

INTRODUCTION

This series of U.S. Geological Survey Open File Reports, numbered 87-495-A through 87-495-F, constitutes a pilot study in the basic requirements of a basin analysis. The study was designed to provide an example of the preliminary geologic data required as the first step in all hydrocarbon resource assessment programs.

The pilot study was prepared in cooperation with the U.S. Geological Survey World Energy Resources Program, the International Union of Geological Sciences, the Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas, and the Circum-Pacific Map Project of the Circum-Pacific Council.

The data have been compiled on a 1:2,000,000 scale, Lambert azimuthal equal-area map base, prepared by the U.S. Geological Survey, from world base map 11, Scripps Institute of Oceanography, and U.S. Geological Survey sources.

The area chosen for the pilot study is the offshore area of the island of Borneo, situated in Southeast Asia. Borneo is divided politically into three countries: Indonesia, Malaysia, and Brunei. That portion of Indonesia comprises the State of Kalimantan; that portion of Malaysia comprises the States of Sarawak and Sabah; and the Sultanate of Brunei is an entity by itself.

All thickness contours, faults, and sedimentary province boundaries are conjectural, and are subject to change or modification. The discrepancies in terminology, such as shelf or platform, basin depression or trough, and the use of isobaths, result from the compilation of many sources of data. They are reported here as published, except as the original author describes them. These terms are familiar to those concerned with petroleum exploration and other geologic and geophysical features very considerably from publication to publication; however, the phonetic pronunciation is invariably the same. Residents of local towns and villages affect nomenclature. The international petroleum companies engaged in petroleum exploration in Borneo also have employed independent means of translation and spelling.

This text is included in its entirety on all maps for the Reader's convenience and information.

GEOLOGIC SETTING

In Southeast Asia, many of the sedimentary basins of a size and volume conducive to hydrocarbon generation and accumulation are Tertiary in age and occur usually or partially in offshore areas. This study attempts to fit the study area of these portions of the countries of Indonesia, Malaysia, and Brunei which constitute the island of Borneo.

Approximately 15 Tertiary depositional and four platform areas lie peripheral to or within the present-day island of Borneo. The oldest Tertiary basin complex, that of the Sarawak and Kuching basins, is located entirely on the island of Borneo. Many of the basins are divided by major structural ridges and are bounded by their southern margins by the Indian-Australian plate. This margin possibly originated in late Mesozoic time and subsisted at the end of the Miocene. The blocks were probably transported along a complex series of transcurrent and transform faults, associated with the south China sea, to their present position and orientation in this region. The subsidence and spreading of these basins, and the development of major Tertiary sedimentary depositional and stable shelves, resulted from tectonic events in the late Miocene and Pliocene. The development of the basins, the formation of melange and allochthonous wedges, and the erosion and deposition of sediments are essential for the development of most of Borneo.

At present, Tertiary clastic and carbonate rocks are the site of all significant hydrocarbon reserves in the circum-Borneo region. This, however, does not preclude future discoveries in Mesozoic and older rocks. The thickness of potentially petroliferous Tertiary rocks in the circum-Borneo region locally exceeds 30,000 feet (10 kilometers). The thickest sections are usually associated with active tectonic and active basin subsidence; neighboring, basin-related carbonate platforms and pinnacle reef buildings, however, may exceed 2,000 feet (600 meters) in thickness.

That part of the Tertiary section referred to as potentially petroliferous is limited to Tertiary sedimentary rocks, which consist of an upperly indurated and highly indurated sand bodies are commonly unconsolidated or extremely friable. These sand bodies, and their associated shales and limestones, are usually well indurated. The shale sequences, although friable, are only weakly indurated.

In addition to the petroliferous sedimentary rocks, many thousands of feet of strongly deformed and highly indurated Tertiary rocks exist in Borneo. They are predominantly Paleogene in age.

TECTONIC AND DEPOSITIONAL SETTING

For major depositional in the circum-Borneo region, tectonic settings have variously been described as continental margin basins, active continental margin basins, and continental margin basins. For this study a simplified classification of continental margin basins is accepted for all but the open shelf basins along the south and, possibly, the southeast coasts of Borneo.

The structure of these continental margin basins is all fault controlled. The basins are formed by faulting along major zones of extension in the pre-Tertiary basement, parallel to the coastline and generally associated with northeast-trending transcurrent faulting. Rifting and volcanism is an element that cannot be ignored. It was probably the subsiding areas of pre-middle Miocene plate tectonic, continental subsidence, and the formation of the North Borneo trough. The basins were collapsed in response either to regional extension or pull-apart processes and the subsidence of the basins was progressively filled by sediment derived from the high-collinear ranges on the landward side. The rugged high-collinear ranges, which are probably tectonic in origin, are typically overlain by older sequences. Most blocks developed in this block-faulted terrain are locally related to the growth of carbonate platforms and pinnacle reefs.

This area substantiates the theory that continental margin basins exhibit highly variable structural styles, which bear strongly on depositional styles. Some of the thickest clastic wedges were deposited over the edge of the continental crust where major delta systems prograded large volumes of sediment into the deep water of adjacent marginal seas. The continental margin basins are generally strongly asymmetrical, and were commonly defined on the seaward, actively tectonic side.

The depositional centers of these clastic wedges lie near the boundary between continental and oceanic crust, such that flooring and downwelling of the continental crust in the circum-Borneo region, sediment rapidly accumulated in the continental shelf edge, slumping down the shelf slope. Where strike-slip movement faulting occurred, the continental shelf edge was displaced, and the depositional wedge, shale diapirism commonly results, as generally observed for the Sarawak Delta, although structural elements for hydrocarbon entrapment certainly occur, as is also true in the Sabahan Delta of the Sarawak Basin. Reef trends developed on horsts, basement highs, or on sedimentary platforms, where active sediment supply had ceased, such as on the central Lucania province.

Where the supply of sediment was abundant, as in the Sarawak, Kuching, and Sarawak basin deltas for example, the deltas have prograded rapidly since early Miocene time, accompanied by differential downing, slumping, and complex faulting. Although the Sabahan Delta of Sarawak, Indonesia, contains more sediment by volume, it is probable that the Sarawak Delta of Borneo was the more tectonically active.

PALEOGEOGRAPHIC DEVELOPMENT

Paleogene through middle Eocene time was a period of major marine regression in the circum-Borneo region. In response to a period of intense orogenic uplift of a young mountain range along the present position of the Malay-Indo-Australian border. Following this, late Eocene to early Miocene time was a period of major marine transgression. Established at this time was an actively subsiding trough in the position of Sarawak, Brunei, and Sabah that was characterized by marine (Pliocene deposits); the orogenic highlands mountain range along the Malay-Indo-Australian border, and associated sea margin conditions in the position of the present-day Sarawak Basin. Through and end basin fill, sequence stratigraphic characteristics of the Malay-Indo-Australian border, whereas sequence stratigraphic characteristics of the Sarawak Basin and Brunei "subduction" basins in the northwest, whereas sequence stratigraphic characteristics of the Sabahan Delta of Sarawak, Indonesia, and the Sarawak Basin. Reef trends developed on horsts, basement highs, or on sedimentary platforms, where active sediment supply had ceased, such as on the central Lucania province.

In contrast to Paleogene and early Miocene time, the Miocene time between middle Miocene and early Pliocene was a major period of regression, accompanied by cyclical periods of intense tectonic activity. This activity of the Miocene was marked by development of large delta systems, carbonate platforms and pinnacle reefs, shallow marine environments, and basin uplift.

Finally, late Pliocene to the present has been characterized by cyclical periods of regression and transgression. Dominant tectonic activity, resulting in considerable subsidence during Pliocene time led to the formation of thick sedimentary deposits in basin low areas, and to the formation of the Sabahan Delta of Sarawak, Indonesia, and the Sarawak Basin.

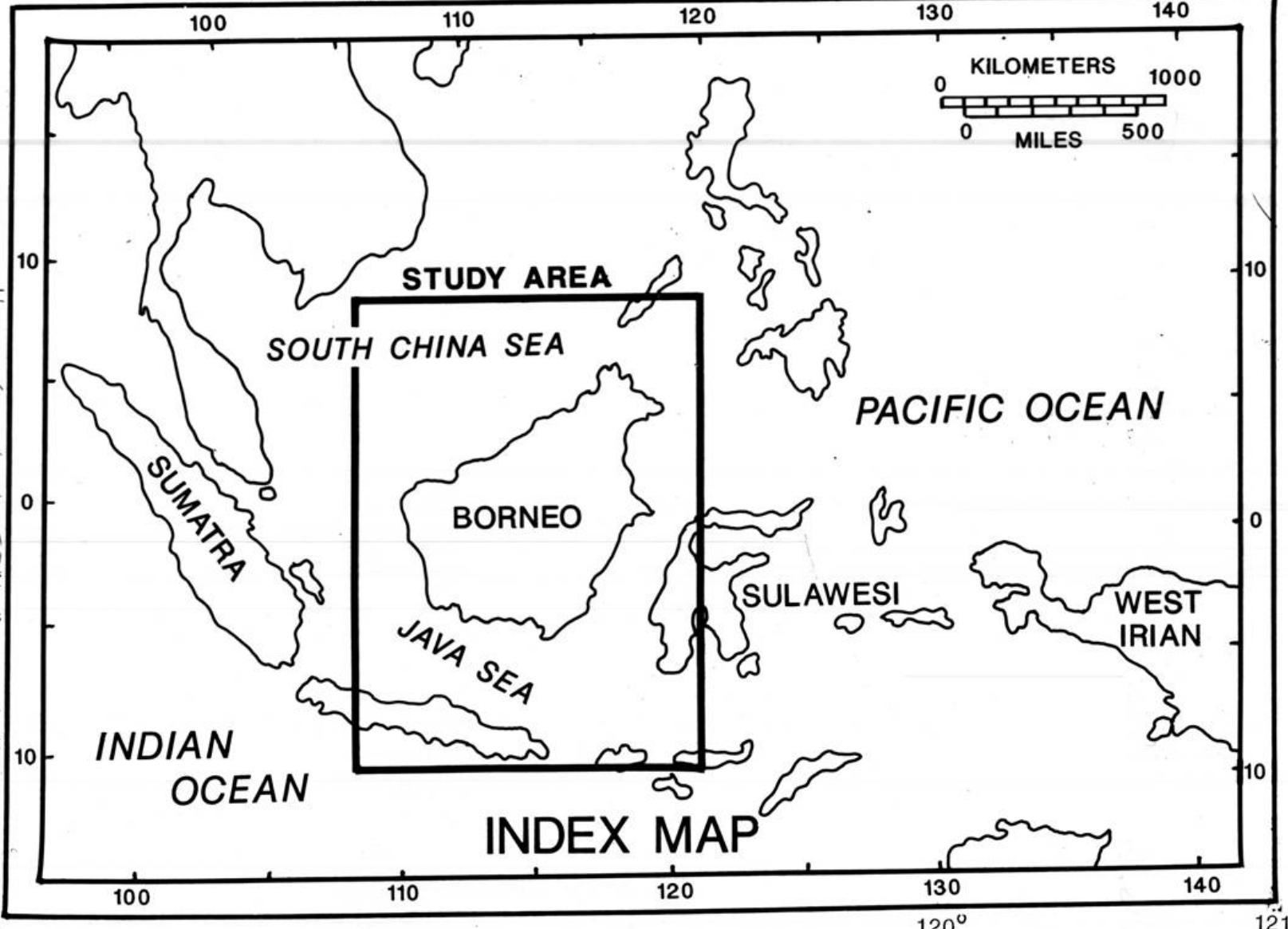
EXPLORATION PLAYS

The complexity of both depositional history and structural development, as illustrated in the circum-Borneo region, points to numerous development prospects in a variety of play types. All play types are characterized by a unique combination of stratigraphic setting and structural geometry. The controlling factors in play development are: first, the environment of deposition and the nature of sedimentary facies deposited in the play area; and second, the structural configuration or physical geometry of the feature receiving the sediment. Structural styles associated with play include fault-bounded horst, graben and half-graben structures; gently folded to highly faulted and asymmetrical anticlines; asymmetrical growth faults and rollover features; structurally controlled deep-marine turbidites, carbonate platforms, pinnacle reefs, complexly faulted, asymmetrical growth faults and structures. Another controlling factor and important variable in basin analysis of prospective play types is the age of hydrocarbon traps. For one basin may contain multiple play types in the same basin.

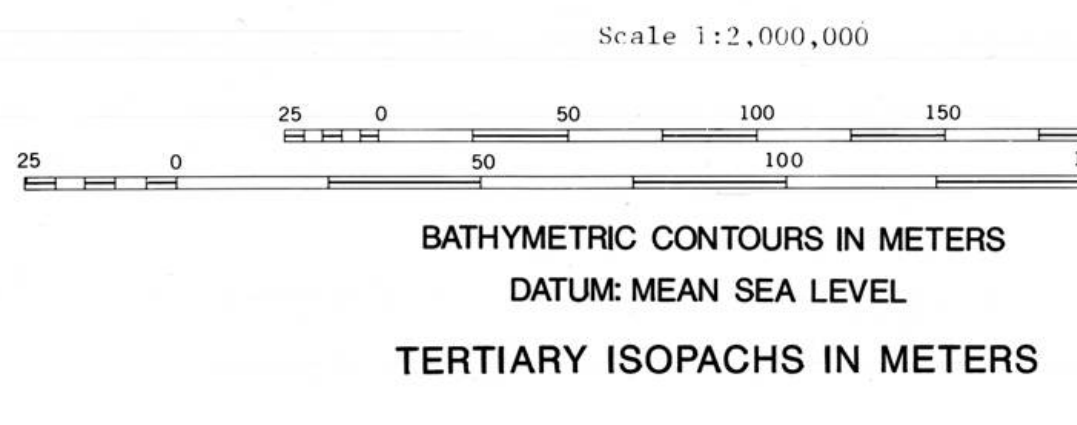
Rapid burial of organic material, as in the Sarawak Delta, has a direct bearing on the ultimate yield of hydrocarbons, by limiting the degree of oxidation of the organic matter. Tectonically derived organic matter is considered to be the primary source for hydrocarbons in the circum-Borneo region.

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORTS

- 87-495-A Thickness map of the petroliferous Tertiary sequence of the circum-Borneo region, Southeast Asia.
- 87-495-B Paleogeographic thickness map of the Paleogene sequence of the circum-Borneo region, Southeast Asia.
- 87-495-C Paleogeographic paleogeographic map of the Paleogene sequence of the circum-Borneo region, Southeast Asia.
- 87-495-D Paleogeographic thickness map of the Miocene sequence of the circum-Borneo region, Southeast Asia.
- 87-495-E Paleogeographic thickness map of the Pliocene sequence of the circum-Borneo region, Southeast Asia.
- 87-495-F Location map of major Tertiary sedimentary provinces and structural elements of the circum-Borneo region, Southeast Asia.



Base: Prepared by the U.S. Geological Survey
Data Sources: The World Data Bank II, Scripps Institute
Lambert Azimuthal Equal-Area
Center point: 120° E, 13° S
Gridlines: 1 degree interval



BATHYMETRIC CONTOURS IN METERS
DATUM: MEAN SEA LEVEL
TERTIARY ISOPACHS IN METERS

THICKNESS MAP OF THE PETROLIFEROUS TERTIARY SEQUENCE OF THE CIRCUM-BORNEO REGION, SOUTHEAST ASIA

By
**Keith Robinson and
E.P. DuBois***
1987

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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