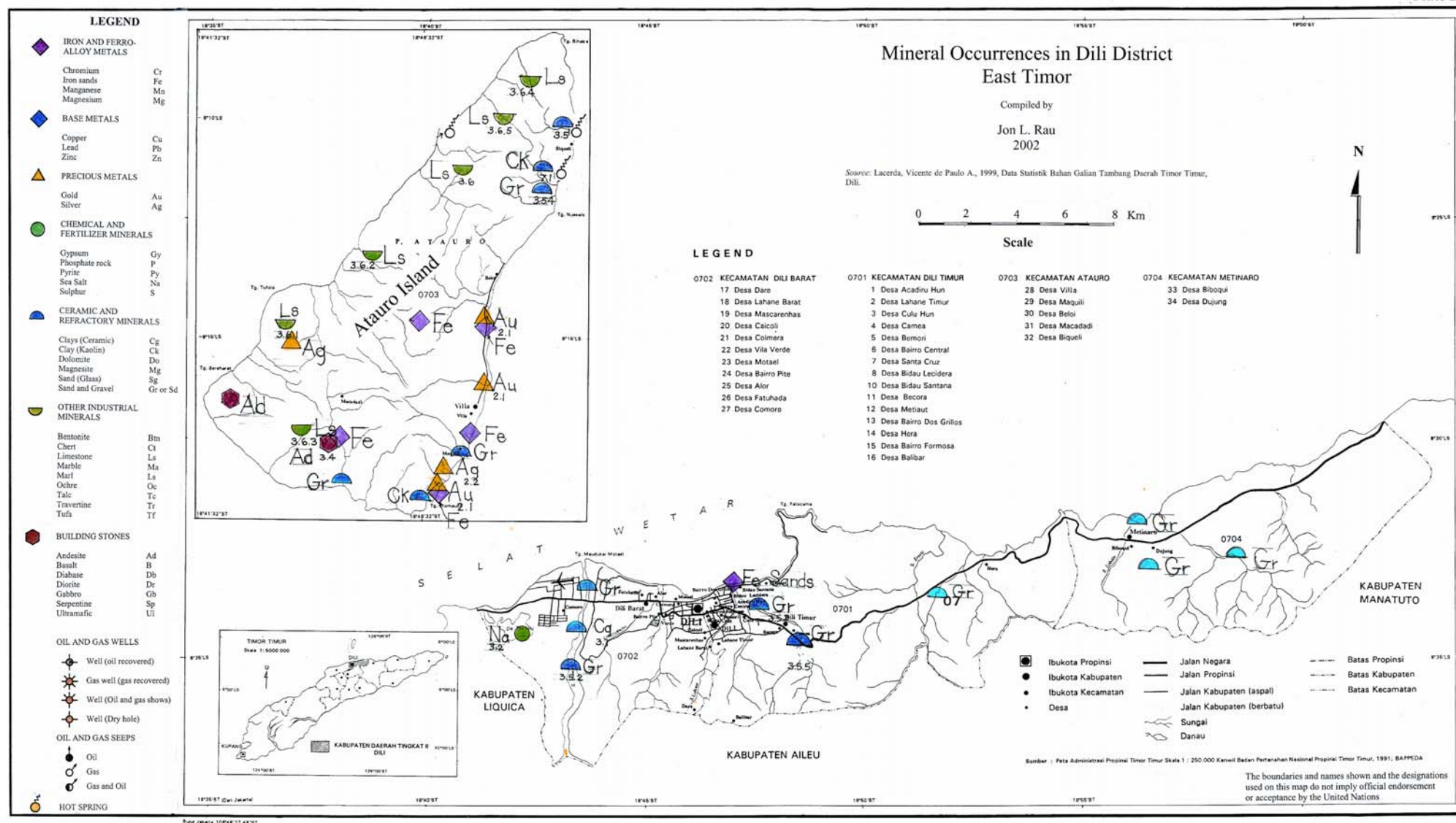
Mineral Occurrences in Covalima District East Timor

Compiled by

Jon L. Rau
2002

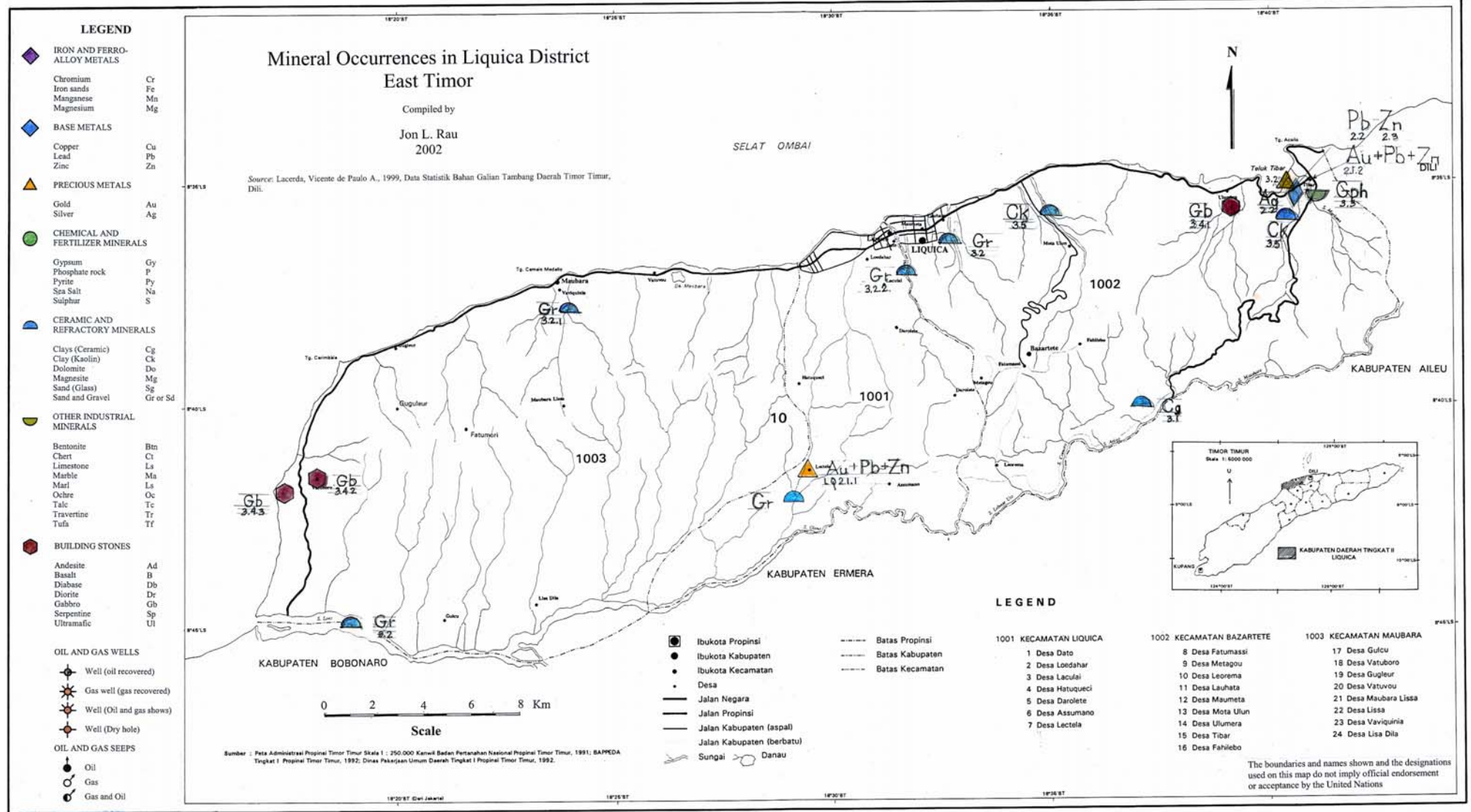
Source: Lacerda, Vicente de Paulo A., 1999, Data Statistik Bahan Galian Tambang Daerah Timor Timur, Dili.

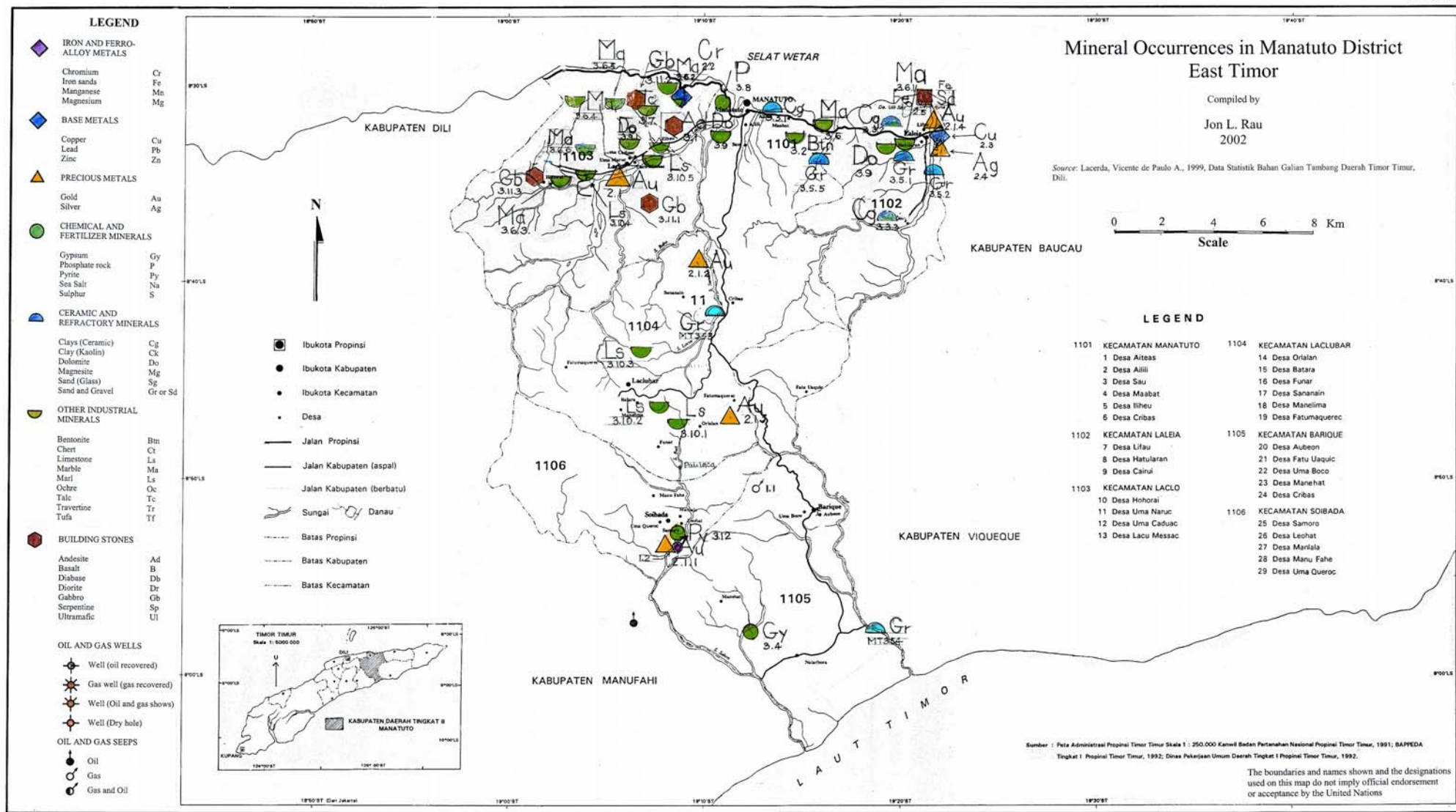


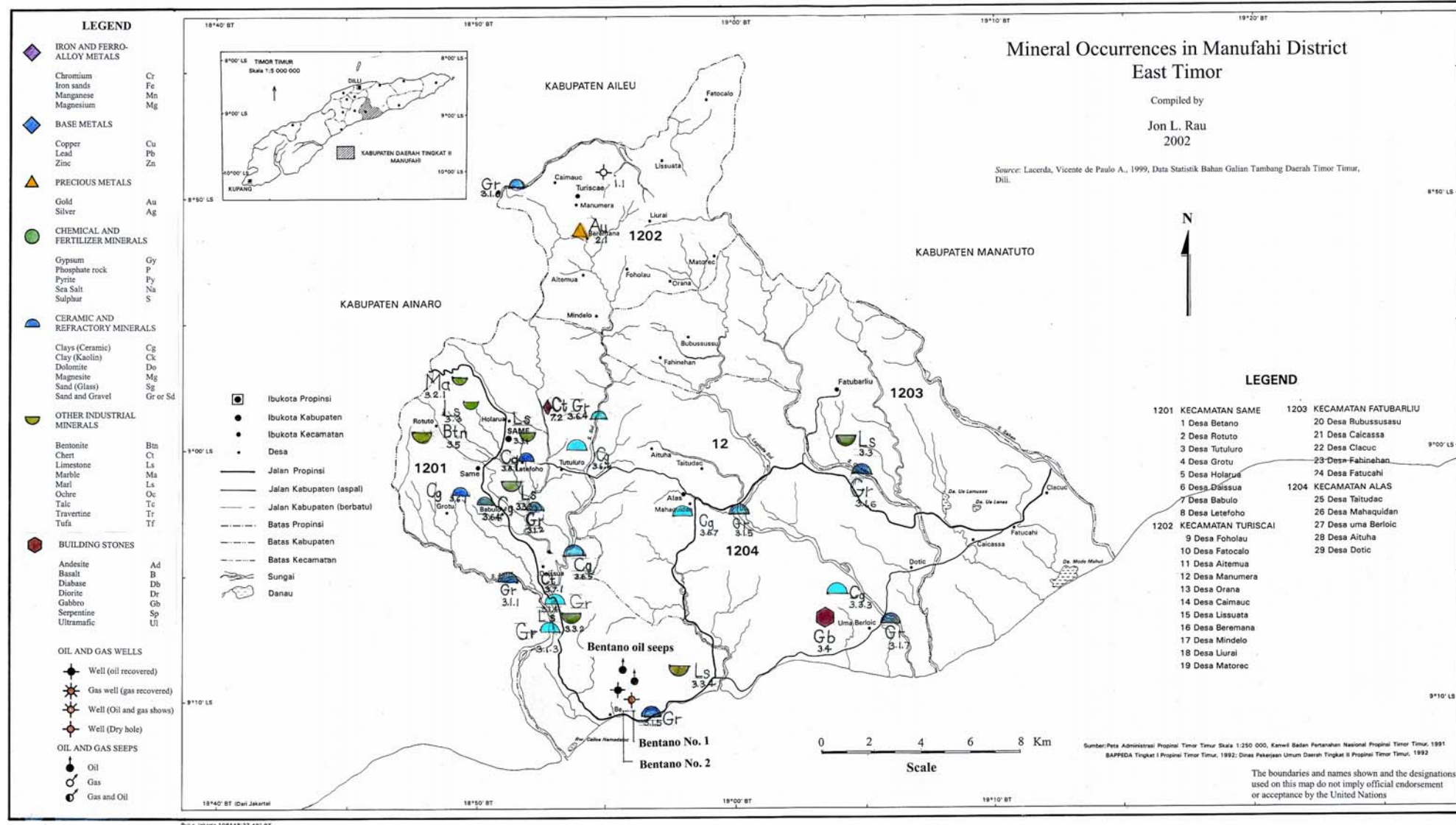


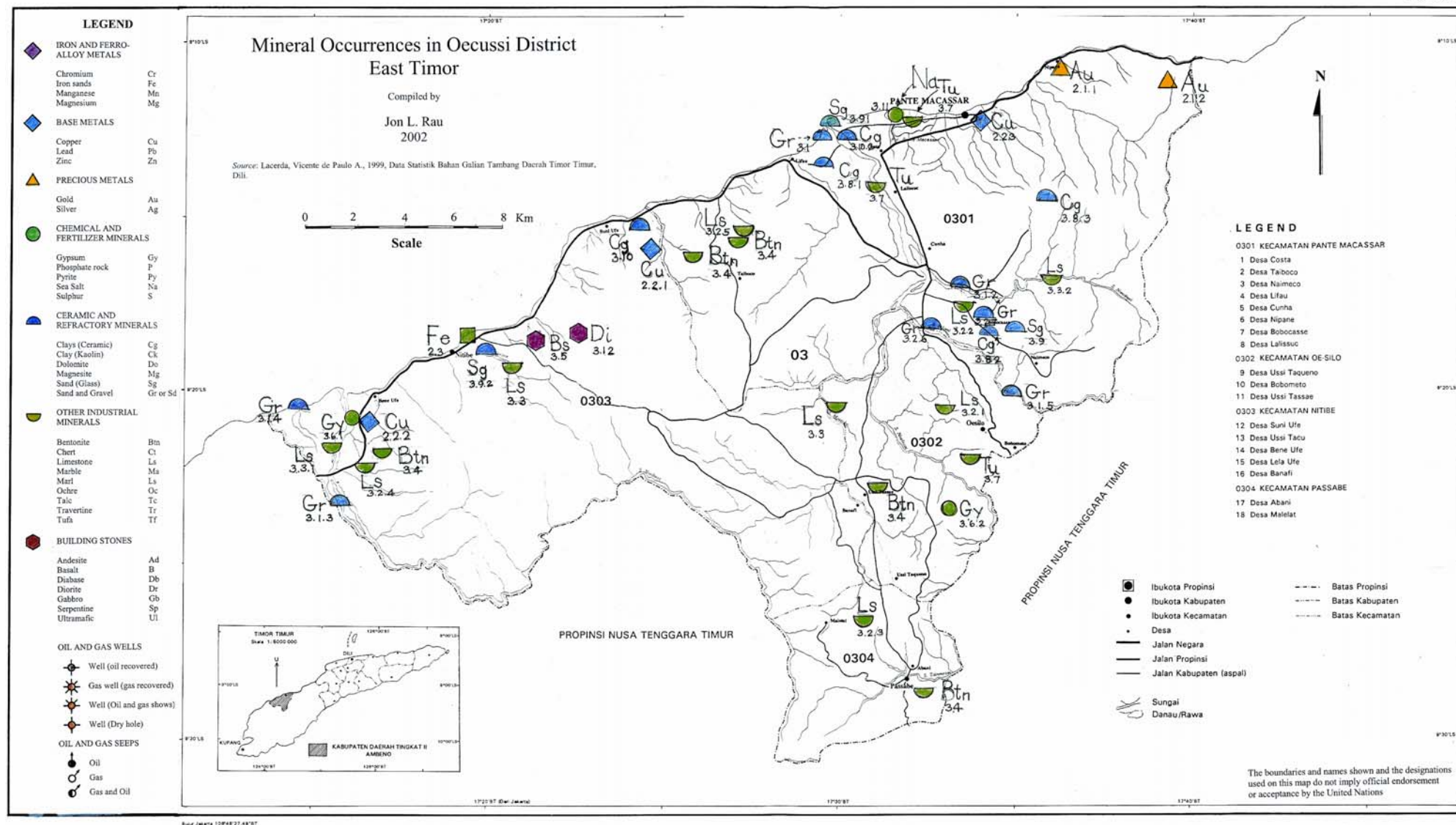












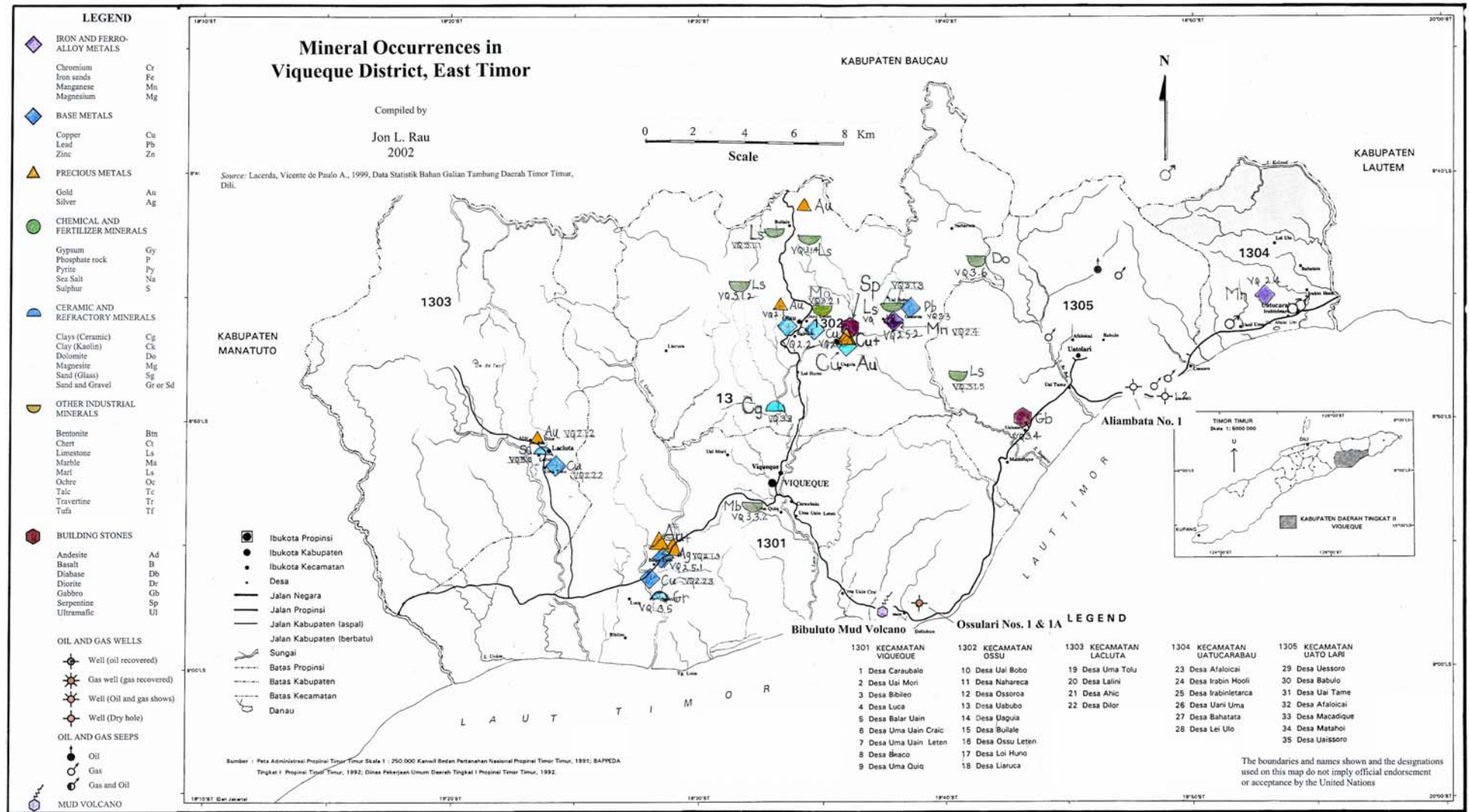




Figure 29. P.J. Bakker examines an outcrop of the Bobonaro Scaly Clay about 3 km southwest of Luro (Lautem District). The locality was reported to have a gold occurrence but the mission only discovered abundant pyrite.



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.

Map reference number	Latitude E	Longitude S	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (per cent)
AB-2.2.1	9 15' 57"	124 13' 55"	Copper	Pante Nitibe	Bihala Bobokase Bauknanan				Indication
BC-2.3.1	8 36' 25"	126 19' 06"	Copper and Gold	Vemassee		Ossuala			0.7-11.4 gr/ton
BC-2.4.1	8 35' 36"	126 19' 06"	Copper and Gold			Ossuala			Indication
CV-2.1.3	9 14' 25"	125 10' 55"	Copper, Gold and Silver	Fatu Lulic	Fatu Lulic		Maubui		Indication
CV-2.2	9 18' 25"	125 05' 52"	Copper, Iron and Gold	Fatu Mean			Maubui		Indication
EM-2.2	8 49' 06"	125 26' 28"	Copper and Gold	Lete Foho					Indication
MT-2.5.1	8 30' 00"	126 26' 02"	Copper				Laleia		Indication
VQ-2.2.1	8 45' 40"	126 21' 49"	Copper and Gold	Ossu	3.5 km E. of Bacai near Ossurua	Eastern ext of Ossu Mtn. ultramafics		Massive sulfide in large ultramafic boulders at base of Hillside on E. side of village near river	10 per cent Cu with Au up to 10 gr/ton
VQ-2.2.2	8 48' 00"	126 16' 30"		Lacluta					
VQ-2.2.3	8 55' 05"	126 17' 03"					UeTuco		

Table 2. Gold database for East Timor.

Map reference number	Latitude East	Longitude South	Resource	Subdistrict.	Village	Mountain	River	Potential (g/t)
AB-2.1.1.	9 10' 33"	124 24' 57"	Gold			Noemeto, Tanjung Luban Batu, Nifane		Indication
AB-2.1.2	9 13' 06"	124 26' 19"	Gold			Mumbal		
BC-2.1.1	8 35' 36"	126 19' 38"	Gold	Vermasse				2.85-3 gr/ton
CV-2.1.1	9 14' 28"	125 10' 58"	Gold,	Fatu Lulic	Dato Tolu			Indication
CV-2.1.2	9 26' 11"	125 05' 44"	Gold	Tilomar	Foho Lulic			Indication
CV-2.1.3	9 14' 36"	125 10' 55"	Gold, Copper and Silver	Fatu Lulic	Fatu Lulic			Indication
DL-2.2.1	8 13' 08"	124 36' 25"	Gold	Atauro			Tanjung Eranmuco	Indication
DL-2.2.2	8 17' 02"	125 35' 03"	Gold	Atauro			Beach (?)	Indication
DL-2.2.3			Gold	Atauro			Beach (?)	Indication
EM-2.1	8 47' 52"	125 26' 36"	Gold and Copper	Letefoho			Gulolo	Indication
LQ-2.1.1	8 41' 44"	125 18' 57"	Gold, Lead and Zinc	Liquica	Lectela			Indication
LQ-2.1.2	8 19' 14"	125 28' 47"	Gold, Lead and Zinc	Bazartete	Pantul Tibar			Indication
LQ-2.1.3	8 38' 03"	125 28' 55"	Gold	Liquica	Kialeulema			Indication
LT-2.2.	8 33' 25"	126 49' 30"	Gold	Luro	Ossalio			Indication
LQ-2.1	8 38' 03"	125 19' 55"	Gold	Liquisa Bazartele	Aeotele Pantai Tibar			Indication

MT-2.1.1	8 46' 14"	125 59' 36"	Gold	Soibada	Diatuto			0.5 gr/ton
MT-2.1.2	8 37' 55"	125 58' 38"	Gold	Laclo	Daerah			0.5 gr/ton
MT-2.1.3	8 46' 14"	125 59' 36"	Gold				Ui Bairac	0.5 gr/ton
MT-2.1.4	8 34' 14"	125 54' 00"	Gold	Laclo			Sumase	0.5 gr/ton
MF-2.1.1	8 50' 44"	125 42' 17"	Gold	Turiscail	Daerah Manufahi	Daerah Manufahi		107 gr /ton 75 gr/ton
VQ-2.1.1	8 45' 57"	126 24' 33"	Gold and Silver	Ossu				Ag 3,968 gr/ton
VQ-2.1.2	8 46' 38"	126 00' 00"	Gold	Lacuta				Indication
VQ-2.1.3	8 53' 44"	126 17' 52"	Gold				UeTuco	Indication

Table 3. Silver database for East Timor.

Map reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River or Beach	Potential (g/ton)
BC-2.2.1	8 35' 03"	126 18' 11"	Silver and Gold	Vemasse				490-560 g/ton
CV-2.3	9 14' 28"	125 10' 58"	Silver, Gold and Copper	Fatu Lulic	Fatu Lulic			Indication
DL-2.3.1	8 14' 28"	125 32' 03"	Silver	Atauro			Conifasi beach	Indication
VQ-2.3.1	8 44 28	126 26 52	Silver	Ossu				73,025 gr/ton

Table 4. Chromite database for East Timor

Map reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (per cent) and Note
BC-2.7.1	8 35 44	125 33 08	Chromite	Quelicaí					Cr ₂ O ₃ – 36.4% and 51.3 %
MT-2.4.1	8 29 55	125 56 30	Chromite	Laclo	Hilimanu Umakaduak	Ossu		Ultramafics - Serpentinite	Cr ₂ O ₃ – 36.4% and 49.6 %

Table 5. Iron sand database for East Timor.

Map reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River or Beach	Geology	Potential (cu m)
AB-2.3.1	9 17' 52"	124 07' 55"	Iron sand		Nitibe		Ambeno beach	Quaternary mineral sand	Indication
DL-2.3.1	8 13' 38"	125 36' 25"	Iron sand	Atauro	Biqueli Maqili		Tanjung Eraumoco beach	Quaternary mineral sand	Indication
DL-2.3.2	8 13' 38"	125 35' 11"	Iron sand	Atauro					
DL-2.3.3	8 16' 22"	125 33' 00"	Iron sand	Atauro					

Table 6. Manganese database for East Timor.

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

Table 7. Limestone database for East Timor.

Map reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
AN-3.3.1	9 08 52	125 33 41	Ls	Hato Udo	Fahoaailako			Pmu	Indication
AN-3.3.2	8 48 16	125 38 53	Ls	Hatubulico	Manutaci			Pmu	15 000 000
AN-3.3.3	8 48 41	125 36 00	Ls	Maubisse	Daerah Mabuno Mau Fatubesi			Pmu	1 650 520 432
AN-3.3.4	8 51 41	125 33 25	Ls	Hatu Udo	Maubissi Utara	Balibo		Pmu	1 884 193 668
AN-3.3.5	8 58 30	125 30 41	Ls	Hatu Udo		Osabo		Pmu	378 000 000
AN-3.3.6	9 08 11	125 35 11	Ls	Hatu Udo		Foho Olica		Pmu	1 969 006 034
AN-3.3.7	8 54 00	125 33 41	Ls	Ainaro	Ainaro			Pmu	1 293 731 115
AN-3.3.8	8 56 44	125 35 52	Ls	Ainaro	Soro	Ainaro		Pmu	10 024 303 492
AN-3.3.9	8 51 57	125 35 03	Ls	Haubuilico	Nunumogue			Pmu	249 602 922
AN-3.3.10	8 52 38	125 33 49	Ls	Hatubuilico	Mulo			Pmu	8 296 632 733
AN-3.3.11	8 52 47	125 31 46	Ls	Hatubuilico	Manuxigue			Pmu	12 057 502 400
AN-3.3.12	8 55 38	125 31 30	Ls	Maubisse	Hororaikik			Pmu	239 095 877
AN-3.3.13	8 49 44	125 34 46	Ls	Maubisse	Edi			Pmu	2 834 960 315
AN-3.3.14	8 50 11	125 39 17	Ls	Maubisse	Aituto			Pmu	6 658 900 455
AL-3.3.1	8 42' 49"	125 34' 05"	La			Hotobaul Colimali Hatoria		Pmu	Indication
AL-3.3.2	8 44' 59"	125 35' 53"	Ls				Berekati	Pmu	2 475 000
AL-3.3.3	8 45' 17"	125 34' 46"	Ls				Manu Fahihum	Pmu	
AL-3.3.4	8 46' 53"	125 37' 12"	Ls				Manefone	Pmu	

AB-3.1.1	9 02' 52"	124 27' 41"	Ls	Magisiao		Sainerao Puas Buna Lasho	Saineerao Puas	n.d.	15 000 000
AB-3.1.3	9 22' 14"	124 04' 22"	Ls						
AB-3.1.4	9 20' 03"	124 04' 38"	Ls						
BC-3.5.1	8 30' 00"	126 21' 00"	Ls	Baucau	Bucoi				18 000 000
BC-3.5.2	8 42' 41"	126 32' 03"	Ls	Baucau	Buruma				11 182 500
BC-3.5.3	8 27' 41"	126 29' 28"	Ls	Quilicai	Sama Fano	Liatai			65 625 000
BC-3.5.4	8 38' 19"	126 24' 24"	Ls	Vinilale		Ariana			468 750 000
BC-3.5.5	8 39' 00"	126 17' 44"	Ls						
BB-3.7.1	9 02' 03"	125 12' 41"	Ls	Balibo	Balibo				High
BB-3.7.2	9 04' 22"	125 12' 00"	Ls	Balibo	Subarai	Tapo			
BB-3.7.3	n.d.	n.d.	Ls			Lalo Tapo Abendate			25 289 050
BB-3.7.4	8 58' 38"	125 03' 00"	Ls	Bobonaro		Lesololi			
BB-3.7.5	8 58' 38"	125 02' 52"	Ls	Kailako		Kailako			
BB-3.7.6	n.d.	n.d.	Ls	Maliana	Memo Kee				
BB-3.5.7	n.d.	n.d.	Ls	Atabae	Balibo Tasmil	Marotoi			
BB-3.5.8	n.d.	n.d.	Ls	Atabae	Tasbui				
CV-3.3.1	9 11' 44"	125 08' 52"	Ls	Fohorem	Foholulik				6 250 000
CV-3.3.2	9 20' 44"	125 10' 55"	Ls	Tiliomar			Tafara		271 000 000
DL-3.6.1	8 16' 22"	125 32' 03"	Ls	Atauro	Maqueli Tulol Arlo Dourullina Hatu Akrema Biqueli	Beloi Conrupo Bibiluha Dimanae Urabe Maco			2 660 500 SiO ₂ = 0.4 – 3.77% CaO = 51.21 – 54.68% Mg ₂ O = 0.46 – 2.84%
DL-3.6.2	8 14' 11"	125 31' 46"	Ls						

DL-3.6.3	8 12' 41"	125 33' 57"	Ls						
DL-3.6.4	8 09' 41"	125 36' 49"	Ls						
DL-3.6.5	8 09' 00"	125 37' 14"	Ls						
LT-3.11.1	8 20' 52"	127 02' 09"	Ls	Moro	Com Pairara Puno				65 507 812
LT-3.11.2	8 42' 17"	126 51' 49"	Ls	Luro	Tirilolo	Titiran			9 000 000
LT-3.11.3	8 25' 30"	126 58' 22"	Ls	Lospalos	Soro				750 000
LT-3.11.4	8 24' 17"	127 11' 36"	Ls	Tutuala	Mehara				1 000 000
LT-3.11.5	8 30' 49"	126 59' 52"	Ls	Lospalos	Asalaino Fuiloro				125 000
LT-3.11.6	8 30' 16"	127 05' 36"	Ls						
LT-3.11.7	8 23' 44"	127 15' 40"	Ls						
LT-3.11.8	8 38' 44"	126 59' 52"	Ls						
LT-3.11.9	8 27' 33"	127 00' 16"	Ls						
MT-3.10.1	8 46' 46"	125 57' 17"	Ls	Laclubar	Orlalan				7 021 250
MF-3.3.1	8 58 14	125 38 11	Ls	Same		Manumet alau Darellau			4 468 750 000
MF-3.3.2	9 06 49	125 42 33	Ls	Same	Fahiluna	Gabblaki Datina			19 968 750 000
MF-3.3.3	9 09 33	125 30 41	Ls	Same	Letefoho				2 024 875 000
MF-3.3.4	9 07 55	125 47 03	Ls	Alas	Berloik	Niguttu Be Susu			1 245 750 000
MF-3.3.5	8 59 03	125 53 52	Ls	Alas	Umaberl oik	Llusi Monouasi Mitutu			481 250 000
MF-3.4.6	9 07 30	125	46L30s	Same		Bandeira Caraulun Loilere Betano			1 311 787 500

MT-3.10.2	8 46 06	125 55' 14"	Ls	Laclubar		Hataderoc			4 250 000
MT-3.10.3	8 43' 22"	125 54' 57"	Ls	Laclubar		Barubi			63 562 500
MT- 3.10.4	8 34' 14"	125 52' 22"	Ls	Laclo	Dili- Manatuto Rd.				4 218 750
MT-3.10.5	n.d.	n.d.	Ls	Laclo	Umacaduac				Indication
VQ-3.1.1	8 41' 52"	126 23' 11"	Ls	Ossu	Ulohau				Indication
VQ-3.1.2	8 42' 49"	126 19' 46"	Ls	Ossu		Mundu Pardido			Indication
VQ-3.1.3	8 44' 36"	126 26' 11"	Ls	Ossu		Ossu Rus			Indication
VQ-3.1.4	8 41' 52"	126 23' 03"	Ls	Ossu	Lariguto				Indication

Table 8. Marble database for East Timor.

Map reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain or Hill	River	Geology	Potential (cu m)
AN-3.6.1	8 54 39	125 32 03	Marble		Mulo	Gabiki			Indication
AN-3.6.2	9 03 03	123 38	Marble						
AL-3.4.1	8 37 55	125 43 22	Marble			Hotobolu			Indication
AL-3.4.2	8 35 00	125 50 10	Marble			Colimali			
AL-3.4.3	8 45 08	125 32 44	Marble			Laubere			
AL-3.4.4	8 47 09	125 32 19	Marble			Haboria			
AL-3.4.5	8 42 00	125 42 17	Marble						
BC-3.6.1	8 39 08	126 37 14	Marble	Bauquia	Ossu	Matebean Feto			1 575 000
BC-3.6.2	8 38 11	126 33 08	Marble	Quelicaí	Maluro	Magalsso			4 500 000
BB-3.8.1	8 58 55	125 01 22	Marble	Balibo		Fatue	Gaguegeu		Indication

						Mutin			
BB-3.8.2	9 05 27	125 12 41	Marble						
EM-3.4.1	8 49 14	125 16 38	Marble	Letefoho	Pebukitan				Indication
EM-3.4.2	8 55 55	125 23 11	Marble	Letefoho	Atsabe				
CV-3.5.1	9 14 52	125 09 00	Marble	Fatoholik Fohorem					33 000 000
CV-3.5.2	9 14 03	125 14 28	Marble	Fatululik Fohorem	Datutolu	Taroman Maubara			15 347 500
LT-3.3.1	8 24 33	127 13 14	Marble	Tutuala		Rusili			Indication
MT-3.19.1	8° 28' 45"	125°54' 53"	Marble	Laclo	Dili-Manatuto Rd.				Quarry 1 000 000+
MF-3.2.1	8 56 52	125 37 47	Marble	Same		Kablaki			Indication
VQ-3.2.1	8 52 30	126 20 27	Marble	Ossu					High

Table 9. Marl, Travertine and Tufa database for East Timor.

Database reference no.	Latitude	Longitude	Mineral	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m) and Note
AB-3.7.1	9 12 25	124 21	Tufa	Pante Makassar	Fatsuba				Indication
AB-3.7.2	9 14 28	124 19 46	Tufa	Pante Makasar	Lifura				
BC-3.9.1	8 27 08	126 12 25	Travertine	Baucau	Buruma				Indication
BC-3.16.1 (new)	8 29 30	128 17 30	Marl	Vemassee	Macadai Birwah				3 000 – 10 000 Small quarry USD 7/ton in May 2002
LT-3.8	8 22 38	126 55 14	Travertine	Lautem	Badura				Indication

Table 10. Phosphate database for East Timor.

Map reference no.	Latitude	Longitude	Mineral	Subdistrict.	Village	Mountain	River	Geology	Potential
BC-3.8.1	8 36 17	126 35 03	Phosphate	Quelicai	Abo				P ₂ O ₅ 21.55%
BC-3.8.2	n.d.		Phosphate	Paatal Utara Baucau					P ₂ O ₅ 1.89-5.85% 1 969 tonnes
MT-3.8.1	8 30 08	125 59 36	Phosphate	Seldtar Jalan Manatuto-Laleia (Km 2)					Indication
MT-3.8.2	8 52 30	125 56 44	Phosphate						

Table 11. Clay database for East Timor.

Map reference no.	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain or hill	River	Fm	Potential (cu m)
AN-3.7.1	9 06 47	125 51 32	Clay	Hatu Udo	Leolima				1 443 849 151
AN-3.7.2	9 04 30	125 55 36	Clay	Hatu Udo	Beikala				297 857 922
AN-3.7.3	8 49 13	125 51 32	Clay	Ainaro	Maunurmo				401 558 464
AN-3.7.4	n.d.	n.d.	Clay	Maubisse	Maubisse				1 350 000
AL-2.2.1	8 44 03	125 32 19	Clay	Aileu	Aileu				High
Al-2.2.2	8 44 19	125 33 25	Clay	Aileu	Aileu				523 100 000
AB-3.8.1	9 13 22	124 18 00	Clay		Bihala Bobokase				75 000
AB-3.8.2	9 18 00	124 22 55	Clay	Pante Makassar	Nukano	Lereng			24 000
AB-3.8.3	9 14 11	124 24 57	Clay	Pante Makassar	Naimeko				162 000
BB-3.2.1	8 59 50	124 58 06	Clay	Tunu Bibi Balibo	Malian Cova Leolima				High
BB-3.2.2	8 58 14	125 08 36	Clay	Bobonaro	Malilait Memo		Lohoman		917 635 000
BB-3.2.3	9 00 32	125 17 52	Clay	Lebo Ballibo	Maliana Lolotoe				High
DL-3.6.1	8 34 14	125 32 52	Clay	Dili Barat	Comoro				6 250 000
EM-3.1.1	8 41 19	125 23 52	Clay	Raiklako	Mota Hare				High

EM-3.1.2	8 46 06	125 26 03	Clay	Letefoho Tanjung Earumoco	Ketrai Kraik				High
LT-3.1.1	8 42 41	126 45 27		Lautem	Ililai	Palrara			High
LT-3.1.2	8 42 03	126 48 33		Illiomar	Badura				

Table 12. Sand and gravel database for East Timor.

Map reference number	Latitude E	Longitude S	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
AN-2.2.1	9 04 30	125 32 44	Sd, gvl	Ainaro			Burumo	Quaternary	16 000 000
AN-2.2.2	8 55 14	125 36 17	Sd, gvl	Ainaro			Belulik	Quaternary	26 000 000
AN-2.2.3	8 50 52	125 40 14	Sd, gvl	Maubisse	Maneta			Quaternary	3 162 654 684
AN-2.2.4	8 56 52	125 33 08	Sd, gvl	Maubisse	Aituto			Quaternary	269 874 604
AN-2.2.5	8 52 55	125 34 40	Sd, gvl	Maubisse	Nunumigu e			Quaternary	856 298 101
AL-3.3.1	8 42 49	125 34 05	Sd, gvl	Aileu	Daisoli		Eramata	Quaternary	High
AL-3.3.2	8 44 59	125 35 52	Sd, gvl	Aileu	Nosi		Eramata	Quaternary	High
AL-3.3.3	8 45 17	125 34 46	Sd, gvl	Aileu					
AL-3.3.4	8 46 53	125 37 12	Sd, gvl				Berecati		2 475 030
AL-3.3.5	8 44 35	125 40 04	Sd, gvl				Manufanihu m		
AL-3.3.6	8 47 19	125 35 52	Sd, gvl				Manofone		
AB-3.1.1	9 02 52	124 27 41	Sd, gvl				Tono, Bilomi, Barata, Colo	Quaternary	High
AB-3.4.2	9 16 38	124 21 49	Sd, gvl		Besai		Tono	Quaternary	High

CV-3.2.1	9 20 27	125 10 55	Sd, gvl	Tiliomar			Tafara	Quaternary	4 100 000
CV-3.2.1	9 18 57	125 08 52	Sd, gvl						
CV-3.2.3	9 18 08	25 09 33	Sd, gvl						
CV-3.2.4	9 21 57	125 13 30	Sd, gvl		-+				
DL-3.5.1	8 16 55	125 36 00	Sd, gvl	Atauro	Pala Biqueli		Lau Beloi	Quaternary	31 325 000
DL-3.5.2	8 33 25	125 31 55	Sd, gvl	West Dili			Comoro	Quaternary	2 400 000
DL-3.5.3	8 33 25	125 31 55	Sd, gvl	Dili Timur	Santana Becora		Bemori Benama Ue	Quaternary	315 000
DL-3.5.4	8 17 27	125 33 16	Sd, gvl	Atauro	Biqueli Arlo Douru			Quaternary	82 500
DL-3.5.5	8 33 29	125 31 55	Sd, gvl						
EM-3.3.1	8 44 44	125 11 19	Sd, gvl	Hatolia			Marobo	Quaternary	High
LT-3.2.1	8 24 57	126	48S25d, gvl				Namanutuda n Irabere	Quaternary	High
LT-3.2.2	8 44 03	126 44 11	Sd, gvl				Laivai Iliomar Baura	Quaternary	n.d.
LT-3.2.3	8 43 55	126 51 33	Sd, gvl	Iliomar	Massosio Miara		Corolai Lihua Nabere	Quaternary	800 000
LT-3.2.4	8 24 57	126 49 55	Sd, gvl				Tehino Ndamaluhu	Quaternary	50 000
LT-3.2.5	n.d.	n.d.	Sd, gvl	Lautem			Raumoco Laivai	Quaternary	1 200 000
LT-3.2.6	n.d.	n.d.	Sd, gvl						
LT-3.2.7	n.d.	n.d.	Sd, gvl						
LT-3.2.8	8 40 47	126 57 00	Sd, gvl						
LT-3.2.9	8 40 47	127 00 00	Sd, gvl						

LT-3.2.10	8 26 28	127 00 26	Sd, gvl						
LQ-3.2.1	8 37 06	125 12 58	Sd, gvl	Liquisa Mubara Loes			Usngai DI	Quaternary	24 049 000
LQ-3.2.2	8 36 17	125 20 11	Sd, gvl						
MF-3.1.1	9 04 22	125 39 57	Sd, gvl	Same			Aiassa	Quaternary	2 012 000
MF-3.1.2	9 01 14	125 40 14	Sd, gvl	Same			Abata	Quaternary	236 250
MF-3.1.3	9 07 47	125 39 57	Sd, gvl	Same			Koloko	Quaternary	147 800
MF-3.1.4	9 05 52	125 41 30	Sd, gvl	Same			Caraqulun	Quaternary	17 887 500
MF-3.1.5	9 09 49	125 45 16	Sd, gvl	Same			Sual	Quaternary	3 750 000
MF-3.1.6	9 05 36	125 56 03	Sd, gvl	Alas			Clere	Quaternary	6 240 000
MF-3.1.7	9 05 36	125 54 49	Sd, gvl	Alas			Laclo Sal	Quaternary	7 280 000
MF-3.1.8	8 49 14	125 39 41	Sd, gvl	Turscai		Fatynaro Manumeta		Quaternary	6 687 000 000
VQ-3.5.0	8 48 00	126 16 30	Sd, gvl	Viqueque			Oetuco	Quaternary	High

Table 13. Bentonite database for East Timor.

Map reference no.	Latitude	Longitude	Resource	Subdistrict	Village	Mountain	River	Geology	Potential (cu m)
AB-3.4.1	9 21 17	124 05 52	Bentonite			Bauknana			Indication
AB-3.4.2	9 15 57	124 14 35	Bentonite		Pante Macassar				
AB-3.4.3	9 15 57	124 16 06	Bentonite		Pante Macassar				
AB-3.4.4	n.d.	n.d.	Bentonite						
AB-3.4.5	9 28 14	124 20 27	Bentonite						
BC-3.1	8 38 11	126 20 52	Bentonite	Venilale	Venilale				408 985 920 SiO ₂ = 65.7 - 67.8% Al ₂ O ₃ = 15.1 - 15.9% Fe ₂ O ₃ = 2.02 – 2.07% CaO = 2.03 – 2.36%
BB-3.1.1	8 56 36	124 59 11	Bentonite	Batu Gade Bobnaro	Batu Gade Taluata Laruba				Indication
BB-3.1.2	9 00 08	125 15 00	Bentonite	Balibo	Ddaerah Aiasa Nunura Leolima				Indication
BB-3.1.3	9 00 16	125 19 46	Bentonite						
MT-3.2	8 32 09	126 03 41	Bentonite		Antara Manatuto Laleia				Indication
MF-3.5	8 59 19	125 36 49	Bentonite	Same		Mucon			Indication

Table 14. Andesite database for East Timor.

Map reference no	Latitude	Longitude	Resource	Subdistrict	Village	Mountain	Stream	Geology	Potential (cu m)
AN-3.1	8 52 20	125 32 44	Andesite	Hatubuilico	Maubisse				7 500 000
AL-3.1.1	8 41 28	125 38 11	Andesite	Liquidoe	Perbatasan	Tamala Liqueno Hau			High
AL-3.1.2	8 39 00	125 35 27	Andesite						
BB-3.9	8 50 27	125 01 55	Andesite			Tuto Baba			High
DL-3.4.1	8 15 40	125 30 40	Andesite	Atauro	Maumeta Vila				31 325 000
DL-3.4.2	8 16 38	125 32 27	Andesite						
CV-3.1	9 23 27	125 05 27	Andesite	Timliomar		Eohotulas			High
LT-3.9	8 21 08	126 58 14	Andesite	Lautem	Irara				High
MT-3.1	8 31 46	125 56 52	Andesite	Laclo	Laclo				n.d.

Table15. Basalt database for East Timor.

Map reference No.	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain Or Hill	River	Geology	Potential (cu m)
AN-3.4.1	8 56 31	125 30 57	Basalt			Maubisse Cocorema			7 500 000
AN-3.4.2	8 50 27	125 33 41	Basalt	Hatubuiliko	Nununmoqie				2 354 030 986
AN-3.4.3	8 48 40	125 36 32	Basalt	Hatubuiliko	Hororailike				64 509 002
AB-3.5	9 18 08	124 10 22	Basalt	Nitibe	Oecusse	Bauknana			21 500 000
BC-3.10.1	8 26 19	126 25 38	Basalt		Baniuga	Tiba Oashuma Samatano Mucobuba			High
BC-3.10.2	8 36 25	126 33 41	Basalt						

Table 16. Dolomite database for East Timor.

Map Reference Number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
AN-3.5.1	n.d.	n.d.	Dolomite	Hatu Udo	Leolima	Huan			3,817 500
BB-3.3.1	9 03 17	125 15 57	Dolomite	Bobonaro	Tapo Carabau				Indication
BB-3.3.2	9 01 31	125 23 11	Dolomite	Bobonaro	Ilal Lun				n.d.
EM-3.2	8 54 33	125 24 25	Dolomite	Letefoho	Atsabe				Indication
CV-3.4	9 03 33	125 09 17	Dolomite	Fohorem	Fatululik				33 000 000
MT-3.9.1	8 32 44	126 07 14	Dolomite	Laclo	Hilimanu				Indication
MT-3.9.2	8 32 44	125 54 57	Dolomite						
VQ-3.6	8 42 33	126 30 49	Dolomite	Ossu					Indication

Table 17. Gabbro-diabase database for East Timor.

Map reference number	Latitude	Longitude	Mineral	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
BC-3.11	8 36 57	126 41 11	Diabase	Bagula	Larisuk		Mauss ocoafu		9 575 000
EM-3.5	8 56 28	125 22 30	Gabbro	Letefoho	Dokurasi				
LQ-3.4.1	8 41 28	125 06 25	Gabbro		Ulmera				
LQ-3.4.2	n.d.	n.d.	Gabbro	Liquisa			Gaulao		
LQ-3.4.3	n.d.	n.d.	Gabbro	Tg. Fatuboro Bo					
MT-3.11.1	8 35 36	125 55 55	Gabbro	Laclo	Umacadua c				
MT-3.11.2	8 29 44	125 54 41	Gabbro	Laclo	Dusun Behau				
MT-3.11.3	8 34 06	125 49 55	Gabbro	Laclo	Hatu Emera Hohorai				
MF-3.4	9 05 03	125 52 47	Gabbro	Alas	Uma Berlele				
VQ-3.5	8 48 49	126 31 46	Gabbro	Untolari					

Table 18. Gypsum database for East Timor.

Map reference number	Latitude	Longitude	Mineral	Subdistrict.	Village	Mountain	River	Geology	Potential
AB-3.6.1	9 20 11	124 04 22	Gypsum		Utara	Gueno			Indication
AB-3.6.2	9 23 19	124 20 00	Gypsum						
MT-3.11.1	8 30 08	125 59 44	Gypsum	Manatuto	Laleia				39,2 93 tons

Table 19. Kaolin database for East Timor.

Database reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
AL-3.2.8	8 45 17	125 33 01	Kaolin	Remixio	Maumeta	Aileu hill			2 500 000
DL-3.12.1	8 16 38	125 34 55	Kaolin	Atauro	Maqueli				Indication
LQ-3.8.1	8 35 11	125 13 30	Kaolin	Bazartete	Ulmera Lebollua				Indication

Table 20. Salt database for East Timor.

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

Table 21. Manganese database for East Timor.

Database reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
DL-2.5.1	8 16 22	125 33 00	Manganese	Atauro	Maqueli				Indication
LT-2.2.1	n.d.	n.d.	Manganese	Moro	Daudere				Indication
LT-2.2.2	8 27 17	126 49 22	Manganese	Buihoman					
LT-2.2.3	8 26 11	126 00 00	Manganese	Banura					
LT-2.2.4	8 34 05.	126 49 30	Manganese	Puno	Laivai				
VQ-2.4.1	8 45 40	126 25 47	Manganese	Uatacarbau					Indication

Table 22. Silica database for East Timor.

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

Table 23. Wollastonite database for East Timor

Map Reference Number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Potential (per cent)
BB-2.1.1	9 00 57	125 23 27	Wollastonite	Bobonaro	Carabau			Indication

Table 24. Talc database for East Timor.

Database reference number	Latitude	Longitude	Resource	Subdistrict.	Village	Mountain	River	Geology	Potential (cu m)
AL-3.9.1	8 43 55	125 35 27	Talc	Aileu	Aisirimou				Indication
MT-3.14.1	8 30 16	125 55 38	Talc	Laclo	Hilimanu				Indication

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