DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with

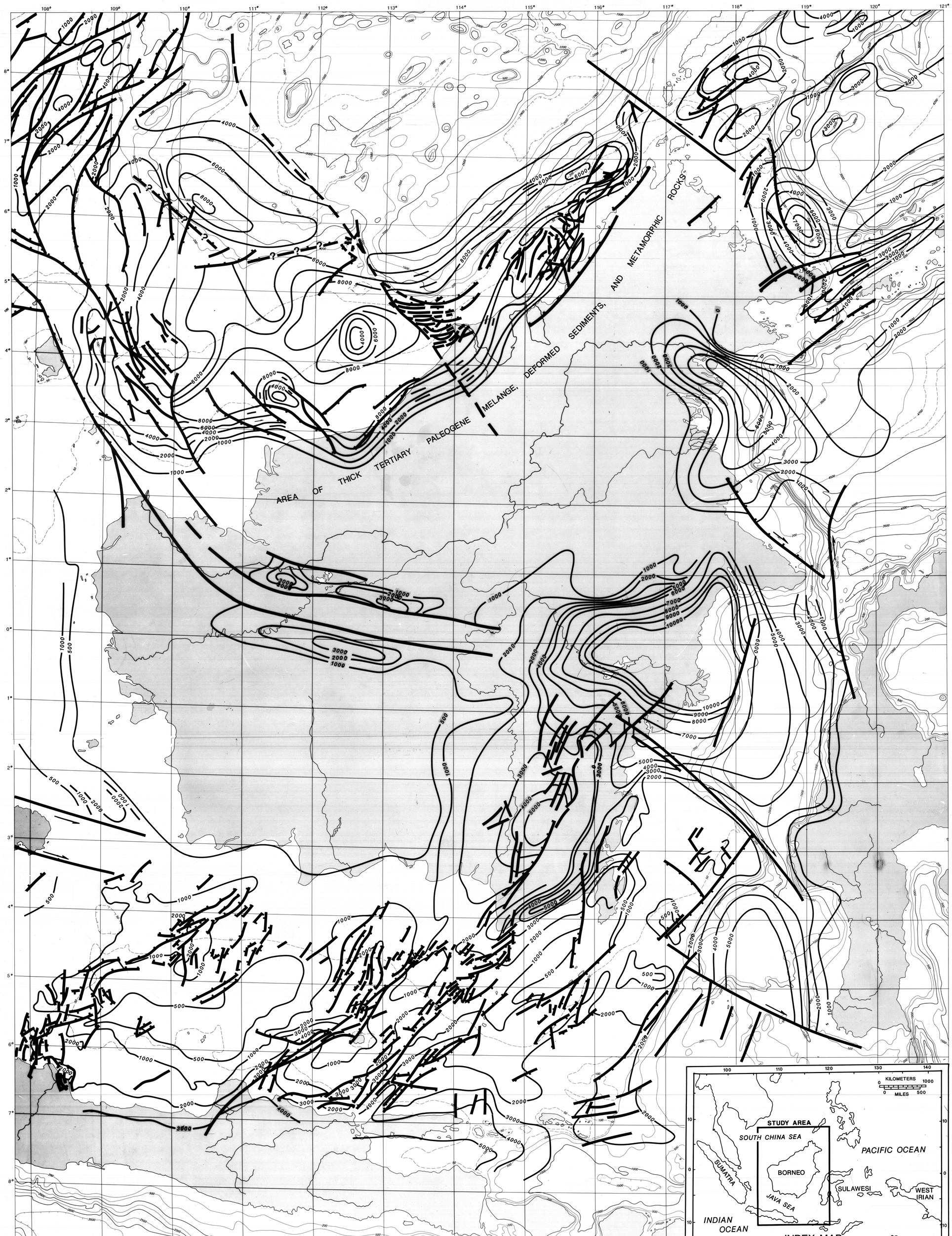
THE U.S.GEOLOGICAL SURVEY WORLD ENERGY RESOURCES PROGRAM

THE INTERNATIONAL UNION OF GEOLOGICAL SCIENCES

THE COMMITTEE FOR CO-ORDINATION OF JOINT PROSPECTING FOR MINERAL RESOURCES IN ASIAN OFFSHORE AREAS (CCOP)

AND THE CIRCUM-PACIFIC MAP PROJECT OF THE CIRCUM-PACIFIC COUNCIL

OPEN-FILE REPORT 87-495-A



Base: Prepared by the U.S. Geological Survey
Data Sources: The World Data Bank II, Scripps Institute and the U.S. Geological Survey
Lambert Azimuthal Equal-Area
Center point: 120 E, 15 N
Graticule: 1 degree interval

Scale 1:2,000,000

25 0 50 100 150 200 KILOMETERS
25 0 50 100 150 200 MILES

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
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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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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 rudimentary 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 Data Bank II, 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 subbasin, result from the compilation of many sources of data. They are reproduced from published reports exactly as the original author described them. These terms are familiar to those conversant with petroleum exploration in this region. The nomenclature and spelling of place names, structures, and other geographic and geologic features vary considerably from publication to publication; however, the phonetic pronunciation is invariably the same. Discrepancies in the terminology and description of geographic names between residents of local towns and villages affect nomenclature. The multinational 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 located totally or partially in offshore areas. This description fits the study area of those portions of the countries of Indonesia, Malaysia, and Brunei which constitute the island of Borneo.

Approximately 15 Tertiary depocenters and four platform areas lie peripheral to or straddle the coastal margins of Borneo. Only one major Tertiary basin complex, that of the Melawi and Ketungau Basins, is located entirely within the interior of Borneo. The Ketungau Basin is frequently referred to as the Mandai Basin. Many of the basins are divided by major basement ridges and can be subdivided into geologic provinces or subbasins separated by lesser structural features. Despite certain similarities, each sedimentary region or subbasin is geologically unique.

The geological development of Borneo itself has been the subject of several theories; in general it appears to have formed as a result of the southward migration, rotation, collision, and accretion of series of micro-continental blocks, rifted from the southern margin of the Asian continent, possibly Indo-China, and impeded in their southerly migration by the Indian-Australasian plate. This migration possibly originated in late Mesozoic time and culminated at the end of the Miocene. The blocks were probably transported along a complex series of transcurrent or transform faults, associated with or directly related to periods of subduction and sea-floor spreading, in both the South China Sea and Makassar Straits. The development of major Tertiary sedimentary depocenters and stable shelf areas resulted from interaction between the plates. Collision and the subduction of microcontinents, the formation of melange and allochthonous wedges, and the erosion and redeposition of sediments are envisioned for the development of most of Borneo.

At present, Tertiary clastic and carbonate rocks are the site of all significant hydrocarbon discoveries in the circum-Borneo region. This, however, does not preclude future discoveries in Mesozoic and older rocks. The thickness of potentially petroliferous Tertiary sedimentary rocks in the circum-Borneo region locally exceeds 30,000 feet (10 kilometers). The thickest sections are usually associated with areas of deltaic sedimentation and active basin subsidence; neighboring, horst-related carbonate platform and pinnacle reef buildups, however, may also exceed 5,000 feet (1500 meters) in thickness.

That part of the Tertiary section referred to as potentially petroliferous is limited to Tertiary sedimentary rocks, which are at most only slightly indurated and moderately deformed. The sand bodies are commonly unconsolidated or extremely friable, whereas the limestone, marl, and chert stringers are mostly well indurated. The shale sequences, although fissile, 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 depocenters in the circum-Borneo region, tectonic settings have variously been described as open-shelf cratonic, foreland, rifted pull-apart, spreading center, 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 weakness in the pre-Tertiary basement, parallel to the coastline and generally associated with northwest-trending transcurrent faulting. Mid-Miocene volcanism is an element that cannot be ignored. It was probably the culminating event of pre-middle Miocene plate tectonism, collision, subduction, and the formation of the Northwest Borneo trench. The continental margin collapsed in response either to regional subduction or pull-apart stresses and to sedimentary loading. As a result of the collapse, a series of normal faults dropped the basement successively seaward. The basins and grabens that formed on the continental edge are progressively filled by sediment derived from the high cordilleran ranges on the landward side. The prograded thick fluvial, coastal plain, deltaic, and prodelta clastic sediments typically overstep older sequences. Horst blocks developed in this block-faulted terrain are ideally suited to the growth of carbonate platform 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 poured large volumes of sediment into the deep water of adjacent marginal seas. The continental margin basins are generally strongly asymmetrical, and were commonly deformed on the seaward, actively tectonic side.

The depositional centers of these clastic wedges lie near the boundary between continental and oceanic crust, such that flexuring and downfaulting of the continental crust occur on the continent side of the depocenter. As stated in the literature, where rapid deposition into bathyal environments occurs, such as in the circum-Borneo region, sediments prograde over the continental shelf edge, slumping down the shelf slope. Where strike-slip transcurrent faulting occurs, involving basement beneath the thicker parts of the depositional wedge, shale diapirism commonly results, as generally accepted for the Baram Delta. Although diapirism cannot be confirmed in areas such as the Tarakan Delta, the requisite structural elements for hydrocarbon entrapment certainly occur, as is also true in the Mahakam Delta of the Kutei Basin. Reef trends developed on horsts, basement highs, or on sedimentary platforms where active sediment supply had ceased, such as in the Central Luconia province.

Where the supply of sediment was abundant, as in the Baram, Kutei, and Tarakan Basin deltas for example, the deltas have prograded rapidly since early Miocene time, accompanied by differential downwarp, slumping, and complex faulting. Although the Mahakam Delta of the Kutei Basin, Indonesia, contains more sediment by volume, it is probable that the Baram Delta of Brunei was the more tectonically active.

PALEOGEOGRAPHIC DEVELOPMENT

Paleocene through middle Eocene time was a period of major marine regression in the circum-Borneo region, in response to a period of intense cordilleran uplift of a young mountain range along the present position of the Malaysian-Brunei-Indonesian 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 open marine flysch deposits; the emergent cordilleran mountain range along the Malaysian-Indonesian border; and quiescent open marine conditions in the position of the present-day Kutei and Tarakan Basins. Flysch and rapid basin-fill deposits characterized the Malaysian and Brunei "subduction" basins to the northwest, whereas open-marine neritic conditions occupied the Indonesian basins southeast of the cordilleran range. Also, in late Eocene to early Miocene, a subduction zone on the northwest coast of Borneo became active; and marine trenches and basins developed offshore northwest and east of Borneo. The basins were rapidly filled as marginal troughs in the northwest, although carbonate platforms with reef growths started to develop locally in response to fault-related horst-and-graben structures. In eastern Kalimantan open-marine conditions existed.

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

Finally, late Pliocene to the present has been characterized by cyclical periods of regression and transgression. Renewed tectonic activity, resulting in considerable subsidence, during Pleistocene time led to the formation of thick sedimentary deposits in basins like West Luconia (located immediately west of the Balingian province), Tarakan and Kutei.

EXPLORATION PLAYS

The complexity of both depositional history and structural development, as illustrated in the circum-Borneo region, points to numerous exploration prospects in a variety of play options. 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 plays include fault-bounded horst, graben and half-graben structures; gently folded to highly faulted and asymmetrical anticlines, synsedimentary growth fault and rollover features, structurally controlled deep-marine turbidites, carbonate platforms, pinnacle reef complexes, and fractured basement reservoir structures. Another controlling factor and important variable in basin analysis of prospective play types is the age of hydrocarbon traps. Any one basin may contain multiple play types of various ages.

Rapid burial of organic material, as in the Baram Delta, has a direct bearing on the volumetric yield of hydrocarbons, by limiting the degree of oxidation of the organic matter. Terrestrially 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 Palinspastic thickness map of the Paleogene sequence of the circum-Borneo region, Southeast Asia.
87-495-C Palinspastic paleogeographic map of the Paleogene sequence of the circum-Borneo region, Southeast Asia.
87-495-D Palinspastic thickness map of the Neogene sequence of the circum-Borneo region, Southeast Asia
87-495-E Palinspastic paleogeographic map of the Neogene 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.

SOURCES OF DATA

Acknowledgements are due to the ASEAN Council on Petroleum (ASCOPE); the Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP); the national oil corporations of Indonesia (PERTAMINA), Malaysia (PETRONAS), and the Philippines (PNOC); to many published and unpublished papers by the Indonesian Petroleum Association (IPA), the Southeast Asia Petroleum Exploration Society (SEAPEX), the Geological Society of Malaysia, the University of Malaya Geological Department and other organizations; and to the Geological Surveys of Indonesia and Malaysia, for their assistance and support in providing the necessary data as the basis for these interpretative maps, and to the many oil companies and consultants active in exploration within the area, who are primarily responsible for compilation of the original data.