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QUATERNARY STRATIGRAPHY OF ASIA AND THE PACIFIC IGCP 296 (1989)

China, Malaysia, Indonesia, Sri Lanka, Thailand, Republic of Korea, Viet Nam, Australia and New Zealand

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FOREWORD

The Economic and Social Commission for Asia and the Pacific (ESCAP), the International Geological Correlation Programme (IGCP), the International Union of Geological Sciences (IUGS) and the Association of Geoscientists for International Development (AGID) jointly sponsor the International Geological Correlation Project 296, Quaternary of the Asia/Pacific, a regional project concerned with the development of Quaternary correlation scheme for the Asia/Pacific area. IGCP Project 296 was first approved by the IGCP Board at its session held in Paris in 1989. The first meeting of IGCP Project 296 was held in Ipoh, Malaysia in September, 1989, and was hosted by the Geological Survey of Malaysia (Ipoh Laboratories). The participants represented 12 countries including Australia, China, France, Indonesia, Malaysia, Netherlands, New Zealand, Philippines, Republic of Korea, Sri Lanka, Thailand, United States and Viet Nam. Representatives of ESCAP and UNESCO also attended.

The papers presented at that meeting are presented herein as Atlas of Stratigraphy X IGCP 296 (1989). All of the papers presented during the life of the project are scheduled to be published by ESCAP in this Atlas series. The IGCP Project 296 also publishes a Newsletter, issued biannually, which is available from ESCAP's Natural Resources Division. A roster of Quaternary geologists from the region is being compiled.

The papers in this volume represent the progress which has been made in correlating the Quaternary in a number of countries of South, East and Southeast Asia. At present, the activity is identifying the most reasonable basis for establishing a correlation scheme and a number of promising lines of research have been identified. The Quaternary deltas and lake deposits of the region offer a fertile basis for establishing a time-stratigraphic basis for regional correlation. Correlation of loess sequences which include tektites in a number of countries was considered to be a fruitful approach to the correlation of the last 700,000 to 800,000 years of Quaternary time. The Ipoh meeting also concluded that marine transgression sequences (which include buried peats) were remarkably similar in many of the coastal areas of East and Southeast Asia and this too showed promise for future correlation.

Continental deposits with well preserved mamallian remains have been known for many years from China and Indonesia and it may be possible to correlate these non-marine sequences with those of the deltaic and offshore sequences. A detailed classification and correlation of climatic phases is especially well advanced in China, Australia and New Zealand. Finally, it was noted that regional cooperation was extremely important in establishing a firm and lasting basis for Quaternary correlation in Asia and the Pacific.

ESCAP would like to express its appreciation to the participating countries and to the donor agencies for their support of IGCP 296.

ESCAP Secretariat

CONTENTS

THE AUSTRALIAN APPROACH TO THE QUATERNARY AND ITS CORRELATION

by

Paul Bishop[1]

1. Introduction

After Antarctica, Australia is the driest continent on Earth; tectonically, it is also one of the most stable, and the interplay of these factors has important consequences for its Quaternary history and the preserved record of this history. Of similar significance are the continent's generally low absolute elevation and relief, its large continental area and its latitudinal extent from roughly 10°S to roughly 45°S. The latter characteristic means that it lies largely within the broad subtropical high pressure belt, the location of which has presumably fluctuated throughout the Quaternary in response to glacial-interglacial cycles.

The size, nature and location of Australia have interacted to give a range of problems and issues that must be addressed by Quaternary geoscientists working in this country. The most important outcome of this interaction is that a strict stratotype approach to the Australian Quaternary has yet to emerge for even the Holocene, let alone the Quaternary, a fact well-recognised and acknowledged by Australian Quaternarists (Thom & Bowler 1982). This brief discussion paper addresses further some of the characteristics of the terrestrial Quaternary in Australia which are of relevance to geoscientists engaged in formulating an approach to the Quaternary of Asia and the Pacific. It then presents the approaches that have been followed to-date, largely based on the CLIMANZ I, II and III meetings. Finally, it concludes with a brief summary of the current conclusions about Quaternary palaeoenvironments of Australia. The survey is concerned with terrestrial environments only. There is also a voluminous literature relating to coastal evolution in Australia, especially with respect to sea level history and Late Quaternary shoreline developments, which is beyond the scope of this review.

2. Impact of environmental characteristics

The dryness of the continent and its generally low relief and tectonic stability mean that, prior to European settlement and severe disturbance of the environment, rates of sediment production and supply to depositional sites were generally very low. Indeed, this condition pertained throughout virtually all of the Cenozoic, although for the Tertiary the important climatic influence seems to have been the presence of closed temperate rainforest or closed sclerophyll forest over much of the more humid parts of the continent until quite late in this period, and the absence of widespread Quaternary glaciation (Young 1983; Bishop 1985). With the breakup of these forests during the late Tertiary and Quaternary, in response to increasing aridity accompanying the growth of Antarctic ice and cooling sea surface temperatures, the potential for greater rates of sediment production and delivery was much higher. However, the very aridity causing the forests to diminish also resulted in a much lower potential for erosion.

Thus, there are no extremely thick Cainozoic sequences in Australia, and most are very thin. The Murray Basin, for example, is one of the principal Cainozoic basins in interior southeastern Australia and is important for its several fresh-water aquifers. It spans the whole of the Tertiary, has probably experienced minimal loss of sediment by bypassing to the Southern Ocean (Bishop 1985), and contains a maximum of about 0.5 km of sediment. The comparison with up to about 2 km of mid to late Cainozoic sediment in the Chao Phya Basin, Thailand, is instructive (Nutalaya & Rau 1981), and the 4 km of Plio-Pleistocene sedimentation in the tectonically active Taranaki Basin, New Zealand, is even more striking.

The low rates of sediment production in Australia mean, however, that relatively thin sequences, less than one hundred metres thick, have the potential to contain relatively long records. Thus, several lakes in tectonic and/or volcanic settings contain relatively long late Cenozoic records (Singh & Geissler 1985; Kershaw 1986; Kershaw *et al.* in press). Because of the fluctuating climate during the Quaternary, however, and the general lack of subsidence in these depositional settings, there is always the potential for loss of information by subaerial erosion and/or weathering at times of low lake levels. On the other hand, this very weathering or erosion may itself be a significant palaeo-environmental indicator.

3. Approaches to Quaternary reconstruction

Two broad approaches to Quaternary palaeoenvironmental reconstruction in Australia may be

[1] Department of Geography & Environmental Science, Monash University, Clayton Vic 3168 Australia.

recognised; that are the biostratigraphic and morphostratigraphic approaches. Substantial, though lesser, use of lithostratigraphic techniques is also made. The best work quite obviously combines as many of these techniques as possible, and increasingly the work of unravelling the Quaternary of Australia is being undertaken by teams of researchers with broad ranges of expertises.

Most University researchers in the Quaternary of Australia have their institutional homes in Geography or general Earth Science departments, generally within Science faculties. The traditional geology departments' lack of interest in the Australian Quaternary probably stems from the great area of the continent and the immense task of relatively few scientists having to map its pre-Quaternary materials. Currently, however, there is new interest in the Quaternary on the part of some traditional geologists, but this may be partly in response to the upsurge in interest in environmental matters and the generally stable or declining numbers of students in geology departments. Non-University Quaternarists are located in a range of governmental research agencies, such as Water Resources Commissions, the CSIRO, and some Federal and State geological instrumentalities. An important, though relatively small, component of the Quaternary geoscience community is constituted by archaeological and palaeo-anthropological researchers. The considerable antiquity of occupance of Australia by *Homo sapiens* (Barbetti & Allen 1972; Nanson *et al.* 1987), and particularly the presence of these people at about latitude 43°S during the height of the last glaciation, is of considerable interest to Quaternarists.

Dating is most commonly by conventional radiocarbon assay, with up to four laboratories supplying this service on a research or commercial basis. There are also at least two thermo-luminescence dating labs and significant advances in the thermo-luminescence dating of fluvial and aeolian sediments are being made. Palaeomagnetism and electron spin resonance dating are also being used.

Biostratigraphic approach

The use of fossil pollen and, to a significantly lesser extent, fossil diatoms and fossil ostracods (see below, Isotope studies), have been very important tools in reconstructing Quaternary environments. There is now fair coverage of sites in the more humid parts of the continent, but the arid interior, which occupies the greater areal proportion of the continent, is still sparsely covered by such work. As already noted, the sites with the longest records are those in either tectonically-formed lake basins (e.g. Lake George in the southeast – Singh *et al.* 1981; Singh & Geissler 1985), or in various types of crater lakes in the relatively young volcanic terrains in the northeast and southeast (Kershaw 1986; Kershaw *et al.* in press).

These sites have been subjected to intensive palaeoenvironmental analysis. In this regard, the records contained in the late Quaternary lakes are of considerable interest because virtually all of these lakes have restricted catchment areas, which greatly simplifies the consideration of the hydrological balance and palaeolake levels. In the case of the maar lakes, the crater rim coincides with the lake catchment boundary and the lake effectively acts as a combined rain gauge-evaporation basin. Moreover, some of these lakes exhibit datable, high-level shoreline features (see below, Morphostratigraphic approach), and these may be correlated with the lake level history deduced from the lake sediments themselves.

Palaeoclimatic reconstructions

The major approach to palaeoclimatic reconstruction has been via palaeo-vegetation reconstruction based on fossil pollen and the subsequent inference of the climate required to support this vegetation. There has usually been careful consideration of the degree to which a fossil pollen assemblage is representative of a fossil vegetation community, such inferences being based on analysis of the modern pollen rain.

Recently, a large data bank of the environmental requirements of many rainforest species throughout eastern Australia (Webb *et al.* 1984) has enabled the estimation of numerical palaeo-climatic parameters for rainforest phases during the Quaternary of eastern Australia (Kershaw & Nix 1988). The precipitation curve obtained by such analysis of fossil pollen data from north Queensland for the last 190 ka is very similar to the oxygen isotope curve from deep-sea core V28-238, pointing to global sealevel/seasurface temperature as the major mechanism in controlling these climatic changes (Kershaw 1986). Palaeo-temperatures may be estimated by the same means.

Isotope studies

Another important advance is the use of stable isotope fractionation in fossil ostracod shells in lake cores as a palaeo-climatic indicator (DeDeckker 1982a, b). In essence, the technique involves the measurement of the fractionation of the stable isotopes of magnesium and strontium in the shells of ostracods grown under controlled laboratory conditions in waters of known salinities and temperatures. These data are then used to deduce the salinities of the waters in which the fossil ostracod grew.

This technique is particularly powerful as it provides an indicator of lake salinity that is completely independent of other indicators, such as sedimentology, palynology and geomorphology. Given the usefulness of the closed lake systems in palaeo-climatic analysis, this technique has much to offer in supplementing the traditional palaeo-climatic techniques.

The analysis of lake cores offers the potential for very precise dating of the palaeo-environmental changes deduced from the lake sediments, depending on the presence of charcoal or other datable material. In some ways, this precision may give a false sense of accuracy for any palaeo-environmental chronology, depending on the degree to which the *local* depositional site integrates *regional* environmental change. Indeed, the various palaeo-environmental approaches based on analysis of palaeo-lake sediments are reliant on an interpretation of the degree to which the lake records are representative of the surrounding (regional) environments, as opposed to their being strictly a function of local effects. On the other hand, the morphostratigraphic approach to the Quaternary in part uses geomorphic features which are functions of regional environments, and this has figured strongly in Australian Quaternary research.

Morphostratigraphic approach

The morphostratigraphic approach uses the morphology and stratigraphy of depositional landforms to reconstruct the environments in which the landforms were formed. An obvious example is longitudinal desert dunes which are currently vegetated and stable, but which were active during the late Quaternary (Wasson 1986). In particular localities, these dunes pass below present sea-level, indicating that the dunes were active during glacial low sealevels (Jennings 1975). Other extremely important dune forms are the clay dunes or 'lunettes'; these form on the lee side of saline lakes in the continental interior and are indicative of both seasonally fluctuating water in the lake and summer windiness (Bowler 1973).

Substantial effort has also been devoted to reconstructions of regional palaeohydrological conditions on the basis of preserved remnants of fluvial palaeo-channels on the interior depositional plains. The generally slow rates of landscape evolution in Australia mean that many such palaeo-geomorphological remnants dating back beyond the range of radiocarbon dating are preserved. (The contrast with the relative youth of comparable features in the northern part of the Central Plain of Thailand, for example, is striking – Bishop 1989a).

The Quaternary palaeo-channels in the southeast of the continent have received significant attention. Schumm (1968) integrated earlier work in identifying palaeo-channels with markedly different hydrological characteristics from the present systems. The main differences were either variations in sediment loads, discharges (seasonal or annual) or channel geometries. Schumm (1968) related these, in turn, to the catchment and climatic conditions at the times the palaeo-streams were active. He also made some attempt to 'retrodict' discharges in the palaeo-channels on the basis of their channel geometries and sediment loads, using the known relationships between various channel geometry parameters and sediment load characteristics in modern streams (cf. Ethridge & Schumm 1978; Williams 1984).

Bowler (1978) continued this approach in another locality on the interior plains, strongly making the point that the value of this morphostratigraphic work lies in its relating the various phases of fluvial activity to the catchment conditions pertaining at the time. This is, the palaeo-channels integrate overall catchment conditions and therefore have the potential to give a more regional view of palaeo-environmental conditions.

On the other hand, precise dating of changes from one broad channel geometry or fluvial style to another is extremely difficult because such dating relies on identifying and dating the earliest deposits from the onset of the second phase. This means that the various fluvial phases tend to be dated to quite broad time periods, and close comparison needs to be made with local, more detailed and closely-dated studies. In other words, the biostratigraphic and morphostratigraphic approaches complement and calibrate each other, and when this complementarity operates considerable advances have been made.

Several lakes in the southeast, including Lake George (Coventry 1976; Singh *et al*. 1981; DeDeckker 1982a) and the volcanic lakes (Dodson 1974, 1979; Bowler [various "Hydrologic Evidence" entries in CLIMANZ 1983]; DeDeckker 1982b) also provide very good examples of this integration of biostratigraphic and morphostratigraphic approaches.

Having summarised briefly the range of approaches to the Australian Quaternary, I will now examine the way in which the conclusions of the many research programmes in Australia are integrated, namely via the CLIMANZ programme.

4. CLIMANZ

CLIMANZ (the CLImate of Australia and New Zealand) is one of at least four loose and relatively informal organisations that exist in Australasia to coordinate and act as a clearing house for Quaternary research. Other groups include the Australasian Quaternary Association (AQUA) which publishes a twice-yearly newsletter, *Quaternary Australasia*, and meets every two years; and the Australian and New Zealand Geomorphology Group (ANZGG) which covers many aspects of the Quaternary at its biennial meeting. Several palynological associations also exist. Finally, there are also several research units engaged specifically in Quaternary investigations within the University system.

The first CLIMANZ was held in Victoria, Australia, in 1981, and CLIMANZ II and CLIMANZ III were held in the South Island of New Zealand in 1985, and in Melbourne in 1987, respectively.

CLIMANZ I

The Preface of the CLIMANZ I volume describes CLIMANZ as the younger brother of CLIMAP, and the objective of the first meeting was to review and synthesise the results of Late Quaternary palaeoclimatic studies in Australasia. The most practical temporal range for the project was seen to be the last 40,000 years, this range being set by the effective limit of accurate radiocarbon dating. It was realised that attempting to cover 40,000 years of such a broad and varied region was virtually impossible and it was decided to identify specific time periods. In doing so, the organisers hoped that "the in-phase and out-of-phase relationships of the various regions within the defined sector would be identified" (CLIMANZ 1983, p. ix).

The organisers identified "periods of climatic or hydrologic extremes" and specified these as 'spikes', with the intervening time periods identified as 'series'. The various spikes and series so identified were:

Spike	Series	Reason for choice
32 +/- 5 ka		Limit of radiocarbon
	25-20 ka	
18 +/- 2 ka		Glacial maximum
	15-10 ka	
7 +/- 2 ka		Holocene climatic optimum; sea level approx. at present; Aboriginal burning & development of agriculture in P.N.-G.

In a workshop setting, each participant with relevant data for the time period under consideration presented these data. At the end of the discussion of each time period, the Chairman and several assistants synthesised all of the data and produced maps and data summaries for discussion on the following day. The maps for the various time spikes are reproduced as an Appendix to this paper. Stratigraphic columns were not produced because, firstly, much of the data are biological or geomorphological and, secondly, because the emphasis was on palaeo-climatic reconstructions, rather than lithostratigraphy.

Jane Soons, in her Introduction to CLIMANZ II (CLIMANZ 1985), noted that explicit discrimination was made at CLIMANZ I between 'hard' and 'soft' data. Firm, established techniques, with known experimental limitations and error bands, such as radiocarbon dating or isotopic determination of temperature, were regarded as 'hard', whereas 'softer' data were treated as second-order. Examples of the latter might include age determination on the basis of degree of soil development, or palaeo-temperature determinations based on geomorphic or palynological evidence.

CLIMANZ II and III

The time-slice approach was not continued in CLIMANZ II or III, the workshops reverting to more conventional summary papers of relevant Quaternary research. The Contents and Program Pages of CLIMANZ II and III are contained in this paper as an Appendix. This change of approach is understandable in light of the fact that the CLIMANZ I compilation had been produced and that conventional papers could be presented within that framework, at least implicitly, if not explicitly. An important aspect of the CLIMANZ III meeting was the strong presence of climatic modellers (see CLIMANZ III Program, Appendix) and their attempts to model palaeoclimates. While these attempts are still very preliminary, valuable advances have been made and will continue. Perhaps one of the greatest potentials for climatic modelling, from the Quaternary geoscientific viewpoint, is the possibility of modelling past climates as a guide to possible future climatic change under scenarios such as the Greenhouse Effect.

5. Summary of the Quaternary of Australia

This section presents a summary in point form of the essential conclusions of CLIMANZ I concerning the Australian Quaternary, using the time slices identified above. The corresponding maps are included as an Appendix in this paper.

32 +/- 5 ka 'Spike' - SL (sealevel) c. -45 m.

[Fairly poor age control for this spike; close to limit of radiocarbon]

Northern Australia and Papua-New Guinea:

Highlands vegetation zones in PNG c. 500-600 m lower than present; temps 2°-4°C lower than present.

N. Aust. rainfall c. 1,300 mm (0.5 present) but may be solely due to lower SL and presence of sites on steep climatic gradients.

Southeast Australia

Widely-spaced sites indicate cooler than present; effective precipitation higher than present.

Inland lakes at their fullest and rivers flowing with higher discharges than present.

Tasmania: cooling and drying through the 32 ka interval.

25 - 20 ka 'Series' - SL c. -80 m.

[Better age control for this series]

Northern Australia and Papua-New Guinea:

Highlands temps 4° - 7°C lower than present; mild warming (tree-line rise of 200 m) towards end of period.

N. Aust. effective precipitation 30 per cent - 40 per cent present.

Southeast Australia

Essentially a transitional phase.

Conditions becoming cooler and drier, although conditions not uniform throughout region.

Inland lakes exhibit widespread falling but some remain full (local catchment conditions).

Pollen indicates continuation of conditions drier than present.

Tasmania cooler, drier than present; grassland replacing forest.

Much evidence of increased windiness throughout the inland and SE of the continent.

18 +/-2 ka 'Spike' - SL c. -150 m.

[Glacial maximum; age control for this spike not equally good for all data]

Northern Australia and Papua-New Guinea:

Glaciation of highlands; temps 7°C lower than present.

N. Aust. continuation of effective precipitation 40 per cent present; longitudinal dune formation in north cental part of continent.

Southeast Australia

Widespread evidence of aridity – harshest climate of last 32 ka. Widespread drying of lakes, mobilization of dunes. Treeline lowered by between 1,000 m and 1,500 m; 6°-10°C cooler than present. Small cirque glaciers in highest parts of continent (Snowy Mts, c. 2,000 m ASL, in the southeast) and Tasmania.

Precise levels of precipitation unclear; increased dune building may have been controlled more by increased windiness than decreased precipitation.

Strong evidence of high discharges in inland rivers; perhaps a sign of increased runoff (depleted vegetation cover, lowered evaporation?).

15 - 10 ka 'Series' - SL c. -135 m (15 ka) to -35 m (10 ka).

[Good age control for this series, but time of deglaciation still subject to debate; time of rapid change]

Northern Australia and Papua-New Guinea:

P-NG highlands glacier retreat started c. 14.5 ka; temps rose 6° - 8°C throughout time period.

Substantial increase of precipitation in western P-NG (flooding of neighbouring seas?).

Southeast Australia

Time of climatic amelioration; onset of sedimentation in high altitude bogs about 15 ka.

Inland rivers changed from being large, high discharge, bedload streams, to smaller, suspended load streams which are essentially the same as the present channels.

Cessation of dune building activity.

7 +/- 2 ka 'Spike' - SL c. -20 m (9 ka) to + 1-2 m (5 ka).

[Early Holocene "climatic optimum" - generally warmer and wetter than present]

Northern Australia and Papua-New Guinea:

Temps and treeline a little higher than present; introduction and expansion of agriculture in P-NG.

Invasion of rainforests in N. Aust. 8.5 - 7.5 ka; consistent evidence for higher precipitation than present.

Southeast Australia

Widespread evidence of conditions wetter than present (+20 per cent?) - high lake levels and wetter vegetation at many sites throughout SE and southern Australia.

6. The environmental "movement"

A final comment should be made about the increasing role of Quaternarists in Australian environmental issues. A growing desire on the part of government authorities for a better understanding of environmental change has meant a greater role for the Quaternary. Quaternarists have been involved, for example, in the following issues:

Heritage and conservation values of north Queensland rainforests;
Logging of native forests in the southeast;
Conservation of important, very early archaeological sites in the inland;
Land degradation, particularly salinisation, in many areas of Australia;
Assessment of rates of landscape change under pre-Aboriginal, Aboriginal and European occupance;
"Natural" and prescribed burning of many parts of the continent.

Unfortunately, some of the scientific community does not acknowledge this role, but happily for the Quaternary there appears to be growing support for the role of historical studies in understanding present environments and future changes to these environments. The "mainstream" geological community also seems to be increasing its support for the Quaternary. In 1985, at the 26th Congress of the International Geographical Union, I convened the Symposium, "Lessons for Human Survival: Nature's Record from the Quaternary." The Proceedings from this Symposium will soon be published as the Geological Society of Australia's first volume in their new Symposium Proceedings series (Bishop 1989b). Several papers in the volume address important environmental issues, an area in which the geological community in Australia has not always been involved. Perhaps this signals a refreshing recognition that Quaternary research ideally integrates the study of past environments, via a consideration of the stratigraphy, geomorphology, palaeontology, and chronology of this most diverse time interval.

References

Barbetti, M. & Allen, H. 1972. Prehistoric man at Lake Mungo, Australia, by 32,000 years BP. *Nature* 240, 46-48.

Bishop, P. 1985. Southeast Australian late Mesozoic and Cenozoic denudation rates: A test for late Tertiary increases in continental denudation. *Geology* 13, 479-482.

Bishop, P. 1989a. Late Holocene alluvial stratigraphy and history in the Si Satchanalai area, north central Thailand. *In* Thiramongkol, N. (ed.), *Proceedings of the Workshop on Correlations of Quaternary Successions in South, East, and Southeast Asia.* Chulalongkorn University, Bangkok, 21-24 November 1988.

Bishop, P. (ed.) 1989b. *Lessons from the Past: Nature's Record from the Quaternary. Geological Society of Australia Symposium Proceedings* 1.

Bowler, J.M. 1973. Clay dunes: their occurrence, formation and environmental significance. *Earth-Science Reviews* 9, 315-338.

Bowler, J.M. 1978. Quaternary climate and tectonics in the evolution of the Riverine Plain, southeastern Australia. *In* Davies, J.L. & Williams, M.A.J. (eds.), *Landform Evolution in Australasia*. Australian National University Press, Canberra Australia and Norwalk Connecticut, 70-112.

CLIMANZ. 1983. Proceedings of the First CLIMANZ Conference, Howmans Gap, Victoria, Australia, February 8-13, 1981. Canberra, Department of Biogeography and Geomorphology, Australian National University, 2 volumes.

CLIMANZ. 1985. *CLIMANZ II. The Second Symposium of Results and Discussions concerned with Late Quaternary Climatic History of Australia, New Zealand and Surrounding Seas.* Pillans, B. (ed.), Geology Department, Victoria University of Wellington 31.

CLIMANZ. 1987. *CLIMANZ III. Program and Extended Abstracts for a Meeting at Melbourne University*, 28 and 29 November 1987.

Coventry, R.J. 1976. Abandoned shorelines and the Late Quaternary history of Lake George, New South Wales. *Journal of the Geological Society of Australia* 23, 249-273.

DeDeckker, P. 1982a. Late Quaternary ostracods from Lake George, New South Wales. *Alcheringa* 6, 305-318.

DeDeckker, P. 1982b. Holocene ostracods, other invertebrates and fish remains from cores of four maar lakes in southeastern Australia. *Proceedings of the Royal Society of Victoria* 94, 183-220.

Dodson, J.R. 1974. Vegetation and climatic history near Lake Keilambete, western Victoria. *Australian Journal of Botany* 22, 709-717.

Dodson, J.R. 1979. Vegetation and climatic history near Lake Bullenmerri, western Victoria. *Australian Journal of Ecology* 4, 419-427.

Ethridge, F.G. & Schumm, S.A. 1978. Reconstructing palaeochannel morphologic and flow characteristics: methodology, limitations, and assessment. *In* Miall, A.D. (ed.) *Fluvial Sedimentology. Canadian Society of Petroleum Geologists Memoir* 5, 703-721.

Jennings, J.N. 1975. Desert dunes and estuarine fill in the Fitzroy estuary (north-western Australia). *Catena* 2, 215-262.

Kershaw, A.P. 1986. Climatic change and Aboriginal burning in north-east Australia during the last two glacial/interglacial cycles. *Nature* 322, 47-49.

Kershaw, A.P., Baird, J.G., D'Costa, D.M., Edney, P.A., Peterson, J.A. & Strickland, K.M. in press, A comparison of long Quaternary pollen records from the Atherton and Western Plains volcanic provinces, Australia. *In* Williams, M.A.J. (ed.) *The Cainozoic of Australia: A Re-examination of the Evidence*. Geological Society of Australia Special Publication.

Kershaw, A.P. & Nix, H.A. 1988. Quantitative palaeoclimatic estimates from pollen data using bioclimatic profiles of extant taxa. *Journal of Biogeography* 15, 589-602.

Nanson, G.C., Young, R.W. & Stockton, E.D. 1987. Chronology and palaeoenvironments of the Cranebrook Terrace (near Sydney) containing artefacts more than 40,000 years old. *Archaeology in Oceania* 22, 72-78.

Nutalaya, P. & Rau, J.L. 1981. Bangkok: the sinking metropolis. *Episodes* 1981, 3-8.

Schumm, S.A. 1968. River adjustment to altered hydrologic regimen – Murrumbidgee River and paleochannels, Australia. *U.S. Geological Survey Professional Paper* 598.

Singh, G. & Geissler, E.A. 1985. Late Cainozoic history of vegetation, fire, lake levels and climate, at Lake George, New South Wales, Australia. *Philosophical Transactions of the Royal Society of London* B311, 379-447.

Singh, G., Opdyke, N.D. & Bowler, J.M. 1981. Late Cainozoic stratigraphy, palaeomagnetic chronology and vegetational history from Lake George, N.S.W. *Journal of the Geological Society of Australia* 28, 435-452.

Thom, B.G. & Bowler, J.M. 1982. Chronostratigraphic subdivision of the Holocene in Australia. *Striae* 16, 7-9.

Wasson, R.J. 1986. Geomorphology and Quaternary history of the Australian continental dunefields. *Geographical Review of Japan* 59 (Ser. B), 55-67.

Webb, L.J., Tracey, J.G. & Williams, W.T. 1984. A floristic framework of Australian rainforests. *Australian Journal of Ecology* 9, 169-198.

Williams, G.P. 1984. Paleohydrologic equations for rivers. *In* Costa, J.E. & Fleisher, P.J. (eds.) *Developments and Applications of Geomorphology*, Springer-Verlag, Berlin, 343-367.

Young, R.W. 1983. The tempo of geomorphological change: Evidence from southeastern Australia. *Journal of Geology* 91, 221-230.

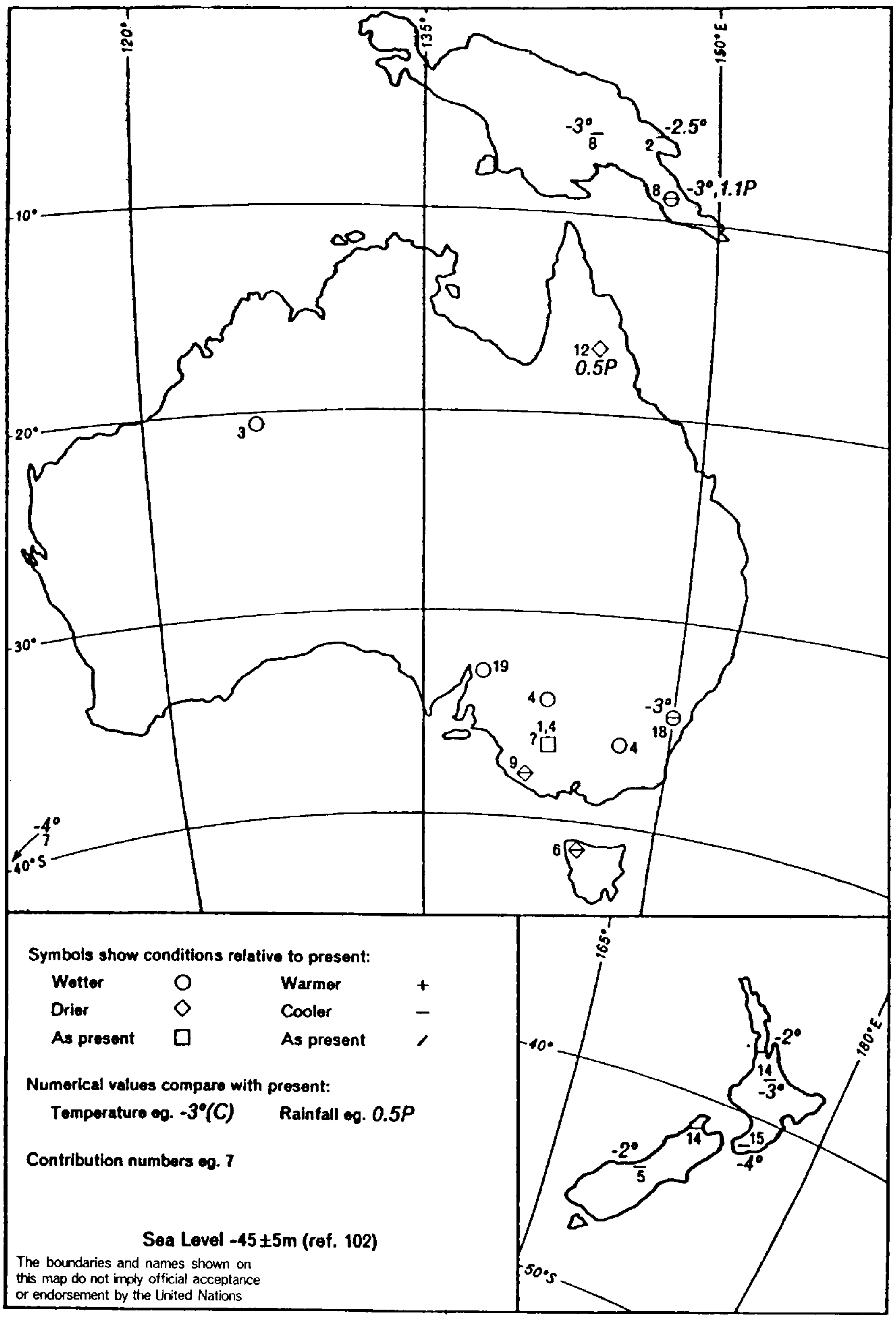


Figure 1. Map showing conditions relative to present at 32,000 B.P. + or – 5,000 B.P. "Spike"

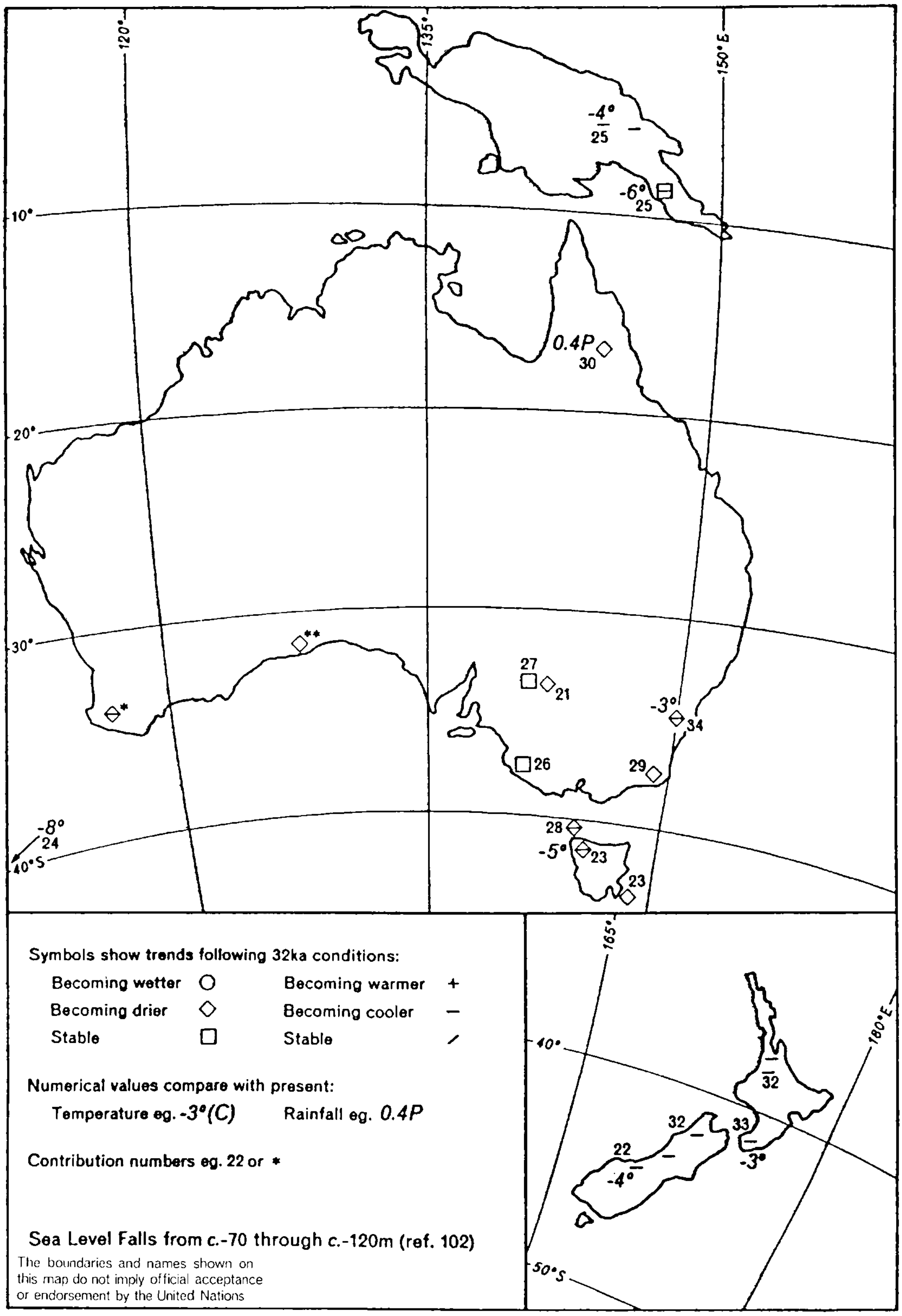


Figure 2. Map showing trends following 32,000 B.P. conditions for the period from 25,000 to 20,000 B.P.

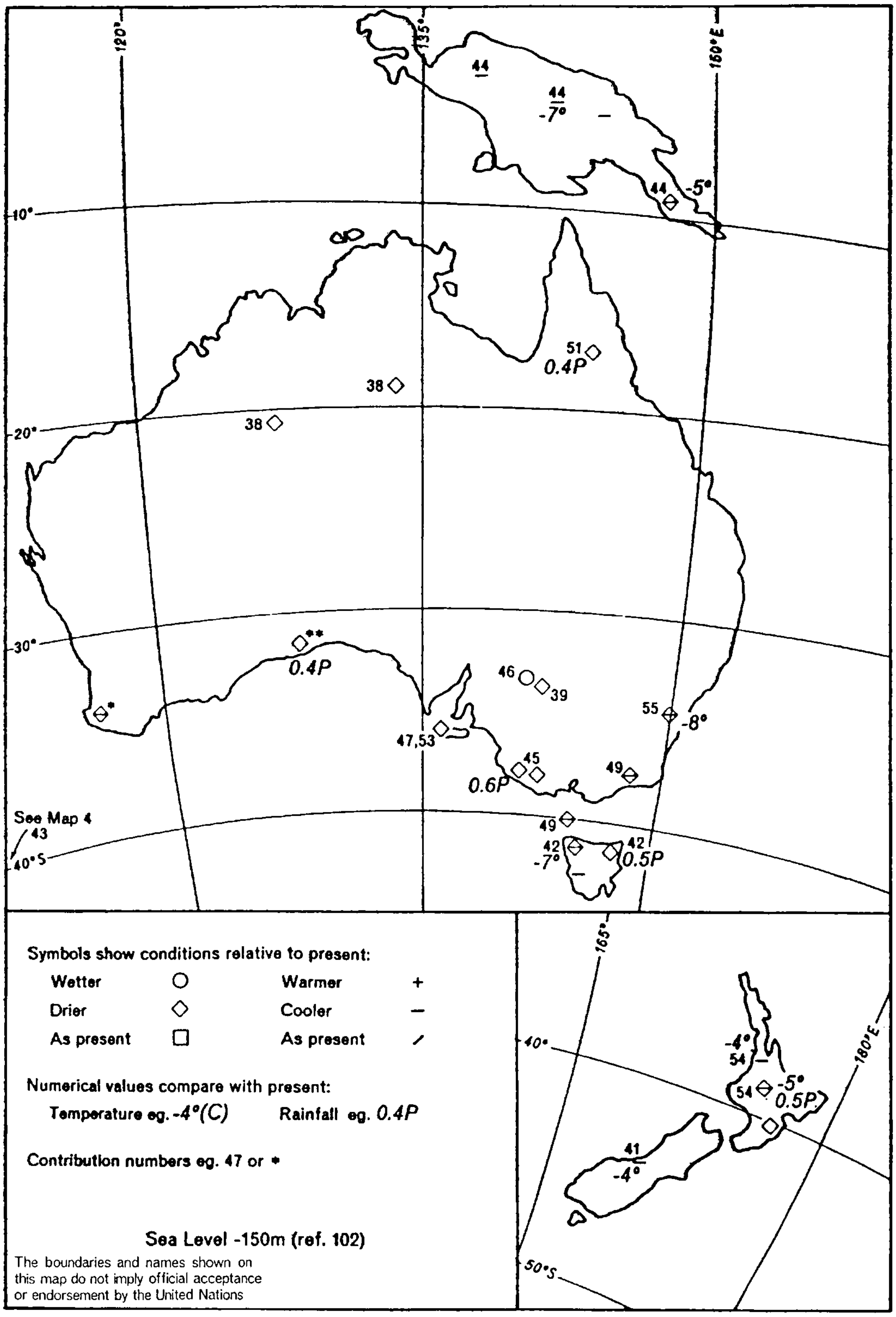


Figure 3. Map showing conditions relative to present at 18,000 B.P. plus or minus 2,000 B.P. "Spike"

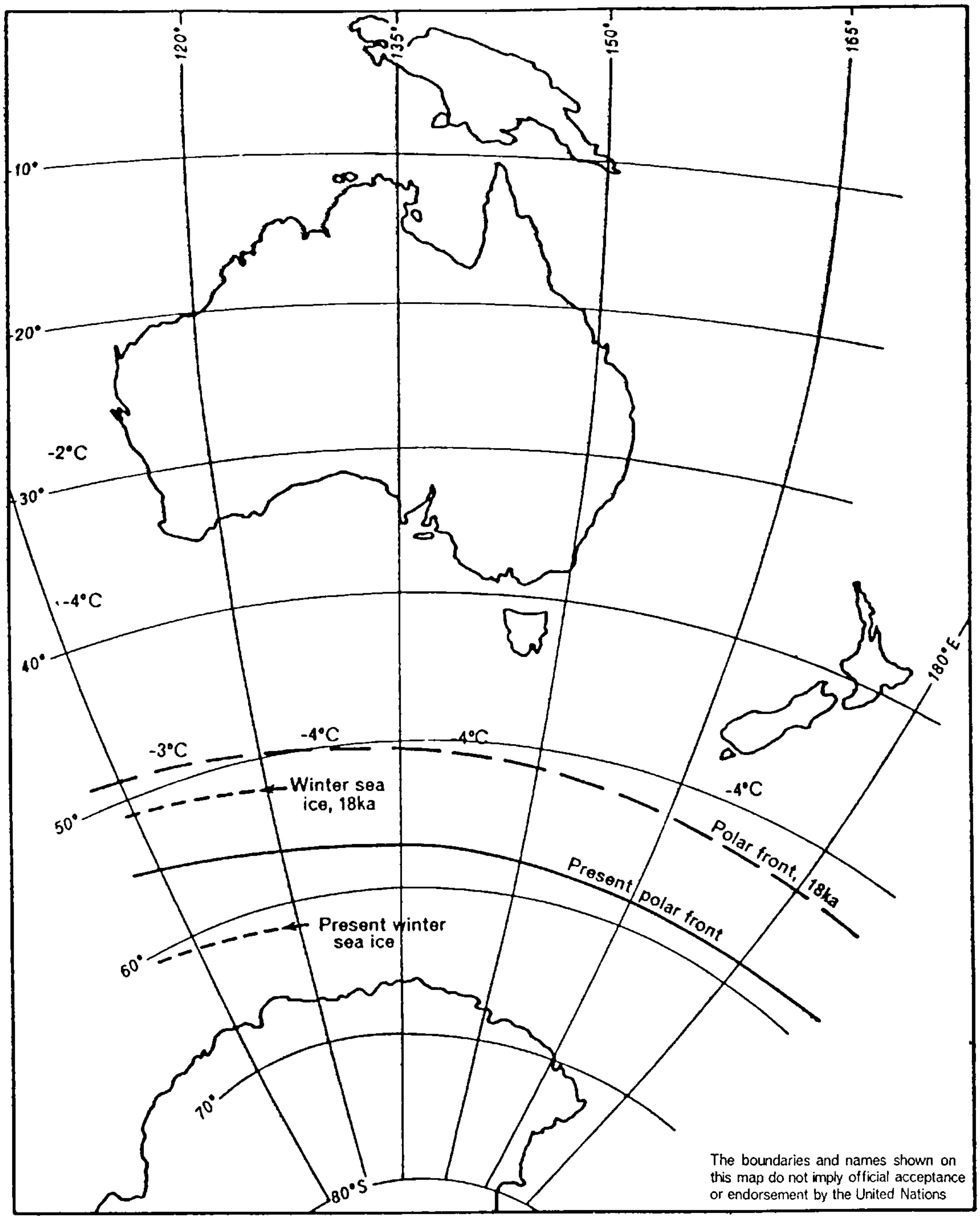


Figure 4. Map showing Southern Ocean at 18,000 B.P. (from Hays, 1985)

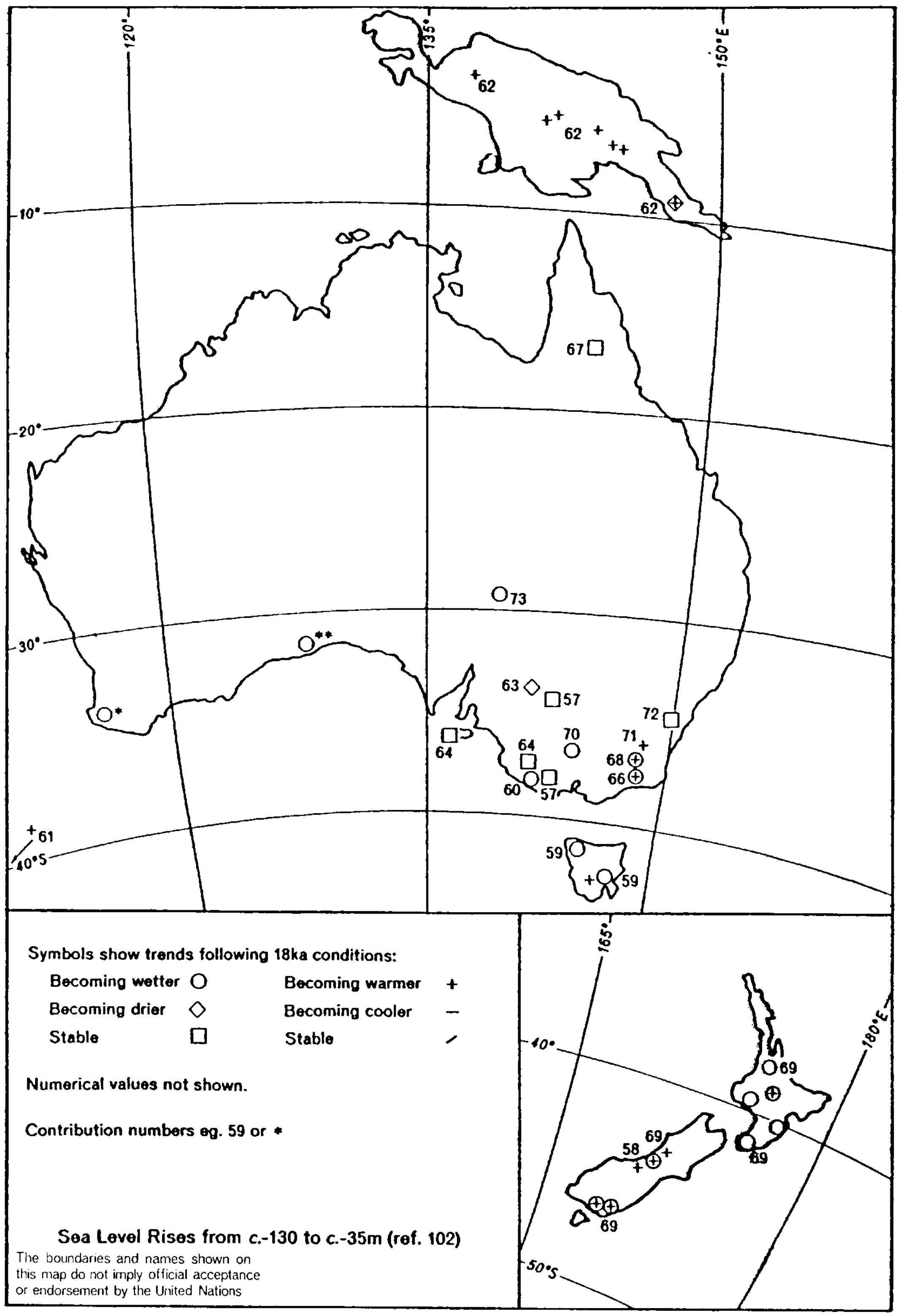


Figure 5. Map showing trends following 18,000 B.P. conditions at 15,000 to 10,000 B.P.

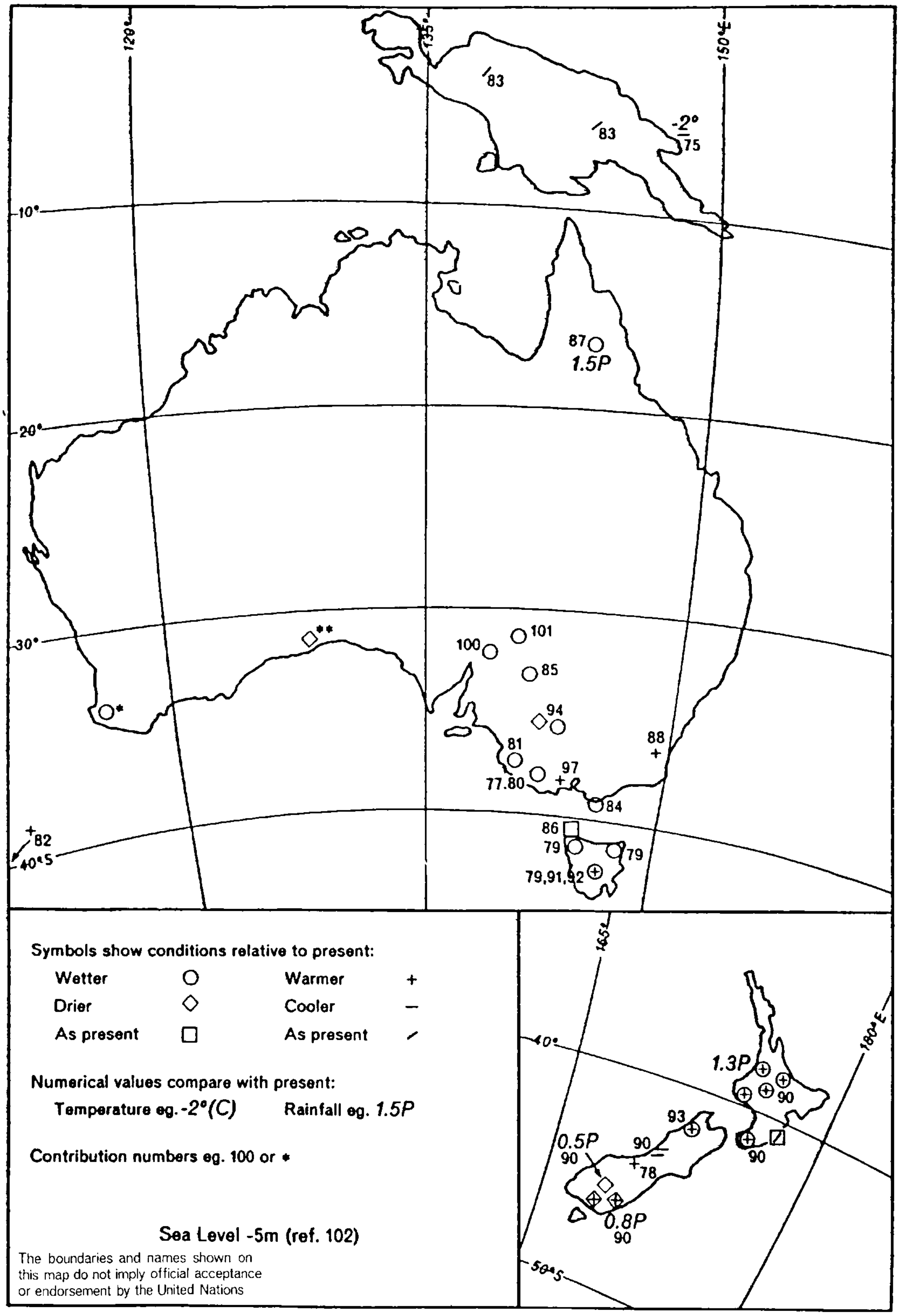


Figure 6. Map showing conditions relative to present at 7,000 B.P. + or – 2,000 B.P. "Spike"

PROPOSED STRATOTYPE SECTION: QUATERNARY MARINE STRATOTYPE OF CORE QC_2 IN HUANGHAI SEA

by

Lin Hemao[1]

1. Introduction

For the correlation of Quaternary stratigraphy between China shelf and adjacent coastal areas, 5 cores were drilled in the south Huanghai Sea onshore and offshore. Core QC_2 is one of the five, located in shelf area (122° 16'E, 34° 18'N) at the water depth of 49.05 metres (m), with average coring rate up to 90.4 per cent (Figure 1). The core is 108.83 m long, in which the subchron Olduvai (about 1.7 Ma) has been reached at bottom of the core according to paleomagnetic analysis. Various samples have been collected and analyzed systematically for lithology, mineralogy, sedimentology, chronology, palaeontology and geochemistry. In the range of Quaternary studies, it is one of the best cores so far in China.

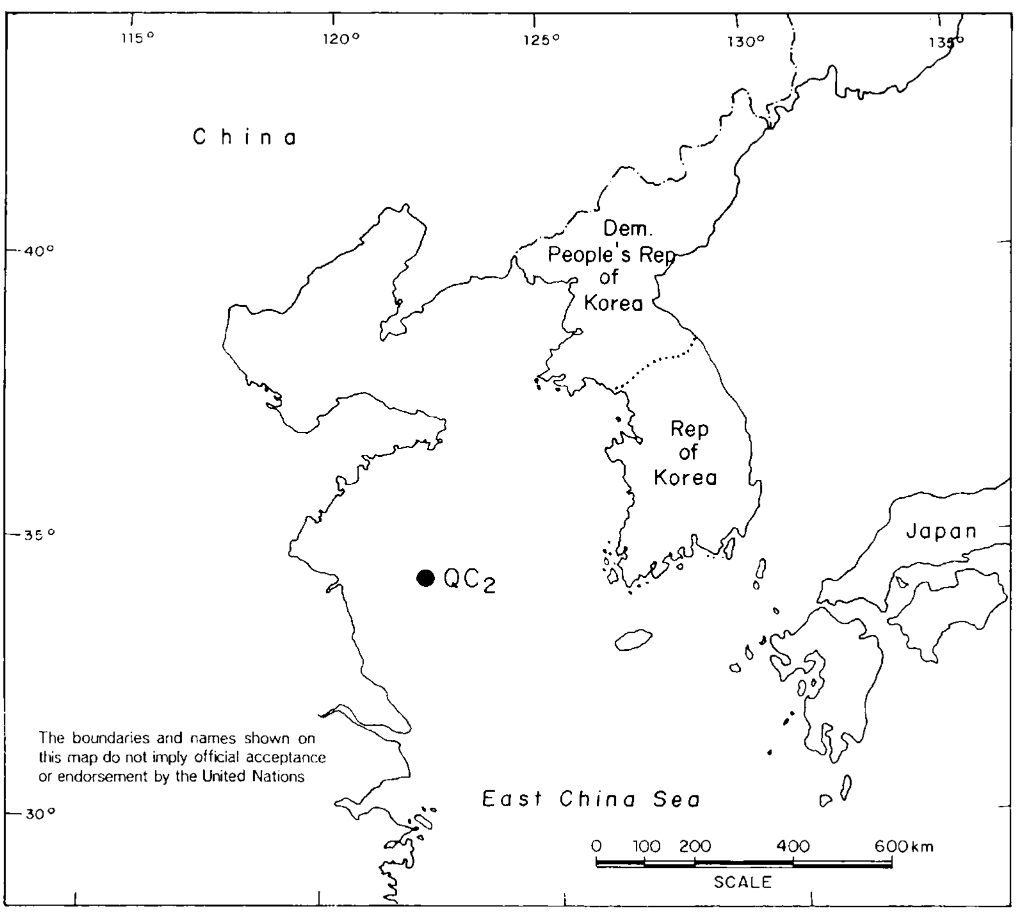


Figure 1. Sketch map of location of core QC_2

[1] Institute of Marine Geology, Ministry of Geology and Mineral Resources, China.

2. Lithological units (Figure 2)

Holocene		0-17.83 m
HI*		0-17.83 m
1.	Dark grey silty mud	1.87 m
2.	Dark grey silt with shells.	0.76 m
3.	Dark grey silt intercalated with yellowish grey coarse silt.	1.63 m
4.	Dark grey to yellowish brown silty mud	0.38 m
5.	Yellowish brown silt-fine sand intercalated with black silt-fine sand mixed with organic matter.	2.12 m
6.	Greyish yellow silt.	0.12 m
7.	Dark grey silt.	0.33 m
8.	Dark greyish brown silty clay	0.59 m
9.	Dark grey silty clay, intercalated with a little yellow silt and black clay	0.95 m
10.	Greyish yellow silt	0.08 m
11.	Grey and dark grey muddy silt	1.42 m
12.	Dark grey silty mud	2.11 m
13.	Black clay with greyish silt	0.28 m
14.	Dark grey silty clay	0.48 m
15.	Dark grey clay	0.88 m
16.	Dark grey clay and yellowish grey fine silt	0.32 m
17.	Dark grey silty clay, intercalated greyish and yellowish grey silt.	0.48 m
18.	Greyish black clay with a few sand lenticles	0.23 m
19.	Black clay and silty clay with peat laminae	0.31 m
20.	Dark grey silty clay and yellowish grey silt with peat and erosional surface at the bottom	0.74 m
21.	Greyish green and black clay	0.04 m
22.	Dark grey silty clay with greyish silt laminae and lenticles.	0.74 m
23.	Greyish black clay intercalated with greyish silt	0.29 m
24.	Black clay with shells	0.08 m
25.	Dark grey clay and silty clay with peat laminae and greyish silt lenticles.	0.34 m
26.	Dark grey silty clay and brownish silt with peat laminae and erosional surface at the bottom	0.27 m
Late Pleistocene		17.83-54.36 m
CI*		17.83-18.52 m
27.	Dark green silty clay interbedded with greyish green silty clay, with silt increasing downwards, and several cm silt at the bottom	0.68 m
HII_1		18.52-20.54 m
28.	Grey and greyish black muddy silt with yellowish grey massive silt.	0.22 m
29.	Dark grey and greyish black clay, with a little massive silty clay at the middle and upper parts	0.78 m
30.	Dark grey and greyish black silty clay	0.19 m
31.	Dark grey and greyish black clay with a few carbonaceous laminae	0.87 m
CII		20.54-21.67 m
32.	Grey and greyish green silt with a little clay	0.48 m
33.	Grey and greyish brown fine sand, with some little silt and a few carbonaceous laminae	0.33 m
34.	Greyish green silt mixed with dark grey silty clay and brown massive silt	0.32 m
HII_2		21.67-28.93 m
35.	Greyish green clay intercalated with brownish grey silt and silty clay	1.27 m
36.	Brownish and grey silt intercalated with dark grey silty clay at the upper, and stained with ferrum	0.57 m
37.	Greyish black silty clay intercalated with black clay and yellowish grey silt lenticles	0.71 m

* HI – Marine Transgressive Bed I of Huanghai Sea.

* CI – Terrestrial Bed I.

38.	Dark grey silty clay intercalated with dark grey clay and yellowish grey silt lenticules	1.35 m
39.	Dark grey silty clay	0.43 m
40.	Dark grey shelly silt	0.14 m
41.	Dark grey clay with sporadic carboniferous laminae	0.18 m
42.	Brownish grey silt, with some little dark grey silty clay and clay, yellowish brown silty clay and carboniferous laminae	1.41 m
43.	Dark grey silty clay with much feralite	0.64 m
44.	Greyish black massive clay with dark brown silty clay	0.70 m
CIII		28.93-31.10 m
45.	Dark grey clay intercalated dark grey and brownish grey clay	1.70 m
46.	Dark grey silty clay with yellowish grey silt lenticles and sporadic carboniferous laminae	0.33 m
HIII		31.10-31.56 m
45.	Greyish black clay mixed with dark grey silty clay	0.46 m
CIV		31.56-33.22 m
48.	Greenish grey silt and silty clay and carbonic laminae	0.91 m
49.	Dark grey silty clay interbedded with yellowish grey silt and fine sand, with carbonaceous lenticles at the lower part and erosional surface at the bottom	0.75 m
HIV		33.22-54.36 m
50.	Grey silty clay or clayey silt	0.18 m
51.	Dark grey silt and some little silty clay at the upper with greyish green silty clay at the top, and dark grey silty clay with dark grey clay and yellowish grey silty clay at the middle and the lower	1.52 m
52.	Grey find silt with silty clay	1.18 m
53.	Dark brown massive clay	0.50 m
54.	Dark grey silty clay and clay, with erosional surface at the bottom	0.85 m
55.	Dark grey silty clay interbedded with clay, and intercalated with sporadic peat laminae	0.55 m
56.	Dark grey clay with greyish silt lenticles, at the bottom with brownish ferruginous silt and a few peat laminae	0.46 m
57.	Dark grey clay and silty clay	0.22 m
58.	Dark grey clay intercalated with greyish silt	0.92 m
59.	Dark brown clay with plenty of organic matter and intercalated with yellowish grey massive silt	0.19 m
60.	Dark grey clay and greyish brown clay	1.07 m
61.	Dark grey and greyish brown clay with erosional surface at the bottom	0.49 m
62.	Dark grey clay and greyish silt, with brown ferugo-silt and sand at the top	0.23 m
63.	Grey clay intercalated with brown clay and greyish silt, with a peat lamina and fragmental shells at the middle	0.86 m
64.	Dark grey and greyish brown clay	0.16 m
65.	Dark grey and greyish brown clay interbedded with greyish and yellowish silt	0.34 m
66.	Dark grey and greyish brown clay	0.15 m
67.	Dark grey clay and some little greyish brown clay intercalated with brown silt	0.52 m
68.	Dark grey and greyish clay, with carbonaceous laminae at the lower	0.70 m
69.	Dark grey clay and a little greyish clay, intercalated greyish and yellowish grey silt	0.85 m
70.	Dark grey clay with brownish silt	0.09 m
71.	Dark grey clay with greyish brown clay in some parts and decreasing down wards	1.78 m
72.	Dark grey clay with brown and greyish brown massive clay, the upper having nodules of Fe and Mn, the middle and the lower having fine grains of pyrite mixing in the massive clay	3.12 m
73.	Dark grey clay intercalated with dark greenish grey massive silty clay	0.37 m
74.	Dark grey and greyish brown clay with pyrite nodule and feralite	1.69 m
75.	Dark grey silty clay intercalated with dark grey clay	1.15 m

Middle	**Pleistocene**	54.36-79.82 m
HV		54.36-62.05 m
76.	Yellowish grey silt and silty-fine sand interbedded with greyish brown clay and dark grey silty clay	0.30 m
77.	Dark grey silty clay with feralite filled with grey silt	0.12 m
78.	Yellowish silt and dark grey silty clay	0.55 m
79.	Dark brownish grey silty clay intercalated with greyish brown silt, with calcareous nodules at the middle and the lower	0.41 m
80.	Greyish white silt with a little dark grey silty clay in the upper, and greyish white shelly fine sand in the lower	0.12 m
81.	Dark grey silty clay with organic matter	0.12 m
82.	Dark grey silty clay and silty	0.86 m
83.	Dark grey silty clay intercalated with yellowish grey and greyish silt, partly having small nodules and grains of FeS_2 and $CaCo_3$ partly	1.66 m
84.	Dark grey clay, occasionally intercalated with brownish grey massive clay	2.69 m
85.	Dark grey silt, intercalated with dark brown silty clay having rust spots at the lower	0.46 m
86.	Greyish black silt with some little dark brown silty clay, having many rust spots in the silt	0.23 m
87.	Greyish green and dark brown silt, with erosional surface at the bottom	0.17 m
CV		62.05-63.42 m
88.	Greyish green silty clay with a few greyish green and greyish white silt lenticles	0.12 m
89.	Greyish green silty clay having many rust spots intercalated with greyish white and greyish green silt	0.30 m
90.	Greyish green clay intercalated with massive silty clay having rust spots in the upper, and dark grey silty clay intercalated with grey silt lenticles having Fe-nodules and feralite in the lower.	0.89 m
91.	Dark grey silty clay and yellowish grey silt with feralite structure	0.34 m
HVI		63.42-74.64 m
92.	Brown silt with shells, having bottom erosion	0.18 m
93.	Greyish green, yellow and brown mottled clay with feralite	0.18 m
94.	Greyish green clay interbedded with mottled clay, having Fe-nodules and greyish black organic laminae	0.61 m
95.	Brown and greyish silt and silty clay and greyish brown clay	0.19 m
96.	Brownish grey silty clay intercalated with dark grey silty clay, having Ca-nodules	0.36 m
97.	Yellowish grey silt interbedded with brownish grey silty clay	1.96 m
98.	Yellowish grey silt intercalated with brownish grey clay and silty clay, having rust spots and feralite	0.39 m
99.	Brownish grey clay intercalated with greyish silt, having a little feralite structure	0.35 m
100.	Brownish grey silt and brown silty clay with mush feralite	0.35 m
101.	Yellowish grey fine sand intercalated with dark grey silty clay, having many shells	0.17 m
102.	Greyish green silt intercalated with brown silty clay, having rust spots, feralite and organic matter	0.58 m
103.	Brownish grey silty clay with big shells	0.13 m
104.	Greyish green silty clay with silt laminae and lenticles	0.20 m
105.	Brownish grey silty clay with big shell fragments	0.06 m
106.	Greyish green silty clay with silt, having shell fragments	0.25 m
107.	Bluish grey intercalated with yellowish white silt, having feralite	0.63 m
108.	Dark grey clay with a little greyish white silt, having feralite and rust spots partly	0.26 m
109.	Dark grey with greyish silt and find sand, and a little greyish black massive clay	0.37 m
110.	Brownish fine sand with a little dark grey clay and more shells	0.12 m
111.	Dark grey and bluish grey silt, with brownish silt downwards	0.23 m
112.	Dark grey clay intercalated with greyish white silt, having feralite structure and shells	0.70 m
113.	Cyclothem of dark grey clay and greyish silty clay, with feralite and organic matter	2.09 m
114.	Greyish black clay with dark grey silt, at the lower having limonite spots	0.49 m
115.	Greyish black silt in the upper, yellowish grey silt intecalated with grey silty clay in the lower, having bottom erosion	0.09 m

CVI		74.64-79.82 m
116.	Bluish grey silty clay having feralite interbedded with dark grey clay,	0.16 m
117.	Cyclothemic interbedding of dark grey and bluish grey clay	0.97 m
118.	Dark grey silt, medium sand and clay having feralite structure	0.58 m
119.	Grey and greyish medium sand intercalated with a few dark grey clay laminae	0.30 m
120.	Dark grey clay with a little silt	0.37 m
121.	Interbedding of greyish and greyish yellow fine sand and silt, having a little dark grey clay	0.21 m
122.	Greyish yellow medium sand	0.09 m
123.	Interbedding of greyish fine sand and a little silt, having organic matter at the bottom	0.19 m
124.	Yellowish grey fine-medium sand intercalated with brownish grey silty clay	0.45 m
125.	Yellowish grey fine sand intercalated with grey to dark grey silty clay	0.23 m
126.	Interbedding of yellowish grey medium and fine sand, and brownish grey silt in the upper and the middle, and yellowish grey silt interbedded with grey silty clay in the lower	1.63 m
Early Pleistocene		79.82-108.83 m
HVII		79.82-91.33 m
127.	Brownish grey clay intercalated with yellowish grey massive silt	0.23 m
128.	Brownish grey clay intercalated with greyish silt, having feralite structure	1.01 m
129.	Brownish grey clay with yellowish grey silt in the upper, and brownish grey and yellowish grey silt in the lower	0.50 m
130.	Brownish grey clay with a little greyish silt, having feralite filled with brown silt	0.41 m
131.	Brownish silt	0.09 m
132.	Brownish grey clay, with fine silt and having feralite structure at the top	0.52 m
133.	Brownish grey clay with lots of feralite structure	0.70 m
134.	Yellowish gray fine sand	0.12 m
135.	Dark grey silt and fine sand with Ca-nodules	0.35 m
136.	Interbedding of dark grey silt and yellowish grey fine sand with shells	0.24 m
137.	Dark grey silt and fine sand	0.10 m
138.	Interbedding of dark grey fine and medium sand and silty clay with shells	0.27 m
139.	Cyclothem interbedding of dark grey silty clay and brownish grey fine sand with shell fragments	0.11 m
140.	Cyclothem interbedding of dark grey silty clay and brownish grey fine sand	0.69 m
141.	Cyclothem interbedding of yellowish grey silt and greyish black silty clay	0.37 m
142.	Mixed dark grey fine sand and yellowish grey medium sand with shell	0.42 m
143.	Yellowish medium-fine sand with laminae containing dark brown biotite, having a few organic lenticles	0.47 m
145.	Yellowish and yellowish grey medium sand	0.35 m
146.	Dark grey fine silt	0.16 m
147.	Dark grey fine sand	0.14 m
148.	Yellowish grey medium-fine massive sand	0.41 m
149.	Yellowish grey medium-fine sand with fine sand laminae sporadically	0.32 m
150.	Interbedding of yellowish grey fine sand, brownish grey silty-fine sand and dark grey silt, with rust spots sporadically	0.30 m
151.	Dark grey fine sand intercalated with dark grey silty clay	0.08 m
152.	Yellowish grey medium sand with black mica lenticles sporadically	1.20 m
153.	Cyclothemic interbedding of brownish grey and dark grey fine sand and silty clay	0.35 m
154.	Yellowish grey medium sand with black mica cross-bedding	0.05 m
155.	Cyclothem interbedding of yellowish grey fine sand and dark grey silty clay	0.13 m
156.	Greyish yellow medium sand with organic metter and biotite laminae in the upper, and normal cyclothem beds of dark grey silty clay - grey fine sand - yellowish grey medium sand in the lower	0.39 m
157.	Dark grey fine sand	0.10 m
158.	Yellowish grey medium-fine sand	0.14 m
159.	Dark grey silt and silty clay	0.21 m
160.	Cyclothem interbedding of greyish fine sand, dark grey silt and silty clay	0.23 m

CVII		91.33-106.95 m
161.	Brownish grey clay	0.29 m
162.	Dark grey silty clay intercalated with silt lamimae	0.32 m
163.	Dark brown silty clay with yellowish grey silt laminae	0.46 m
164.	Yellowish grey silt with a little dark brown silty clay	0.25 m
165.	Brownish grey clay	0.18 m
166.	Dark brown clay with a few greyish and dark grey silt laminae, with erosion at the bottom	0.47 m
167.	Brownish grey clay with a few greyish silt laminae and verticle feralite structure, having erosion at the bottom	0.28 m
168.	Dark grey silty clay and clay with feralite structure	0.23 m
169.	Brownish grey clay, becoming into silty clay and dark grey clay upwards	0.10 m
170.	Yellowish grey silt and silty-fine sand	0.11 m
171.	Yellowish fine sand interbedded with dark grey silty clay	0.12 m
172.	Cyclothem interbedding of dark grey silt and silty clay	0.13 m
173.	Dark grey and brownish grey silty clay, with a carbonaceous lamina at the top	0.39 m
174.	Dark grey silt and brownish grey silty clay	0.09 m
175.	Dark grey silty clay with a few silt laminae	0.45 m
176.	Cyclothem interbedding of dark grey silt and silty clay with oblique bedding	0.14 m
177.	Yellowish grey fine sand	0.12 m
178.	Dark grey silty clay with a little greyish silt	0.73 m
179.	Dark grey silt and silty-fine sand	0.12 m
180.	Dark grey silty clay with a few silt laminae having carbonaceous lanticles in the	0.67 m
181.	middle	0.31 m
182.	Dark grey silty clay intercalated with greyish silt laminae, having small cross-bedding	0.17 m
183.	Dark grey fine sand with indistinct cross-bedding	0.70 m
184.	Dark grey silty clay with a few greyish silt laminae, having small feralite	0.43 m
185.	Dark grey silty clay intercalated with greyish silt and peat laminae upper, and wave-bedding in the lower	0.43 m
186.	Brownish grey silty clay and greyish and yellowish grey silts with laminae and cross-bedding	0.22 m
187.	Brownish grey silty clay with dark grey clay and silt laminae	0.72 m
188.	Yellowish grey silt intercalated with dark brown beds containing mica	0.30 m
189.	Brownish grey silty clay with a few silt laminae	0.56 m
190.	Yellowish grey and greyish silt intercalated with dark brown silty clay	0.30 m
191.	Grey silt and fine sand intercalated with silty clay	0.37 m
192.	Grey fine sand, with silty clay partly	0.32 m
193.	Grey fine sand intercalated with brown silty clay	0.78 m
194.	Grey fine sand, with silty-fine sand partly	2.06 m
195.	Greyish silty-fine sand and brownish grey silty clay with feralite structure	0.36 m
196.	Yellowish grey medium-fine sand, having massive structure at the top and oblique-bedding consisted of biotite and dark minerals in the middle and the lower	0.71 m
197.	Yellowish grey medium-fine sand	0.61 m
198.	Yellowish grey medium-fine sand interbedded with dark grey silty clay	0.36 m
HVIII		107.09-108.8 m
199.	Dark grey medium sand and yellowish grey medium sand	0.15 m
200.	Yellowish grey medium sand with massive structure	0.41 m
201.	Dark grey medium sand intercalated with yellowish grey medium sand intercalated with yellowish grey medium sand	0.12 m
202.	Yellowish grey medium sand	0.15 m
203.	Cyclothem interbedding of yellowish grey medium sand, dark grey medium sand and silty clay	0.41 m
204.	Greyish medium sand with oblique bedding containing biotite and dark minerals	0.36 m
205.	Yellowish grey medium sand with massive structure, having a little fine sand at the top	0.14 m

Depth (m)	Epoch	Column	Lithologic unit: Layer	Lithologic unit: Member	Biologic unit: Foraminifera assemblage	Biologic unit: Ostracoda assemblage	Biologic unit: Environment	Chronologic unit: Sporopollen zone		Chronologic unit: Geomagnetism	Chronologic unit: ^{14}C (a)	Chronologic unit: $\delta ^{18}O$
	Holocene		1		$\overline{S}$39.4 $\overline{N}$2740 Ammonia ketienziensis Asterononion tasmanensis	$\overline{S}$16.8 $\overline{N}$88 Munseyella japonica Hanai Amphileberis gibbera Guan	Shallow sea (50 m)	X	c			1
			3, 5, 9	HI	$\overline{S}$13.9 $\overline{N}$2282 Elphidium magellanicum	$\overline{S}$185 $\overline{N}$439 Neomonoceratina chenae Zhao	Shallow sea (5-20 m)		b			
10			12		S2 N1248 Ammonia beccarii vars.	S4 N369 Sinocytheridea impressa (Brady)	Salty marsh					
			15		$\overline{S}$19 $\overline{N}$1883 E. magellanicum	$\overline{S}$205 $\overline{N}$336 N. chenae	Shallow sea (5-20 m)		a			2
			21, 24		S3-21 N143-1152 A. beccarii vars.	S1-9 N9-561 S. impressa	Salty marsh inter-subtidal				9910 ∓ 100 10340 ∓ 110	
			27	CI				IX	c			
20			31	HII_1	S17 N912 A. beccarii vars. – E. magellanicum	S17 N136 S. inpressa – N. chenae	Inter-subtidal		b			
				CII	S3, 3 N20, 366 A. beccarii	S5 N162 S. impressa	Salty marsh					
			35									
			38	HII_2	S10.8 N4378 A. beccarii vars. – E. magellanicum	$\overline{S}$13.4 $\overline{N}$1097 S. impressa – N. chenae	Inter-subtidal					3
			42		S4, 4 N4070, 498 A. beccarii vars.	S4, 5 N47, 75 S. impressa	Salty marsh				28500 + 820	

Figure 2. Columnar section of core QC_2

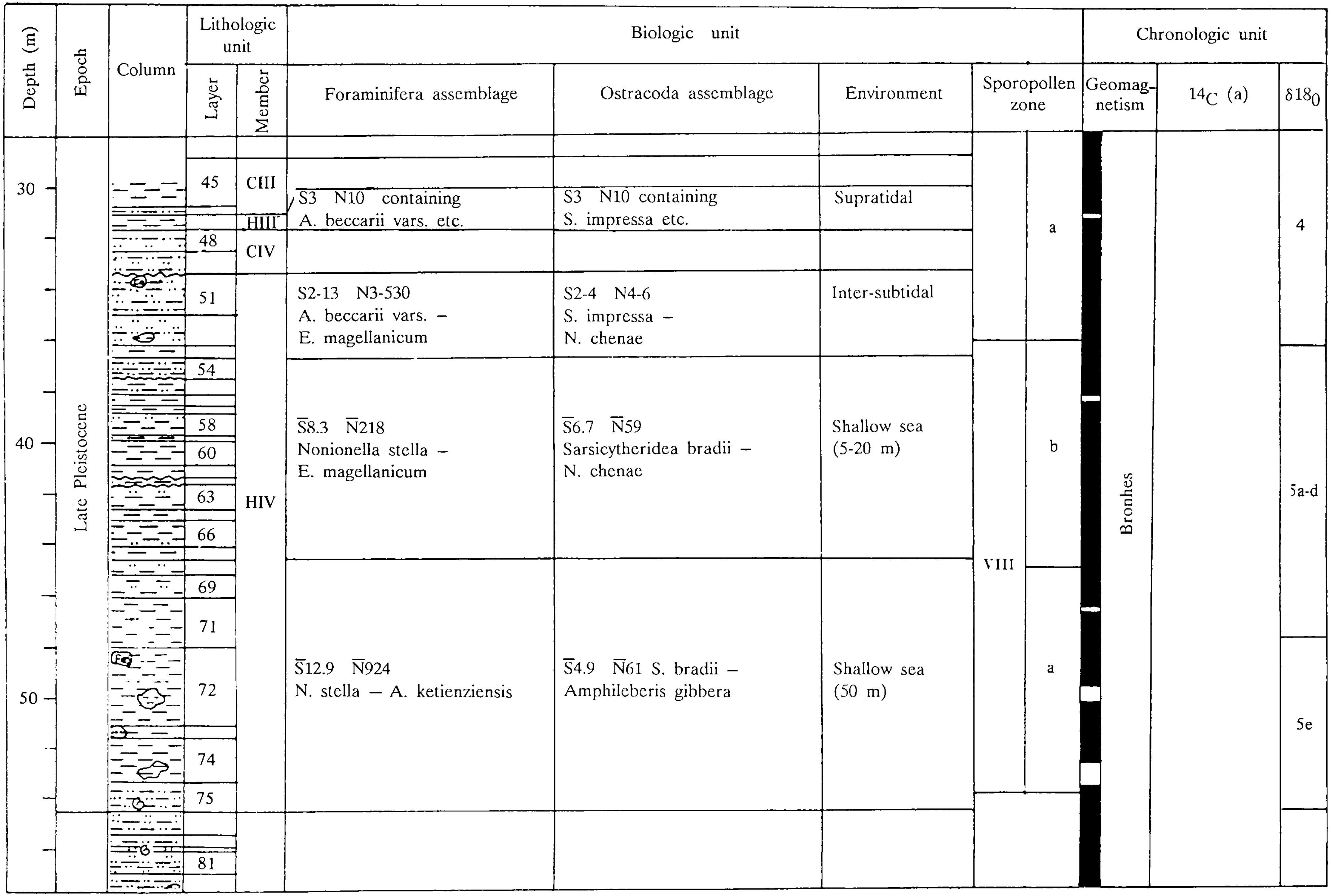


Figure 2 *(Continued)*

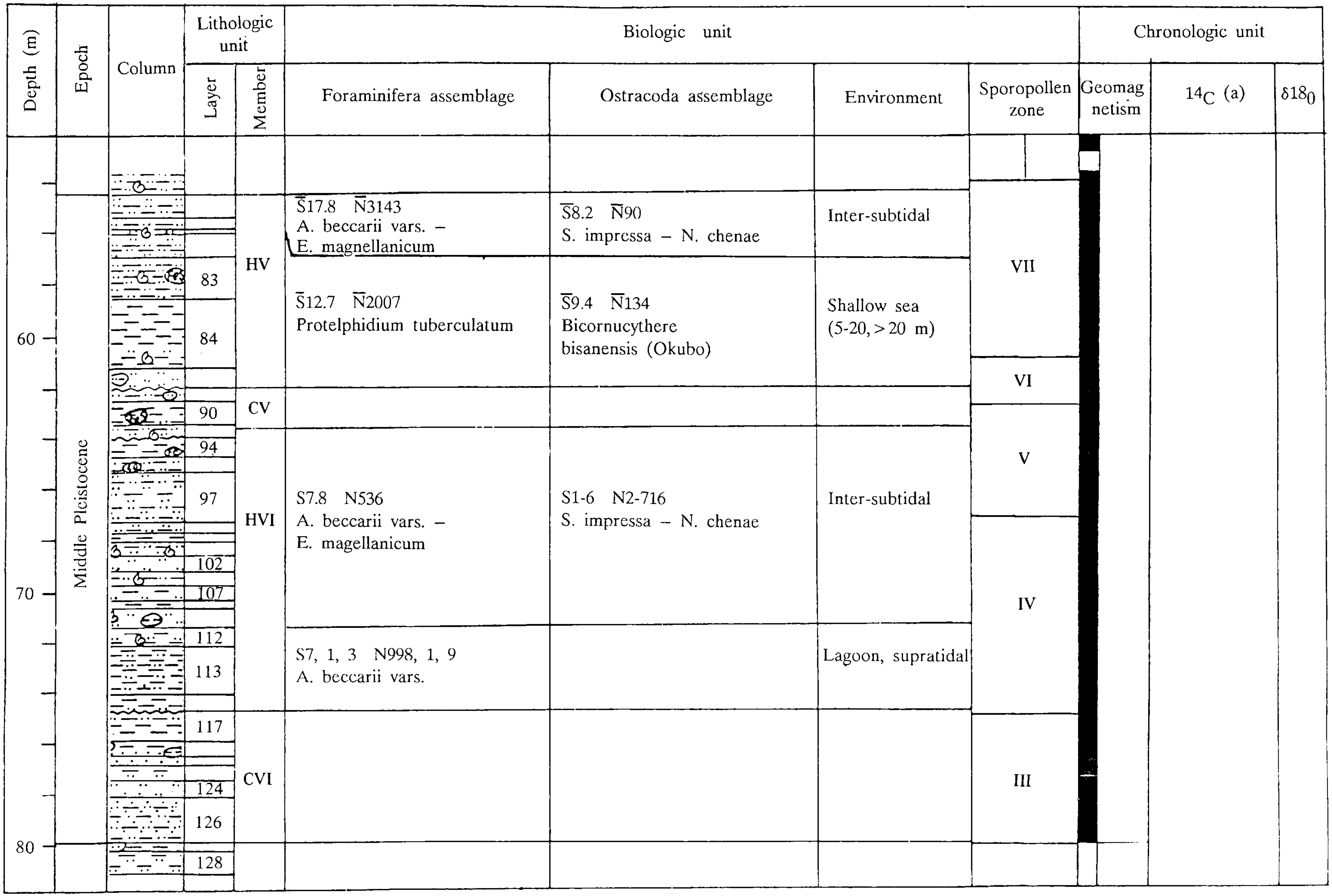


Figure 2 *(Continued)*

Depth (m)	Epoch	Column	Lithologic unit: Layer	Lithologic unit: Member	Biologic unit: Foraminifera assemblage	Biologic unit: Ostracoda assemblage	Biologic unit: Environment	Biologic unit: Sporopollen zone		Chronologic unit: Geomagnetism	Chronologic unit: ^{14}C (a)	Chronologic unit: $\delta 18_0$
80	Early Pleistocene		130	HVII	$\overline{S}$7.6 $\overline{N}$603 P. tuberculatum – Bucella frigida	2 samples containing Loxoconcha tarda Guan Echinocy thereis bradyi Ishizaki	Inter-subtidal shallow sea (5-20 m)	II	b	Matuyama		
			133									
			138		$\overline{S}$3.5 $\overline{N}$43 A. beccarii vars.	S. impressa etc.	Lagoon-supratidal					
			140									
			144									
			148									
			152									
90			158						a	Jaramillo		
			163	GVII								
			166									
			172									
			177									
			182									
			185									
100			189									
			192					I				
			194									
			196							Olduvai Gilsa		
			200	HVIII	S1-2 N1-4 containing A. beccarii vars. etc.		Supratidal					
			205									

Figure 2 *(Continued)*

3. Biological units

Foraminifera assemblages (Figure 3)

Layer 1 and 2 (Sample No. F101-105):
Ammonia Ketienziensis–Astrononion tasmanensis assemblage $\overline{S}$ 39.4, $\overline{N}$ 2740, $\overline{H(S)}$ 2.75 * (Figure 4)

Dominant species:
Ammonia ketienziensis (Ishizaki)
Astrononion tasmanensis Carter

High-content and common species:
Elphidium advenum Cushman
Bolivina robusta Brady
Bulimina marginata (d'Orbigny)
Hanzawaia nipponica Asano
Elphidium magellanicum Heron-Allen and Farland
Protelphidium tuberculatum (d'Orbigny)
Gaudryina sp.
Ammonia maruhasii (Kuwano)
Pseudoeponides japonicus Uchio
etc.

Showing shallow-sea environment with water depth about 50 m and normal salinity.

Layer 3-12 (F106-116):
Elphidium magellanicum assemblage
$\overline{S}$ 13.9, $\overline{N}$ 2282, $\overline{H(S)}$ 1.82

Main species:
Elphidium magellanicum
Ammonia beccarii (Linne') vars.

Common species:
Cribrononion incertum (Williamson)
Protelphidium tuberculatum
Buccella frigida (Cushman)
Elphidium advenum
Ammonia globosa (Millett)
etc.

Showing shallow-sea environment with a water depth of 5-20 m. Its upper and lower parts come closely to an inter-subtidal environment because the fossil specimens in the two parts are poorly preserved, the S and N are comparatively lower, and the content of *A. beccarii* vars. higher than in the middle parts.

Layer 13 (F 117):
Ammonia beccarii vars. assemblage
S2, N 1243
Ammonia beccarii vars. (93.6 per cent)
Protelphidium glabrum (Ho, Hu et Wang) (6.4 per cent)
Showing salty marsh environment.

*S – Diversity, i.e. Species Number; $\overline{S}$ – its Average Value.
N – Abundance, i.e. Specimen Number; $\overline{N}$ – its Average Value.
H(S) – Information Function; $\overline{H(S)}$ – its Average Value.

Layer 14-16 (F 118-121):
Elphidium magellanicum assemblage
$\overline{S}$ 19, $\overline{N}$ 1883, $\overline{H(S)}$ 2.11

Dominant species:
Elphidium magellanicum

High-content species:
Cribrononion incertum
Ammonia globosa
Elphidium advenum
Buccella frigida
Ammonia beccarii vars.
A. convexidorsa S.Y. Zheng
A. flevensis (Hofker)
A. pauciloculata (Phleger and Parker)
Protelphidium tuberculatum
Brizalina striatula (Cushman)
etc.

Showing shallow sea environment with a water depth of 5-20 m.

Layer 17-20 (F 122-124) and layer 23-26 (F 127-129): Except sample F 123 containing only one test of *Jadamina* sp., the other samples belong to *Ammonia beccarii* vars, assemblage.
S 3-7, N 143-775, H(S) < 0.57.
Ammonia beccarii vars. (82.7 per cent)
Protelphidium glabrum etc.
Showing salty marsh environment.

Layer 21-22 (F 125-126):
Ammonia beccarii vars. assemblage
S 20, 21; N 518, 1152: H(S) 2.08, 2.49
Ammonia beccarii vars. (20.6 per cent)
Elphidium magellanicum
Cribrononion incertum
Buccella frigida
Protelphidium tuberculatum etc.
Showing inter-subtidal environment.

Layer 29 (F 132):
Ammonia beccarii vars. *Elphidium magellanicum* assemblage
S 17, N 912, H(S) 2.21

Dominant species:
Ammonia beccarii vars.
Quinqueloculina akneriana rotunda

High-content species:
Cribrononion incertum
Buccella frigida
Ammonia globosa
Elphidium advenum
Protelphidium tuberculatum
Brizalina striatula
Elphidium magellanicum
etc.
Showing inter-subtidal environment.

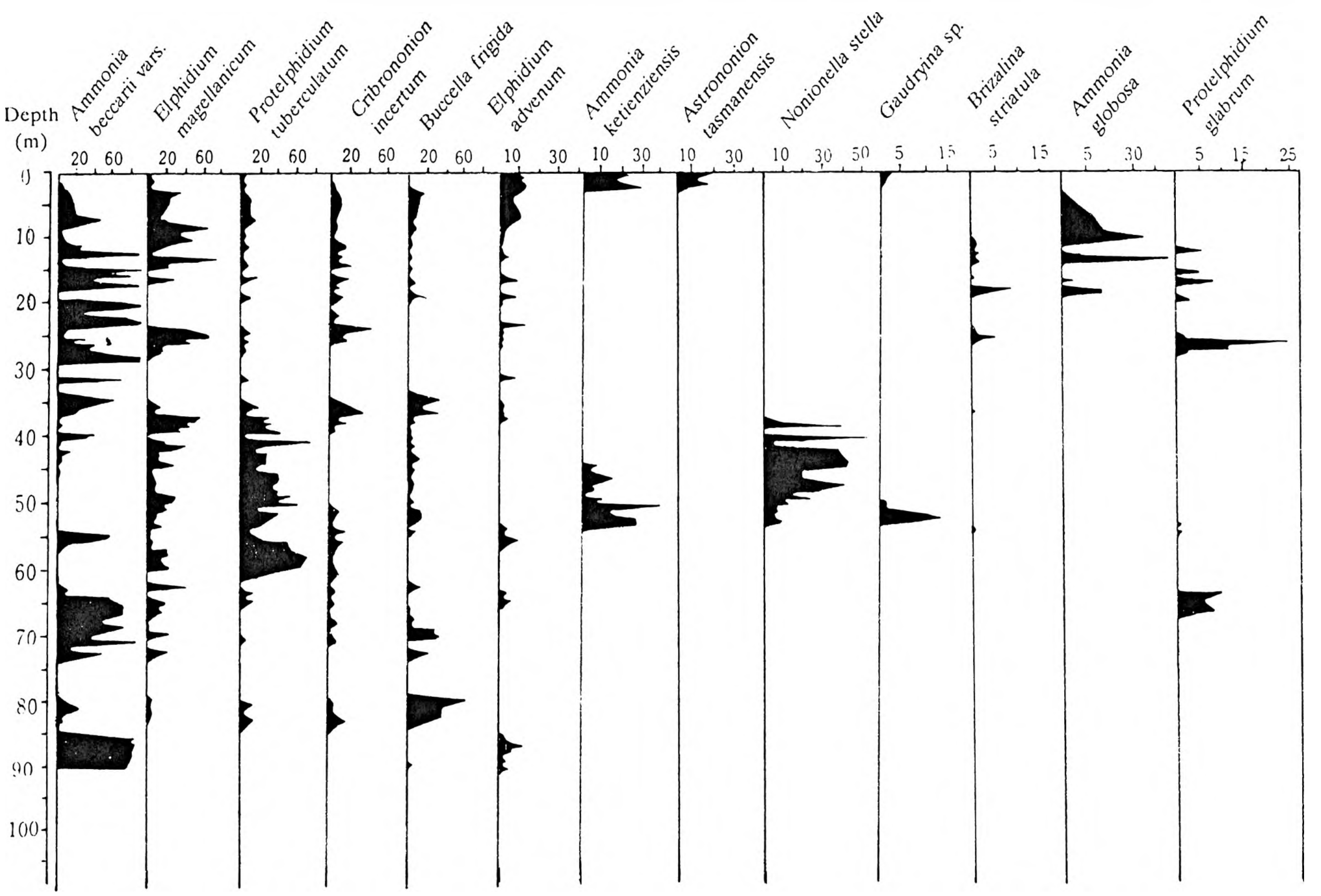


Figure 3. Content of main species of foraminifera in core QC_2

Layer 30-31 (F 133, 134):
Ammonia beccarii vars. assemblage
S 3, 3, N 20, 366; H(S) < 0.73
Dominated by *Ammonia beccarii* vars. (85.3 per cent).
Showing salty marsh environment.

Layer 35-42 (F 137-149):
Ammonia beccarii vars. Elphidium magellanicum assemblage
$\overline{S}$ 10.8, $\overline{N}$ 4378, $\overline{H(S)}$ 1.37.

Dominant species:
Ammonia beccarii vars.

High-content and common species:
Elphidium magellanicum
Cribrononion incertum
Buccella frigida
Protelphidium tuberculatum
Brizalina striatula
Qinqueloculina akneriana rotunda
Protelphidium glabrum
Elphidium kiangsuensis (Ho, Hu et Wang)
Pseudononionella variabilis S.Y. Zheng
etc.
Showing inter-subtidal environment.

Layer 43-44 (F 150, 151):
Ammonia beccarii vars. assemblage
S 4, 4; N 4070, 498; H(S) < 0.5.

Dominant species:
Ammonia beccarii vars. (93.1 per cent)

Other species:
Cribrononion porisuturalis S.Y. Zheng
Protelphidium glabrum
Showing salty marsh environment.

Layer 47 (F 158):
S 3, N 10
Ammonia beccarii vars.
Elphidium advenum
Protelphidium tuberculatum
Showing supratidal environment.

Layer 50-53 (F 162-164):
Ammonia beccarii vars. Elphidium magellanicum assemblage
S 2-13, N 3-530, H(S) 1.28

Dominant species:
Ammonia beccarii vars. (35.5 per cent)

High-content species:
Elphidium magellanicum
Cribrononion incertum
Buccella frigida
Protelphidium tuberculatum
etc.
Showing inter-subtidal environment.

Layer 54-67 (F 165-181)
Nonionella stella–Elphidium magellanicum assemblage
S 8.3, N 218, H(S) 1.38.
Main species (> 18 per cent respectively)
Elphidium magellanicum
Protelphidium tuberculatum
Nonionella stellata Cushman and Moyer

High-content and common species:
Buccella frigida
Ammonia beccarii vars.
Cribrononion incertum
Quinqueloculina sp.
etc.
Showing shallow-sea environment with water depth of 5-20 m and low water temperature.

Layer 68-75 (F 182-199):
Nonionella stella--Ammonia ketienziensis assemblage
S 12.9, N 924, H(S) 1.57
Main species (80.4 per cent for all the next 4 species):
Protelphidium tuberculatum
Nonionella stella
Ammonia ketienziensis
Elphidium magellanicum

High-content and common species:
Buccella frigida
Stainfofthia sp.
Gaudryina sp.
Globocassidulina spp.
Lagena spp.
Fissiurina spp.
etc.
Showing shallow sea environment with water depth about 50 m and low water temperature.

Layer 76-80 (F 200-203):
Ammonia beccarii vars. Elphidium magellanicum assemblage
S 17.8, N 3143, H(S) 1.64
Dominant species:
Ammonia beccarii vars. (43.9 per cent)

High-content and common species:
Cribrononion incertum
Protelphidium tuberculatum
Elphidium magellanicum
E. advenum
Brizalina striatula
etc.
Showing inter-subtidal environment.

Layer 81-87 (F 204-213):
Protelphidium tuberculatum assemblage
S 12.7, N 2007, H(S) 1.34
Dominant species:
Protelphidium tuberculatum

High-content and common species:
Elphidium magellanicum
Cribrononion incertum
Fissurina ssp.
Lagena spp.
Globocassidulina subglobosa
Epistominella naraensis (Kuwano)
Buliminella elegantissima (d'orbigny)
etc.
Showing shallow sea environment with water depth > 20 m, but the water depth of its upper part become more shallow to < 20 m.

Layer 112-115 (F 215-227):
Ammonia beccarii vars. *Elphidium magellanicum* assemblage
S 7.8, N 536, H(S) < 1.5
Dominant species:
Ammonia beccarii vars.

High-content and common species:
Elphidium magellanicum
Cribrononion incertum
Protelphidium tuberculatum
P. glabrum
Buccella frigida
etc.
Showing inter-subtidal environment.

Layer 112-115 (F 228-230):
Ammonia beccarii vars. assemblage
S 7, 1, 3; N 998, 1, 9
Dominant species:
Ammonia beccarii vars.

Other species:
Asterorotalia subtrispinosa (Ishizaki)
Protelphidium glabrum
Elphidium hispidulum (Cushman)
etc.
Showing supratidal-lagoon environment.

Layer 127-133 (F 242-244):
Protelphidium tuberculata–Buccella frigida assemblage
S 7.6, N 603, H(S) 1.20
Dominant species:
Buccella frigida
Protelphidium tuberculatum

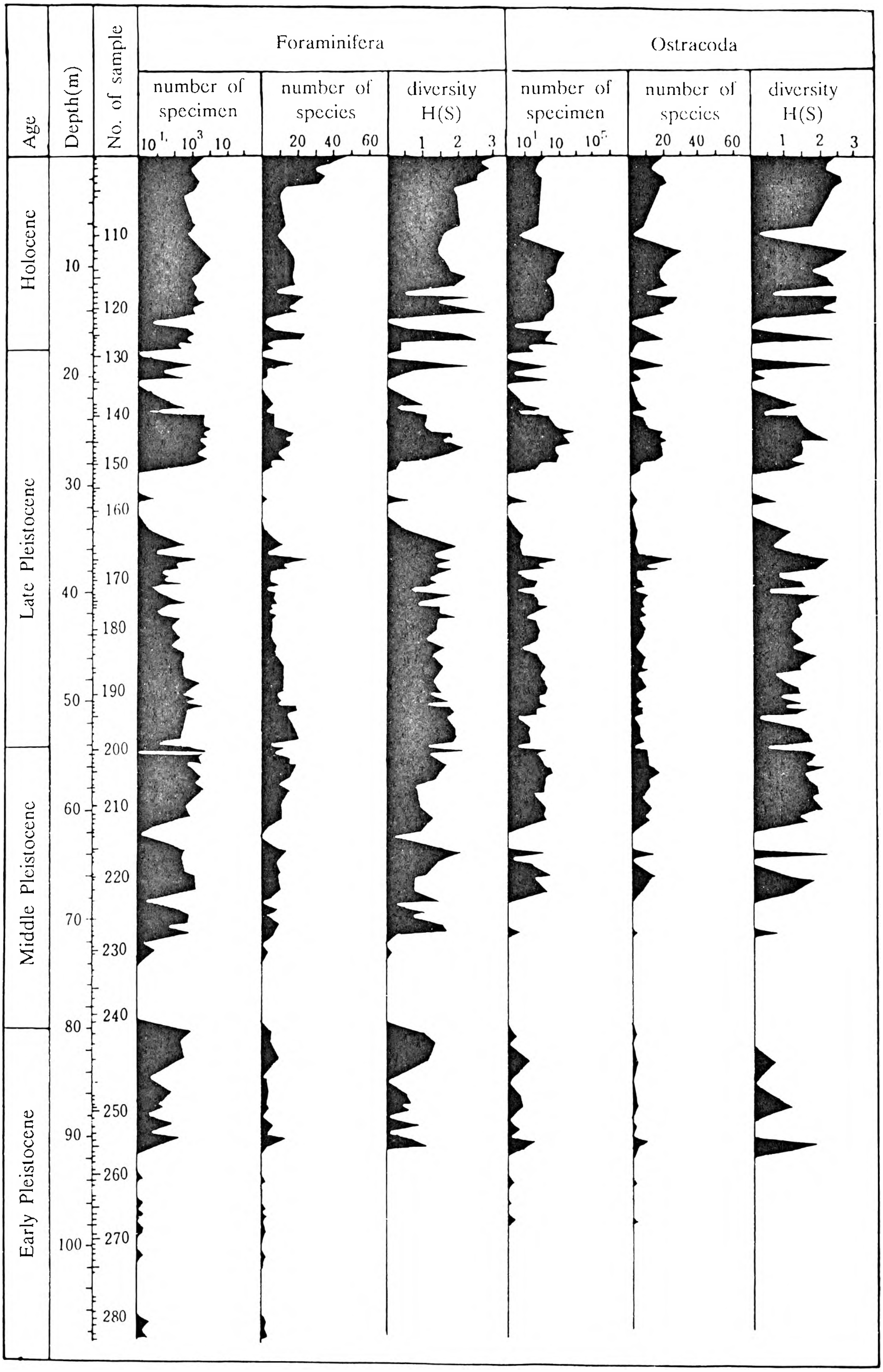


Figure 4. Diversities and abundances of Formaminifera and Ostracoda in core QC_2

Ammonia beccarii vars.

High-content species:
Elphidium magellanicum
Cribrononion incertum
Ammonia limbatobeccarii (Mclean)
etc.
Showing shallow sea (5-20 m deep) to inter-subtidal environment.

Layer 134-160 (F 245-256):
Ammonia beccarii vars. assemblage
S 3.5, N 43.
Dominant species:
Ammonia beccarii vars.

Common species:
Elphidium advenum
Protelphidium glabrum
Asterorotalia subtrispinosa
etc.
Showing supratidal-lagoon environment.

Layer 198-205 (F 281-283):
S 1-2, N 1-4
Ammonia beccarii vars.
Elphidium advenum
etc.
Showing supratidal environment.

Ostracoda assemblages (Figure 5)

Layer 1 and 2 (Sample No. F 101-105):
Munseyella japonica–Amphileberis gibbera assemblage
S 16.8, N 88, H(S) 2.38
Dominant species:
Amphileberis gibbera Guan
Munseyella japonica (Hanai)

High-content and common species:
Hirsutocythere? hanaii Ishizaki
Cytheropteron miurese Hanai
C. sawanense Hanai
Argilloecia hanaii Ishizaki
Bicornucythere bisanensis (Okubo)
Ambocythere reticulata Jiang et Q.J. Wu
Krithe producta Brady
etc.
Showing shallow-sea environment with water depth about 50 m and normal salinity.

Layer 3-12 (F 106-116):
Neomonoceratina chenae assemblage
Except sample F 107 no Ostracoda was found, the other samples show S 18.5 and N 439
Main species:
Neomonoceratina chenae Zhao et Whatley
Sinocytheridea impressa (Brady)

Common species:
Sinocythere sinensis Hou
Cushmanidea subjaponica Hanai
Bicornucythere bisanensis
Echinocythereis bradyformis Ishizaki
etc.
Showing a shallow-sea environment with a water depth of 5-20 m. Its upper and lower parts show closely to an inter-subtidal environment.

Layer 13 (117):
Sinocytheridea impressa assemblage
S 4, N 396
Sinocytheridea impressa (99.2 per cent)
Neomonoceratina chenae etc.
Showing a salty marsh environment.

Layer 14-16 (F 118-121):
Neomonoceratina chenae assemblage
S 20.5, N 335.8, H(S) 2.43.
Main species:
Neomonoceratina chenae
Sinocytheridea impressa

Common species:
Sinocythere sinensis
Cushmanidea triangulata Hou
Ponocythere littoralis Zhao
Leguminocythereis coronaris Ho
etc.
Showing shallow-sea environment with a water depth of 5-20 m.

Layer 17-26 (F 122-129):
The upper and lower parts (Layer 17-20 and 23-26): Except sample F 123 containing no Ostracoda, the other samples belong to *Sinocytheridea impressa* assemblage (F 122-124, F 127-129):
S 1-3, N 9-561, H(S) < 0.94
Sinocytheridea impressa (90.4 per cent)
Neomonoceratina chenae etc.
F 124 containing few valves of fresh-water species *Ilyocypris bradyi* etc.
Showing salty marsh environment.

The middle part (Layer 21-22, F 125-126) is of the *Sinocytheridea impressa* assemblage too. But there are differences as follows:
S 19, 18; N 185, 104; H(S) 2.23, 2.28
Sinocytheridea impressa (31.5 per cent)
Neomonoceratina chenae
Echinocythereis bradyi etc.
Showing inter-subtidal environment.

Layer 29 (F 132):
Sinocytheridea impressa–Neomonoceratina chenae assemblage
S 17, N 136, H(S) 2.21

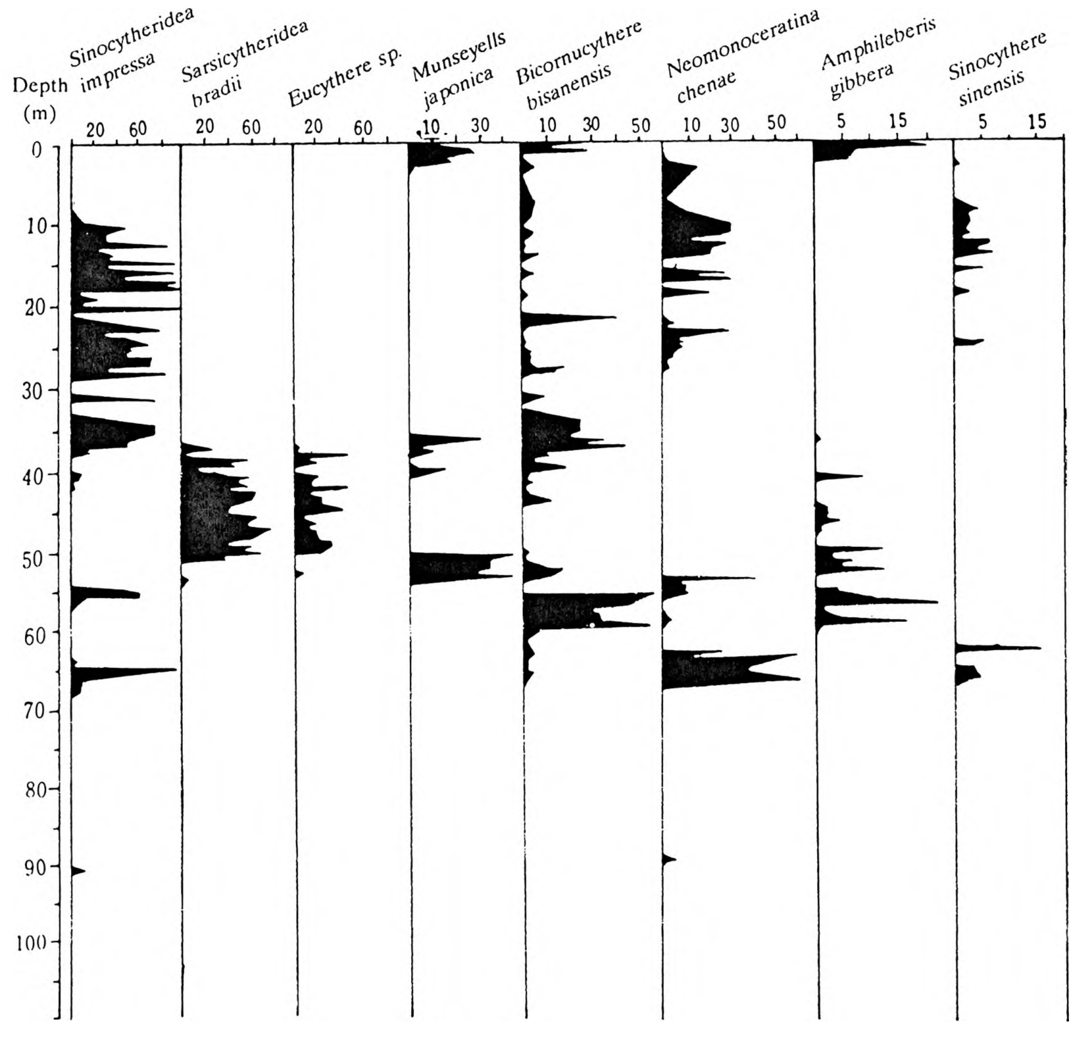


Figure 5. Content of main species of Ostracoda in core QC_2

Dominant species:

Sinocytheridea impressa

Neomonoceratina chenae

High-content species:

Loxoconcha ocellata Ho

Pontocythere spp.

Sinocythere sinensis

etc.

Showing inter-subtidal environment.

Layer 31 (F 134):

Sinocytheridea impressa assemblage

S 5, N 162

Dominated by *Sinocytheridea impressa* (97.5 per cent).

Few valves of *Neomonoceratina chenae* and *Ilyocypris bradyi*.

Showing salty marsh environment.

Layer 35-42 (F 137-149):

Sinocytheridea impressa–Neomonoceratina chenae assemblage

Except F 139 containing no ostracoda, the other samples:

S 13.4, N 1097, H(S) 1.25

Dominant species:

Sinocytheridea impressa (62.3 per cent)

High-content and common species:

Neomonoceratina chenae

Echinocythereis bradyformis

Echinocythereis bradyi Ishizaki

Neopellucistoma inflatum Ikeya et Hanai

Sinocythere retidulata Chen

Pontocythere littoralis Zhao

P. spatiosus Hou

Perissocytheridea trapeziformis Hou et Chen

Loxoconcha ocellata

Leptocythere ventriclivosa Chen

etc.

Showing inter-subtidal environment.

Layer 43-44 (F 150,151):

Sinocythereidea impressa assemblage

S 4, 5; N 47, 75

Dominant species:

Sinocytheridea impressa (73.8 per cent)

Other species:

Loxoconcha ocellata
Bicornucythere bisanensis
etc.
Showing salty marsh environment.

Layer 47 (F 158):
S 3, N 10
Sinocytheridea impressa
Echinocythereis bradyformis
Bicornucythere bisanensis
Showing supratidal environment.

Layer 50-53 (F 162-164):
Sinocytheridea impressa–Neomonoceratina chenae assemblage
S 2-4, N 4-6
Sinocytheridea impressa
Neomonoceratina chenae.
etc.
Showing inter-subtidal environment.

Layer 54-67 (F 165-181):
Sarsicytheridea bradii–Neomonoceratina chenae assemblage
S 6.7, N 59.5, H(S) 1.31

Dominant species:

Sarsicytheridea bradii (Norman)
Eucytherl sp.

High-content species:

Sinocytheridea impressa
Bicornucythere bisanensis
Neomonoceratina chenae
Trachyleberis sp.
etc.

Showing shallow sea environment with water depth of 5-20 m and low water temperature.

Layer 68-75 (F 182-199):
Sarsicytheridea bradii–Amphileberis gibbera assemolage
S 4.9, N 61, H(S) 1.10

Main species (> 70 per cent for all the next 4 species):

Sarsicytheridea bradii
Eucytherl sp.
Munseyella japonica
Amphileberis gibbera

Common species:

Bicornucythere bisanensis
Leguminocythereis sp.
Trachyleberis sp.
Cytheromorpha acupunctata (Brady)
etc.

Showing shallow sea environment with water depth about 50 m and low water temperature.

Layer 76-80 (F 200-203):
Sinocytheridea impressa–Neomonoceratina chenae assemblage
S 8.2, N 90, H(S) 1.60

Dominant species

Sinocytheridea impressa (55.5 per cent)

High-content species:

Neomonoceratina chenal
Cushmanidea subjaponica Hanai

Other species:

Albileberis sinesis Hou
Propontocypris euryhalina Zhao
Tanella opima Chen
Candoniella mirabilis
Ilyocypris gibba
etc.
Showing inter-subtidal environment

Layer 81-87 (F 204-213):
Bicornucythere bisanensis assemblage
S 9.4, N 134, H(S) 1.67

Dominant species:

Bicornucythere bisanensis

High-content species:

Cytheromorpha acupunctata
Trachyleberis sp.
Amphileberis gibbera
Nipponocythere obesa (Hu)
Acanthocythereis mutsuensis Ishizaki
etc.

Showing shallow-sea environment with water depth > 20 m, but the water depth of its upper part becomes more shallow to < 20 m.

Layer 112-115 (F 215-227):
Sinocytheridea impressa--Neomonoceratina chenae assemblage. No Ostracoda were found in samples of F 215, F 217, F 222--F 226. For the other six samples:
S 1-13, N 2-216

Main species:

Neomonoceratina chenae
Sinocytheridea impressa

Common species:

Albileberis sinensis Hou
Sinocythere sinensis
etc.
F 218 and F 219 containing few valves of fresh water species *Ilyocypris* sp. and *limnocythere* sp.
Showing inter-subtidal environment.

Layer 127-133 (F 242-F 244):
S 1-3, N 2-11
Echinocythereis bradyi
Loxoconcha tarda Guan
Ilyocypris bradyi

etc.

Showing shallow-sea (5-20 m deep) to inter-subtidal environment.

Layer 134-160 (F 245-F 256):
Except F 245, F 246, F 251 and F 253 containing no Ostracoda, the other 8 samples having:
S 1-8, N 1-26
Sinocytheridea impressa
Cushmanidea subjaponica Hanai
Loxoconcha ocellata
Ilyocypris bradyi
etc.
Showing supratidal-lagoon environment.

Layer 161-198 (F 257-F 280):
Only one valve of Ostracoda was found

Mollusca

Layer 1 (P011, 012).
Corbicula fluminea (Muller)
Cycladicama cumingii
Ostrea plicata Gmelin

Layer 2 (P013):
Mactra chinensis Philippi
Saecella cuspidata
Thyasira sp.
Venoridae
Neverita ampla (Philippi)

Layer 3 (P014):
Aloidis laevis
Corbicula fluminea

Layer 12 (P015):
Corbicula fluminea

Layer 16 (P016):
Nassarius variciferus (A. Adams)

Layer 18 (P017, 018):
Corbicula fluminea
Parafossarulus sp.

Layer 20 (P019):
Corbicula fluminea

Layer 22 (P020)
Ostrea plicatula

Layer 23 (P021)
Corbicula fluminea
Alocinma sp.
Neverita ampla
Parafossarulus sp.

Layer 28 (P023)
Corbicula fluminea

Layer 31 (P024):
Corbicula fluminea

Layer 36 (P025)
Corbicula fluminea

Layer 38 (P026, 027)
Lutraria sp.
Aloidis laevis
Corbicula fluminea

Layer 40 (P028)
Arca subcrenata Lischke
Alocinma sp.

Layer 41 (P029)
Alocinma sp.

Layer 42 (P030, 031)
Alocima sp.

Layer 43 (P032, 033)
Aloidis sp.
Alocinma sp.
Retusa minima Yamakawa

Layer 54 (P034)
Parafossarulus sp.

Layer 60 (P035):
Parafossarulus sp.

Layer 73 (P037):
Neverita ampla
Turritella sp.

Layer 75 (P038):
Aloidis laevis
A. sp.
Arca boucar Jousseaume
Chlamys farreri (Jones & Preston)
Diplodonta usta
Dosinia gibba
Mactra chinensis philippi
Macoma sp.
Ostrea plicatula

Layer 101 (P040):
Aloidis laevis
Arca sp.

Layer 138 (P041):
Lymnaea sp.
Turritella sp.
Valvata sp.

Layer 140 (P042):
Nassarius sp.

Sporo-pollen assemblages (Figure 6)

Zone x (0-17.O m)

Subzone Xc (0-2.6 m): High-content of *Pinus*, secondly *Castanopsis/Catanea, Quercus and Ulmus* etc.. Herbs mainly *Artemisia* (30 per cent), then Gramineae, Chenopodiaceae, Cyperaceae and Compositae etc.. Ferns more Polypodiaceae (10 per cent), then *Microlepia, Selaginella, Hicriopteris* and *Lycopodium*. The vegetation and climate similar to present.

Subzone Xb (2.6-14.5): More *Quercus* (15-20 per cent), then Pinus, *Ulmus, Castanopsis/Castanea, Betula, Juglans, Fagus* and *Carpinus* etc.. Herbs mainly *Artemisia* (40-50 per cent), then Gramineae, Chenopodiaceae and Cyperaceae etc.. A little of *Typha* and Polypodiaceae. Indicating a climatic optimum period.

Subzone Xa (14.5-17.0 m): Trees mainly *Quercus* (12 per cent), and *Ulmus, Castanopsis/Castanea and Betula* etc. under 16 m, but trees decreasing shaply above 16 m. Herbs mainly *Artemisia* (30-40 per cent), and secondly Gramineae, Chenopodiaceae, Cypreceae, Compositae etc. A little of *Typha* and Polypodiaceae. Indicating the climate changes from warm to cold.

Zone IX (17.0-36.0 m)

Subzone IXc (17.0-19.0 m): Poor of pollen and spore. A little pollen of herb only. Indicating arid-cold climate.

Subzone IXb (19.0-28.0 m): Dominated by herbs, and a little tree pollen as *Ulmus, Quercus, Pinus, Betula and Corylus* etc. Indicating cold climate.

Subzone IXa (28.0-36.0 m): Rare of tree pollen. Herbs mainly *Artemisia* (25-79 per cent), secondly Chenopodiaceae, Cypraceae, Compositae, Craciferae and Umbelliferae etc. Indicating cold climate of the last glaciation.

Zone VIII (36.0-54.3 m)

Subzone VIIIb (36.0-45.5 m): *Pinus* (10 per cent), and *Quercus, Betula, Corylus, Carpinus, Pterocarya and Fagus* etc.. Herbs mainly *Artemisia* (30-40 per cent), and Chenopodiaceae, Compositae, Graminaea, Umbelliferae and Cypraceae etc.. *Typha* and Polypodiaceae of Hydrophyte. Indicating warm climate, but the temperature a little bit lower than subzone VIIIa.

Subzone VIIIa (45.0-54.3 m): In trees mainly *Quercus* (10 per cent), secondly *Pinus, Castanopsis/Castanea, Fagus,* Rosaceae, *Betula, Corylus* and *Ephedra* etc.. Herbs decreasing in *Artemisia* (20-30 per cent), Gramineae, Chonopodiaceae and Cypraceae. A little of *Typha*, Polypodiaceae and *Sphagnum* etc.. Indicating warm climate.

Zone VII (54.3-61.0 m)

Only a little of *Pinus* and *Quercus* in tree pollen. Dominated by herbs, mainly *Artemisia* (50 per cent, the maximum up to 64 per cent) and Chenopodiaceae (20 per cent, the max. up to 48 per cent), and Gramineae and Cypraceae. A little of *Typha*, Polypodiaceae and *Sphagnum*(?) etc.. Indicating a very cold and arid climate. The annual average temperature was 10°-15°C lower than now.

Zone VI (61.0-63.0 m)

Distinguished from the adjacent zones by containing more *Quercus* (18 per cent) and *Castanopsis/castenea* (12 per cent). Other trees *Pinus, Carpinus, Betula, Corylus, Ephedra* etc.. More herbs, mainly *Artemisia* (20 per cent), Gramineae and Chenopodiceae. A little of *Typha*, indicating the climate was warm again.

Zone V (63.0-67.2 m)

In trees, a little of *Pinus, Betula, Alnus, Quercus* etc. only. *Artemisia*, Cypraceae, Chenopodiaceae, Gramineae and Compositae in herbs. Hydrophyte mainly *Typha* (30 per cent) and a little Polypodiaceae. Indicating the climate was cold and wet.

Zone IV (67.2-75.0 m)

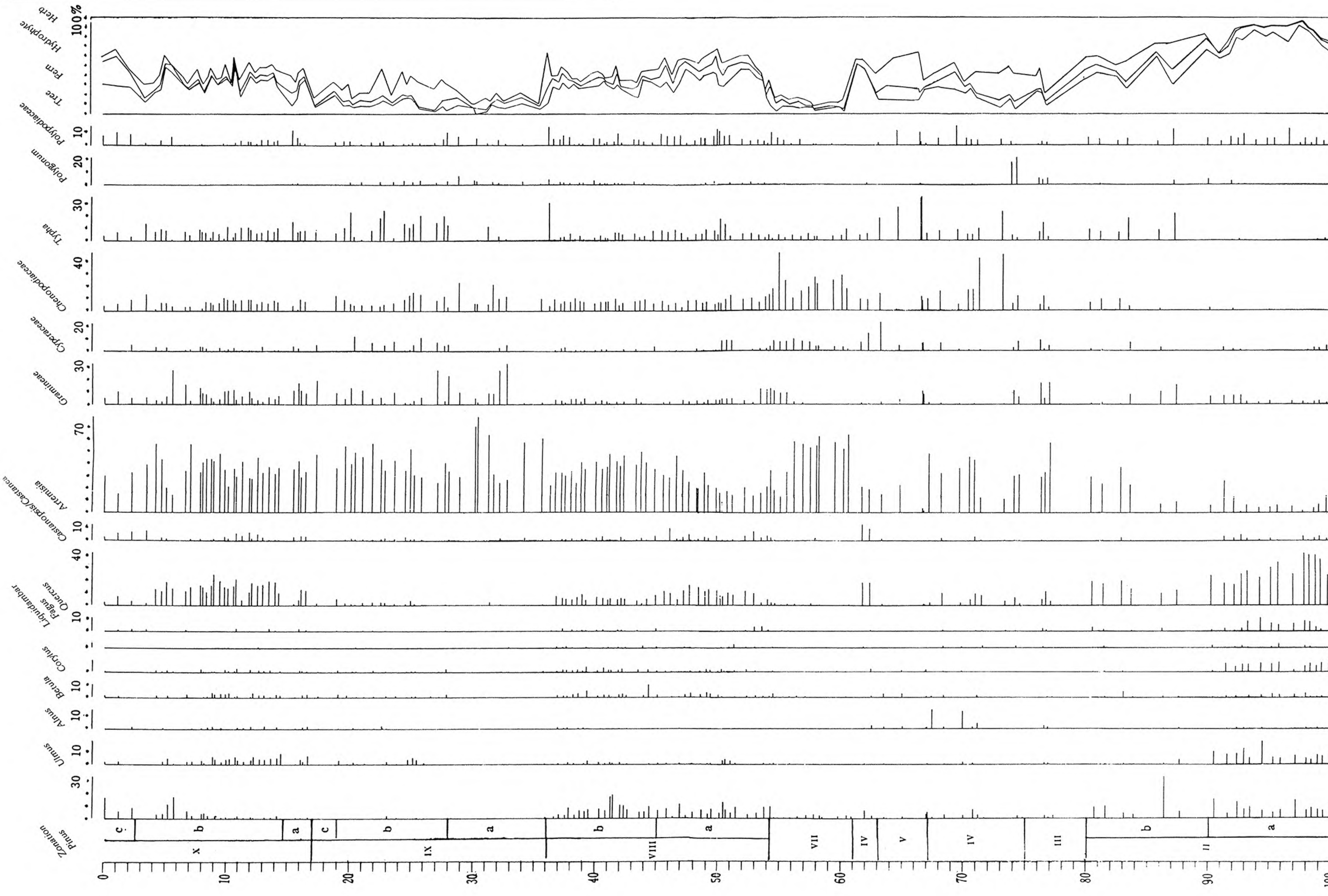
In trees, *Alnus* up to 15 per cent, secondly *Quercus* and *Pinus*. Plenty of *Artemisia* (40 per cent) in herbs, secondly Chenopodiaceae and Cypraceae. And some *Typha* and Polypodiaceae. Indicating the climate was turning for the better.

Zone III (75.0-80.0 m)

Pollen and spore not too many. In trees, only a little of *Quercus, Pinus* and *Alnus*. Dominated by herbs, mainly *Artemisia* (30-50 per cent), Gramineae, Chenoposiaceae and Cypraceae. A little of *Typhy* and *Polygonum*. Indicating a cool climate.

Zone II (80.0-101.0 m)

Subzone IIb (80.0-90.0 m): 3 m of the lowest part no pollen or spore. The others similar to IIa, but the content of sporopollen decreased. Herbs increased, mainly *Artemisia* (25-30 per cent), secondly Gramineae, Chenopodiaceae and Cypraceae. More Hydrophyte of *Typha* and a little Polypodiaceae. Indicating the temperature was higher than now, but a little bit cooler than IIa.



Figue 6. Pollen diagram of core QC_2

Subzone IIa (90.0-101.0 m): Dominated absolutely by tree pollen, containing a lot of *Quercus* (30 per cent maximum up to 43 per cent), secondly *Pinus, Ulmus, Fagus, Corylus, Carpinus, Castanopsis/Castanea* and *Liquidambar* etc.. Poor in herbs. A little of Polypodiaceae. Indicating a subtropic climate, the annual average temperature 2°-3°C was higher than now, similar to the climate in the middle-lower reaches of Yangtze River now.

Zone I (101.0-108.80 m)

Poor in pollen and spore.

4. Chronology

Carbon-14 dating

Sample no.	Depth (m)	Layer no.	Material	Age (a)
^{14}C-029	15.02-15.12	19	Clay	9,910 + 100
^{14}C-030	17.23-17.40	25	Clay	10,340 + 110
^{14}C-032	28.26	43	Clay	28,500 + 820

Palaeomagnetic units

Chron	Polarity	Events or Excursions: Depth (m)	Sample no.	Inclination		Age
(Om)		4.03	MQC$_2$001	−21.9		
		4.13	MQC$_2$002	−23.7		
		4.23	MQC3003	−46.3		
		8.31	MQC2006	−40.4		
		8.45	MQC2007	−4.2		
		8.59	MQC2008	−28.3		
		16.85	MQC2066	−11.4		
		16.96	MQC2067	−14.9		
		17.02	MQC2068	−45.6		
		26.47	MQC2123	−7.3		
		26.64	MQC2124	−15.1		
		31.10	MQC2165	−43.9		
Brunhes	Normal	31.18	MQC2166	−70.7		
		38.20	MQC2198	−30.7		
		38.35	MQC2199	−40.6		
		46.51	MQC2262	−24.8		
		46.66	MQC2263	−46.3		
		49.60	MQC2289	−57.0		
		49.77	MQC2291	−34.6		
		49.94	MQC2293	−5.3		
		50.17	MQC2296	−56.5		
		50.23	MQC2297	−33.4		
		52.64	MQC2318	−57.1		
		52.77	MQC2319	−87.5		
		53.01	MQC2321	−40.4		
		53.13	MQC2322	−48.5		
		53.26	MQC2323	−61.3		
		53.33	MQC2324	−31.4		
		53.46	MQC2325	−50.1		
(79.95 m)						0.73 Ma
(79.95 m)						
		84.04	MQC2490	17.6		
		84.23	MQC2491	10.8		
		84.33	MQC2492	10.8		
		89.80	MQC2508	43.6		
		89.90	MQC2509	46.0		
		90.00	MQC2510	46.8		0.90 Ma
		90.06	MQC2511	23.5		
Reversal	Matuyama	90.20	MQC2512	14.5	Jaramillo	
		90.63	MQC2513	12.4		0.97 Ma
		91.25	MQC2516	37.7		
		91.35	MQC2517	11.6		
		106.78	MQC2593	29.6		
		107.68	MQC2595	49.9	Cilsa	1.67Ma-1.69Ma
(108.83 m)		108.23	MQC2598	27.2	Olduvaii	1.70Ma–

Stable isotopic analysis

It is well known that successful achievements in stable isotopic analysis were made in oceans by using planktonic foraminifera. Because of the rarity in planktonic forams in shallow shelf seas, research on stable isotopic analysis was made by using mainly benthic forams sampled from nearshore sea areas influenced by fresh water. Some available results are available from core QC_2. Now, the upper half of the 18_O^{16} curve of core QC_2 is presented here for reference (Figure 7).

References

Zheng Guangying (the editor) et al., 1989, *Quaternary Stratotype Stratigraphic Correlation of South Huanghai Sea*. Science Press.

Notes

1. The lithological characters of this paper's part 2 are from the description by Prof. Yang Zigeng.

2. Part 3, Biological units, is from Chapter 3 and 5 of the above-mentioned book. Chapter 3 is written by Lin Hemao and Zhu Xionghua and Chapter 5 by Heng Ping, Li Xu and Yang Meifang.

3. Part 4, Chronological units, is from Chapter 4 of the book written by Zhou Moqing, Ge Zongshi and Sun Jiashi, and Chapter 6 is by Sun Jiashi.

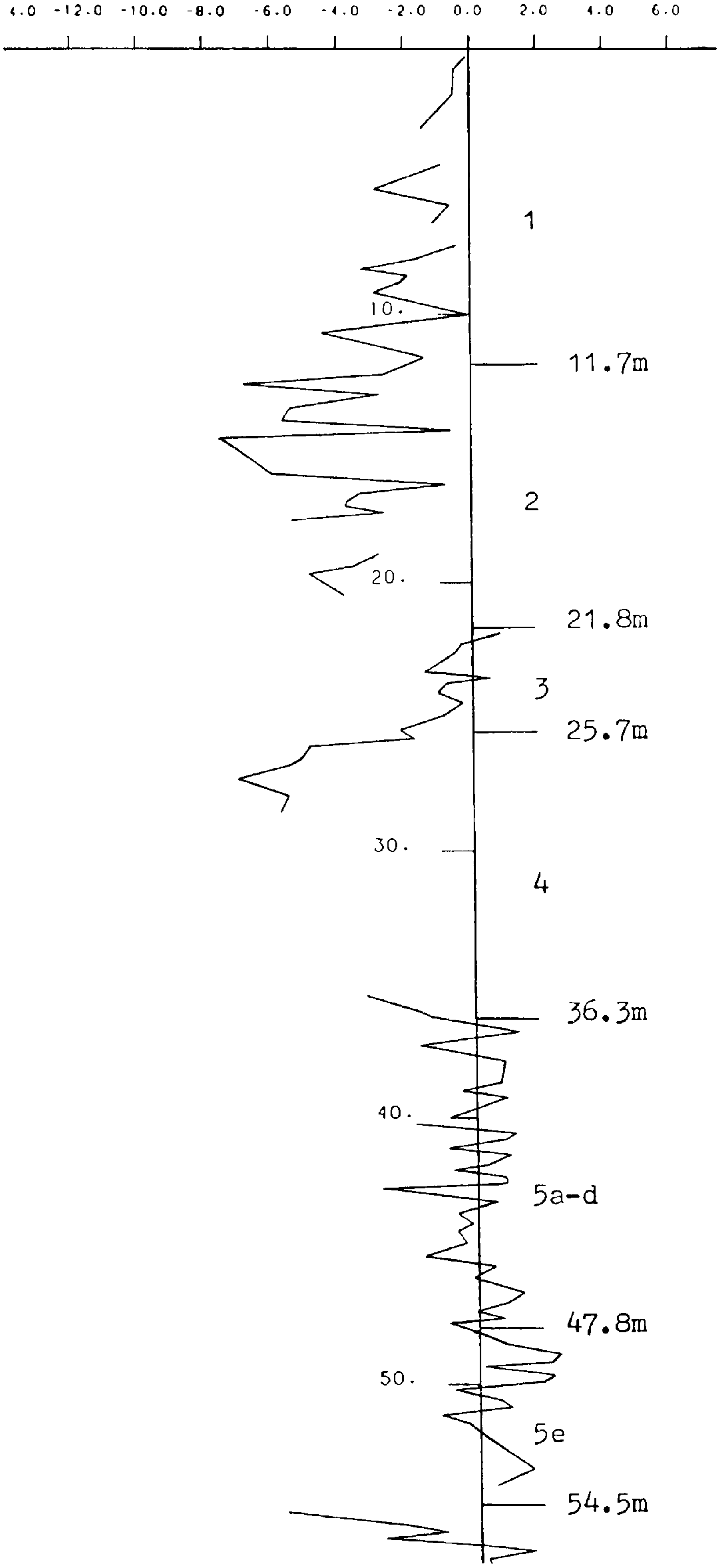


Figure 7. $\delta^{18}O^{16}$ curve of core QC_2

PROPOSED STRATOTYPE SECTION: MIDDLE PLEISTOCENE TERRESTRIAL STRATOTYPE, CAVE DEPOSITS OF PEKING MAN IN THE ZHOUKOUDIAN AREA

by

Yang Zigeng[1]

1. Introduction

60 years have passed since Prof. Pei, W.C. and his colleagues first found a complete skull of Peking Man at Zhoukoudian on 2 of Dec., 1929, only two years later than the beginning of systematic excavation for the Peking Man site in this area in 1927. The Peking Man -site at Zhoukoudian serves as a treasure-house of human fossils, and also provides standard strata of the middle Pleistocene due to the rich mammal faunas. Chronologic study in recent years has fitted the strata to the establishment of stratotype.

2. Location of Section

The Peking Man Cave (Locality 1) of Zhoukoudian lies at the foot of the Yan Shan Mountain (39.6°N, 115.9°E), about 40 km to the southwest of Beijing proper, where there is a hill of Ordovician limestones, named Longgushan and with its top elevation of 143.38 m. On the west side of the hill, flows the Zhoukouhe stream, 85.6 m above sealevel at the bottom. The vertical-sack-shaped cave is just located on the west bank of the stream, and at the northeast side of the hill. Layer 17* (the cave bottom) reads an elevation of 81.7 m above sealevel, and the top layers (layers 1 and 2) are 128.99 m high (Figure 1). The middle and early Pleistocene layers of the Zhoukoudian cave consist of the following 3 component sections: 1) component section 1 represents a test well dug near the south wall of the Peking Man Cave in 1979. The well mouth, 91.70 m above sealevel, is located at the intersection point of the intersecting line of columns E and F with the central line of rank 2 in the coordinate worked out for the excavation. The well is 10 m deep, revealing layers 14-17 of the cave; 2) component section 2 shows the west wall of the Peking Man Cave (Figure 2). This section, situated 1 m west of the boundary line of columns A and B, is the most complete in strata preservation at present and keeps layers 3-10. Another test well that was dug right close to the west wall exposes layers 10-13. Right next to the west wall section are the southern fissure and "Locus H", which open to us the accumulated materials in layers 1-4. Zhoukoudian Formation represents a part of middle Pleistocene accumulation (0.70-0.23 Ma B.P.) in the Peking Man Cave; 3) component section 3, also named "New Cave section", indicates accumulation later than 0.23 Ma B.P. This section comes from a small horizontal corroded cave on the east slope of the Longgushan hill, about 70 m away from the Peking Man Cave. The mouth of the small cave gives an elevation of 117 m above sealevel.

3. Lithostratic Units (Figure 3)

Accumulational "New Cave" layers of middle Pleistocene (Gu, Y.M. 1978). Total thickness of about 2.2 m.

(1) Travertine layer. 0-0.5 m.
(2) Yellow sandy clay and breccia layer. Unce-mented. About 1 m.
(3) Calcareous-cemented yellow sandy clay and limestone breccia, with 3-4 thin inter-sublayers of travertine and ashes. Nearly 1 m.
(4) Ash layer. Banding 0.12-0.9 m.

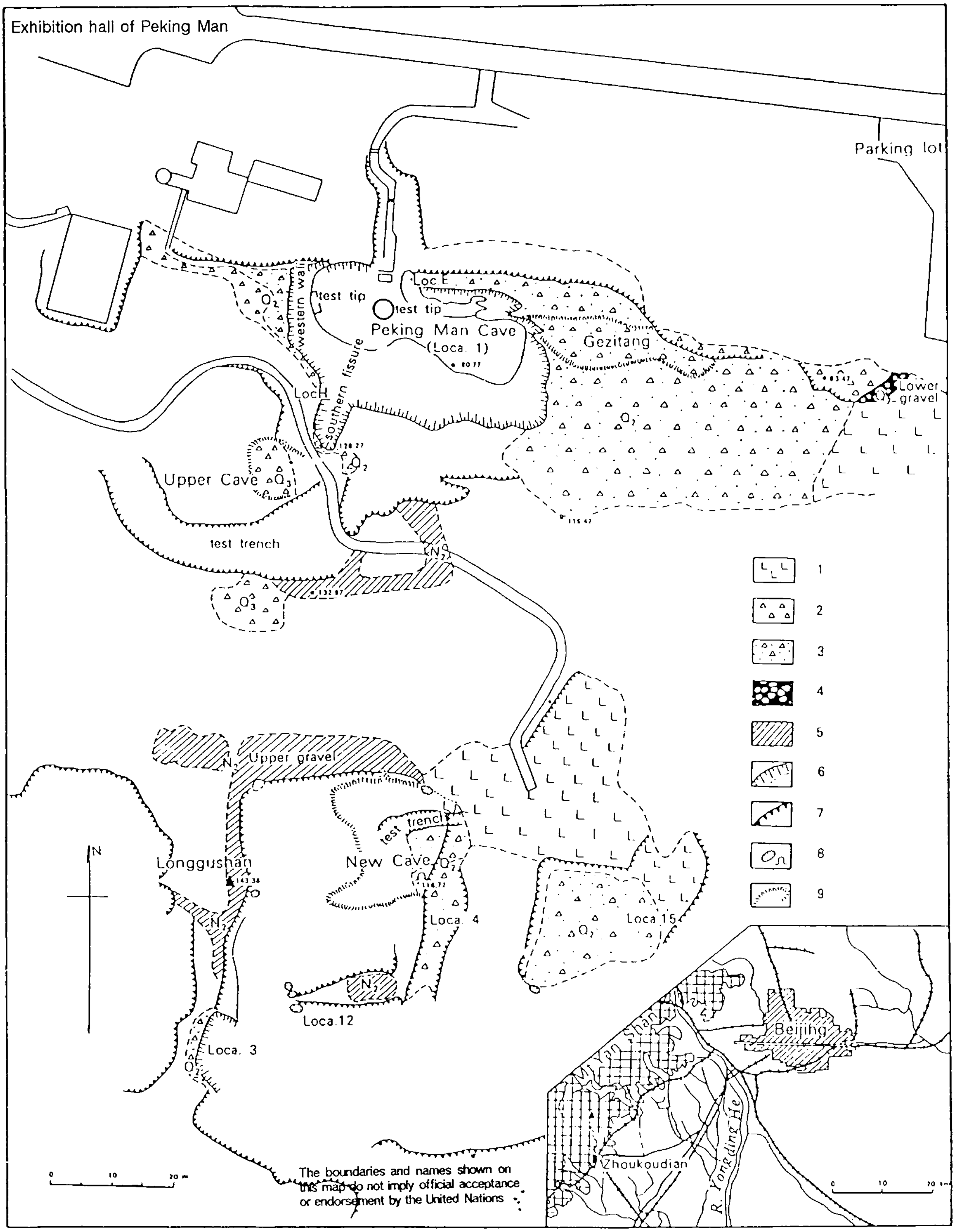
Zhoukoudian Formation of middle Pleistocene (Q_2zh) (Yang Zigeng et al. 1985), with an added-up thickness of 35.43 m.

(1)-(2) Silty breccia intercalated with travertine layers. More exactly speaking, brown-yellowish silty breccia, brown-reddish clayey silty breccia and calcareous cement are alternated with fine-crystalline-grained travertine. There are 5 travertine sublayers, generally 3-5 cm thick each, but the thickest one up to 31 cm. The surface of limestone breccia in the silt is shallowly weathered and some secondary calcite attached to it forms a thin encrustation. Also calcareous nodules can be seen inlaid in the silt. The two layers are 1.70 m.

(3) Calareous-cemented breccia layer with huge limestone blocks contained in it. In the west wall section, some blocks can be as large as 1 m in diameter. The breccias weather shallowly and cement hard, and, in Locus H, are filled with sandy silt. Brown-yellowish clayey silt lenses can be found locally. 3.60 m.

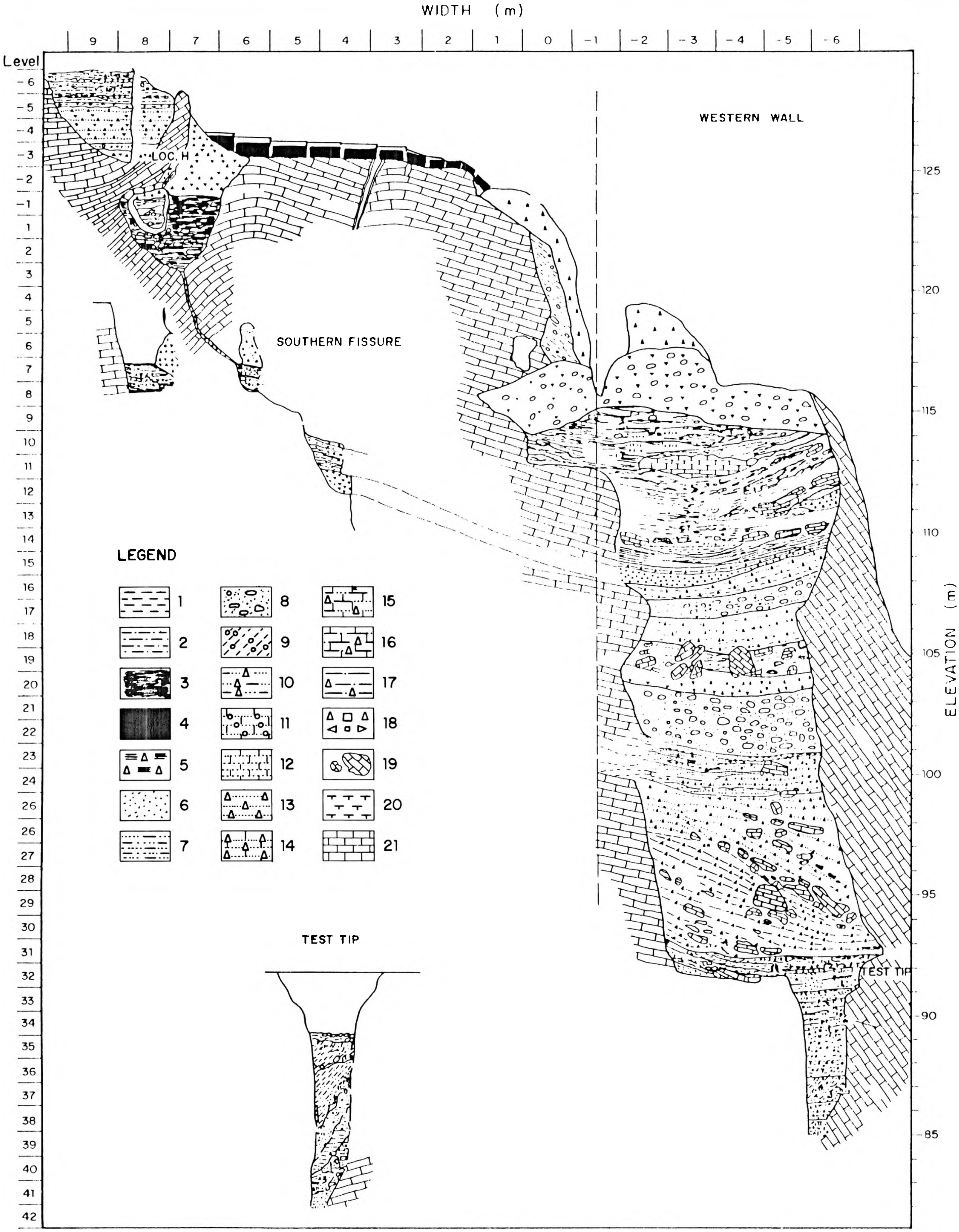
[1] China National Center for Quaternary Geology (CNCQ).

* According to descending order of excavation.



1 – artificial accumulate; 2 – breccia; 3 – breccia with sand; 4 – gravel; 5 – sandy gravel of Pliocene; 6 – cave wall; 7 – limestone scarp; 8 – karst funnel and cave inlet; 9 – cavern.

Figure 1. The location of Zhoukoudian and a sketch map showing the distribution of Plio-Pleistocene deposits at Peking Man site



1 – clay; 2 – clayey silt; 3 – ash; 4 – dark grey ash; 5 – ash with breccia; 6 – silt; 7 – thin bedded silt; 8 – coarse sand-gravel; 9 – clayey silt-gravel; 10 – clayey silt-breccia; 11 – calareous-cemented coarse sand-gravel; 12 – calareous-cemented coarse sand; 13 – silty breccia; 14 – calareous-cemented coarse sand-breccia; 15 calareous-cemented fine sand-breccia; 16 – calareous-cemented clayey silty breccia; 17 – silty clay- breccia; 18 – calareous-cemented breccia; 19 – limestone blocks; 20 – travertine; 21 – limestone; 22 – fossils; 23 – samples.

Figure 2. The profile of western wall, southern fissure, Locus H and test tip of Locality 1 of Zhoukoudian. (After Yang Zigeng et al. 1985.)

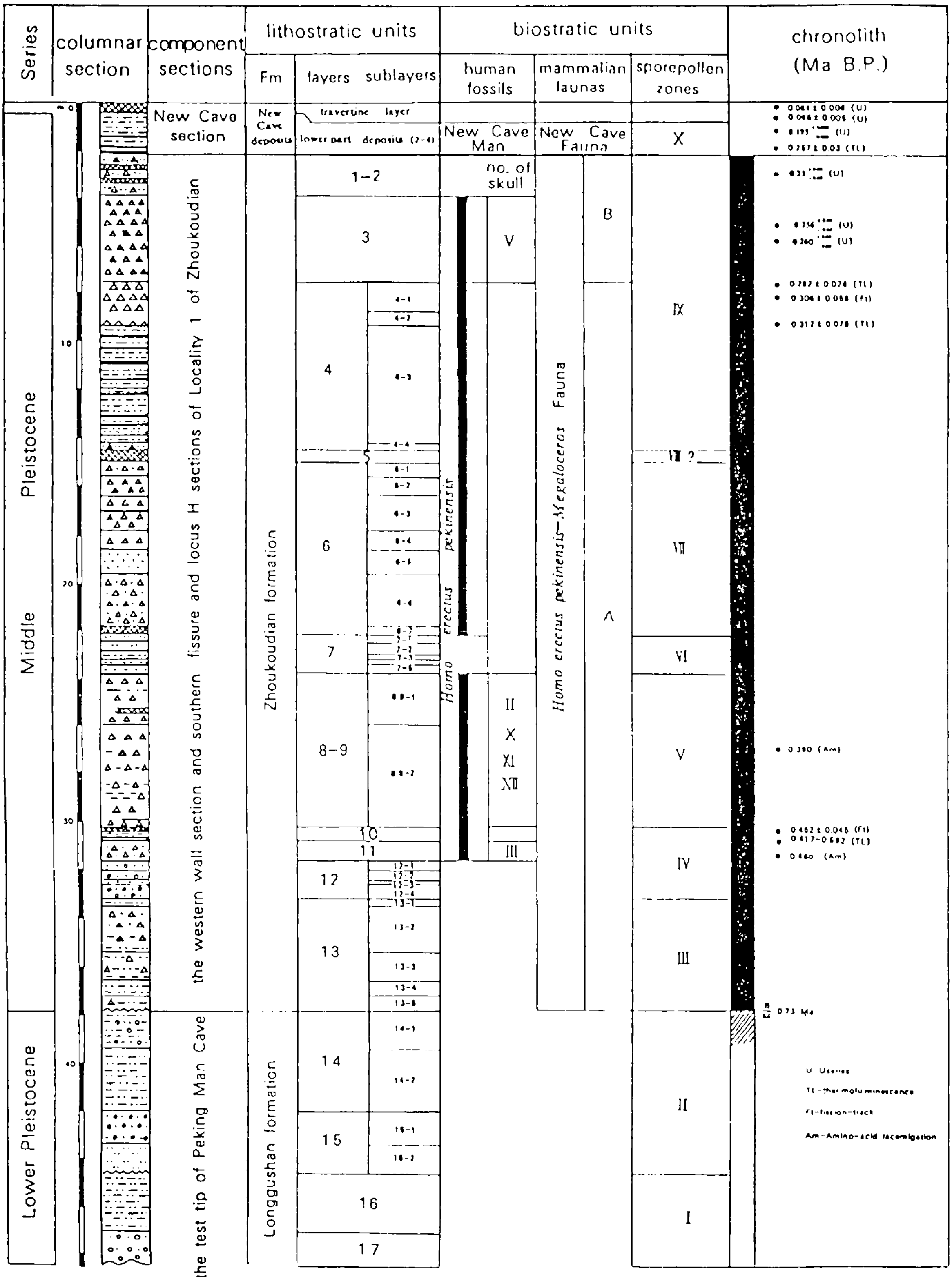


Figure 3. The Zhoukoudian Section. (The explanation is in the text.)

(4) Ash layer, subdivided into 4 sublayers, layer surface stays in the center. Several travertine microlayers exist in the ash of the southern fissure. The total thickness is 6.92 m.

(4)-1 Grey-browish breccia sublayer, intercalated with grey and brown ash bands, 4 cm and 10 cm thick respectively. The shallowly weathered limestone breccia usually has a size of 10-15 cm. 1.20 m.

(4)-2 Ash sublayer in mixed colours, made up of mostly grey-white and minor light brown, brown, brown-yellowish and dark grey ash bands, which are horizontal, loose and containing charcoal chips. At the bottom of the sublayer lie huge limestone blocks collapsed from the cave top. The ash thickness varies from 1.40 m to 0.3 m. 0.62-1.40 m.

(4)-3 Brown-reddish ash sublayer with accumulated clayey silt, containing charcoal chips and purplish-red burned soil, bones and stones. Limestone breccias can also be seen, often 20x40 cm in size and distributing in stratified or lens forms. 4.83 m.

(4)-4 Brown silty clay with small breccia. Clear bedding. 0.27 m.

(5) "Travertine layer", i.e., crystallized travertine layer with breccia and sand, with the east and south parts much thicker than their opposite counterparts. For example, the northernmost thickness of the west wall only reads 10 cm and in the middle, 45 cm, while 80 cm can be reached at the southern fissure. 0.45 m.

(6) Breccia layer, subdivided into 7 sublayers according to breccia sizes and cements, totally 7.12 m.

(6)-1 Loose breccia, 10-30 cm in size, shallowly weathered and filled with brown-reddish fine sandy silt 0.6 m.

(6)-2 Hard breccia, solidly calcareous-cemented, layer in size and filled with silt. 0.80 m.

(6)-3 Breccia sublayer with brown-reddish calcareous cements. Smaller in size and shallowly weathered. Fills in the spaces between breccia clasts are brown-reddish clayey silts with fine gravels. 1.40 m.

(6)-4 Huge breccia. Diameter can reach 1.20 m. Loosely cemented. Clayey silt filling. Brown ash accumulation of 75 cm thick and 1.2 m wide has been found among the huge blocks, similar to a "fire pond" in shape, and with bone pieces around. Inferred from the 75 cm thick compressed ashes, the apes once for a long time took this block-enclosed open space as a fixed spot to use fire with control, and also had very simple skills of building a "fire pond," 0.75-1.30 m.

(6)-5 Firmly calcareous-cemented sandy breccia in brown colour. Calcite crystals can be found in the cements. Breccia size is reatively small, usually 7-8 cm. 1.00 m.

(6)-6 Breccia sublayer. Great diameter. Shallowly weathered. Brown sandy cements. 2.30 m.

(6)-7 Travertine with limestone breccia. 0.27 m.

(7) Fine silt layer, subdivided into 5 sublayers. Total thickness of 1.53 m.

(7)-1 Banded sublayer of pink and gray-green clayey silt containing fine gravels and sporadic limestone breccia. The breccia looks flat or thin in shape. 0.23 m.

(7)-2 Gray-green fine silt with breccia. Thin travertine is distributed haphazardly in the lower part. The largest thickness of the travertine is 17 cm. 0.41 m.

(7)-3 Gray-yellowish clayey silt with limestone breccia and slacking slags. 0.49 m.

(7)-4 Breccia sublayer filled with gray-green silt. 0.20 m.

(7)-5 Gray-white silty sand with brown-reddish clay balls and limestone clasts. These clasts are 1 cm large in diameter and show weathered spots in gray-white colour. 0.20 m.

(8)-(9) Breccia layer, subdivided into two sublayers according to cement type. Their bedding dips 30° northwards. Totally 6.45 m.

(8)-(9)-1 Gray-white weathered breccia. Breccia makes up 70-80 per cent of the sublayer and are deeply weathered. Corroded marks spread widely on the surface. Pore spaces are filled by sand, gray-white medium-grained sand in the upper part and brown silty sand in the lower. At the bottom, collapsed huge limestone blocks can be found relatively concentrated. And at the top, a 10-18 cm thick ash bed is distributed uncontinuously, and intercalates 10 cm thick lens-like crystallized travertine in its southern part. Ashes are inlaid sporadically in the middle. 2.05-5.50 m.

(8)-(9)-2 Gray-white weathered breccia sublayer, with breccia about 70 per cent. More in flat form. Placed side by side along the slopes, dipping 15-20° to NNW. The breccia is a little more deeply weathered than that in the overlying sublayer and becomes graywhite powder after weathered. Secondary corrosion is rarely seen, and on the surfaces of some large breccias appear calcite network veinules and corroded hollows. Brown-reddish clayey silt fills the breccia pore spaces, and clay gathers together into lumps locally. Occasionally, scattered ashes can be found between large breccias. 0.9-4.4 m.

(10) Ash layer, of which, the brown-reddish, orange-yellow, dark brown and brown ashes contain deeply-weathered limestone clastics and phyllite fragments, and also burnt bones and burning-cracked stone artifacts, while the black ashes contain a large number of charcoal chips. The layer dips to the north, with an occurrence of $35^{o} < 10\text{-}25^{o}$. Totally 0.56-0.65 m thick. The detailed subdivision is described as follows.

(10)-1 Brown-reddish travertine with small limestone breccias. 0.07 m.

(10)-2 Red clay with calcareous clastics and charcoal chips. 0.06 m.

(10)-3 Orange-red silt with white calcareous thin pieces and black ashes. 0.06-0.1 m.

(10)-4 Brown-reddish sandy clay, calcareous micro-bed and calcareous cement sand, with phyllite fragments and black charcoal ashes. 0.06-0.20 m.

(10)-5 Red and gray-yellowish clay. 0.03-0.12 m.

(10)-6 Ash sublayer. Dark brown and thinner brown-reddish ashes, intercalated calcareous fragments, burnt bones and charcoal chips, with laminated structure. 0.07-0.15 m.

(10)-7 Weathered limestone breccia, wedging out northwards. 0.18 m.

(10)-8 Brown-reddish and gray-yellowish breccia-clay, with charcoal chips and burnt bones.

(11) Breccia layer. Gray-brown silty medium-fine sands contain limestone breccia with lens-like coarse sand. 0.80 m.

(12) Brown coarse sand containing breccia, subdivided into 4 sublayers, with a total thickness of 1.50 m.

(12)-1 Brown calcareous-cemented silty medium and coarse-grained sands, containing small gravels dominated by vein quartz and sandstone in a size of 0.2-1 cm. In the sands, there are mica flakes, clay lumps and various scouring-rounded bone fossils. 0.35 m.

(12)-2 Brown medium and coarse sands containing gravels and small breccias, with a bed of calcareous-cemented sand in between, in which large red clay balls are inlaid. The quartz gravels look about 1 cm large in size and show good rounding, and contain corroded fossils. At the bottom of the sublayer spread a thin bed of travertine. 0.50 m.

(12)-3 Brown medium coarse sands with gravels. The gravels, mostly schist and phyllite fragments and minor quartz, are very small in size, generally with a diameter of 0.2-0.5 cm. The sands are loose and with lamination. 0.15 m.

(12)-4 Brown medium and coarse gravelly sands with limestone breccias. The breccias, making up 10 per cent of sublayer, are deeply weathered, with net-veined calcite and secondary calcite microcrystals left over by corrosion on the surface. The small gravels are well rounded and sands poorly sorted. The bottom part contains a bed of white and light brown travertine, coasely crystallized. 0.50 m.

(13) Red silty clay-breccia layer, consisting of 5 sublayers, with a total thickness of 4.8 m.

(13)-1 Red-brown silty clay with breccias. The breccias lie isolated from each other in the clay. Medium-weathered. Small breccias are deeply weathered. 0.30 m.

(13)-2 Breccia sublayer. Limestone breccias are over 70 per cent and mainly in flat shape, lying down side by side. Mostly medium and minor deeply weathered. Fillings are silty medium-fine sands in the top part, and silty clays in the middle and in the lower part. Clayey silt gathers to become lumps locally. 1.90 m.

(13)-3 Red-brown clayey silt-breccia. Limestone breccias make up nearly 50 per cent content, with larger diameters in the lower part than in the upper. Mostly in flake pieces, lying side by side. Very shallowly weathered. Red-brown clayey silt fills between the breccias, with coarse sand-grave; lenses, which appear in nested forms and correspondingly in the south and north walls of the well, indicating a small E-W water channel. Gravels are well rounded, dominated by quartz and in a size of 2x1x0.8 cm. Coarse sands are mostly composed of quartz and feldspar grains, and also mica can be see. The sand and gravels are poorly sorted, containing rounded teeth and bone fragments. 1.10 m.

(13)-4 Brown silty clay with weathered limestone breccias. The breccias are quite deeply weathered, more in flake pieces and lying down horizontally. 0.70 m. thick.

(13)-5 Brown fine silty clay-breccias, with large collapsed rock blocks. The limestone breccias are wholy weathered. In the lower part, there are more clays containing small breccias, and also clay-sand lenses can be seen. 0.8 m. exposed.

-erosion surface (?)-

Longgusha Formation of lower Pleistocene ($Q_1 1$) (Yang Zigeng et al. 1985), 10.0-10.85 m thick totally.

(14) Brown-reddish clayey silt containing gravels, subdivided into two sublayers, with a gradual contact between the two.

(14)-1 Brown-reddish clayey silt-gravels. The matrix-supported gravels, dominated by Carboniferous shallow-metametamorphic rocks and nearly wholy weathered, generally look well-rounded, arrange nonorientedly and scatter in the clayey silt, with a relatively large diameter of 5-15 cm (the largest can be 35 cm). Limestone breccias are occasionally found in the gravels. 1.6 m.

(14)-2 Brown-reddish clayey silt containing gravels. The gravels are fewer in number than in (14)-1, and show a very irregular distribution, concentrated in some parts and scattered far and wide in other parts, and also have a disorder in arrangement. Subrounded or rounded. Medium-weathered. With the same compositions as (14)-1 and smaller diameter than the overlying sublayer. The lower part of (14)-2 wedges into layer (15), with a very steep interface, over 60^{o} or nearly vertical. 0.7-3.25 m.

(15) Brown-reddish sand-gravel layer, subdivided two parts.

(15)-1 Brown-reddish sand-gravel. Carboniferous metamorphic rocks make up the majority of the gravels, which have a good roundedness, arrange undirectedly and show a deep weatheredness, arrange undirectedly and show a deep weatheredness. Coarse gravels are nearly wholy weathered. Gravel diameter is generally 2-10 cm. Matrix-supported. The cements consist of brown-reddish sands containing clays. A few surface-corroded limestone breccias have been found in the sand-gravel sublayer. Due to the wedging of (14), the top has an interrupted erosion surface. The occurrence is very steep, with a dip up to 60^{o}. 1.3-1.6 m.

(15)-2 Red-brown silty fine sand-sand-silt-clay, containign a small number of gravels. The gravels are unitary, mainly fine-grained sandstone and phyllite, and dominated by fine gravels in a relatively small size. This sublayer also has a steep occurrence with a dip of 50-60^{o}. 0.45-1.20 m.

-erosion surface-

(16) Gray and brown-gray thin clayey silt beds, with rust-coloured silt intercalated. Parallel bedding. Only occasionally ball-like silt lenses without bedding can be seen inlaid in it. The steep occurrence is 80^{o} < 10^{o}. The top part is eroded and has crevices perpendicular to the layer surface. Fillings in the crevices are brown-reddish coarse, the same as in those of layer (15) lithologically. Due to the erosion at the top, the thickness of the layer varies greatly from 1.50 m to 2.5 m. 2.5 m.

(17) Yellow-brown silty coarse sands with gravels. The gravels are well rounded. Brown silty clays are intercalated within the sands and gravels. Sporadic breccias and gravels spread at the top and in the contact plane with layer (16). The bottom has not been struck. 0.7 m exposed.

4. Biostratigraphic units

3.1 Mammalian faunas

Two mammalian faunas and three biostratigraphic units are included. That is to say, the fauna in Locality 1 of Zhoukoudian contains two biostratigraphic units and "New Cave" fauna.

Locality 1 of Zhoukoudian contributes layers 1-13, with 97 species of mammalian fossils (Figure 4), called *Homo erectus pekinensis – Megaloceros pachyosteus* fauna, which has the following characteristics: a) *Megaloceros* is widely spread; b) *Myspalax tingi M. chaoyatsen* in early Pleistocene are replaced by *M. epitingi* and *M. wongi* respectively and many new animals appeared: c) there are still remains of Pliocene and early Pleistocene mammals such as *Machairodus inexpectatus*, *Equus sanmeniensis*, *Sus lydekkeri* and *Paracamelus gigas*; d) of the fauna, extinct genera make up 11 per cent, extinct species 63 per cent, and the existing species 37 per cent (XueXiangxu, 1985).

Hu Changkang (1985) has divided this fauna into two units, Units A (from layer 4 downwards) and Unit B (layers 1-3), and compared Unit A with Tiraspol Fauna of the Soviet Union and Sussenborn and Steinheim II Faunas of Germany. All these faunas contain the same or nearly the same genera and species as Unit A of Locality 1 fauna of Zhoukoudian, such as *Hyaena brevirostris*, *Homotherium* sp. *Ursus spelaous*, *Meles meles*, *Dicerorhinus irchbergensis*, *Sus scrofa*, *Megaloceros giganteus antecedens* and *Palaeoloxodon antiquus* etc. Unit B lacks ancient Carnivora such as *Hyaena brevirostris sinensis*, *Machairodus inexpectatus*, *Felis teilhardi* and *Ursus spelaeus* etc., *(Hyaena brevirostris* is replaced by *Crosuta ultima)* and can be compared with Khaazar faunal complex of of the Soviet Union.

"New Cave" mammalian fauna has provided 40 species of fossils (Figure 4) (Gu Yumin, 1978), with the following characteristics: a) containing surviving genera and species representing the life time of Peking Man, such as *Macaca robusta*, *Myospalax wongi*, *Sus* cf. *lydekkeri*, *Megaloceros pachyostleus*, and *Lepus* cf. *wongi* etc.; b) containing new species (sp. nov,) indicating "New Cave" fauna, such as *Sciurolamias davidianus* and *Cervus elaphus*; c) of the fauna, extinct genera making up 6 per cent, extinct species 17.5 per cent, and the existing species 82.5 per cent.

	New Cave	Locality 1 of Zhoukoudian								
		layers 1-3	layer 4	layer 5	layer 6	layer 7	layers 8-9	layers 10-11	layers 12-13	unclean layers
Homo erectus pekinensis (Black)		●	●	●	●		●	●		
New Cave Man	●									
Macaca robusta Young	●	●	●	●	●	●	●			
Scaptochiras primitivus Zdansky			●	●				●		
Scaptochrus moschatus Milne-Edwards	●									
Neomys behlini Young		●	●					●		
Neomys sinensis Zdansky		●	●					●		
Crocidura suaveolens Pallas	●	sp.	sp.							
Erinaceus olgai Young	sp.	●	●	●	●					
Sorex sp.										●
Rhinolophus pleistocanicus Young			●							
Rhinolophus ferrumequinum Schreber	●									
Miniopteris cf. schrebersi (Kuhl)		●	●							
Myotis sp.										3-6
Ia io Thomas	●	●	●							
? *Pipistrellus* sp.										●
Sciurotamias davidianus Milne-Edwards	●									
Citellus cf. mongolicus (Milne-Edward)										3-6
Citellus undulatus Pallas	●									
Tamias wimani Young										●
Eutamias cf. sibiricus	●									
Petaurista brachyodous (Young)										●
Marmata bobak (Radde)							sp.			●
Marmota complicidens (Young)						●			●	
? *Castor* sp.					●					
Trogontherium cuvieri Fischer v. Waldheim				●	●	●	●			
Cricetinus varians Zdansky		●	●	●	●					
Cricetulus cf. griseus Milne-Edwards		●	●	●		●				
Cricetulus cf. obscurus Milne-Edwards		●	●	●	●	●		●		
Cricetulus triton de Winton	●									
Cricetulus barabensis Pallas	●									
Mus sylvaticus L.								●		
Mus musculus Linnaeus	●							●		
Micromys cf. minutus Pallas		●	●	●	●	●				
Rattus rattus L.			●	●						
Rattus noroegicus Berkenhout	●									
Gerbillus roborowskii Bucher			●					●		
Clethrionomys rofucanus (Sundevall)										●

Figure 4. Distribution of fossil mammals of Locality 1 and New Cave of Zhoukoudian (From Wu Rukang et al. 1985., Gu Yumin 1985., Hu Changkang 1985.)

	NC.	1-3	4	5	6	7	8-9	10-11	12-13	uc
? *Eothenomys*										●
Alticola cf. stracheyi	●									sp.
Pitymys simplicidens Young										●
Microtus brandtioides Young	●		●	●						
Microtus epiratticeps Young	●		●	●				●		
Microtus complicidens Pei										3-6
? *Phaiomys* sp.										●
Meriones meridianus Pallas	●									3-6
Apodemus sylvaticus Linnaeus	●									3-6
Myospalax wongi (Young)	●									●
Myospalax epitingi Teilhard et Pei										● sp.
Hystrix cf. subcristata Swinhoe							●			
Ochotona koslowi Bucher	●		●					●		
Ochotona daurica Pallas	●									sp.A,B
Lepus cf. wongi Young	●									●
Lepus sp.	sp.									sp.A,B
Canis lupus L.		●		●		●	●			
Canis lupus variabilis Pei			●	●	●		●	●		
Canis cyonoides Pei	sp.						●			
Nyctereutes sinensis (Schlosser)				●	●	●	●	●		
Cuon antiquus Matthew et Granger							●			
Vulpes cf. vulpes L.	●							●		
Vulpes cf. corsac L.		●		●	●		●			
Canidae gen. et sp. indet.										●
Ursus thibetanus kokeni Matthew et Granger		●	●	●	●		●			
Ursus arctos L.	●	●	●	●	●		●	●		
Ursus cf. spelaeus Rosenmuller et Heinroth							●	●	●	
? *Ailuropoda* sp.				●						
Meles cf. leucurus Hodgeson	●	●		●	●		●			
Lutra melina Pei						●				
Gulo sp.							●			
Mustela cf. sibirica Pallas				●						
Mustela nivalis Linnaeus	●									sp.
Martes sp.										●
Hyaena brevirostris sinensis Owen				●	●	●	●	●	●	
Crocuta ultima (Matsumoto)		●								
Machairodus inexpectatus Teilhard de Chardin				●			●	●		
Panthera youngi (Pei)										●
Panthera cf. pardus (L.)				●				●		
Panthera cf. tigris (L.)		●		●	●	●	●		●	
Felis sp.	sp.1,2			sp.A,B		sp.B	sp.A			

Figure 4 *(Continued)*

	NC.	1-3	4	5	6	7	8-9	10-11	12-13	uc
Felis teilhardi Pei				●			●	●	●	
Felis lynx Linnaeus	●									
Felis cf. microtis Milhe-Edwards				●						
Cynailulus sp.				●			●			
Palaeoloxodon cf. namadicus Falconer et Cautley			●				●			
Elephantidae	●									
Dicerorhinus choukoutiensis Wang		●	●		●	●	●	●	●	
Coelodonta antiquitatis yenshanensis Chow	sp.	●					●	●		
Equus sanmeniensis Teilhard et Piveteau	cf.	●	●		●	●	●	●	●	
Sus lydekkeri Zdansky	●					●		●	●	3-6 sp.
Paracamelus gigas Schlosser.										●
Camelidae gen. et sp. indet.										●
Moschus moschiferus pekinensis Young			●	●	●	●				
? *Hydropetes* sp.										●
Caprcolus sp.	●									sp.
Cervus claphus Linnacus	●									
Pseudaxis grayi Zdansky	●	●		●	●	●	●	●		
Megaloceros pachyosteus (Young)	●	●	●	●	●	●	●	●	●	
Cervus sp.		●								
Gazella sp.				●	●					
Spiroccrus pcii Young							●			
Spiroccrus cf. wongi Teilhard et Piveteau										●
Ovis cf. ammon L.				●	●	●	●			
Ovis sp.			●							
Ovibovinae gen. et sp. indet.										●
Bubatus teilhardi Young						●	●			
Bison sp.										●
? *Naemorhedus* sp.										●
Bovidae gen. et sp. indet.										●

Figure 4 *(Continued)*

3.2 Human fossils

In the 197 fossils of *Homo erectus pekinensis* that have been found up to now, there are 6 complete and nearly complete skulls (numbered II, III, V, X, XI and XII), and a lot of skull fragments, mandibles, limp bones and teeth, which distributed in layers 3-11 (Figure 4). In the New Cave, only one human tooth has been found and numbered PA 537. After determination, this tooth is thought to belong to a kind of human being between *Homo erectus pekinensis* and Upper Cave Man *(Homo sapiens sapie)*, that is, New Cave Man, a transient kind from Peking Man to Upper Cave Man (Gu Yumin, 1978) (see Figure 4).

Sporopollen

Sporopollen reflects (Kong Zhaohen et al. 1985) layers 14-17 (prior to 0.70 Ma. B.P.) to be in a warm-temperate climate of coniferous broad-leaved mixed forest, with a tendence to become slightly drier, Middle Pleistocene is shown in warm climate, dominated by deciduous broad-leaved forest and deciduous broad leaved forest-steppe, but warm-humid in some periods and cool-dry in others. Unit B, corresponding to the mammalian fauna, is indicated by sporopollen analysis to be in a gradually drier climate with the increase of bushveld. The period of "New Cave" deposition is represented by temperate forest-steppe, dominated by herbaceous vegetation. In this paper, I have redrawn and recalculated the pollen diagram from Kong Zhaochen et al. (1985) and redivided the cave into ten pollen zones (Figure 5).

5. Chronostratigraphy

The bottom boundary of Zhoukoudian Formation is determined just on palaeomagnetic B/M boundary (0.73 Ma B.P.) with its top of 0.23 Ma B.P. (U- series dating) by chronology. The lower accumulation of "New Cave" is about 0.25-0.12 Ma B.P. (thermoluminescence and U-series dating) and Peking Man's living period is about *0 50-0.23* Ma B.P. (Table I).

6. Conclusion

The rich mammalian fossils of Zhoukoudian come from the Paleoarctic region in the zoogeographical classification of the global land areas. This fossil fauna is very typical in the region and has provided a biostratigraphic basis for establishing a stratotype strata. With the development of chronology, the middle Pleistocene layers in the Zhoukoudian section have become the middle Pleistocene stratotype section of China for the last ten years. The bottom boundary of the middle Pleistocene is that of layer 13 of the Zhoukoudian Formation, and the top boundary is the delineation between the travertine layer in the upper part and the yellow sandy clay bed in the lower part of the "New Cave" accumulation.

Table 1. Results of dating of Locality 1 and New Cave deposits of Zhoukoudian

Methocl date Ma B.P. layers	Fissol-track (Guo S.L. et al. 1980)	U-series (Zhao S.S. et al. 1980,1984)	Thermolu-minescence (Pei J.X. 1985)	Amion-acid Racemization (Li R.W. et al. 1979)	Paleomagnetic (Liu C. et al. 1977. Qian F. et al. 1980)
New Cave Deposits: Top & upper Travertine		0.084 + 0.008 0.098 + 0.005 0.117 + 0.011 − 0.008			
Travertine interbed in lower part		0.195 + 0.025 − 0.020			
Ash at bottom			0.257 + 0.036		
Layers of Locality 1: 1-2		0.23 + 0.03 − 0.023			
3		0.256 + 0.06 − 0.04 0.260 + 0.08 − 0.05			
4	0.306 + 0.056		0.292 + 0.026 0.312 + 0.028		
5					
6					Brunhes
7					
8-9				0.390	
10	0.462 + 0.045		0.417 – 0.592		
11				0.460	
12-13					0.73
14-17					Matuyama

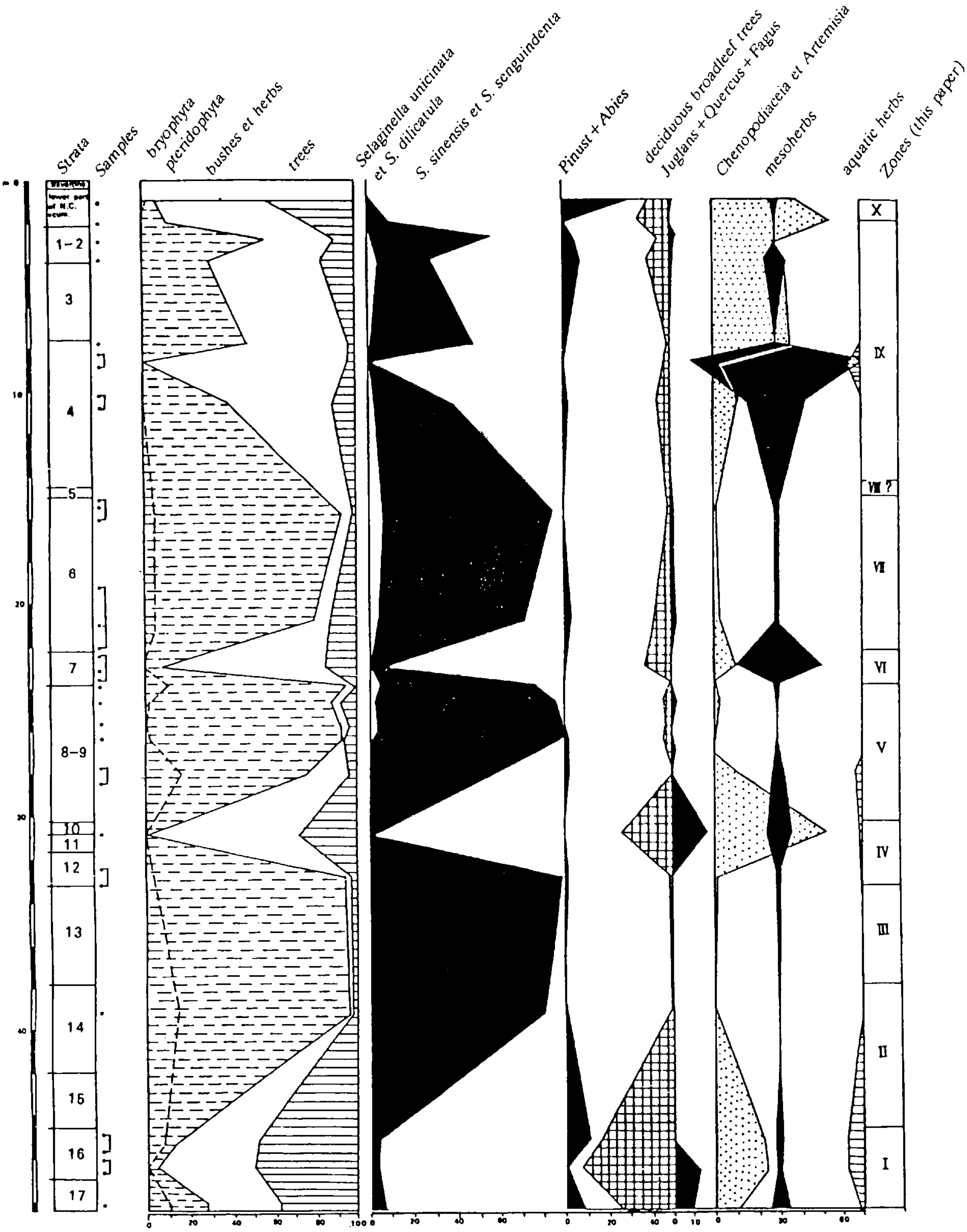


Figure 5. Sporopollen diagram from Locality 1 and New Cave of Zhoukoudian. (Redrawn and recalculated from Kong Zhaochen et al. 1985.)

References

Gu Yumin 1978. New Cave Man at Zhoukoudain and its living environment. In *Professional Papers of Palaeoanthropology*, pp. 158-171. Science Press.

Guo Shilun et al. 1980. Age determination of Peking Man by fission-track dating. *Kexue Tongbao* (A Monthly Journal of Science), Vol. 25, p. 535.

Hu Changkang 1985. The history of mammalian fauna of Locality 1 of Zhoukoudian and its recent advances. In *Multi-disciplinary Study of the Peking Man Site at Zhoukoudian*. (Wu Rukang et al, eds.) pp. 107-113, Science Press.

Kong Zhaochen et al. 1985. Vegetational and climatic changes since Paleogene at Zhoukoudain and its adjacent regions. *Ibid.*, pp. 119-154.

Li Renwei & Lin Daxin, 1979. Geochemistry of Amino-acid of bonefossils at "Peking Man", "Latian Man" and "Yuanmu Man" sites. *Scientia Geol. Sinica* No. 1. pp. 51-61.

Liu Chun, Zhu Xiangyuan & Ye Sujuin 1977. A palaeomagnetic study on the cave-deposits of Zhoukoudian, the locality of *Sinanthropus*. *Scientia Geol. Sinica*, No. 1. pp. 26-33.

Pei Jingxian 1985. Thermoluminescence dating of the Peking Man site and other caves. In *Multi-disciplinary Study of the Peking Man Site at Zhoukoudian*. (Wu Rukang et al. eds.) pp. 256-260. Science Press.

Qian Fang et al. 1980. Magnetostratigraphic study on the cave deposits containing fossil Peking Man at Zhoukoudian. *Kexue Tongbao*, Vol. 25, No. 4, p. 359.

Wu Rukang & Dong Xingren 1985. Retrospect and prospect of the study of Peking Man. In *The Multi-disciplinary Study of the Peking Man Site at Zhoukoudian*. (Wu Rukang et al. eds.) pp. 86-94. Science Press.

Xue Xiangxu 1984. The Quaternary mammalian fossils in the loess area of China. In *The Recent Research of Loess in China*. (S. Sasajima & Wang Yongyan, eds.) pp. 112-159, Kyotoi University & Northwest University.

Yang Zigeng et al. 1985. Study of the Late Cenozoic strata at Zhoukoudian. In *Multi-disciplinary Study of the Peking Man Site at Zhoukoudian*. (Wu Rukang et al. eds.) pp. 1-85. Science Press.

Zhao Shusen et al. 1980. Uranium-series dating of Peking Man. *Kexue Tongbao*, Vol. 25, No. 5, p. 447.

______. 1984. A report of the U-series dating of speleothems. *Ibid.*, Vol. 29, No. 16, pp. 1004-1006.

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A LATE QUATERNARY SEDIMENTARY SEQUENCE FROM THE BANDUNG BASIN WEST JAVA, INDONESIA

R. Dam[1] and P. Suparan[2]

Abstract

The Bandung basin is a 15 km wide, 35 km long intramontane basin at an approximate altitude of 660-675 m in the central part of West-Java, Indonesia. Structurally it has been interpreted as the central part of the geo-anticline of West-Java which collapsed during or after its arching up at the end of the Tertiary.

Since then a considerable sedimentary sequence (75-200 m) accumulated in the basin, as a result of the various denudational processes in the surrounding, mainly volcanic, upland area. In the sequence a wide range of deposits has been encountered and interpreted as airfall, fluvial, alluvial fan and debris flow deposits, and notably several facies of lacustrine deposits. So far, at least three seperate lake sequences alternating with paleosol levels, have been recognised. The most recent lake sequence has been radiocarbon dated approximately 35.000-15.000 years Before Present (BP).

For the preparation of a Quaternary geological map a large number of hand drillings were carried out to determine the type of shallow subsurface sediments, which have been classified in a limited number of lithological units.

Interpretation of these units in terms of sedimentary process and sedimentary environmental conditions, together with radiocarbon dating, enables the preliminary reconstruction of the course of events during and after the youngest lake phase.

A proper study of the most recent deposits (Late Pleistocene-Holocene) enables the understanding and interpretation of older parts of the sedimentary sequence. To obtain a longer core a deep drilling was made to a depth of 64 meters, with the above mentioned, preliminary result. Research in progress comprises detailed lithostratigraphical surveys, a geo-resistivity survey and preparations for more deep drillings and includes sampling for mineralogical, chemical, palynological and grain size analysis, as well as for further dating. More results will be available in the period 1989-1991.

[1] Quaternary Section, Earth Sciences Farth, Vrije Universiteit Amsterdam. The Netherlands (c/o GRDC).

[2] Quaternary Section, Geological Research and Development Centre Jalan Diponegoro 57, Bandung, Indonesia.

1. Introduction

The Geological Research and Development Centre (GRDE) and Vrije Universiteit Amsterdam (VUA) joint activities contain two major components; Quaternary Geological Mapping and Quaternary Geological Research. It is the task of GRDC to produce Quaternary geological maps of designated areas, such as coastal developing regions and also the Bandung plain area. Mapping activities were carried out here in the period from 1986 to 1989, including a survey of the shallow subsurface deposits by means of hand drillings and description of exposures. Two deep drillings were made to investigate the deeper subsurface deposits.

The Quaternary Section of the Earth Sciences faculty of the VUA has cooperated in GRDC's mapping activities, with special emphasis on Quaternary geological scientific aspects (landform development, chronology, stratigraphy). Recently, a four year study called" The Late Quaternary Development of the Bandung Basin," was started. It's goal is to identify the nature and intensity over longer time ranges of the exogeneous processes which have governed the geological and geomorphological development of the mountain areas of West-Java during the Late Quaternary. The study's emphasis is on the Bandung basin sedimentary fill and the surrounding upland area. This paper presents the first results of the mapping and research activities.

2. Geographical and geological setting

The Bandung basin is located in the central part of West-Java. It can be characterized as an upland plain, or an intramontane basin, with an elevation of approximately 660-675 m. The depression is bordered by volcanoes to the north, south and east. To the west of the Bandung plain a comparable structure, the Batujajar basin, is located.

The Bandung basin is generally interpreted as the central part of the Bandung Zone, a Tertiary tectonic depressional structure extending through West-Java (Figure 2). Along the sides of this zone major fault systems have developed where Quaternary volcanism occurs (Figure 3).

The Bandung plain is a rather flat surface locally with some conspicuous morphological features such as intrusive bodies and distinct sediment accumulations.

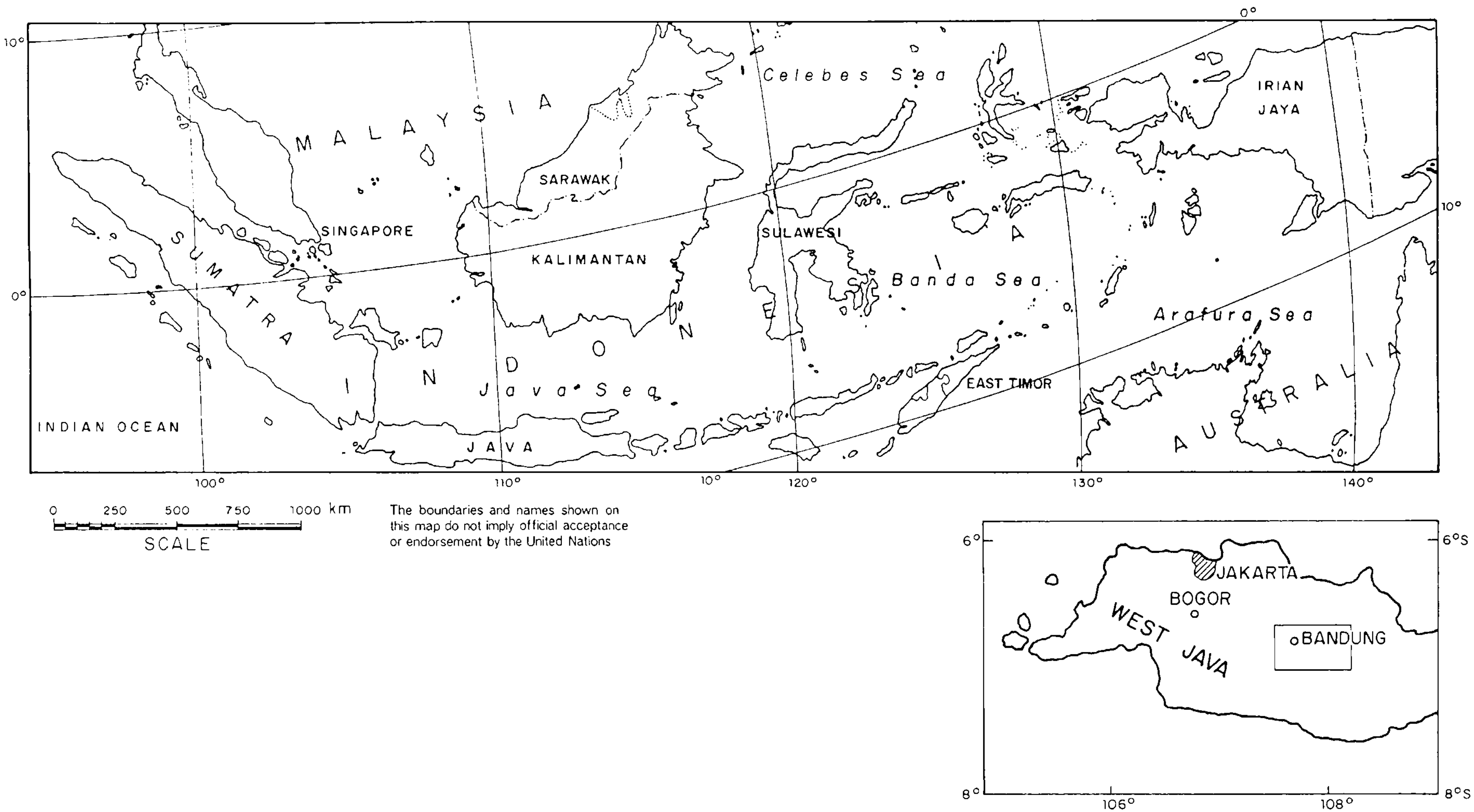


Figure 1. Location of the project area

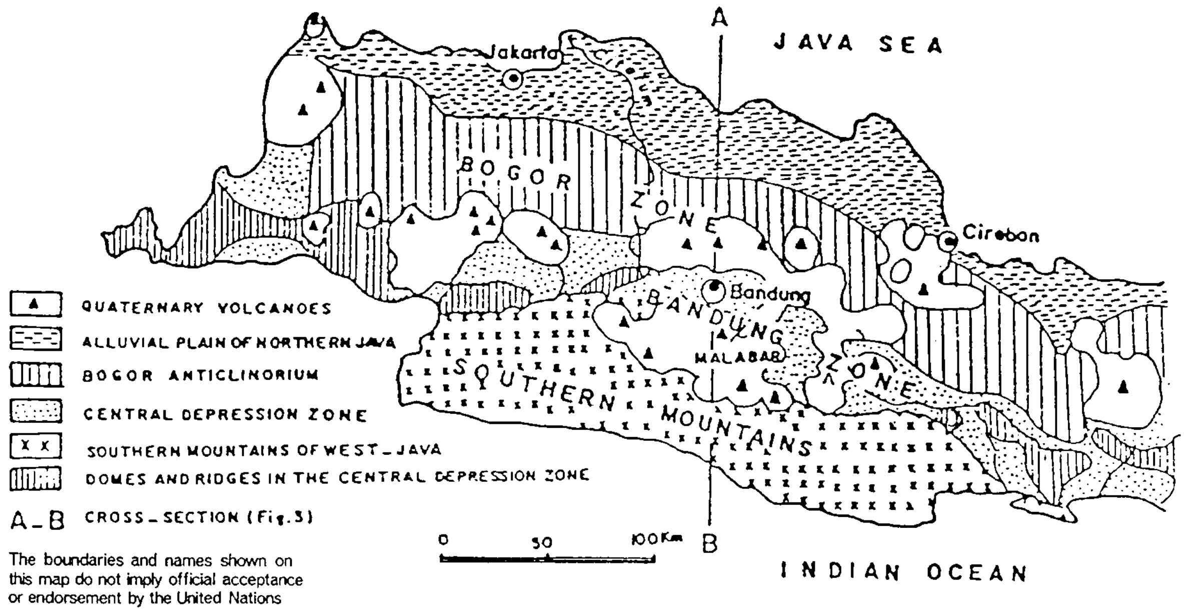


Figure 2. Physiographic zonation of West Java according to Van Bemmelen (Priowirjanto, 1985; after Van Bemmelen, 1949)

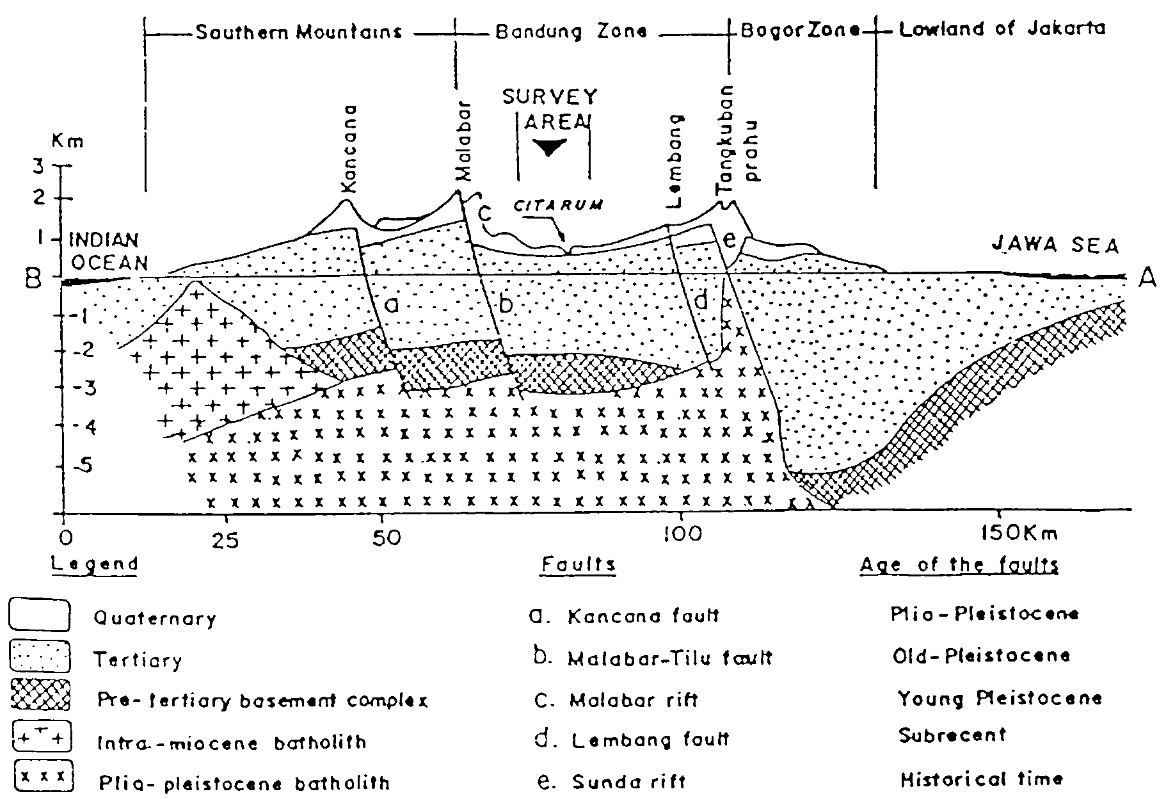


Figure 3. Schematic section across West Java (107°37' E. long.)
(Adapted from Priowirjanto, 1985; after Van Bemmelen, 1949)

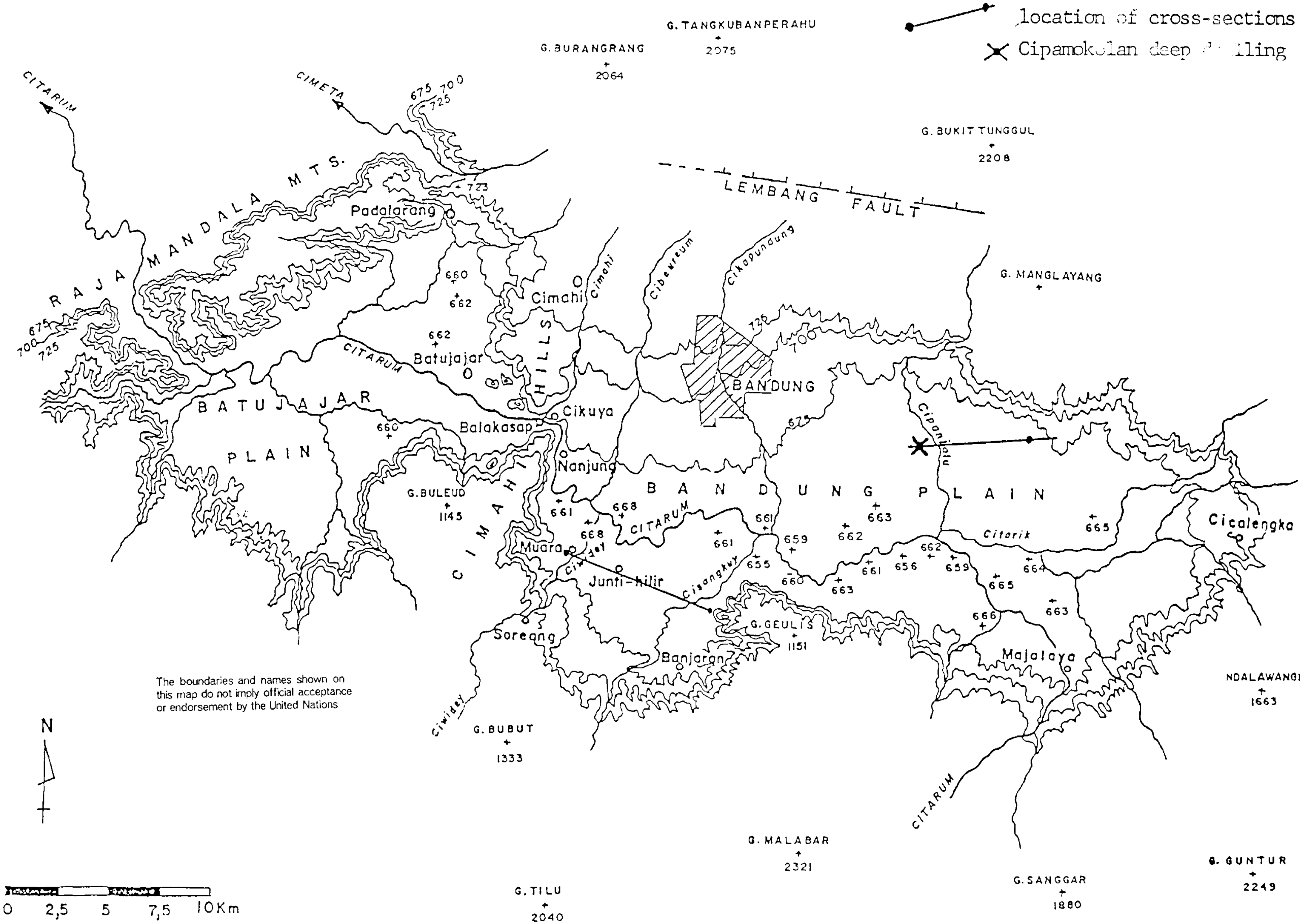


Figure 4. Bandung-Batujajar plain and surroundings. Topographical sketch map.

The Bandung fan is composed of volcanic deposits derived of fairly recent eruptions of the Tangkuban complex. The Soreang fan is located in the southwestern corner of the plain and, being composed of coarse gravelly, unsorted debris, might be interpreted as a lahar deposit. We find some comparable features along the southeastern basin boundary. The major morphological feature is obviously the extensive flat plain. Drainage of the whole relevant (upland) area is through the Citarum river which has a narrow outlet through the Cimahi hills, a steep ridge of Tertiairy intrusive rock on the western side of the plain.

The basinal structure was illustrated in a gravimetric survey by Kridoharto (1976) and Besari (1984) who concluded that high density basement rock can be found at a depth of 200-300 m (covered by Tertiary and Quaternary sediments). It also made clear the basement structure is rather complicated. Figure 5 shows, by means of Bouguer gravity isolines, the basement contours. Clearly visible is a ridge (horst, anticlinal) structure through the basin south of Ujungbrung, and deep gravity lows in the eastern part of the basin and below Bandung city. The intrusive bodies at the south and western basin boundaries show up as significant gravity highs.

We are dealing with a basinal structure, bordered by volcanic complexes and of which the basement is composed of crustal rock and folded Tertiary sediments. The basin is party filled up with older Quaternary volcanic and apparently with interfingering fluviatile deposits. The upper sequences are composed of young volcanic deposits alternating with fluviatile and lacustrine sediments.

3. Previous studies of the basin sedimentary fill

Older studies include Mesdag (1928), Stehn & Umbgrove (1929), Van Bemmelen (1934, 1949), Silitonga (1973). More recently conducted research is often focused on hydrogeology and civil engineering aspects of the subsoil.

Koesoemadinata and Hartono (1981) suggest lithostratigraphy with four formations (their research is mainly valid for the Bandung city area and is based on well logs and drilling descriptions). Here the most relevant are the Cibeureum and the Kosambi Formations (Figure 6).

The Cibeureum Formation is composed of several tuff/volcanic breccia successions. It is coarse, very unsorted material which shows some fining upward sequences. These deposits have been interpreted as density flow or fluviatile deposits of primary volcanic origin. The Kosambi Formation is largely comparable with those deposits formerly called "lake deposits" (Van Bemmelen, 1934, 1949; Silitonga, 1973). They are composed of compact clay, silt and sand, and locally lithified. The thickness of these deposits is estimated to vary from 0-125 m; the formation occurs throughout the plain.

A geo-resistivity survey carried out by Marino *et al.* (1976) in the southwestern part of the plain, lead to the following conclusions (Figure 7). Low 5-10 ohm/m resistivity deposits form the top 2-20 metres (m) and are interpreted as lake deposits composed of clay and sandy clay. Below this, deposits with a resistivity of 13-17 ohm/m occur interpreted as sandy tuff and clayey sand. They are 60 m thick along the boundary and wedge out towards the centre of the basin. Below this the occurrence of a layer of volcanic breccia and tuffaceous sand, 30-35 ohm/m resistivity, has been deduced. Underlying this layer are again clay and sandy clay deposits, also interpreted as lake deposits.

It can be concluded that so far the available descriptions of the basin fill are very general and based on limited field data.

4. Quaternary geological map

For the preparation of a Quaternary geological map, scale 1 : 50,000, a large number of hand drillings were carried out to determine the type of shallow subsurface sediments. The wide range of deposits encountered were classified in a limited number of legend units.

In accordance with the map legend for the coastal areas main legend units are based on sedimentary environmental units (Floodplain deposits, Lacustrine deposits, Alluvial fan deposits etc.). Map areal units represent specific sequences of 1, 2 or 3 combinations of main legend units (profile type system). To acquire a more detailed map image, and also to ensure a greater lithologic homogeneity of the main legend units, these have been subdivided according to a number of facies (as there are
-sandy lacustrine fan facies
-peaty lacustrine facies)

The map image reveals the distribution of major profile types, as well as the occurrence of specific facies of profile type components. Cross-sections illustrate the observed stratigraphic position and thickness of the respective deposits.

In brief, the map shows the following sediment occurrences. Floodplain deposits are indicated in large areas throughout the plain area. Channel sand occurs as minor deposits, commonly as narrow, elongate bodies along the main river systems.

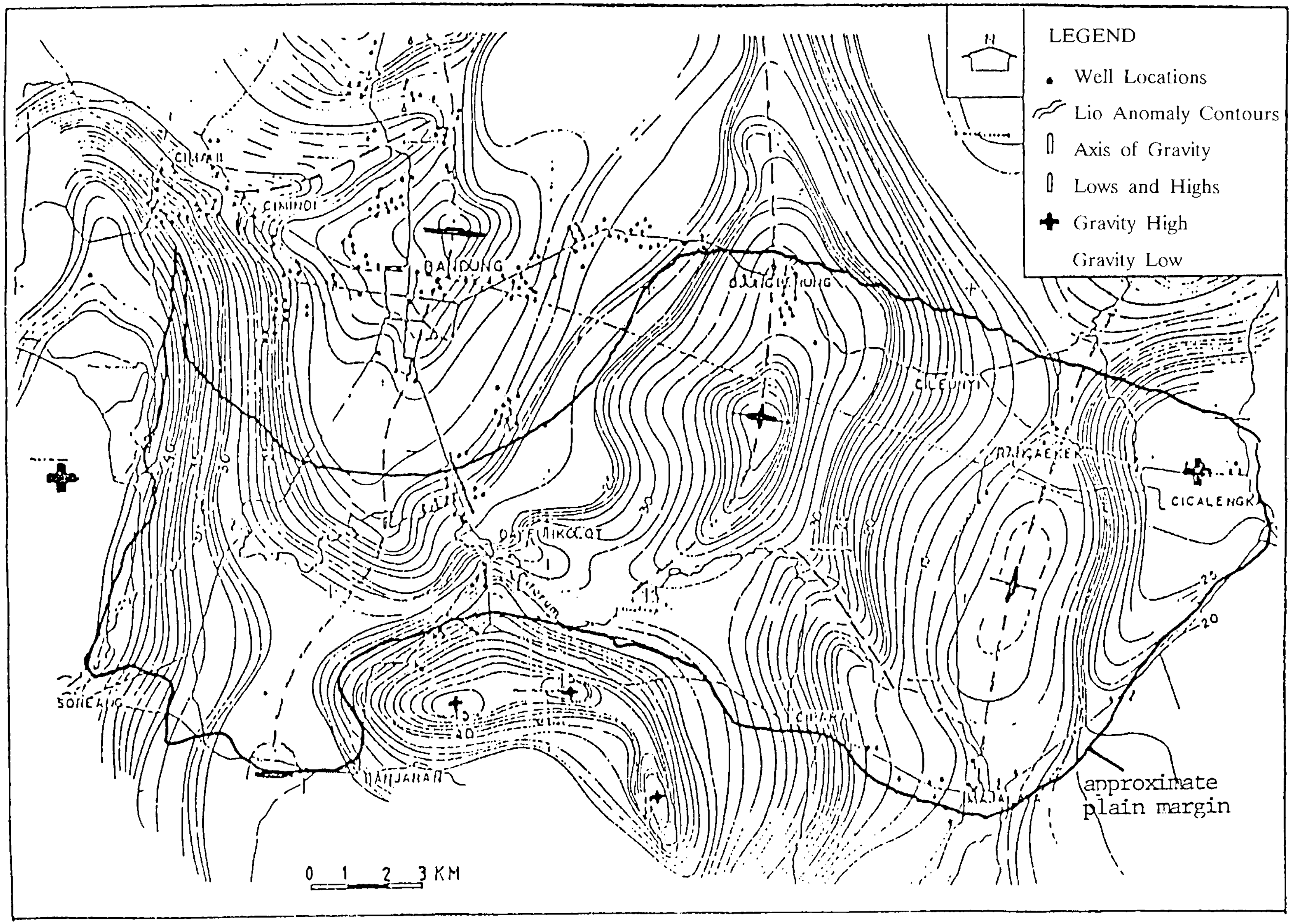


Figure 5. Bouguer gravity anomaly map (Kridoharto, 1978)

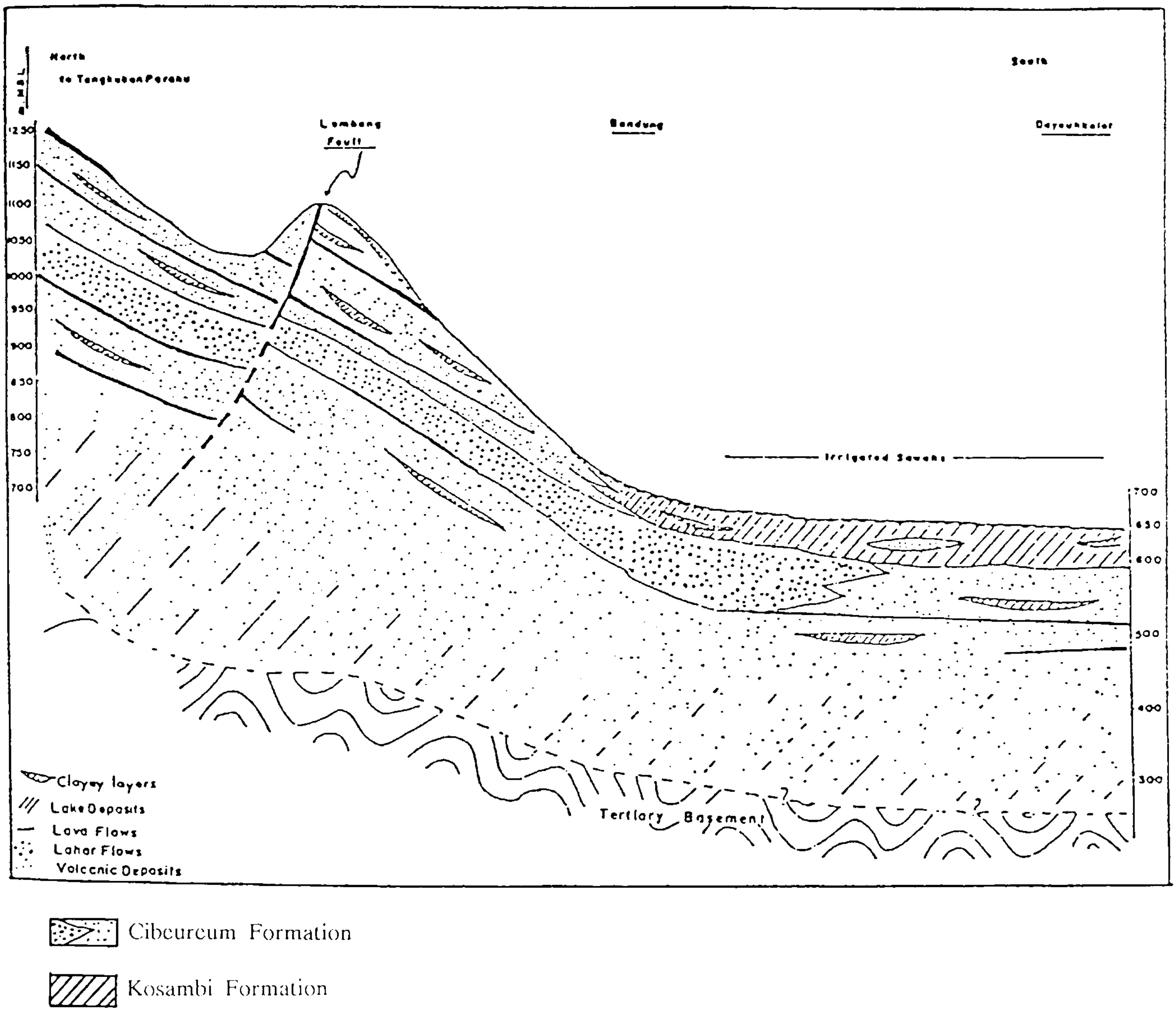


Figure 6. Section from the upper Tangkuban Perahu slopes, through Bandung city, to the Bandung basin

The lacustrine deposits occur over nearly all of the basin. Such sediments rarely occur in topographical high positions. Lacustrine deposits with a peaty facies are indicated with a grass symbol. Such deposits are found mainly in the central and eastern part of the basin. The transitional lacustrine fan deposits are present along most of the basin boundary. Locally lacustrine deposits are very prominent, but in other places, for instance the central southern basin margin, hardly any lacustrine fan deposits occur. In several places a sandy facies is indicated, i.e., places where active fluvial systems have caused the development of a more sandy lacustrine fan facies. Along the basin boundary the regular pattern can be described as a transition zone of lacustrine fan deposits interfingering with lacustrine deposits on the "lake" side and interfingering with coarser alluvial fan deposits towards higher ground (see also the cross-sections). Noticed is the deviation from this pattern along the central southern basin margin, where only a very narrow transition zone is present. Attention is drawn to the prominent occurrence of the Bandung alluvial fan deposits, and to minor extent the Soreang fan deposits. As can be inferred from the sediment distribution pattern on the map the presence of the Bandung alluvial fan system has influenced a large part of the basin through the influx of vast amounts of coarser clastic material. Comparable alluvial fan deposits, but on a much smaller scale occur along the northern basin margin.

So far we have presented a brief synthesis of the recent work carried out for the preparation of a Quaternary geological map for the Bandung basin deposits. It can be concluded that for a presentation of the areal distribution of shallow subsurface sediments the map that is presently being prepared, gives a fairly

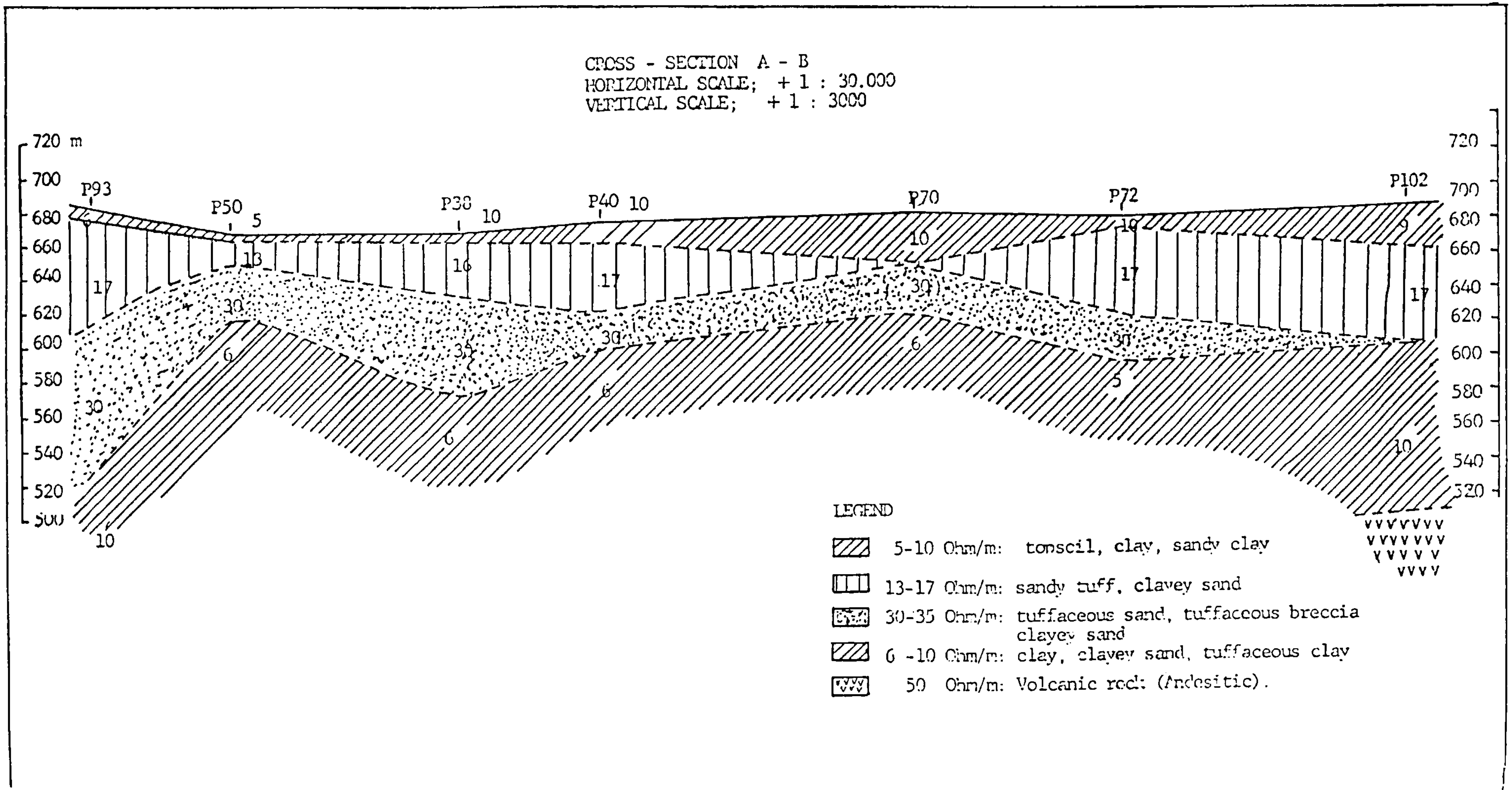


Figure 7. A geo-resistivity soundings profile. It shows the occurrence of low resistivity clay layers that might be interpreted as lake deposits (Marino et al., 1976) For location see Figure 4.

detailed and reliable overview. Considering however, the map scale in combination with the intricate patterns of sediment distribution, especially in the basin margin, a drilling density denser then the present 1.02 drillings-exposures/sqkm would be more optimal. Nevertheless, it is expected that the geological information given on the map will support local development by providing important data concerning subsoil characteristics and geological build up.

Regarding the deeper subsurface deposits encountered in the basin, it can be stated that work presently under way will greatly enhance our knowledge concerning lithological characteristics and sediment distribution. Moreover, other interesting aspects also deserve attention and will be discussed in the second part of this paper.

5. The development of a Late Quaternary sedimentary sequence in the Bandung basin

During the foregoing field surveys it became clear that a wide range of different deposits occur at the surface and shallow subsurface of the basin's sedimentary fill, such as airfall, fluvial, alluvial fan, debris flow and lacustrine deposits. Recently, a detailed distinction, based on lithological characteristics, between the different deposits encountered has been prepared. (This differs from a classification in geological map legend units, which, for mapping purposes, has a different character). Following the indication of these lithological units an attempt is now made to place them in a lithostratigraphic framework. Subsequently, interpretation of respective units in terms of depositional process (es), sedimentary environmental conditions and inference of sediment provenance, enables us to reconstruct the course of events that produced the present geological and geomorphological situation.

Lithological units

So far nine lithological units have been distinguished.

1) Green, sandy clay member (substrate I)

An extremely stiff, sandy clay to clayey sand with a very distinct green colour (Munsell 5 G 3/1). It has a blocky angular structure when broken. The material contains some plant remains in growing position, and occasionally has a humic top layer. Vague humic mottling may be present. It's typical colour and stratigraphic position are sufficient arguments to distinguish it, for the time being, as a single, separate lithological unit. The presence of an old soil horizon at the top of this unit is important.

2) Organic clay and gyttja member

Soft, organic clays with very gradual transitions to gyttjas and sometimes more peaty clays or gyttjas. This distinct type of sediment is always encountered in the central part of the basin, in thick deposits. It wedges out towards the basin margins.

3) Humic sandy clay, to clayey sand member

Deposits composed of dominantly clay with varying amounts of silt and/or sand. It has a rather stiff, moderately ripened consistency and is slightly to moderately humic with dark-greyish colours. Transported/ *in situ* plant remains may be observed. Occasionally sandy beds are intercalated.

4) Sandy silt, silt- to clay (stone) member

Homogeneous grey, laminated layers of this material with an extensive distribution (lobe-like occurrences). Bedding varies from massive sandy clays and silts, to thinly laminated clay/silt. Often the material is compact and may be slightly cemented. Locally wedge-like intercalations of sandy, fluvial channel deposits, occur. This unit is interpreted as the distal facies of the sandstone member.

5) Sandstone member

Fine to coarse sandstones nearly always hard cemented by iron and silica precipitates. It is encountered in thick sequences, rather massive, to vaguely laminated, with blackish - grey colours. No distinct sedimentary structures have been observed. The sand is moderately sorted, with rare large boulders. Besides the overall nearly horizontal bedding there are no special bedding or grading characteristics. The sand has a rather homogeneous scoriaceous/andesitic composition. These deposits build up an important part of the Bandung alluvial fan (proximal position).

6) Coarse gravel member

Composed of subangular to rounded gravels and cobbles, with minor intercalations of sand layers. It has an heterogeneous composition and is poorly sorted. Clearly visible are channel fill structures with shallow troughs and an eroded lower boundary. This unit is found in a position transitional with, and partly underlying the sandstone member.

7) Channel sand member

Occasionally observed layers of fine to coarse sand, moderately rounded and sorted, with a heterogeneo composition. These seem to occur in small, local deposits. They show erosional lower boundaries and fining upward trends to clayey, silty sand. Channel sands occur intercalated in the clay member, and intercalated, but mainly overlying (partly eroding) the other lithologic units. The occurrence in recent and subrecent river channels makes it obvious that they can be interpreted as fluvial channel deposits.

8) Clay member

Soft to moderately stiff, heavy clay, to (very) sandy, silty clay usually occurring at the surface of the surveyed area. Locally these deposits contain more than 50 per cent sand or silt. Mostly the clays are slightly humic, contain some plant remains in growing position, iron and manganese concretions, and show oxidation mottling. Gradual transitions to the underlying organic clays or lake gyttjas are most common, but transitions to all other units occur (except unit 1).

9) Ash member

Throughout the whole sedimentary sequence thin layers (usually several centimetres thick but some up to 0.5 m thick) of fine sand, silt and clay are encountered. They have mainly pale, whiteish colours, occasionally reddish or bluish. Some encountered layers may show a composite build up, with distinguishable laminae. Others are disturbed by biologic activity and difficult to recognize. Their occurrence in all previously described lithological units and their overall appearance and dimensions suggests that they can be interpreted as either eolian deposits or volcanic ash layers.

The various lithological units and their interpretation in terms of sedimentary environments and depositional process (es) are shown in Figure 8.

6. Lithostratigraphical framework

Field data obtained so far suggest the following lithostratigraphical - genetical framework (Figure 9); several relations are still unclear. The position of two significant paleosols is indicated. Eleven available radiocarbon datings make it possible to place the course of events in a provisional chronological framework.

Five major members are believed to occur at the same stratigraphic position in the sequence. Sufficient field evidence shows further that transitions between these members are gradual, and that complex interfingering situations exist. The green clay member (substrate I) is regularly encountered underlying the other members. The presence of a significant paleosol is indicated. Presently, insufficient data are available to interpret this member in terms of sedimentary environment. Whether the same green clay member, including paleosol, also occurs under the sandstone member remains unclear. The radiocarbon dating result however supports the presently assumed position. Recent fluviatile sediments, the channel sand member and the clay member are mainly overlying the other deposits. Ash deposits have been found to occur as minor intercalations in all stratigraphic positions.

C -14 datings further enable us to discern the deposits' age relations.

Sample no.	Drilling/ Exposure	Elevation + msl	Age BP
A45	Nanjung	655	>49.000
C14	F73	656.5	35.720 + 900/--840
C10	Cikuya E17	670	34.750 + 1,000
C40	C40	650	34.600 + 1,000
C3	Exposure E4	662.5	27.060 + 260
Cib 2	Exp. Ciburial	678.6	26.800 + 2,200/1,700
Cib 1	Exp. Ciburial	683	24.560 + 300
C12	Cikuya E17	687.9	18.020 + 100
C2	C2	666.7	15.280 + 330
GRDC 1	Ciharuman	650--670	36.390 + 2,500
GRDC 2	Kandang Sapi	–	42.360 +1,925

Concluding, it can be stated that this approach enables a fairly detailed paleoenvironmental reconstruction. The characteristics and meaning of the paleosols encountered remains to be determined.

7. Lake level movements

Likewise, lake level fluctuations inferred from lithological evidence, might justify further investigation regarding their cause and paleoenvironmental significance. Combining the results of the discussed radiocarbon datings with the topographical elevation of the sample positions it is possible to plot an approximate lake level curve. It has to be assumed though, that all interpretations of the sample material, ie. humic peaty clays supposedly lake/lake shore deposits, are correct and that organic remains also originated during the moment of deposition. The curve is plotted in Figure 10.

8. The older part of the sedimentary sequence

So far, the emphasis has been on the most recent, + 35,000 years and younger, surficial part (uppermost 10-20 m) of the Bandung basin sedimentary sequence. However, as was stated above, this is only a small part of the sediment accumulation in the basin. Various sources of information have contributed to our knowledge concerning the older part of the sequence.

As mentioned before the data collected in the geo-resistivity survey by Marino *et al.* (1976) suggest the occurrence of older lake deposits. This seems to be

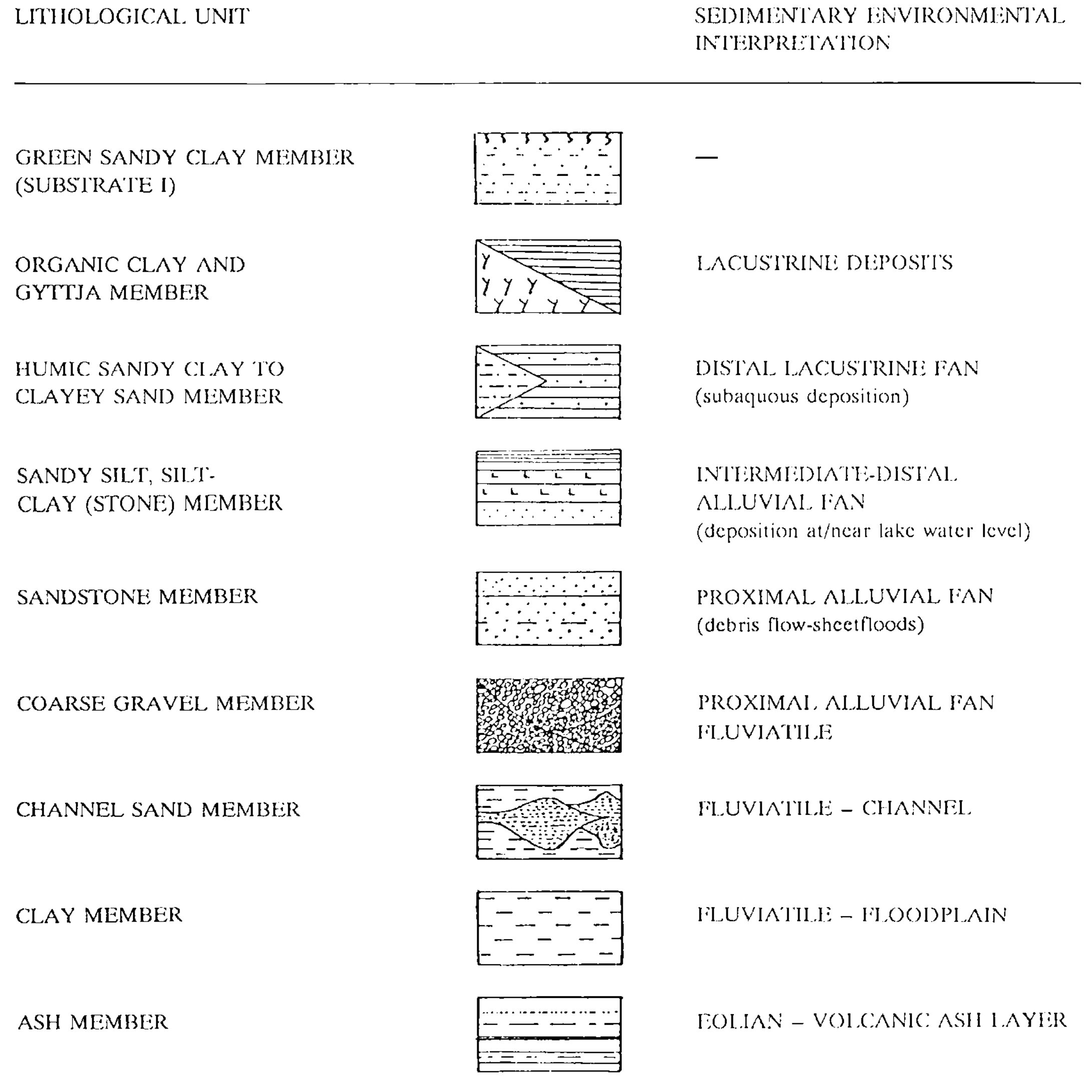


Figure 8. The various lithological units of the Bandung basin and their sedimentary environments

confirmed by a small number of geo-resistivity soundings recently carried out in the central part of the basin (Marino *et al.* worked in the southwestern part).

A few exposures are stratigraphically deep enough to reveal material underlying the lithological unit indicated as substrate I; it can be described as a very humic, silty, sandy clay with a soft and sticky consistency, and is interpreted as a lake deposit. It proves the presence of deposits that originated during an earlier lake phase.

Drilling descriptions from a considerable number of deep drillings, made for various purposes, are available (especially for an extensive section along a new major toll road). In order to investigate the subsurface sediments GRDC's team made two deep drillings. The results of the Cipamokolan drilling, near the central part of basin, are shown in Figure 11. It can be compared with the sequence encountered in other deep drillings further east. (Figure 14).

Besides the rather coarse lithologic description (due to poor sample quality) of the sedimentary sequences, analysis carried out for civil engineering purposes to determine sediment physical properties provides more information about the character of the deposits. (Figures 12 and 13).

Figure 12 shows a generalised curve for the moisture content and the initial void ratio for the upper 28 meters of sediment (for location Figure 4). Both curves show the same pattern, which for the moisture content curve means high moisture content layers alternating with low moisture content layers (for the void ratio curve; desiccated, compact layers alternating with soft, water rich horizons the structure of which contains a high percentage of pore spaces). Respectively, these layers have been interpreted as desiccated, air dried and physically ripened farmer soil horizons, alternating with soft, watery clayey lake deposits, probably with a high organic content. In addition, these lake deposits (?) contain large amounts of diatomaceous silica, while

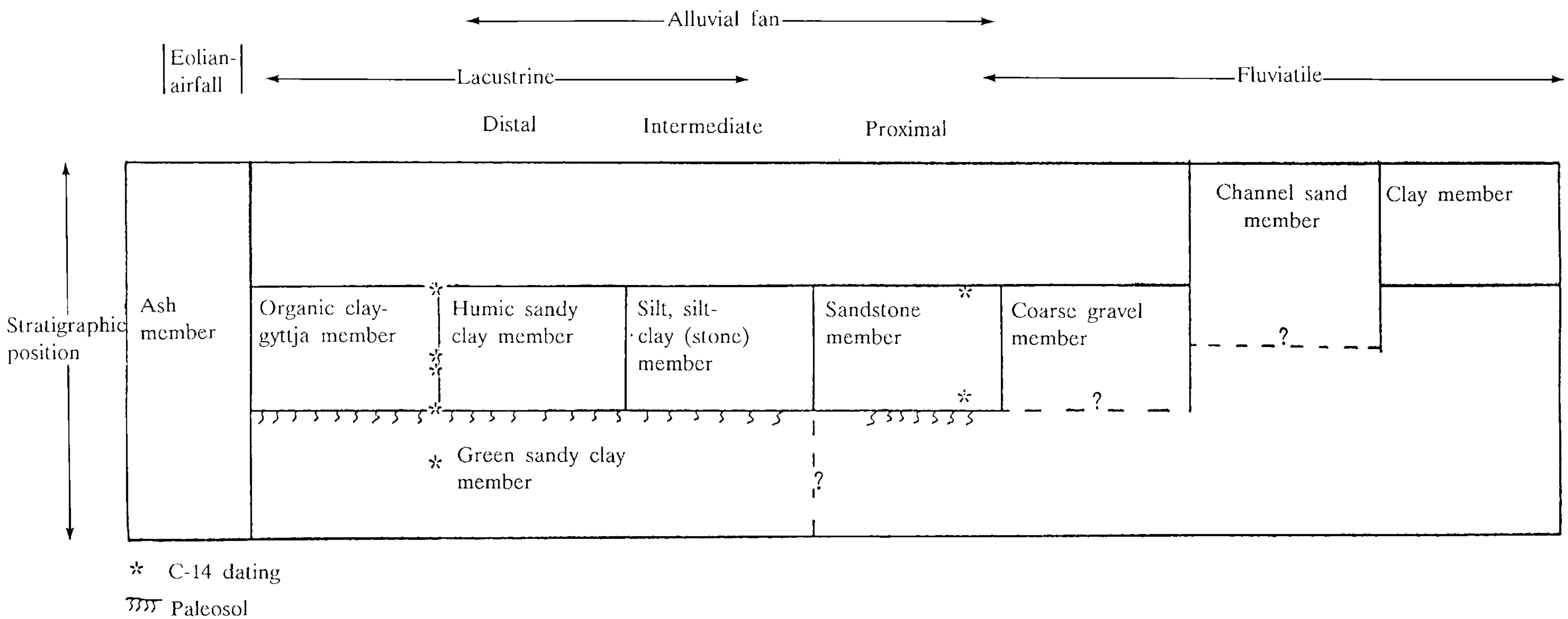


Figure 9. A preliminary lithostratigraphical framework for shallow subsurface deposits encountered in the Bandung basin. Interpretation in terms of sedimentary environments is indicated, as well as the position of a number of C-14 datings and two paleosols.

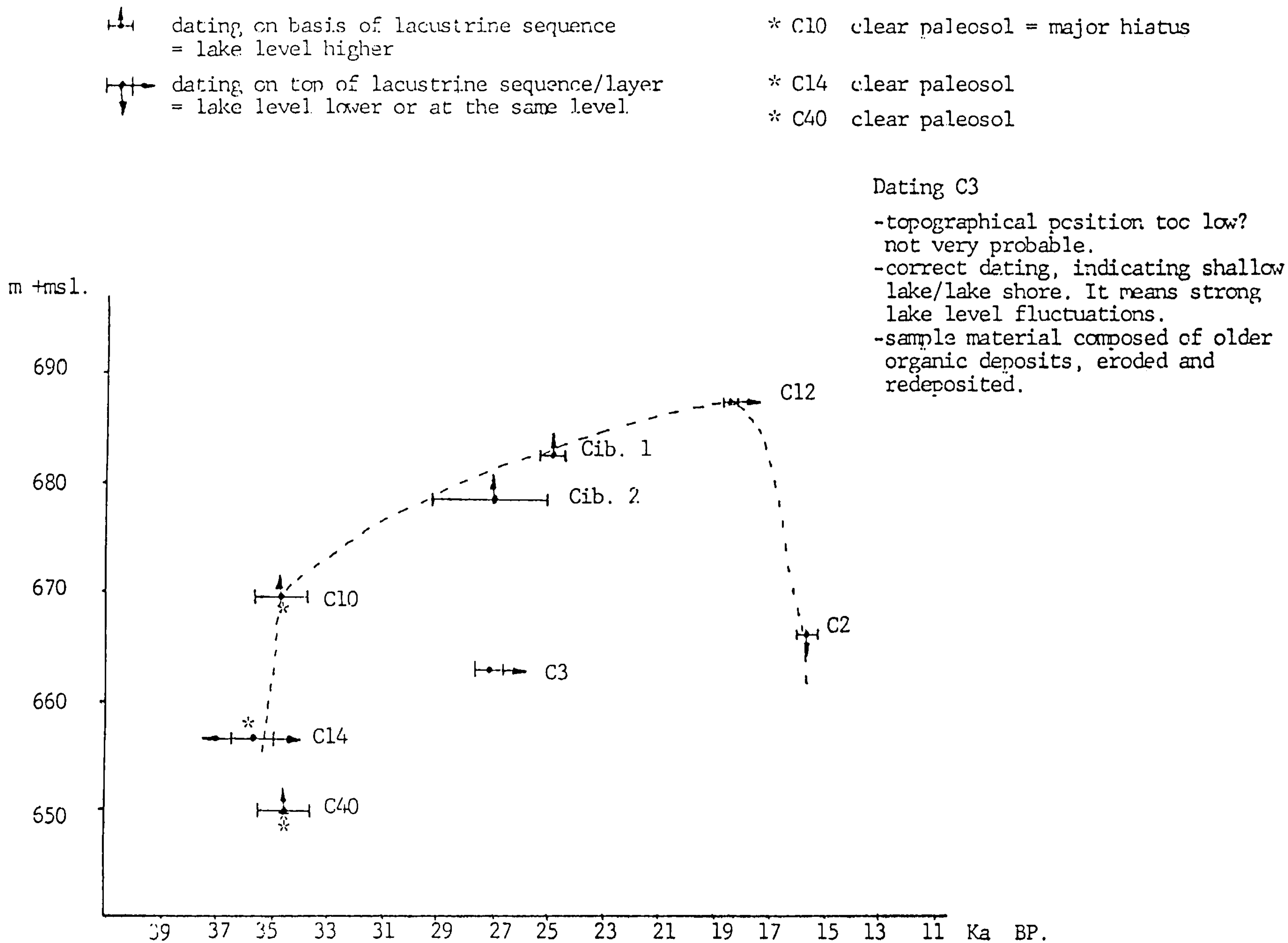


Figure 10. A provisional lake level curve for the Bandung lake

depth
in m

LITHOLOGY

660 m + msl

-top layer of disturbed brownish grey clay
-clay,dark grey,humic,some plant remains,soft
gradual changing to clay,soft and black
-clay,silty,greenish grey,slightly crumby,some
parts very friable
-gyttja
-clay,black,very soft,containing very thin silty
clay layers (volcanic ash)
-thin layers of tuffaceous clay,reddish
-clay soft and black,containing volcanic ash
-coarse sand,greyish white,moderately sorted,
subangular
-tuffaceous silt,light grey, very compact
-sand,coarse, greyish white
-gyttja,clayey, very soft
-clay, silty, with degree of gyttja, moderate
plant remains, dark grey to black
-clay,silty,slight degree of gyttja,plant remains
dark grey
-clay, dark grey, very soft, homogeneous
-clay,silty, dark greenish grey, leave remains
-gyttja. light greenish grey
-clay, greenish grey, stiff to very stiff
-sand,thin intercalations of clay, fining upw.
from coarse to fine, angular.
-gyttja, peaty, brown
-clay, tuffaceous, very compact
-gyttja, peaty, brown
-clay,tuffaceous,greenish grey, very hard
-peaty clay, brownish grey
-clay,silty,greenish black,bright green mottles
compact and crumby
-clayey sand, top of fining upward sequence
-coarse sand, angular black
-gyttja, very clayey
-sand, clayey, blackish
-medium coarse sand
-clay moderate degree of gyttja
-sand,fine,moderately sorted,subangular/angular
-clay,greenish,thin black sand layers,some gyttja
-greenish grey clay,crumby
-gyttja,very clayey,pieces of lignite
-lignite like material (charcoaled wood)
-sandy clay, black
-sand, coarse and gravelly
-sand, coarse, gravelly, pumiceous
-sand, gravelly, black
sand up to 1400 m
gravel up to 5 - 10 mm 0
intercalations of fine sand,overall poor sorting
gravel greenish black,scoriaceous,abundant glass
minerals, vague fining upward trend.
-sand,coarse,gravelly, up to 20 mm 0
-gyttja,homogeneous,some plant remains,compact
grey-green,crumby consistency
-clay,tuffaceous,grey,containing a white ash
layer, compacted
-clay,tuffaceous,gravelly,extremely firm,green
-idem, bright green, slightly sandy
-clay,tuffaceous, sandy, moderate pebbles,scoria-
ceous, grey to black, some andesites
-idem, increasing igneous pebbles, very hard
-thin layer of sandstone, intercalations of green
clay, main colour greenish,bright
-idem, clay decreasing
-Sandstone, or compacted and, fine,well sorted
-idem, with moderate amount of gravel
-clay, sandy,greenish-blue, coarsening dww. to
-greenish sandstone, minor black colours
-as above, minor amount of clay and silt, very hard.

Figure 11. Record of deep drill hole at Cipamokolan

electron microscopy reveals the presence of complete diatom shells.

The organic content curves, Figure 13, from samples along the same section, show a more complicated pattern. Material with a high organic content can be interpreted as highly organic, clayey lake deposits (probably lake gyttjas). It is expected that the highest peaks in the curves represent peaty layers, rich in vegetation remains, that formed when a wet pre-lake soil drowned and subsequently became a lake bottom.

The data discussed so far leave little doubt regarding the most obvious interpretation of the sequence of deposits encountered in the deep drillings. Looking back to the drilling logs along the section, it is clear that sequences of organic lake deposits are alternating with soil horizons, or layers of subaerially deposited clastic material. (Figure 14).

9. Conclusions

Research presently being carried out comprises detailed lithostratigraphical surveys and a closer investigation of lithological characteristics and sedimentary structures of exposed deposits. Results of radiocarbon, grainsize, heavy minerals, clay mineralogy and probably palynological analysis, for which sampling has been carried out, will be available in the near future and hopefully support the preliminary synthesis presented here. A larger number of radiocarbon datings will enable us to place events in a more detailed chronological framework. As was illustrated this will make it possible to reconstruct, with a fair amount of detail, the geological development of the area since the beginning of the youngest lake phase until present.

A geo-resistivity survey will be carried out during the coming months. Together with the study of the available deep drilling data, the interpretation of the sediment's resistivity values will elucidate important geological characteristics of a major part of the basin sedimentary fill. Thus, optimal locations can be chosen for a number of deep drillings to be made, with the intention to obtain undisturbed samples of the complete sedimentary sequence.

As will be clear from the foregoing it is expected that an interesting sequence of lake deposits, alternating with subaerially deposited sediments will be encountered. The knowledge of the most recent geological developments in the area enables the interpretation of this older sequence, and any significant deviations regarding character and intensity of exogeneous processes. Following the study and interpretation of these new geologic data, inference of the most relevant factors causing changes in the regional evolution, be it either geomorphologic, volcanic, tectonic or climatic, will be the next step. We hope that we will be able to present these future results to this forum.

10. Acknowledgements

The preparation and presentation of the foregoing paper was made possible with the assistance of the following persons. We sincerely thank them. Dr. R. Sukamto and Drs. R. Wikarno of GRDC, Bandung for enabling us to conduct this research and study the data obtained. Dr. J. Rau for his contributions to the organization of the IGCP 296 meeting and for his kind invitation to attend the meeting in Ipoh, Malaysia. IGCP, AGID and WOTRO (grant W75-293) sponsoring organizations. All contributors to the publications and reports used. All others who have, either organizationally or in the actual field work, participated in and contributed to this project.

References

This paper is partly based on data discussed in the following reports:

Dam, M.A.C., P. Suparan and S. Hidayat. 1986. *Reconnaissance survey in the Bandung basin, a preparation for Quaternary geological mapping and research*. GRDC/VU report, Bandung.

Kok, H.L., P.E. Van Olst, P. Suparan and S. Hidayat, 1987. *Quaternary geological research in the southwestern part of the Bandung plain*. Field survey report GRDC/VU, Bandung.

Mulyana, H. and P. Suparan, 1988/89. *Laporan semetara pemboran inti di daerah Cipamokolan dan Pameuntasan*, Kab. Bandung, Jawa Barat. Proyek PPKG, PPPG, Bandung.

Eernisse, N. and E. Koomen, 1989. *Quaternary geological research in the central part of the Bandung basin*. GRDC/VU report, Bandung (report in progress).

Besari, S.Z., and I. Sabari, 1984. *Laporan: Penyelidikan Takanan Jenis dan Gaya Berat daerah Cimareme-Cimahi*, Jawa Barat. PPPG-Bandung.

Koesoemadinata, R. P., dan D. Hartono, 1981. *Stratigrafi dan Sedimentasi daerah Bandung*. Paper presented at IAGI Bandung.

Kridoharto, P., 1976. *Laporan: Gaya Berat daerah Bandung Raya*. PPPG, Bandung.

Marino, A., R. Suharna and B. Sal Sjaiful. 1976. *Penyelidikan Geolistrik daerah Bandung dan Sekitarnya*. PPPG, Bandung.

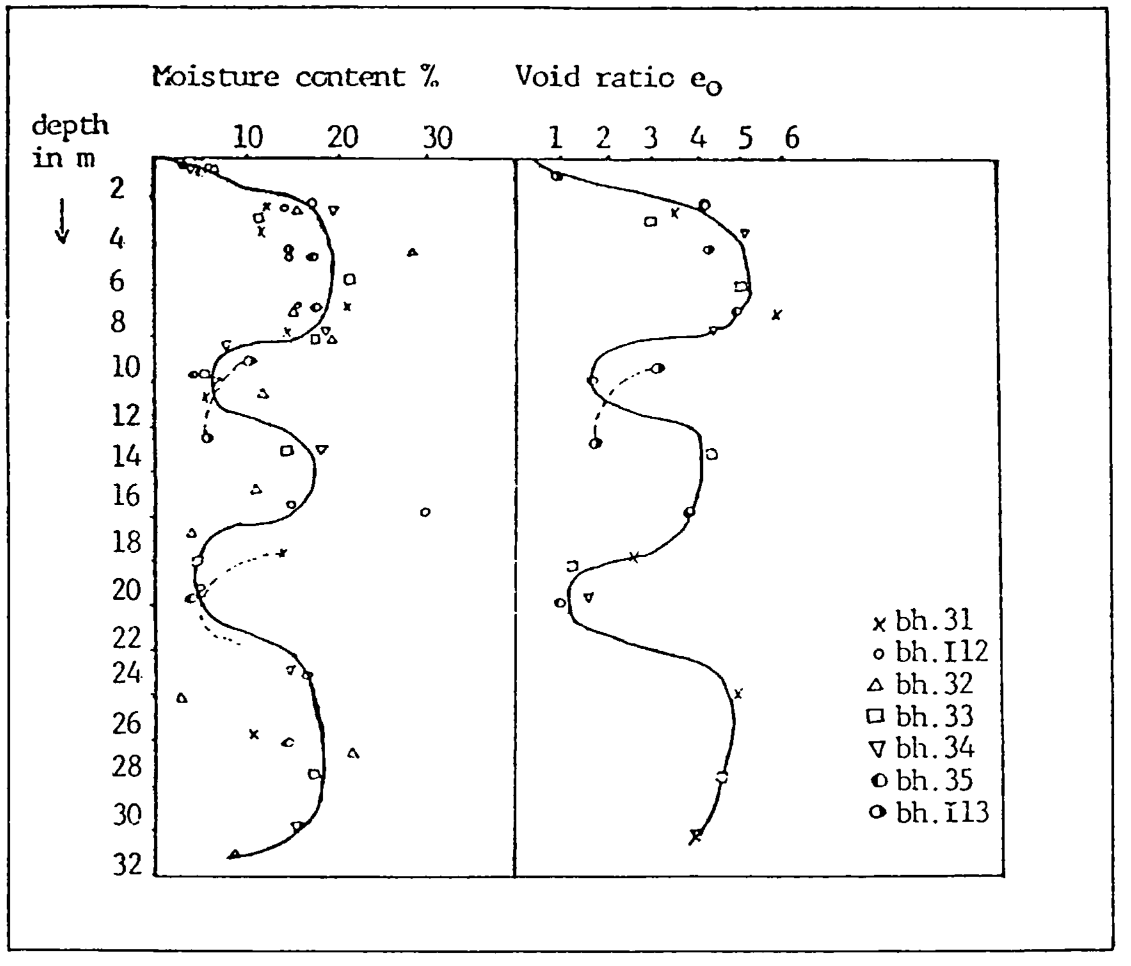


Figure 12. Profiles of natural moisture content and initial void ratio for boreholes between kilometre 40 and kilometre 43 (After Younger, 1986)

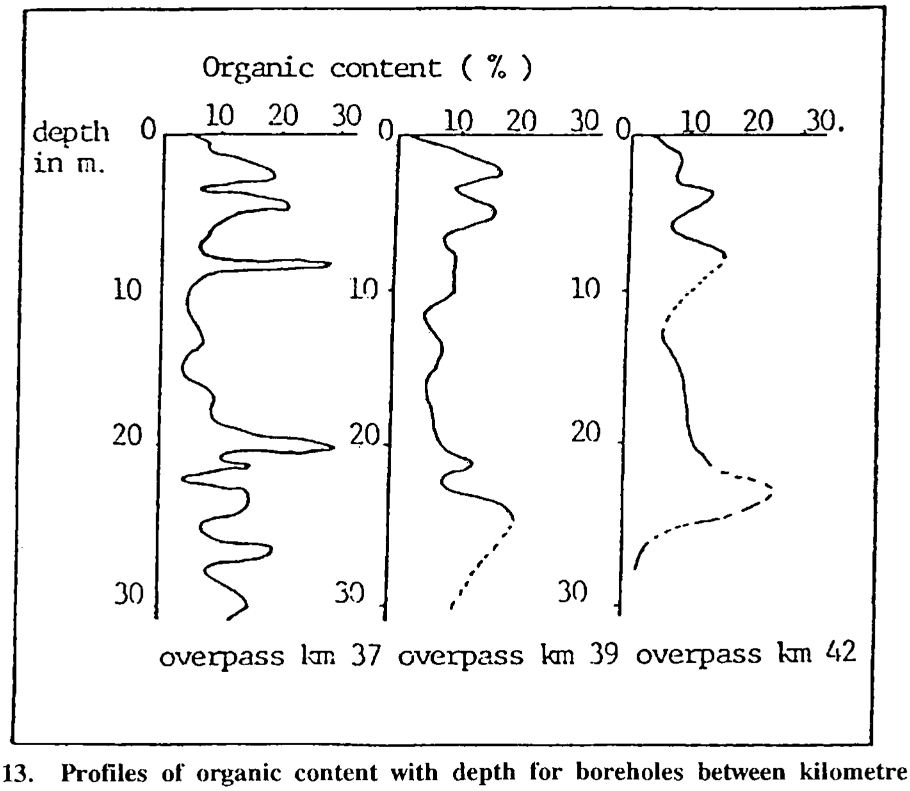


Figure 13. Profiles of organic content with depth for boreholes between kilometre 37 and kilometre 42 (After Younger, 1986)

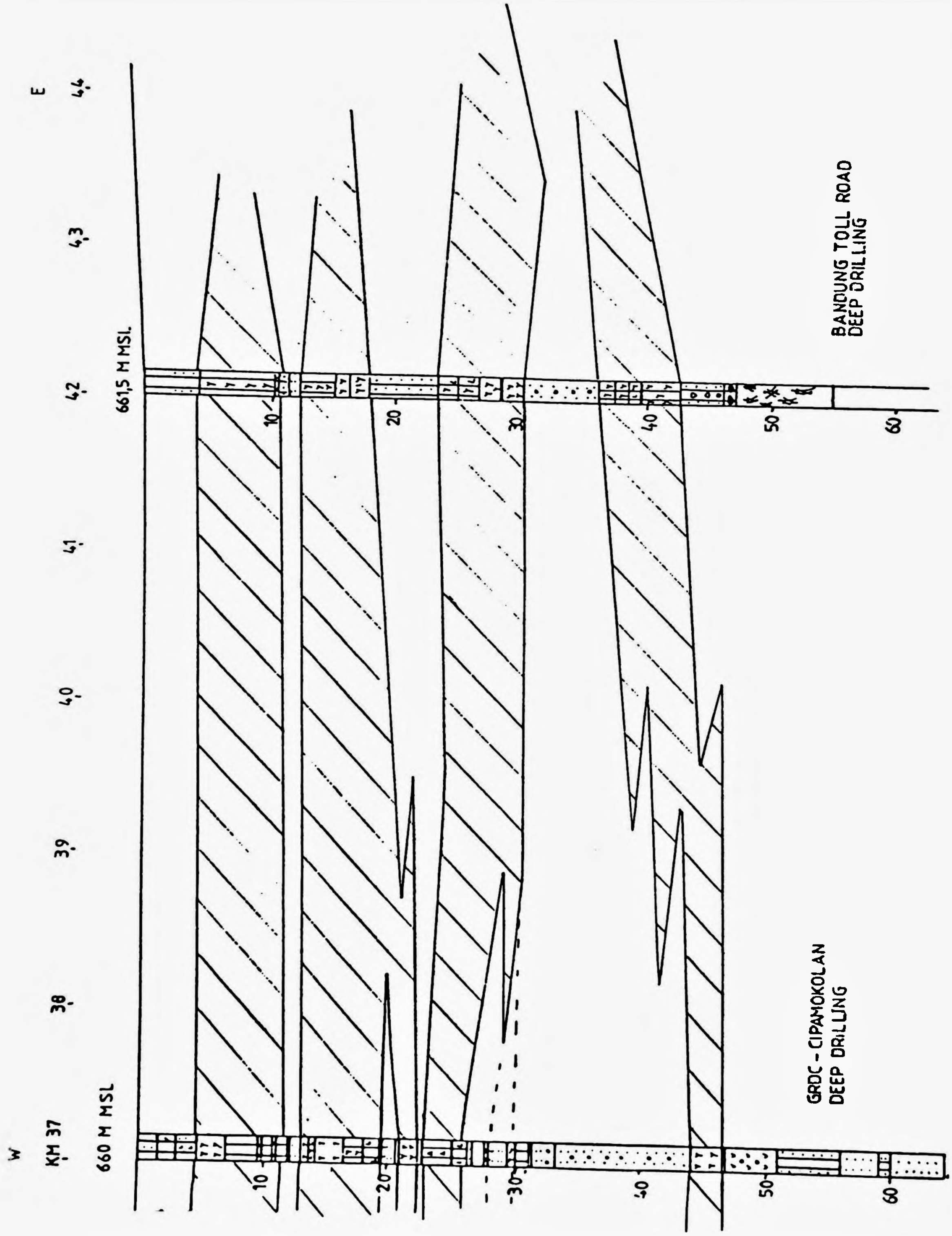


Figure 14. A section through the northern part of the central basin area (for location see Figure 4). It shows a sequence of lake deposits alternating with subaerially deposited clastic materials.

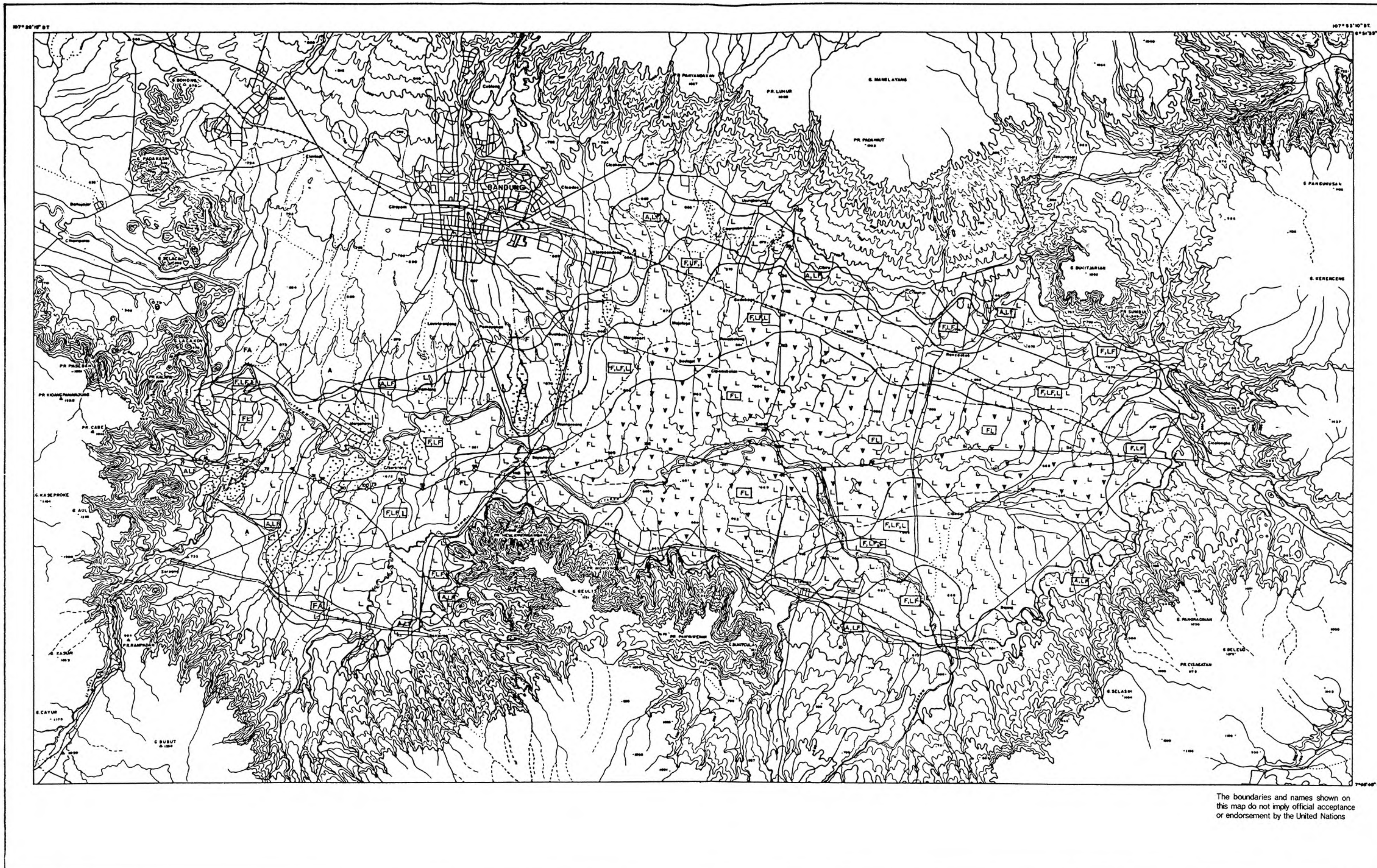


Figure 15. Preliminary Quaternary geological map of Bandung basin, West Java

Mesdag, F.T., 1928. De fossiele delta der Tjiwidej. *De Mijningenieur.* No. 3 Leiden.

Priowirjanto, G.H., 1985. Untersuchungen zur Hydrogeologie des Bandung Beckens und zur Wassergewinnung der Stadt Bandung mit Hilfe eines mathematischen Modells.
Mitt. Ing. und Hydrogeologie, 21, Aachen.

Silitonga, P.H., 1973. *Peta Geologi Bersistim Jawa*, 1:100.000, Lember Bandung, Geological Survey of Indonesia, Bandung.

Stehn, Ch.E. and J.H.F. Umbgrove, 1929. Bijdrage tot de geologie der vlakte van Bandoeng. *Tijdschrift KNAG,* 2e serie, deel KLVI, afl. 3, Leiden.

Van Bemmelen, R.W., 1934. *Geologische kaart van* Java, 1:100.000, Toelichting bij blad 36 (Bandoeng). Dienst van den Mijnbouw in Nederlandsch Indie, Bandoeng.

______ 1949. *The Geology of Indonesia,* Volume Ia General Geology of Indonesia and adjacent archipelagoes. Martinus Nijhoff, Den Haag.

Younger, J.S., 1986. Construction over soft ground, *Proc. of Pasca Sarjana Workshop on Developments in Highways and Transportation Engineering,* Bandung.

IGCP 296

PROGRESS IN ESTABLISHING QUATERNARY STRATOTYPES IN MALAYSIA

by

T. Suntharalingam[1]

Abstract

The historical development of Quaternary geological studies, especially the stratigraphy of Peninsular Malaysia, extends from the time of early placer tin mining activities to that of the studies by Walker (1955), Sivam (1969), Newell (1971), Batchelor (1979) and Yeap (1980). This paper also gives an account of the systematic Quaternary mapping programme carried out by the Geological Survey of Malaysia since 1976.

The various techniques employed by the Geological Survey of Malaysia to map the Quaternary deposits are described in the 'Manual of Quaternary Geology Methods' (Suntharalingam *et al.* 1986). This manual gives a comprehensive account of the various field methods, laboratory techniques, data storage, interpretation of data and the compilation of the various types of maps, cross-sections and bulletins.

The coastal deposits of Peninsular Malaysia have been divided into four stratigraphic units on the basis of lithology, heavy mineral content, age and paleoenvironment. They are the continental Simpang Formation (mainly fluviatile deposits of Pleistocene age), the Kempadang Formation (an older marine formation of Pleistocene age), the Gula Formation (a Holocene marine unit) and the continental Beruas Formation (mainly fluviatile and lacustrine deposits of Holocene age).

Stratotypes for Peninsular Malaysia and Sarawak will be prepared and presented during the period of this project.

1. Preliminary research and planning

Preliminary studies on the literature of an area to be mapped are important because good background knowledge ensures proper and efficient planning of a project. Initial research and planning to be carried out includes:

- Literature survey and data collection.
- Topographical map study and aerial photograph interpretation.
- Reconnaissance fieldwork.

2. Geophysics

Geophysical surveys are generally undertaken prior to drilling operations to:

i) Determine the thickness of the unconsolidated sediments.

ii) Determine palaeochannels and other subsurface features.

iii) Indicate the different lithological units.

iv) Guide the laying-out of the boreholes and type of drill to be used.

3. Drilling

Drilling is carried out to determine the distribution, thickness and nature of unconsolidated deposits.

Shallow holes

A borehole of less than 20 m depth. Equipment is light, manually operated by 1-3 persons and core recovery is generally good but of small diameter.

- Edelman auger
- Guts auger
- Linneman auger
- Van der Staay suction corer

Deep holes

Depth greater than 20 m. Samples disturbed and used for evaluation of placer mineral deposits.

[1] Geological Survey of Malaysia, Ipoh, Malaysia.

Percussion system

- Hand Banka
- Semi-Mechanized Banka (Portable)
- Semi-Mechanized Banka
- Fully Mechanized unit

Flush drilling

- Conrad-Mini 200

All deep boreholes have to be levelled

4. Laboratory studies

- Grain size analysis
- Palynology
- Palaeontology
- Firing test
- Silica sand classification
- Geochemical analysis
- Identification of clay minerals by X-ray/DTA.
- Radiocardon dating (overseas)
- Geotechnical properties

References

Batchelor, B.C., 1979. Geological characteristics of certain coastal and offshore placers as essential guides for tin exploration in Sundaland, Southeast Asia: *Bull. Geol. Soc. Malaysia*, 11, 283-33.

Bosch, J.H.A., 1988. *The Quaternary Deposits in the Coastal Plains of Peninsular Malaysia*. Report No. QG/1, Geological Survey of Malaysia.

Newell, C.A., 1971. Characteristics of the stanniferous alluvium in the southern Kinta Valley, West Malaysia. *Bull. Geol. Soc. Malaysia*, 4, p. 15-37.

Sivam, S.P., 1969. *Quaternary alluvial deposits in the north Kinta Valley, Perak*. Unpublished M.Sc. thesis, Univ. of Malaya, Kuala Lumpur.

Suntharalingam, T. and others, 1987. *A Manual of Quaternary Geology Methods*. Report No. QG/1, Geological Survey of Malaysia.

Suntharalingam, T. and others, 1987. *A manual of Quaternary geology methods*. Report No. QG/1, Geological Survey of Malaysia.

Walker, D., 1955. Studies of the Quaternary of the Malay Peninsular I. Alluvial deposits of Perak and the relative levels of land and sea. *Fed. Mus. Jour.*, 1 and 2, p. 19-34.

Yeap, C.H., 1980. Exploration of a Deep Tin Deposit at Kuala Langkat. *Inst. of Mining & Metallurgy (Malaysian Section) Annual Magazine*, 1980, p. 72-87.

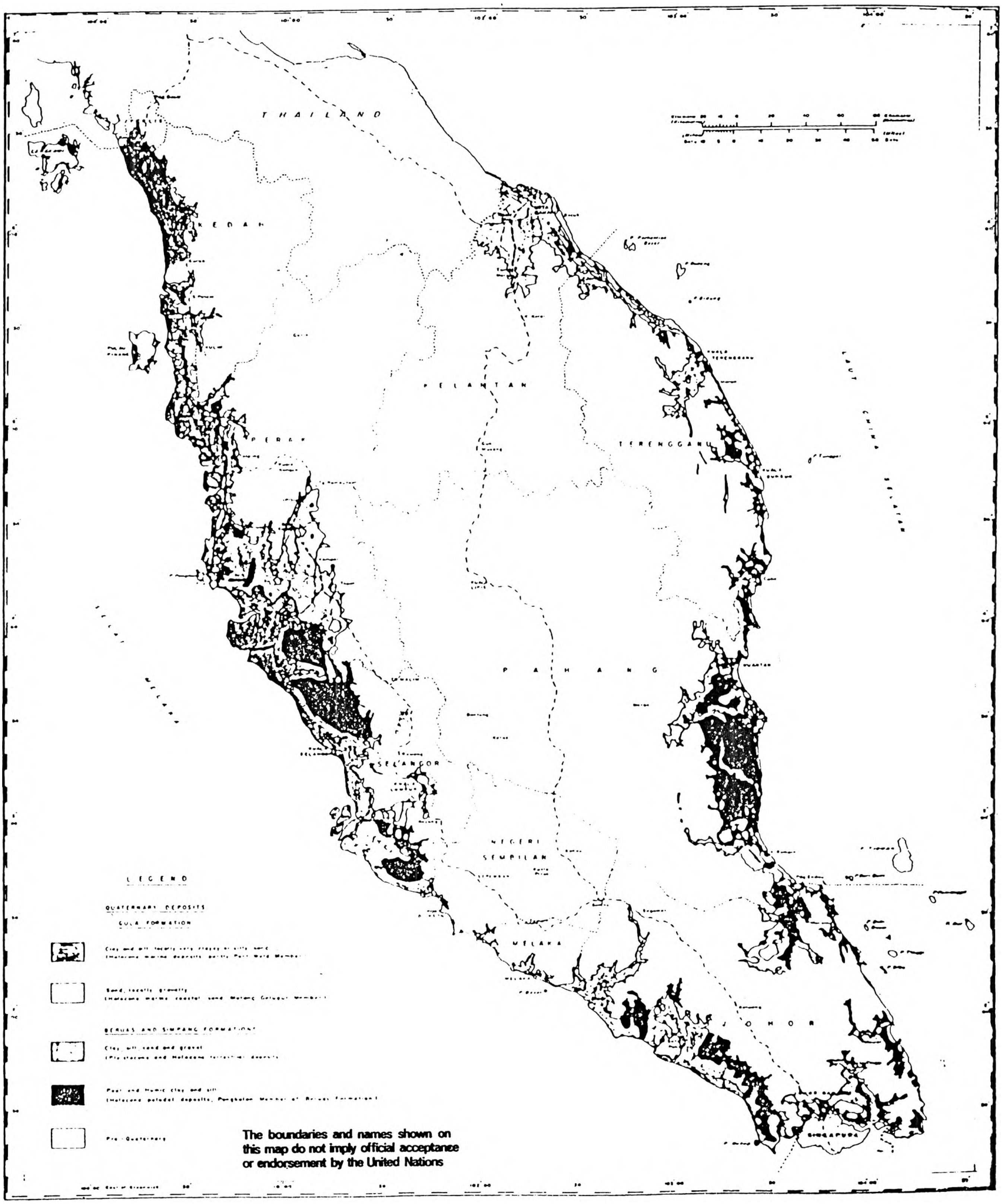


Figure 1. Provisional Quaternary geological map of Peninsular Malaysia

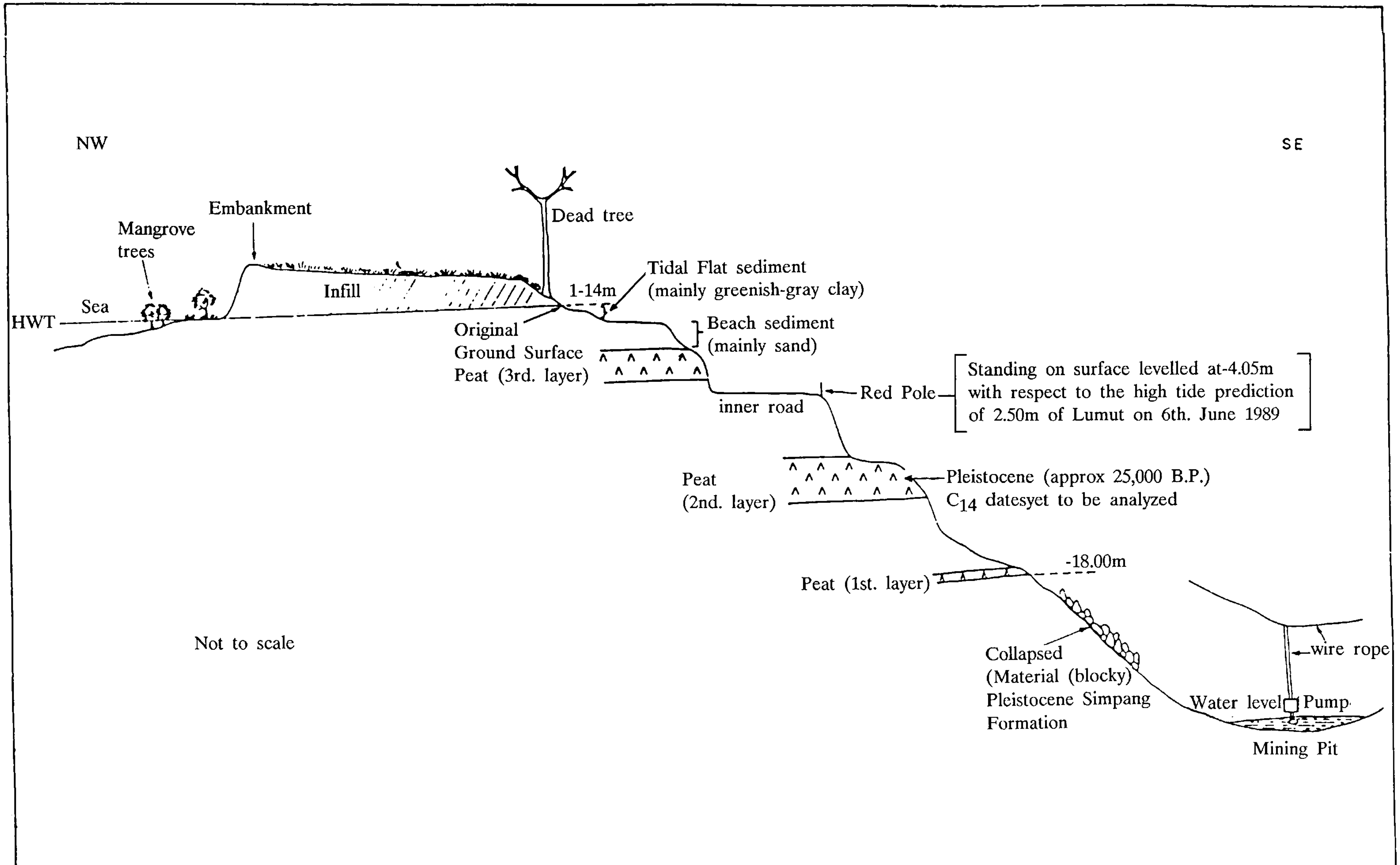
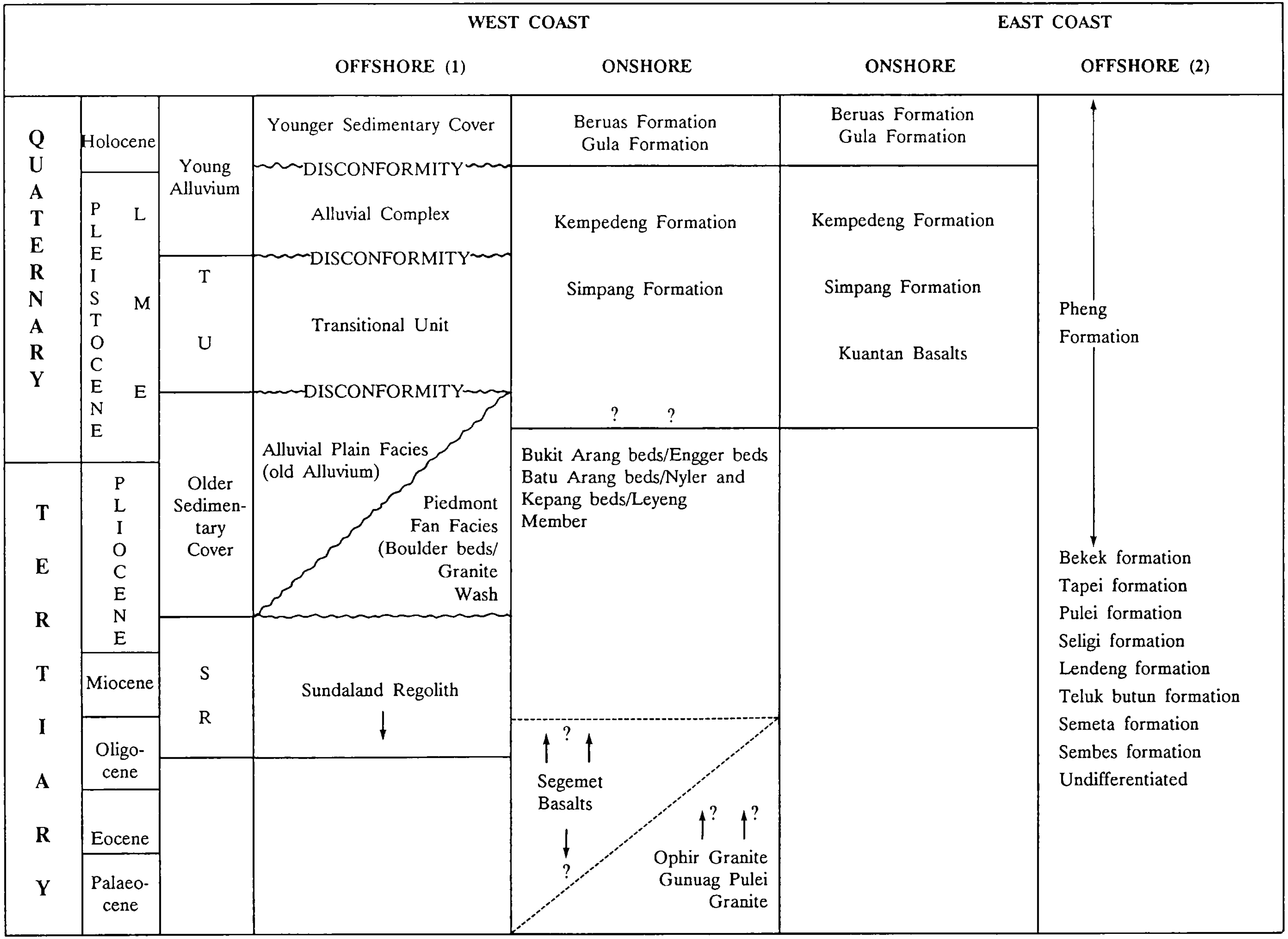


Figure 2. Draft schematic cross-section (Face 2) of Pantai Tin Mine (as of 7th June 1989). Radiocarbon dates are tentative only!



Source: (1) Diameter, D.C. (1979) (2) After Armitage and Violate, 1977 – South Malay Basin.

Figure 3. Cenozoic correlation chart for Peninsular Malaysia

Table 1. Late Cenozoic correlation chart, Perak

		BERUAS (1)		TAIPING (2)	KINTA VALLEY (3)	NORTH KINTA VALLEY (4)	LUMUT– Dindings offshore (5)	
HOLOCENE		Gula Formation Matang Gelugor Member Port Weld Member	Beruas Formation Pengkalan Member	Port Weld formation Kurau formation Kerian formation Matang Timbal formation Asam Kumbang Peat Matang Gelugor formation ↑ ? ↑ Gula clay	Organic mud and peat Young Alluvium	Young Alluvium ? ?	Younger Sedimentary Cover DISCONFORMITY Alluvial Complex DISCONFORMITY	YOUNG ALLUVIUM
PLEISTOCENE	Late	Simpang Formation (a) Upper clay member (b) Lower sand member			? ?	? ?		
	Middle	↓ ↓ ↓		Simpang Formation	Old Alluvium	Old Alluvium	Transitional Unit DISCONFORMITY	T U
	Early	? ? ?		Kulim Granite wash	? ?	? ?	Alluvium Plain Facies (Old Alluvium) Piedmont Fan Facies (Boulder beds / Granite wash)	OLDER SEDIMENTARY COVER
PLIOCENE	Late			↓ ? ↓	Boulder beds ? ?			
	Early						DISCONFORMITY Sundaland Regolith ↓	S R
LATE MIOCENE								

Source. (1) T. Suntharalingam. (2) T. Suntharalingam and Teoh. L. H. (1980) (3) Walker. D (1955) (4) S. P. Sivam (1969) (5) Batchelor. B. C. (1979)

IUGS UNESCO

IGCP 296

PROGRESS IN ESTABLISHING QUATERNARY STRATOTYPES IN NEW ZEALAND

by

Kelvin Berryman[1]

1. Summary

The physical setting of New Zealand; astride the Pacific/Australia plate boundary in mid-southern latitudes (35-50°S), and surrounded by ocean, are underlying reasons for an extensive cover of Quaternary deposits over most of New Zealand (Figure 1). High rates of tectonism result in rapid uplift and erosion of the landmass, and formation of subsiding basins that are depositional sites for erosional debris. Rhyolitic arc volcanism is also a feature of the Quaternary of the North Island and have generated extensive ignimbrite sheets and even more widespread airfall ash deposits. Because of mid-latitude setting, New Zealand has experienced extensive glaciation during the Quaternary with widespread glacial and periglacial landforms, and extensive cold-climate loess sheets have formed in some places. During interglacial periods climate ameliorated to such an extent that soils formed on glacial and periglacial deposits providing a striking alternation in the stratigraphy.

The oceans that surround New Zealand exert a strong influence on terrestrial climate systems. This is fortunate in time-stratigraphic studies because terrestrial systems are in tune with the oceanic record. The stratigraphic subdivision of the New Zealand Quaternary can therefore be linked with the global oceanic record.

This paper will concentrate on studies that have proved valuable in establishing the Quaternary chronostratigraphy of the Wanganui region of western North Island (Figure 1), and the integration of that stratigraphy with the oceanic record obtained from DSDP sites 284 and 593, about 600 km west of Wanganui and DSDP site 594, about 600 km south of Wanganui.

Fossiliferous Plio/Pleistocene shallow marine sequences are extensively exposed on land in the Wanganui basin. Gradual uplift accompanied by seaward tilting toward the Wanganui basin depocentre allowed the cutting of interglacial marine terraces in older, more inland strata, while coeval marine rocks were deposited in thickening wedges offshore (Figure 2).

Biostratigraphic subdivision of the Wanganui marine sediments have been the basis of the Plio/Pleistocene stages for New Zealand. More recently, paleomagnetic, stable isotope, and tephra dating and chemical fingerprinting studies have complimented and revised earlier statigraphic schemes and correlations. The occurrence of tephra in shallow marine sediments, terrestrial cover deposits and deep sea sediments provide very valuable tie points (Figure 3). Difficulties in stratigraphy and correlation within the Wanganui sequence still exist with a substantial (c. 0.5 Ma) unconformity in the coastal sequence (Figure 3), imprecise fission track ages on tephra, lack of unique chemical differentiation criteria for some tephra and the suggestion that some of the biostratigraphic markers are time transgressive between deep sea and shallow marine sites.

At DSDP sites 284 and 593 to the west of New Zealand, age control provided by radiocarbon dates, biostratigraphy, oxygen isotope records and paleomagnetic stratigraphy (Figure 4) tie the cores to on-land sequences in Wanganui. DSDP site 594 to the southeast of New Zealand provided a thick (probably 88 m to the Brunhes/Matuyama boundary), rhythmically banded, section of light coloured pelagic ooze and dark coloured hemipelagic sediment. Marked variation in quartz and feldspar occurrence, carbonate content of sediment, and ^{18}O enrichment depict glacial/interglacial cycles and oxygen isotope stages. There remains some difficulty in establishing the Brunhes/Matuyama boundary in this core, but accepting the usual position of boundary at the base of oxygen isotope stage 19, then a prominent tephra at 36.5 m sub-bottom appears to fall in oxygen isotope stage 10 (Figure 5) and may be the Rangitawa Pumice of the Wanganui Sequence.

Although New Zealand's geographic setting has provided a favourable setting for Quaternary stratigraphic studies, standard methods of investigation, that may be employed in any setting, have been used to establish the stratotypes. Biostratigraphic markers, tephra and paleomagnetic reversals provide links between shallow marine and deep sea environments.

[1] New Zealand Geological Survey, P.O.Box 30368, Lower Hutt.

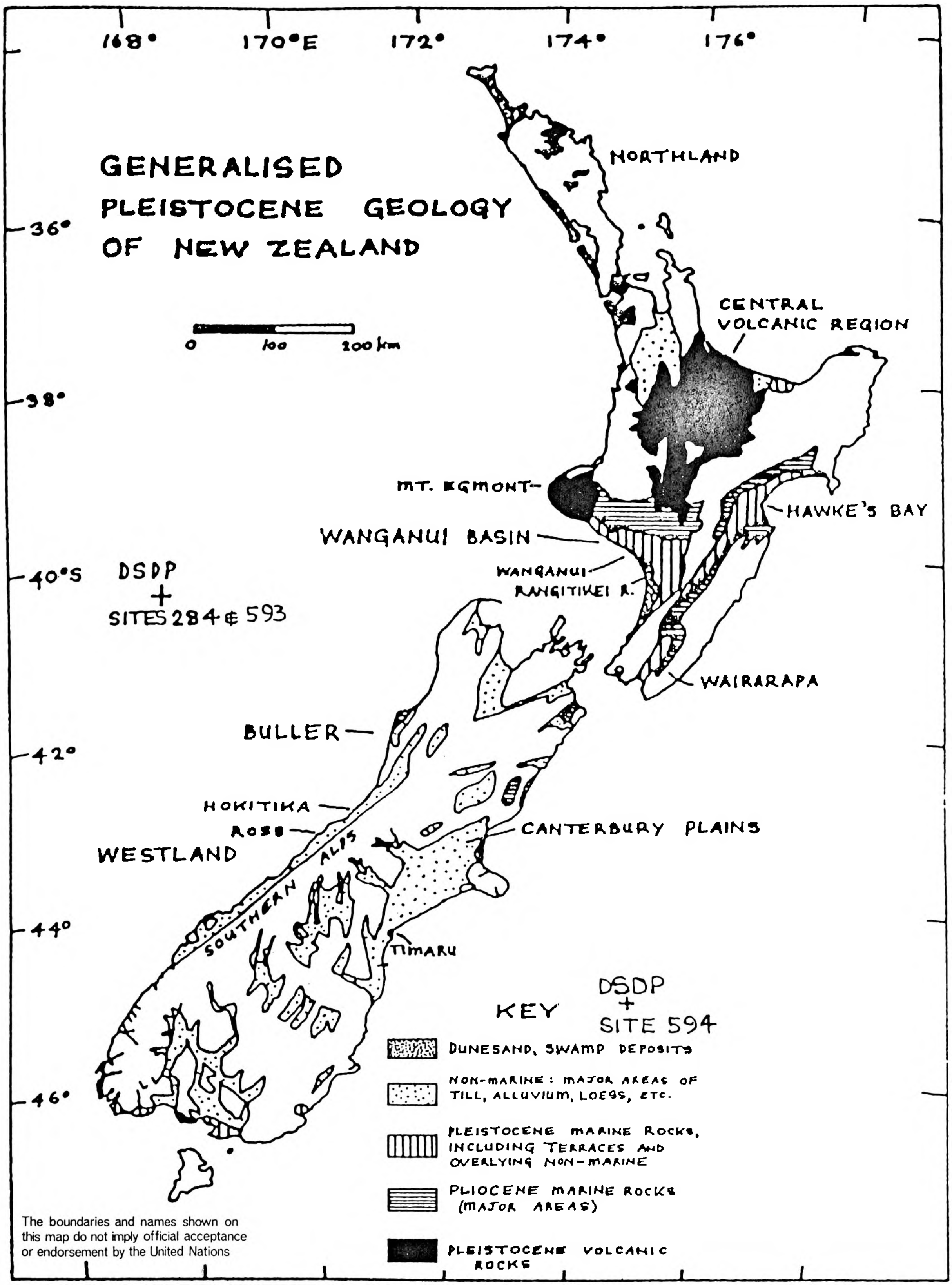


Figure 1. Generalised Pleistocene geology of New Zealand. Important Plio-Pleistocene stratigraphic sections occur at the place names listed including the Wanganui Basin. DSDP sites 284, 593 and 594 are shown.

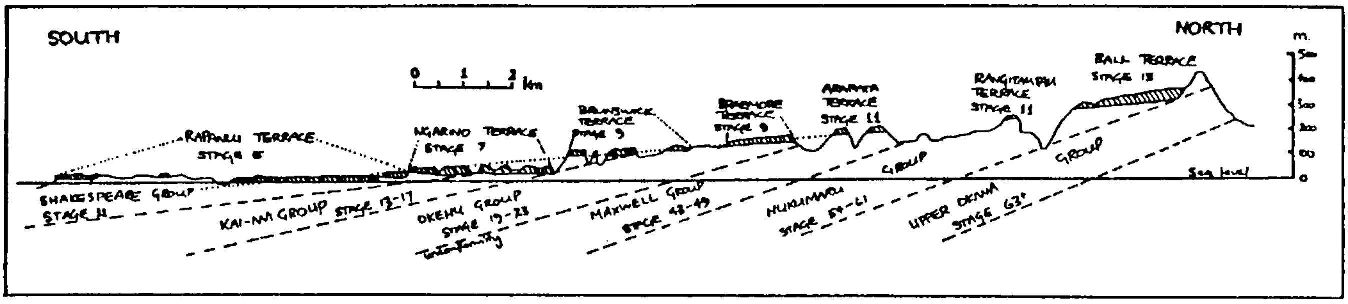
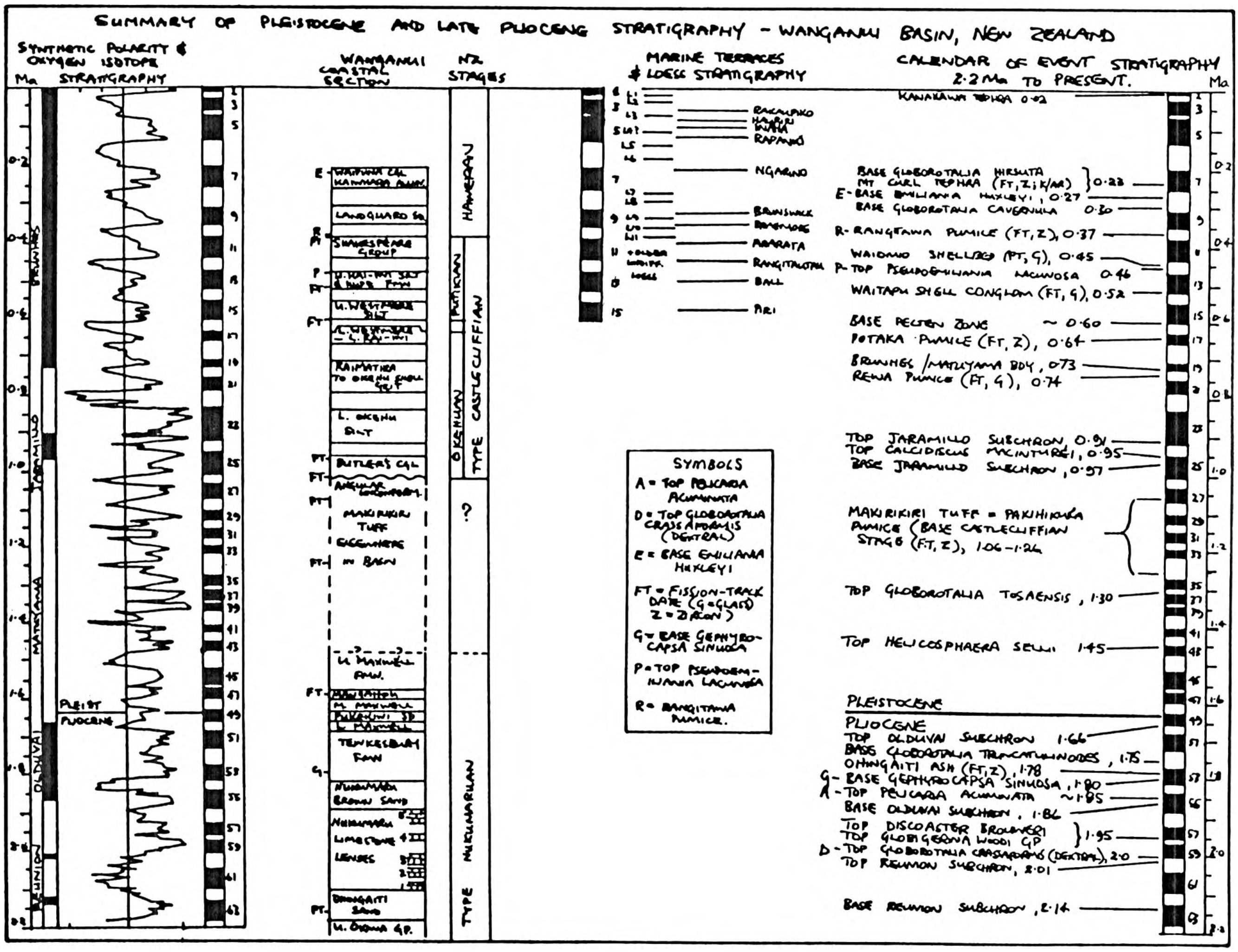


Figure 2. North-south section through the Wanganui area showing relationship of shallow marine sediments to marine terraces. Based on original work of Fleming (1955), updated from Beu and Edwards (1984), Beu et al. (1987) and Pillans (1988).



Figur 3. Correlation of oxygen isotope stages in the synthetic standard curve (Prell et al. 1986 – Paleoceanography 1(2): 137-162) and in core V28-239 with a calender of biostratigraphic, magnetostratigraphic and tephrostratigraphic datums for the Wanganui region of New Zealand. Based on Beu et al. (1987) and Pillans (1988).

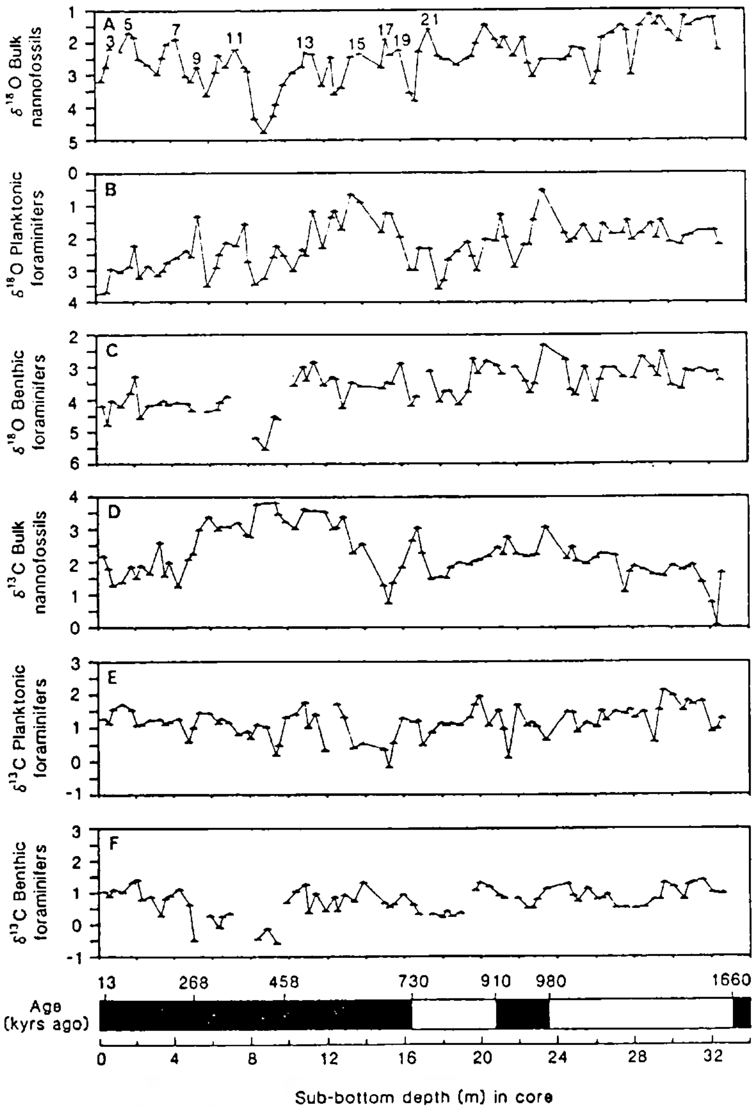


Figure 4. ^{18}O **and** ^{13}C **records from nannofossils from the Quaternary section of DSDP Site 593 compared with planktonic (*Globigerina bulloides*) and benthic foraminiferal (mainly *Uvigerina* sp.) analyses from the same horizons. Dating control in the section from radiocarbon analysis, magnetostratigraphy and biostratigraphy events. From Dudley and Nelson (1989).**

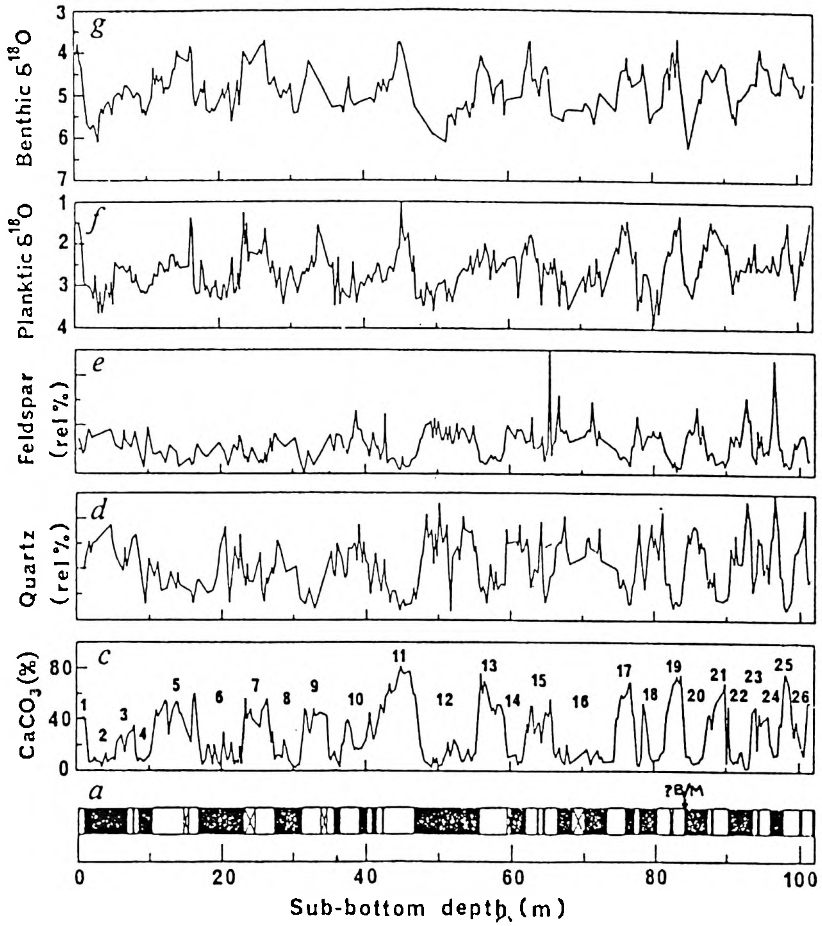


Figure 5. Colour (a) – (black = hemipelagic sediment), calcium carbonate content (c), quartz (d), plagioclase feldspar (e), and planktonic and benthic foraminiferal oxygen isotope (f and g respectively) records for the mid-late Quaternary section of DSDP site 594. The Brunhes/Matuyama boundary is shown at about 84 m sub-bottom, in its usual position at the base of oxygen isotope stage 19. The exact position of this important magnetostratigraphic has yet to be accurately defined, however. After Nelson et al. (1985).

2. Annotated bibliography

Wanganui stratotype

Beu, A.G.; Edwards, A.R. 1984: New Zealand Pleistocene and Late Pliocene glacio-eustatic cycles. Palaeogeog, Palaeolim, Palaeoecol, 46: 119-142.
- Refines the biostratigraphic subdivision, aided by lithostratigraphy and fission-track dates on tephra. Local sedimentation includes approximately 20 cycles of sandstone and siltstone representative of glacial/interglacial episodes. Authors recognise coeval nature of marine terrace deposits and offshore sedimentary wedges (now exposed by modest long-term uplift).

Beu, A.G.; Edwards, A.R.; Pillans, B.J. 1987: A review of New Zealand Pleistocene stratigraphy with emphasis on marine rocks. Proceedings of 1st Int. Coll on Quaternary stratigraphy of Asia and Pacific area. Osaka 1986: 250-269.
- Refined biostratigraphic subdivision and correlated NZ stages to oxygen isotope record obtained from DSDP site 284. The value of tephra in both marine terrace cover deposits and shallow marine strata recognised as a valuable correlation tool. Authors present an integrated stratigraphic scheme for the Plio/Pleistocene of NZ linked with paleomagnetic and oxygen isotope stage chronologies.

Edwards, A.R. 1987: An integrated biostratigraphy, magnetostratigraphy and oxygen isotope stratigraphy for the late Neogene of New Zealand. New Zealand Geological Survey record 23: 76 pp.
- Presents detailed analysis of most of the important Neogene sections in New Zealand, including the Wanganui stratotype and relates the onshore stratigraphy to that at DSDP Site 284.

Fleming, C.A. 1953: The geology of Wanganui subdivision. New Zealand Geological Survey Bulletin 52: 362 pp. The seminal work on New Zealand Pleistocene stages.

Pillans, B.J. 1983: Upper Quaternary marine terrace chronology and deformation, South Taranaki, New Zealand. Geology 11: 292-297.
- Extended the work of Fleming and others on the sequence of marine terraces, adding dating control from fission track dates on tephra, and amino acid racemisation dates on wood and peat in terrace cover deposits.

Pillans, B.J. 1988: Loess chronology in Wanganui Basin, New Zealand. In Loess; its distribution, geology and soils. D.N. Eden; R.J. Furkert (eds) Balkema Press. 175-191.
- Described loess and tephra sequences in marine terraces in the Wanganui area. Correlated the loess/paleosol pairs with oxygen isotope stages.

Seward, D. 1976: Tephrostratigraphy of the marine sediments in the Wanganui Basin, New Zealand. NZ J. Geology & Geophysics 19: 9-20.
- Summarised mineralogy and stratigraphy of tephra in marine sediments and marine terrace cover deposits across the Wanganui Basin. Fission track ages on glass shards were reported. Later work suggests these ages may be too young by about 20 per cent.

Seward, D.; Christoffel, D.A.; Liernert, B. 1986: Magnetic polarity stratigraphy of a Plio-Pleistocene marine sequence of North Island, New Zealand. Earth & Planetary Science Letters 80: 353-360.
- Described the paleomagnetic stratigraphy of an early Pliocene to early Pleistocene shallow marine sequence in the Rangitikei valley at the eastern magin of the Wanganui Basin.

Marine Stratotype–DSDP Site 284/593

Dudley, W.C.; Nelson, C.S. 1989: Quaternary surface-water stable isotope signal from calcareous nannofossils at DSDP Site 593, southern Tasman Sea. Marine Micropaleontology 13: 353-373.
- Authors compare oxygen isotope values from calcareous nannofossils with the ^{18}O record of planktonic and benthic foraminifera. Mid-late Quaternary isotope stages are well expressed.

Hornibrook, N. de B. 1980; Correlation of Pliocene biostratigraphy, magnetostratigraphy and ^{18}O fluctuations in New Zealand and DSDP 284. Newsletters on Stratigraphy 9: 114-120.
- Content as the title indicates.

Kennett, J.P.; Shackleton, N.J.; Margolis, S.V.; Goodney, D.E.; Dudley, W.C.; Kroopnick, P.M. 1979: Late Cenozoic oxygen and carbon isotope history and volcanic ash stratigraphy: DSDP Site 284, South Pacific. American Journal of Science 179: 52-69.
- Authors present oxygen and carbon isotope records from benthic and planktonic foraminifera and calcareous nannofossils that span the late Cenozoic record in DSDP 284. Marked isotopic shifts are related to polar ice volumes and sea temperature variation.

Kennett, J.P.; Van der Borch, C.C. et al., 1986: Site 593 Challenger Plateau. In J.P. Kennett, C.C. Van der.

Borch et al., (eds.). Initial Reports of the Deep Sea Drilling Project, 90. U.S. Govt Print Office, Washington, D.C. pp 551-1651.

- Provides summary of data from DSDP Site 593 including data control from radiocarbon dates, biostratigraphy and paleomagnetic reversal stratigraphy.

Marine Stratotype–DSDP Site 594

Black, K.P.; Nelson, C.S.; Hendy, C.H. 1988: A spectral analysis procedure for dating Quaternary deep-sea cores and its applications to a high resolution Brunhes record from the southwest Pacific. Marine Geology 83: 21-30.
- Authors use model of orbital forcing to tune the oxygen isotope record from the high resolution (i.e. rapid sedimentation) core obtained from DSDP Site 594.

Froggatt, P.C.; Nelson, C.S.; Carter, L.; Griggs, G.; Black, K.P. 1986: An exceptionally large late Quaternary eruption from New Zealand. Nature 319: 578-582.
- Authors infer that prominent tephra found at 36.5 m subbottom in DSDP core 594 is Mt Curl Tephra and assign a date of 254 ± 2 Ka. However age is assigned from sedimentation rate and picking B/M boundary at c. 100 m subbottom. It now seems likely that B/M boundary is c. 88 m subbottom and that tephra falls in oxygen isotope stage 10 and is probably Rangitawa Pumice dated at c. 370 ± 50 ka. Mt Curl Tephra and Rangitawa Pumice have the same chemistry as determined by microprobe analysis.

Nelson, C.S.; Hendy, C.H.; Jarrett, G.R.; Cuthbertson, A.M. 1985: Near-synchroneity of New Zealand alpine glaciations and northern hemisphere continental glaciations during the past 750 kyr. Nature 318; 361-363.
- Authors pick B/M boundary in the rhymically banded core at c. 100 m subbottom (now considered to be c. 88 m) and interpret alteration of quartz rich, carbonate poor hemipelagic sediment as glacially derived sediment alternating with quartz poor, carbonate rich pelagic ooze. Increased quartz and feldspar input are considered to be aeolian input as a result of increased erosion in the South Island of NZ during glacial periods. This record provides a strong arguement for synchroneity of marine oxygen isotope stages and on-land glacial/interglacial cycles.

IGCP 296

STRATIGRAPHY OF THE DOGYUNG AND GOEDONG FORMATIONS, REPUBLIC OF KOREA

by

Dong Young Lee[1]

1. Dogyung Formation

Location

At the middle of the east coast of the Peninsula, the Tertiary Bukpyung basin is located. The substrata consists of mudstone intercalated with a lignite horizon. The Quaternary sediments crop out along the gentle mountain slope of the basin, overlying the Tertiary semi-consolidated mudstone. The best exposure is found at the clay excavation pit, in Iwondong at the southern valley of Bukpyung.

Exposure

The underlying substrata consists of dark yellowish brown, semi-consolidated organic rich mudstone, named the Bukpyung Formation of Pliocene age. Along the marginal foothill of the mountain slope, the coarse sands deposits unconformably overlie the substrata at the level of + 35 m and extend upward up to about + 53 m (Dogyung Formation). The lowest part consists of horizontally laminated sand and sandy silt layers. At each single layer, the base is yellowish brown iron-cemented with coarse grained sediments and upward shows a graded-bedding structure. A gravel sequence is successively overlain with fine sandy silts. The uppermost gravel deposits are highly weathered and gradually mixed with colluvial top soil. The lithofacies of the lower part is interpreted to be characteristic of channel fill deposits of low sinusity and the gravel layers of the upper part are channel-lag deposits brought by stream floods.

Age

The Bukpyung basin is one of the large Tertiary basins whose sediments belong to the upper Neogene on the basis of foraminifera studies. The overlying sediments differ significantly from the Tertiary substrata in lithology, color, degree of consolidation and weathering, inferring their age is younger than the Tertiary. It is also possible to postulate a hiatus in time and deposition from the presence of an iron crust along the lithological contact. The topographic position of this Dogyung Formation is the highest among all Quaternary outcrops found up to now in the Korean Peninsula. The paleomagnetic directions in all the samples measured from the Bukpyung Formation are all of reversed polarities and continue to show the same polarity throughout the Dogyung Formation except in the uppermost part where the polarity changes into normal. All those results infer the age of the Dogyung Formation is Lowest Pleistocene, probably belonging to the lower part of the Matuyama magneto-zone.

2. Goedong Formation

Location

At the Pohang basin located in the south-eastern part of the Peninsula, the Pleistocene deposits are scarcely exposed along valley cuttings or artificially excavated sites. The best vertical exposure is found along the downslope of the small hill near Goedong, located about 5 km south of Pohang city.

Exposure

The underlying substratum is a dark gray semiconsolidated mudstone, named the Idong Formation of Upper Miocene age. The Neogene unit outcrops on a gently inclined slope. The gravelly sand deposits unconformably overlie the Neogene substratum at the level of +27 m and extend upward up to about +58 m.

The lowest basal gravels are composed of several rock types, which can be easily recognized by the difference in lithology from the Neogene substratum. The profile consists of six gravel members and each of them shows gravels or gravelly sands at the base, and fining upward in general up to a silty clay. The uppermost part of each sequences is characterized by an iron enriched yellowish brown and weakly laminated silty clay layer. All these gravel deposits are interpreted to have been formed by a process of sheetflood, based on gravel fabric study.

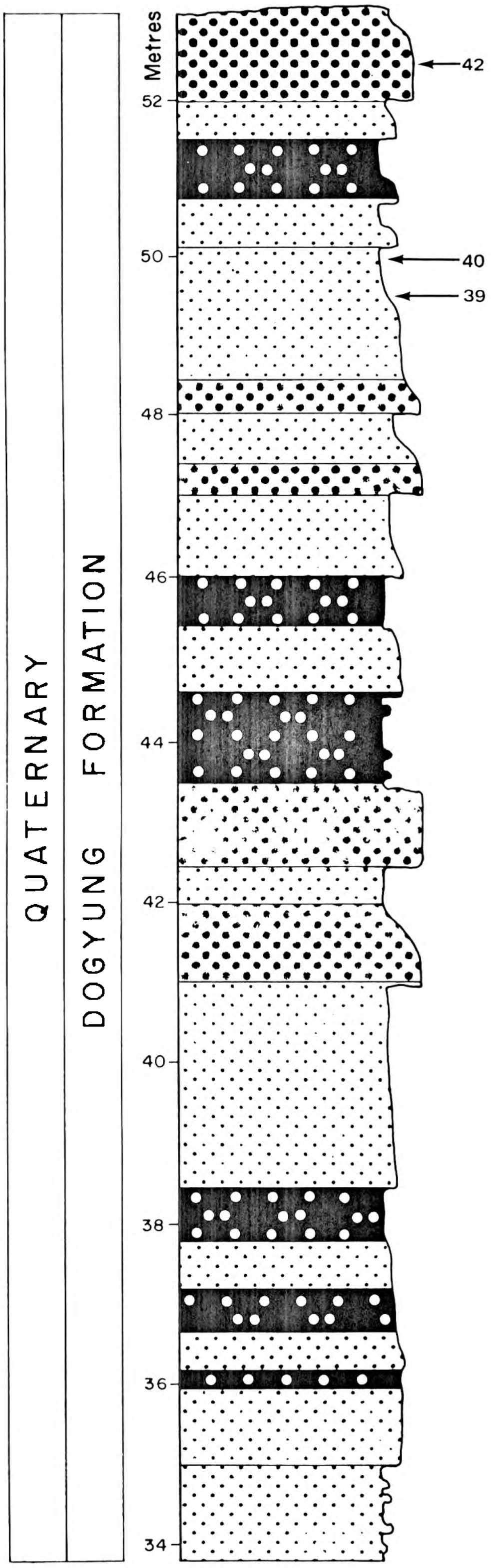
Age

No fossils have been recorded in this profile. For

[1] Korea Institute of Energy and Resources, 219-5, Geribond-dong, Guro-gu, Seoul, Republic of Korea.

magnetostratigraphy, oriented paleomagnetic samples were taken from each gravel member. The results of the directional measurements obtained after magnetic cleaning in all the specimens all show normal polarity with slightly dispersed magnetization direction.

The normal polarity of the Goedong Formation is interpreted as belonging to the Olduvai magneto-subzone. This age is based also on the other stratigraphic correlations and the base-level fluctuation during the Quaternary period.



GRAVELS, uppermost gravel layer at the Outcrop 2, well rounded but unsorted.

SAND, brown, medium sand-grade

SANDY SILT to CLAY SILT, alternation of sandy silt and clay silt layers, slightly laminated, but very vrittle.

GRAVELLY SAND to SILTY SAND, very thin granule layer in the lower part and yellowish brown fine sand to silt layer on top, all layers are horizontally laminated.

GRAVELLY SAND, very thin granule layer in bottom, changing gradually into dark greyish brown (2.5Y 4/2) coarse sand on top.

SILTY SAND, reddish brown ironified medium sands in the lower part and gradually fining-upward to grey silt on top.

SANDY SILT, grey, brittle and massive. iron-cemented at the base, reddish brown, ironified layer is intercalated in the middle part.

SAND, yellowish brown, coarse to medium sand layers, intercalated by very thin grey silt layers, sesquioxide coatings around coarse sands surfaces.

SANDY SILT, alternation of silty sand and silt layers, with several ironified very thin horizons, all are horizontally laminated.

GRAVELS, strong brown, well sorted, rounded fine pebbles (3-5cm), coatings of iron and manganese around the gravel surfaces, mudstone pellets are less common than the lower gravel bed.

SILT, light grey, slightly laminated, gradual change from the lower gravelly sequence.

GRAVELS, most gravels are granule-sized (1-2cm) with coarse sand matrix, coatings of iron and manganese around the gravel surfaces resulting the colour in yellowish brown to strong brown (7.5YR 4/6), about 20% of the total gravels are of mudstone pellets.

SILTY SAND, light grey medium sand in bottom, overlying the iron-cemented contact, gradual change to silty sand on top, horizontally laminated, with scatters of iron concretions along the laminated horizons.

SILTY SAND, light grey, well sorted and laminated silty sand layer, very thin ironified horizons are often intercalated.

SAND to SILT, light grey very massive medium sand in the lower part, fining-upward to well sorted silt on top, the middle part shows small scale planar-foresets, the upper part shows brittle but slightly laminated structure.

SANDY SILT, light grey, fining-upward sequence form medium sand at the base, very thin ironified horizons are intercalated.

SAND to SILTY SAND, alternation of yellowish brown (10YR 5/8) ironified fine sand and grey silty sand layers, loose, horizontally laminated, the lower contact is iron-cemented.

SILTY SAND, alternation of very fine sandy silt and silt sand layers, small scale cross lamination in the latter layer, the others show horizontal lamination in general, very thin organic coated horizons (less than 5 mm) are interlayered.

Figure 1. The main lithosequence of the Dogyung Formation. The lower part up to the sample number 39 indicates negative polarity zone (Matuyama) and the upper part (40-42) indicates positive polarity zone (Reunion).

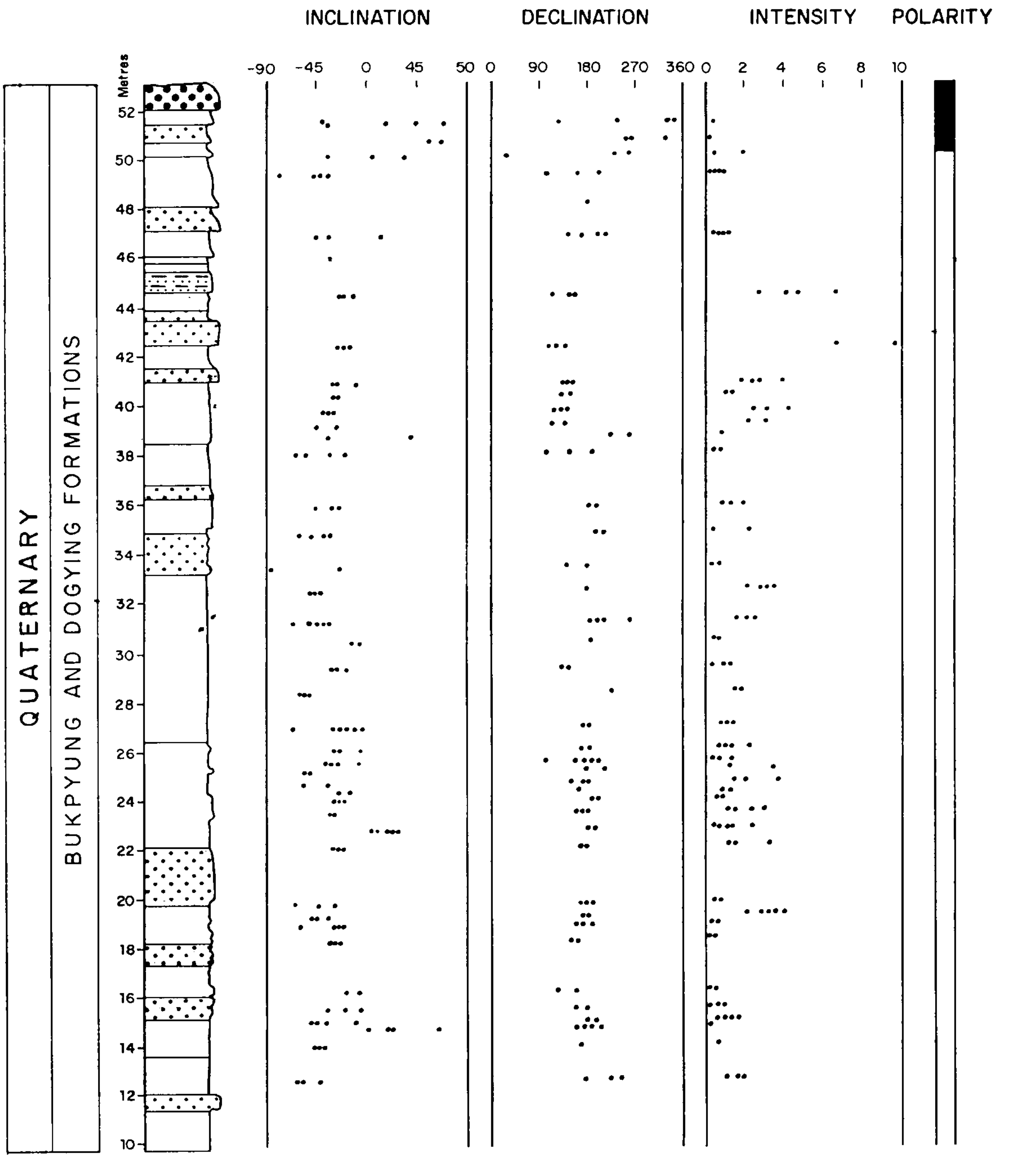


Figure 2. Stratigraphic variations of the intensities and directions of the cleaned NRM (200°C) in the Bukpyung and the Dogyung formations

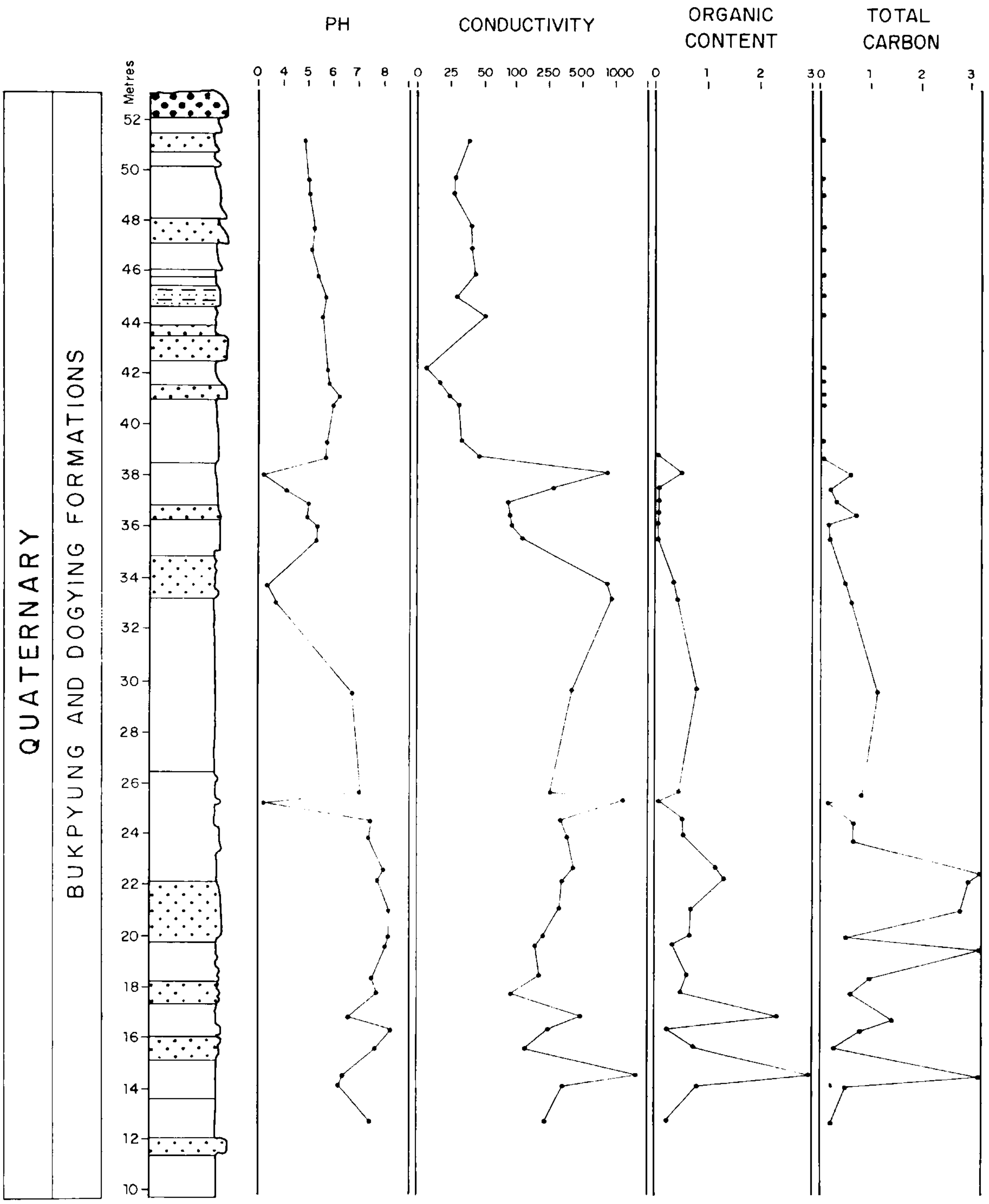


Figure 3. Stratigraphic variation of pH, electrical conductivity, and carbon content in the Bukpyung and the Dogyung formations

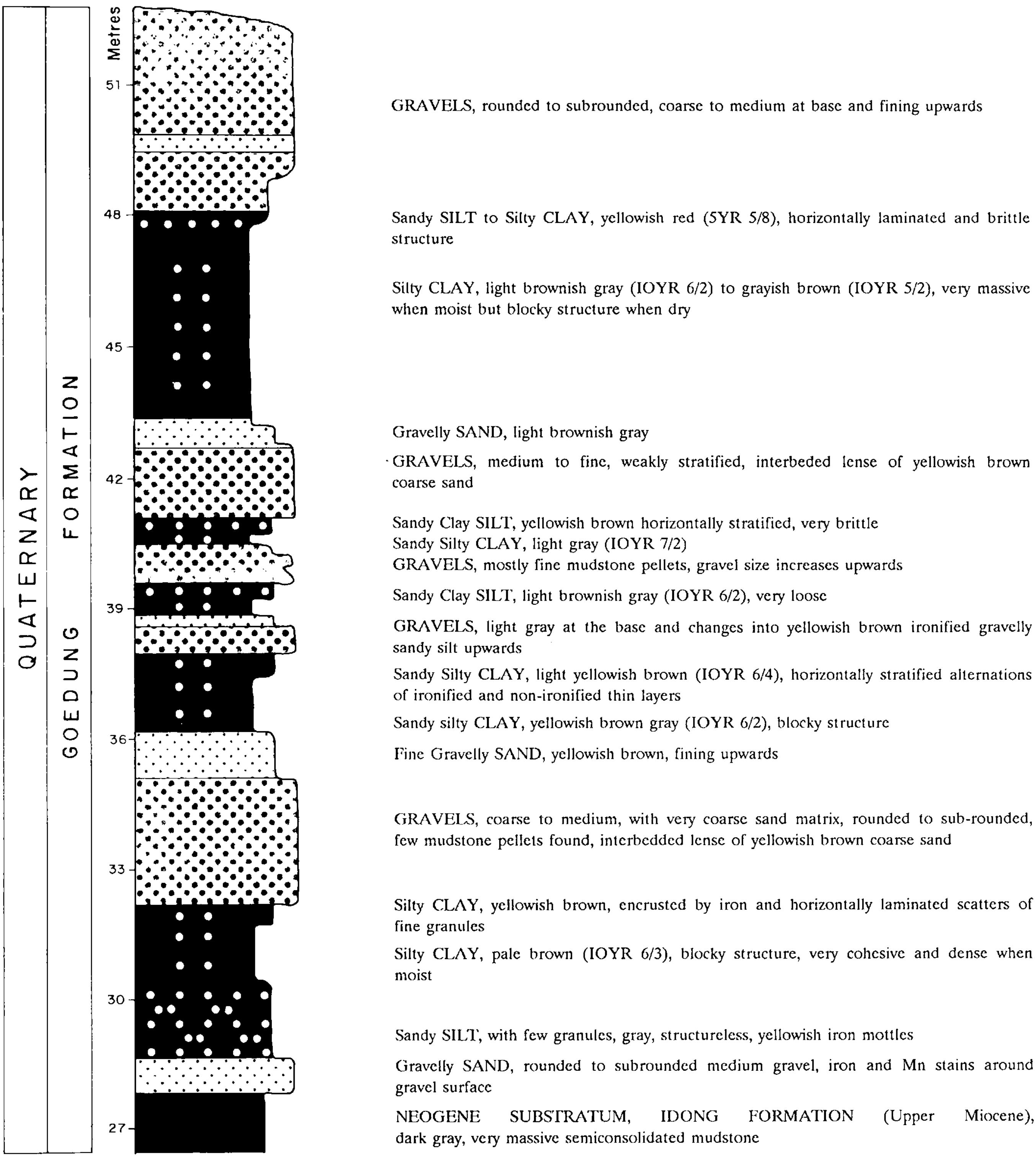


Figure 4. The complete lithosequence of the Goedong Formation cropping out in the Pohang basin

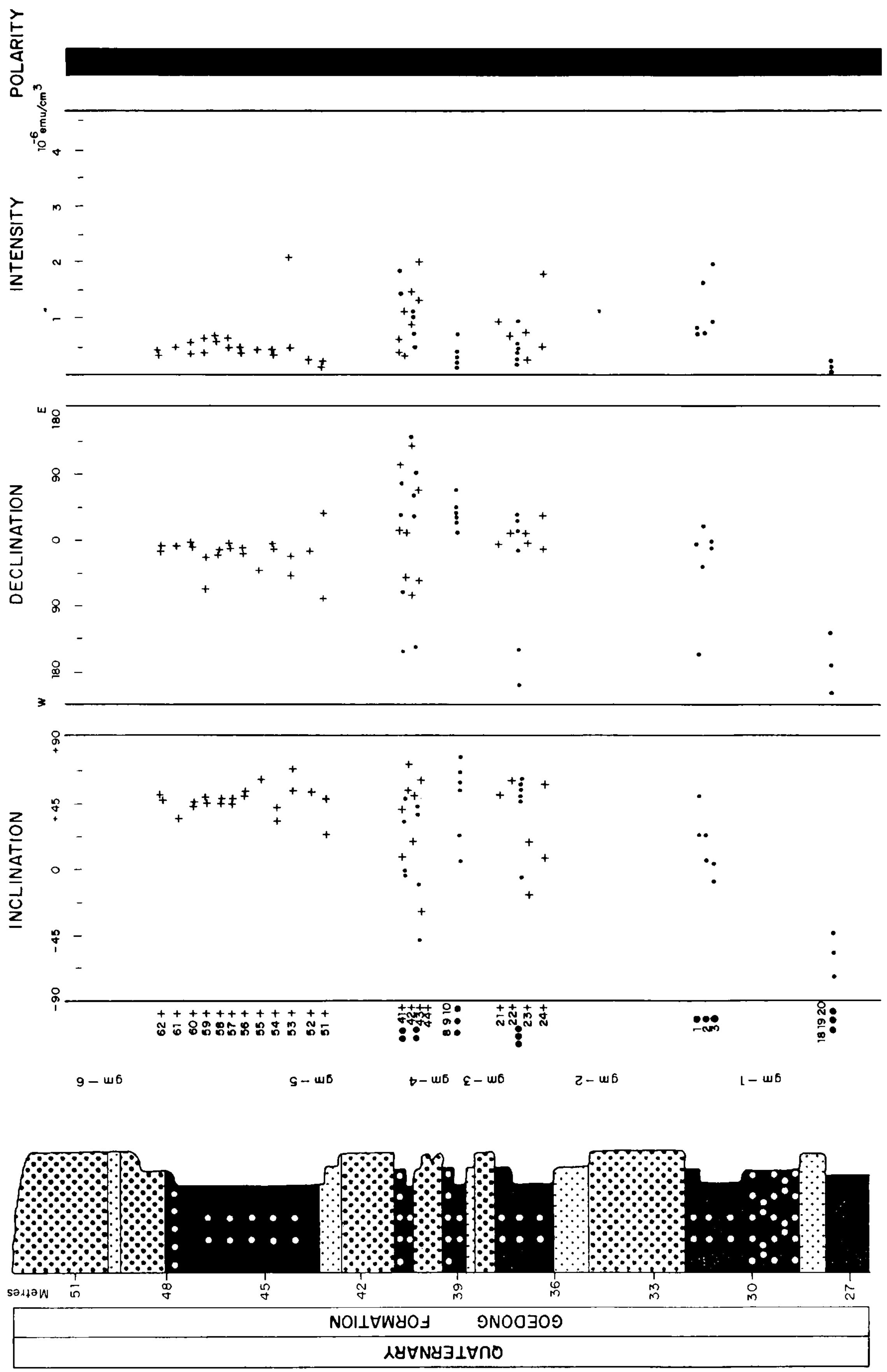


Figure 5. The cleaned NRM of the Goedong Formation

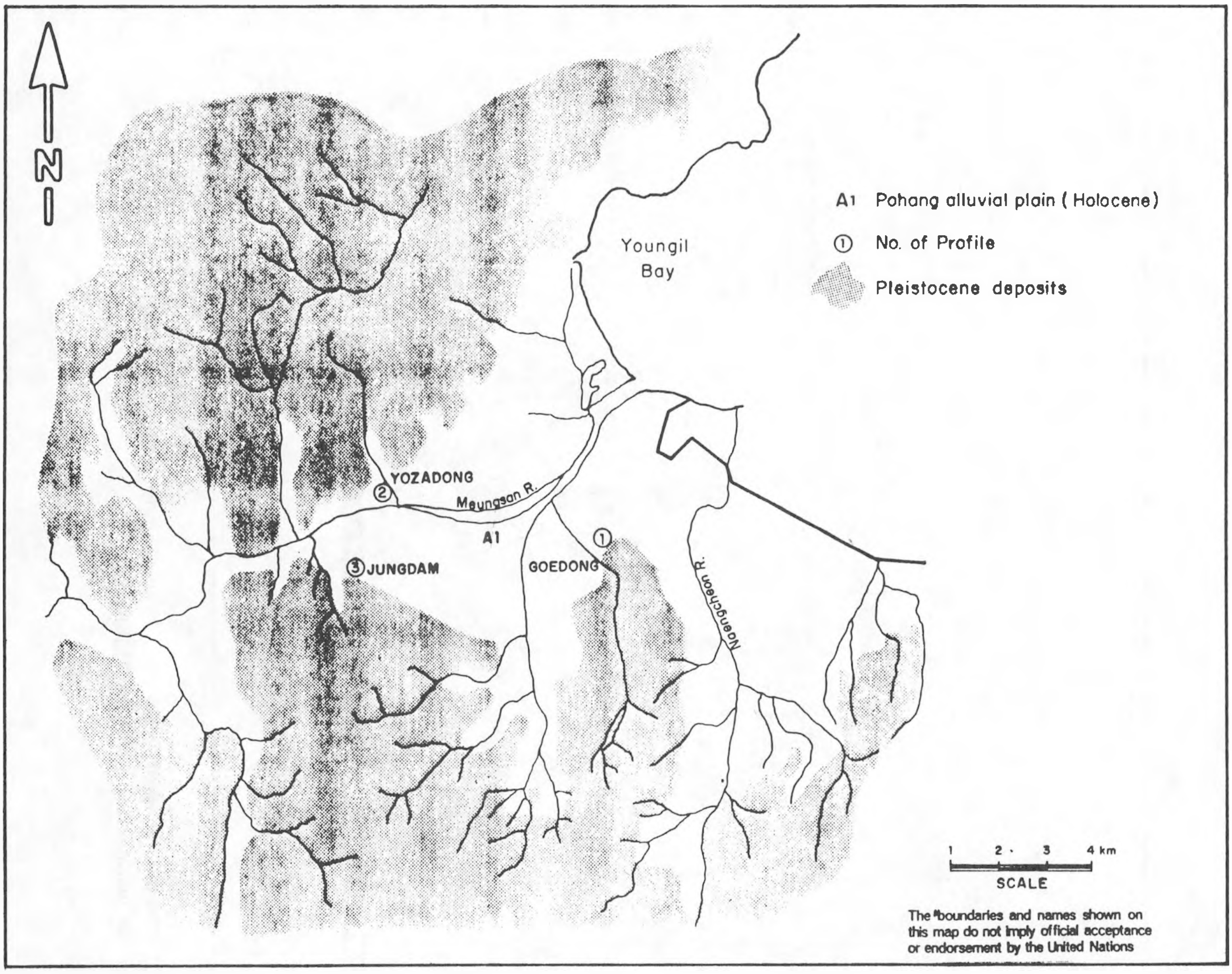


Figure 6. Map showing the outcrops of the Pleistocene deposits in the Pohang plain

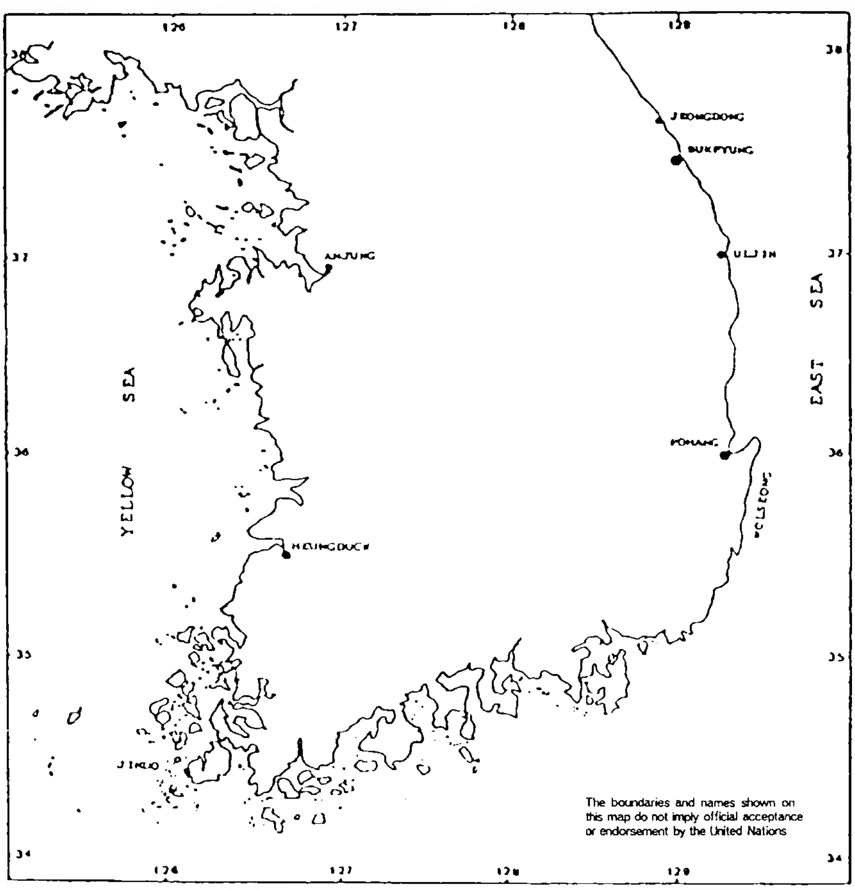


Figure 7. Location of the Quaternary outcrops cited in the text

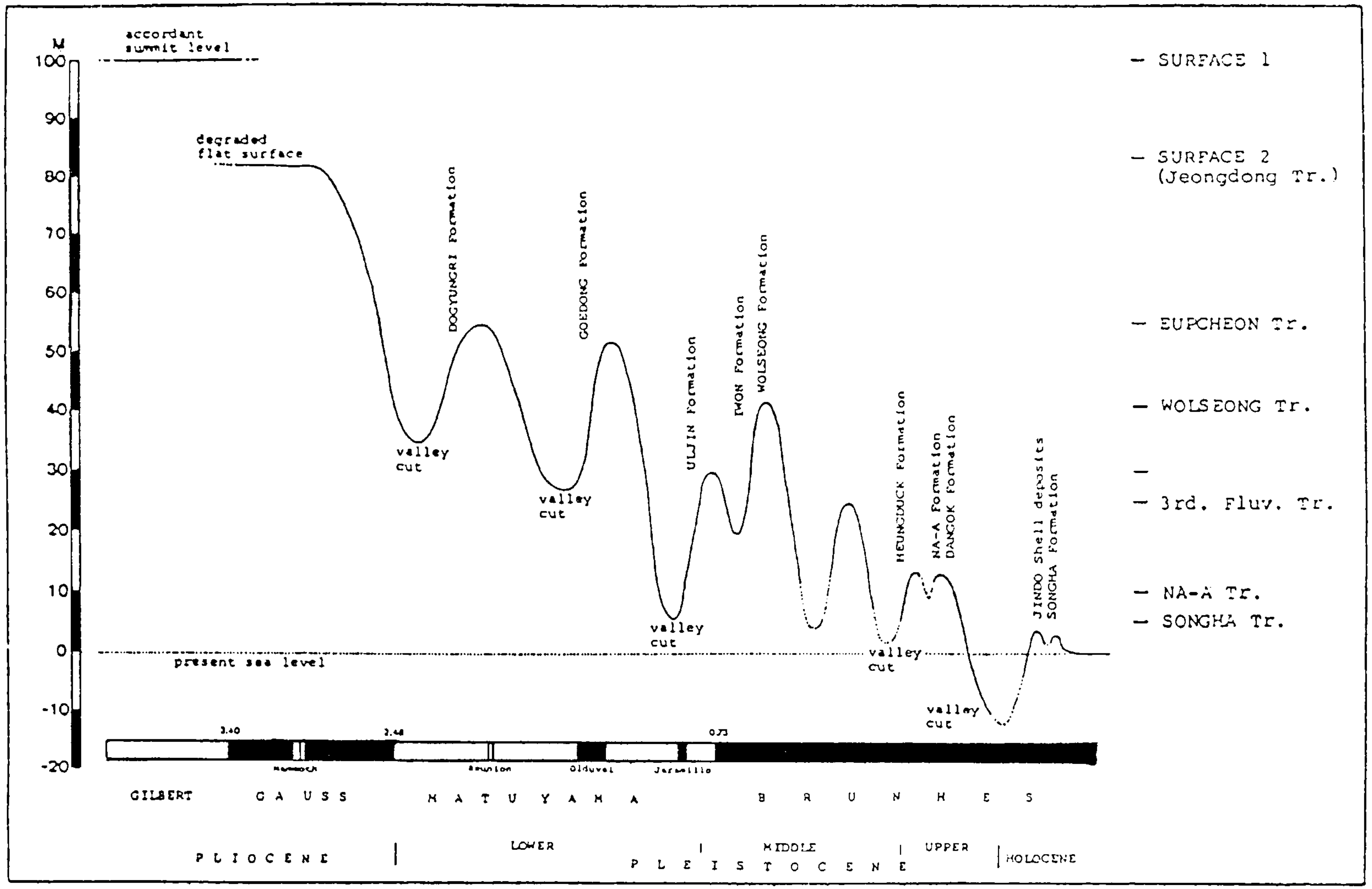


Figure 8. Generalized curve depicting local base-level changes along the coast of the Korean peninsula during the Quaternary

Table I. Quaternary Stratigraphy of the Korean Peninsula

Chronostratigraphy			Paleomagnetism	Lithostratigraphy: Eastern Part – Inland	Eastern Part – Coast	Western Part – Inland	Western Part – Coast	Geomorphology – Marine	Geomorphology – Fluv	Pedology	Climate	Tectonism and Volcanic Sediments
Quaternary	Holocene		Brunhes	Kimjae Formation	Songha Formation	Kimjae Formation; Anjung Peat Member	Kimjae Formation (Upper shell dep.; Lower shell dep.)	Songha Terrace (3-5m); Valley fill	1st Terrace (3-4m); Valley fill		Moderate vegetated	Seongin Formation (Caldera deposits)
Quaternary	Pleistocene	Upper	Brunhes (Laschamp)					Valley cut	Valley cut	Gumandong soil; Seogkyo soil; Gumsan soil	Cold, humid; Warm, humid vegetated	
Quaternary	Pleistocene	Upper	Brunhes	Dangok Gravel Member	Na-a Formation			Na-a Terrace (10-15m)	2nd Terrace (10-12m)			Sinyangri Formation
Quaternary	Pleistocene	Middle	Brunhes			Heungduck Formation		Cut and fill; Valley fill; Valley cut	3rd Terrace (25-30m); Valley cut	Bongil soil complex	Warm, humid; Warm, dry less vegetated; Moderate vegetated	Volcanic eruptions along the Hantan River (6 flows) 0.54my–0.28my
Quaternary	Pleistocene	Middle	Brunhes (0.73)	Jungdan Formation; Iwon[?] Formation	Wolseong Formation			Wolseong Terrace (35-42m)	4th Terrace (40-45m)		Warm, dry (less vegetated); Cold, humid; Warm, humid	Gosan Formation
Quaternary	Pleistocene	Lower	Matuyama (Jaramillo)	Uljin Formation				Valley fill; Valley cut (Phase III)				
Quaternary	Pleistocene	Lower	Matuyama (Olduvai)	Oedong Formation				Valley fill; Valley cut (Phase II)			Warm, dry-wet	Creation of the Ulreung Island (1.82my)
Quaternary	Pleistocene	Lower	Matuyama (Reunion)	Docyung Formation				Eupcheon Terrace (50-60m) (Phase I)			Temperate wet-dry	
Tertiary	Pliocene		Gauss (2.48; Kaena; Mammoth; 3.40)	Yonam Formation							Warm, dry less vegetated	Seoguipo Formation; Hwasoon Formation
Tertiary	Pliocene		Gilbert	Bukpyung Formation				Bongwhajae Terrace (75-90m)	5th Terrace (80-90m)		Warm, humid vegetated	Creation of the Jeju Island

IUGS UNESCO IGCP 296

STRATIGRAPHIC CORRELATION OF BURIED CORAL DEPOSITS AT AKURALA AND MIHIRIPENNA, SOUTHWEST COAST OF SRI LANKA

by

Jinadasa Katupotha[1]

Radiocarbon dates from buried coral deposits at Akurala and Mihiripenna on the southwest coast indicate that the mid-Holocene sealevel reached landward at least 250 m, and locally as far as 3 or 4 km, inland of its present position. The corals thrived in palaeo-embayments and around small headlands between 5,980 ± 70 and 5,350 ± 80 yr BP. It is evident that the mid-Holocene sealevel was at least 1 m above that of the present level.

1. Introduction

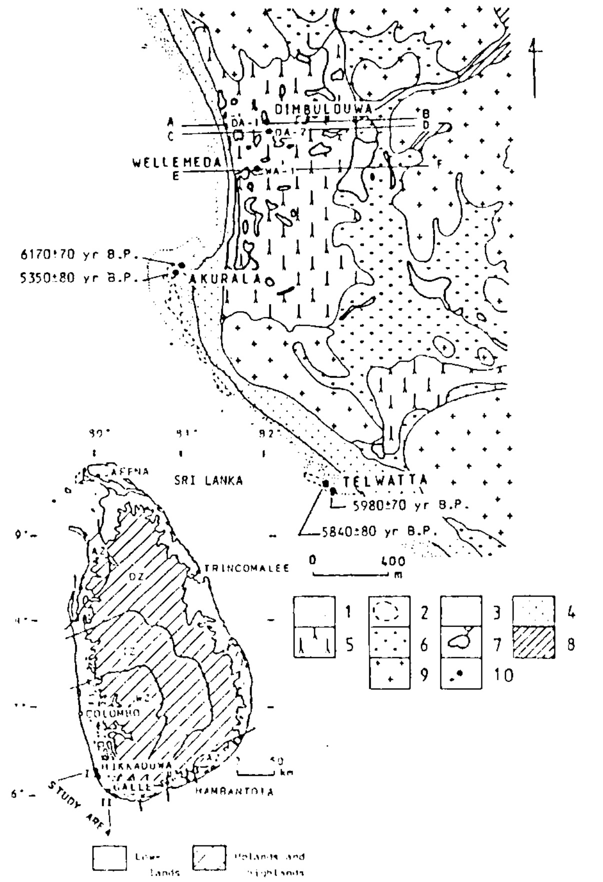
During the Last-Glacial Maximum (LGM), ~18 ka BP ago, the palaeoclimatic conditions were significantly different from that of the modern pattern over much of tropical Africa, Australia and India. There was less rain in summer and stronger winds occurred in the winter monsoon months (Williams 1982). At this time, the shoreline lay several kilometres seaward of the present shore forming erosional and depositional surfaces in these areas. The Post-Glacial Transgression (PGT) appears to have started around 17 ka to 18 ka BP, from about 80 m in many tropical and Mediterranian coasts, thereby forming submerged coral reefs, sandstones, emerged and buried coral deposits at different levels. These are well-known indicators for the study of sealevel variations (Hopley 1986a, 1986b; Pirazzolli 1988).

The present continental shelf between 100 fathoms (180 m) and 10 fathoms (ca. 20 m) depth in Sri Lanka is a drowned extension of the land and is characterized by former river courses, low-lying ridges, troughs, terraces and rocknobs. These features indicate that they have been formed during the LGM. Following the PGT, these features have been covered with marine features such as coralline algae, limestone and calcareous sandstone. Submerged forests also occur at different levels. Furthermore, during the mid-Holocene, low coastal hills and ridges were submerged, creating headlands and bay-head beaches. Radiocarbon dates from inland buried corals and emerged coral reef patches at Akurala and Mihiripenna provide evidence for the fact that the mid-Holocene sealevel was located inland of the present shoreline. Corals thrived in former embayments and on small headlands created by this high stand of the sea.

[1] Department of Geography, University of Sri Jayewardenepura, Nugegoda, Sri Lanka.

2. Study sites

Akurala (6°10'-6°12'N and 80°02-80°03'E) and Mihiripenna (6°00'N and 80°15'E) on the southwest coast were selected for the stratigraphic correlation of the buried coral deposits (Figure 1). In both sites, well-



The boundaries and names shown on this map do not imply official acceptance or endorsement by the United Nations

Figure 1. Sketch map showing the location of study sites. I = Akurala, II = Mihiripenna. Cross-sections are referred to in Figure 2. Da-1 = Dimbulduwa-Akurala, DA-2 = Dimbulduwa-Akurala. WA-1 = Wellameda-Akurala. (1) Inter-tidal reef patch, (2) emerged reef patch, (3) foreshore, (4) beach ridge, (5) mangrove swamp, (6) marsh, (7) water hole, lake and ditch, (8) flood or valley plain, (9) residual hills and ridges, (10) sample location (Katupotha 1988C; Katupota and Fujiwara 1988).

development old coral deposits extend from the present shore up to 250 m inland and sometimes up to 3 or 4 kilometres towards the interior. They overlie lateritized and weathered granulite facies rocks and are overlain by muddy silt washed down to the coral areas by terrestrial waters. Due to coral mining, most of the open coral quarries have become swamps, mangrove swamps, ponds and ditches at many localities. As well, emerged coral reef patches occur a few metres above the mean sealevel in the areas of small headlands.

3. Stratigraphic correlation

The age sequences of 13 buried and 4 emerged coral samples collected from four coral quarries and emerged coral reef patches at Akurala and Mihiripenna are shown in Figures 1, 2 and 3. Radiocarbon (^{14}C) dates are listed in Table I. The upper layers of the coral quarries in both sites are covered by calcareous sandy clay with coral debris. The upright branching *Acropora*, plate type *Echinopora* and massive *Porites* are in growth positions. The coral layers vary from 4 m to 5 or 6 m in thickness and overlie a sand and mud layer which in turn overlies lateritized and weathered granulite facies rocks. The sand and mud horizon is suggestive of a fluvial to brackish swampy depositional environment.

The radiocarbon ages of corals buried to depths of between 1.4 and 3.9 m below MSL in three coral quarries (DA-1, DA-2 and WA-1 in Figure 2) at Akurala

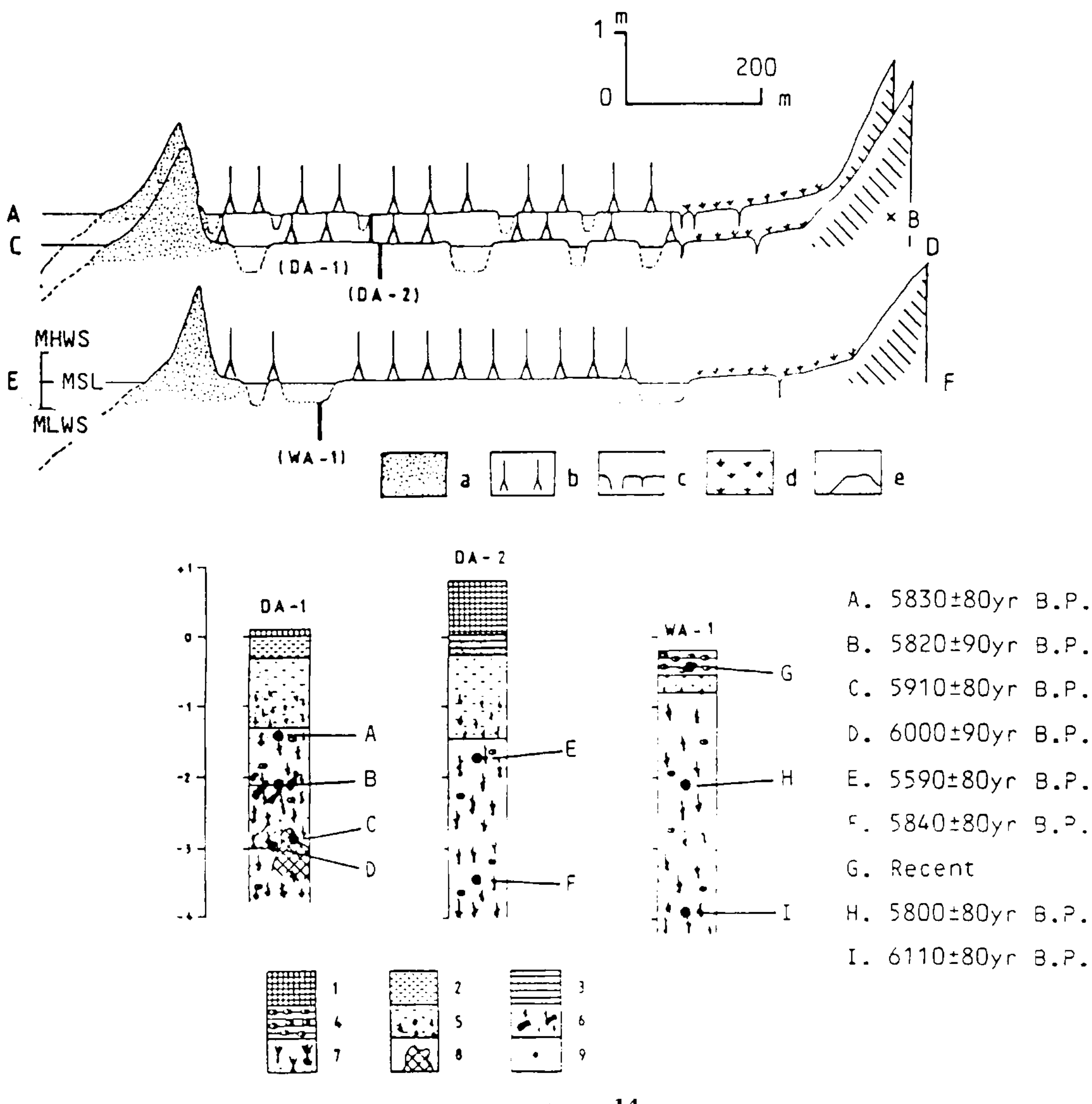


Figure 2. Cross-section, stratigraphic and radiocarbon (^{14}C) dates of three coral quarries at Akurala. ^{14}C dates are referred to in Table I. DA-1 = Dimbulduwa-Akurala, DA-2 = Dimbulduwa-Akurala, WA-1 = Wellameda-Akurala, (a) beach ridge, (b) mangrove swamp, (c) water hole, lake and ditch,; (d) marsh, (e) residual hills and ridges, (1) top soil, (2) brownish grey soil, (3) dark grey mud, (4) dark olive grey mud with shells, (5) calcareous sandy clay with coral fragments, (6) stratified coral (*Acropora*), (8) massive coral (*Porites*), (9) Sample location (Katupotha 1988c; Katupotha and Fujiwara 1988).

Table I. Ages of buried and emerged corals at Akurala and Mihiripenna

No.	Locality	Elevation (m ASL)	Age (yr B.P.) (Half-life = 5,568 + 30 years)	Laboratory No.
Akurala				
Coral quarry 1, DA-1				
1	*Acropora*	−1.4	5,830 + 90	HR 111
2	*Echinopora*	−2.0	5,820 + 90	HR 112
3	*Porites*	−2.9	5,910 + 70	HR 113
4	*Acropora*	−3.0	6,000 + 90	HR 114
Coral quarry 2, DA-2				
5	*Acropora*	−1.7	5,590 + 80	HR 236
6	*Acropora*	−3.4	5,840 + 80	HR 237
Coral quarry 3, WA-1				
7	Thiaridae	−0.3	Recent	HR 115a
8	*Acropora*	−2.1	5,800 + 80	HR 115b
9	*Acropora*	−3.9	6,110 + 80	HR 109
Emerged coral				
10	·*Acropora*	+0.5	5,350 + 80	HR 238
11	*Platygyra*	+0.1	6,170 + 70	HR 239
Akurala-Telwatta				
12	*Acropora*	+0.7	5,840 + 80	HR 240
13	*Montipora*	+0.6	5,980 + 70	HR 241
Mihiripenna				
Coral quarry 4				
14	*Acropora*	−0.7	5,600 + 70	HR 246
15	Tridacnidae	−1.2	5,630 + 70	HR 247
16	*Porites*	−1.4	5,970 + 70	HR 248
17	*Acropora*	−2.0	5,910 + 70	HR 249

Source: Katuptoha, 1988a and 1988b.

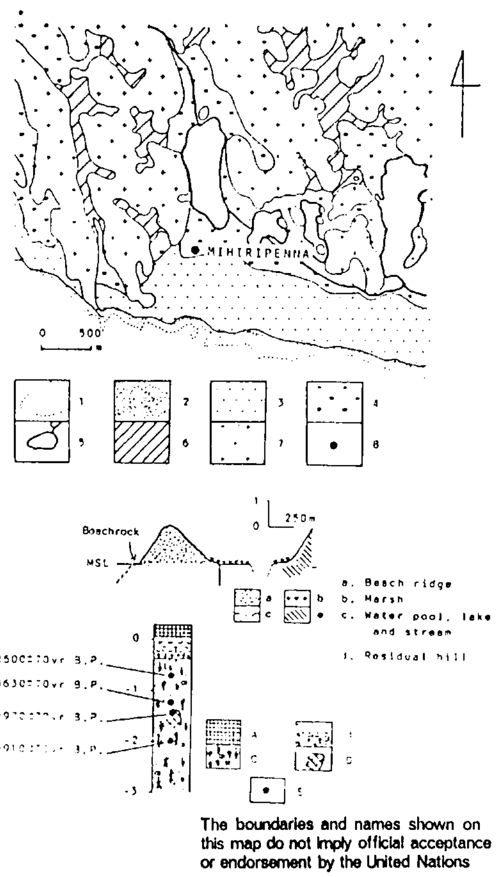


Figure 3. Map showing the location of coral quarry No. 4 at Mihiripenna. ^{14}C dates are referred to Table I. (1) Inter-tidal reef patch, (2) foreshore, (3) beach ridge, (4) marsh, (5) water hole, lake and ditch, (6) flood or valley plain, (7) residual hills and ridges, (8) sample location. (A) top soil, (B) light grey soil, calcareous sandy clay with coral fragments, (c) stratified coral (*Acropora*), (D) massive coral (*Porites*), (E) sample location (Katupotha and Fujiwara 1988).

vary between 5,580 ± 80 and 6,110 ± yr BP, and three corals and one shell sample at Mihiripenna vary between 5,600 ± 70 and 5,910 ± 70 yr BP (depths of sample vary between -0.7 and -2.0 m below MSL) (Table I). Furthermore, emerged coral reef patches at Akurala and Akurala-Telwatta also developed during the period between 5,350 ± 80 and 6,170 ± 70 yr BP (height varies between + 0.1 m and + 0.6 m). The ages, depth and height sequences of both sites clearly indicate that the mid-Holocene high sealevel existed in both areas between 5,980 ± 70 yr BP and 5,350 ± 80 yr BP and former sealevel was at least 1 m above that of the present level. During this transgression theformer river courses of the lowlands were drowned and low hills and ridges became a headland bay beaches. During the transgression, the now-buried corals thrived as reef patches in the embayments, and emerged coral reef patches grew on the small headlands.

Subsequent changes in salinity and temperature as well as the emergence at low tide resulted in the destruction of biota of the coral reef (Endean 1976). It is surmised that the buried coral deposits at Akurala and Mihiripenna may be the result of such changes due to a fall of sealevel since 5,350 ± 80 yr BP. These results correlate with the mid-Holocene sealevel which has been described by Fairbridge (1961).

As a result of the fall in sealevel, corals have not been able to thrive in former embayments in both areas during the Late Holocene. The deposits were buried by muddy silt washed down to the bay by terrestrial water. Therefore the coral colonies were intermittently covered by vast quantities of coral sand and various type of debris resulting from severe monsoon waves. Such influences have locally caused the coral to be disturbed from the position of growth.

4. Conclusions

The age, depth and height sequences of buried coral deposits and emerged coral reef patches at Akurala and Mihiripenna indicate that the corals have thrived in palaeo embayments and the small headlands between 5,980 ± 70 and 5,350 ± 80 yr BP when the mid-Holocene sealevel was at least 1 m above that of the present level. As a result of a coastal progradation since 5,350 ± 80 yr BP the embayments became somewhat dry and coral was deposited *in situ*. It is suggested that these corals were covered occasionally by terrestrial materials and intermittently by marine materials.

5. Acknowledgements

Grateful thanks are extended to Dr (Mrs) Y.A.D.S. Wanasinghe, Department of Geography, University of Sri Jayewardenepura, for help on this manuscript.

References

Endean, R. 1976. Destruction and recovery of coral communities. *In:* Jones, O.A. and Endean, R. (eds.). *Biology and Geology of Coral Reefs.* Academic Press, 217-254.

Fairbridge, R.W. 1961. Eustatic changes in sea level. *Physics and Chemistry of the Earth* 4, 99-185.

Gerritsen, F. 1974. Coastal Engineering of Sri Lanka. *Report on United Nations Misson,* 45 pp.

Hopley, D. 1986a. Beachrock as a sealevel indicator. *In:* van de Plassche, O. (ed.). *Sealevel Research: A Manual of the Collection and Evaluation of Data.* Geo Books, Norwich, 157-175.

Katupotha, J. 1988a. Hiroshima University radiocarbon dates 1, West and south coasts of Sri Lanka. *Radiocarbon* 30 (1), 125-128.

Katupotha, J. 1988b. Hiroshima University radiocarbon dates 2, West and south coasts of Sri Lanka. *Radiocarbon* 30 (3), 341-346.

Katupotha, J. 1988c. Evidence of high sealevel during the mid-Holocene on the southwest coast of Sri Lanka. *Boreas* 17, 209-213.

Katupotha, J. and Fujiwara, K. 1988. Holocene sea level change on the south-west and south coasts of Sri Lanka. *Palaeogeogr., Palaeoclimatol., Palaeoecol.* 68, 189-203.

Pirazzoli, P.A. 1987. Sealevel changes in the Mediterranean. *In*: Tooley, M.J. and Shennan, I. (eds.). *Sea-level Changes.* Basic Blackwell Inc, Oxford, 152-182.

Pirazzoli, P.A. and Montaggioni, L.F. 1988. Holocene sealevel; changes in French Polynesia. *Palaeogeogr., Palaeoclimatol., Palaeocol.*, 68, 153-176.

Williams, M.A.J. 1985. Pleistocene aridity in tropical Africa, Australia and Asia. *In*: Douglas, I. and Spencer, T. (eds.). *Tropical Landforms,* 219-233.

IUGS UNESCO IGCP 296

STRATOTYPES OF THE HOLOCENE BANGKOK CLAY AND PLEISTOCENE NAM MAE CHANG FORMATIONS

by

Phisit Dheeradilok[1], Niran Chaimanee[1] and Narametr Thirarangsikul[1]

1. Introduction

Systematic Quaternary geological mapping has been conducted by the Department of Mineral Resources since 1981. Several significant areas of Quaternary deposits were mapped and detailed studies on lithology, geomorphology, paleontology and radiometric age dating were undertaken by a number of Quaternary geologists. The data available at this stage indicate that two stratotypes of Quaternary deposits can be proposed in Thailand, one in the north and the other in the Central Plain. The first is the Bangkok Clay Formation of Holocene age and the second is the Nam Mae Chang Formation of Pleistocene age. The stratigraphic columns are plotted following ESCAP's legend for the Atlas of Stratigraphy and detailed descriptions are also presented.

Bangkok Clay Formation

Kind & Rank:

Chronostratigraphy	–	Holocene stage
Lithostratigraphy	–	Bangkok Clay Formation
Biostratigraphy	–	*Placuna* sp. zone
	–	*Callianassa* sp. zone
	–	*Rhizophoraceae* zone

Background

The name Bangkok Clay was first proposed by Chai Muktaphan as cited by Phianchareoen, C., et al., (1976). Phianchareoen and Chuamthaisong (1976) described Bangkok's aquifers and recognized the topmost formation as of marine origin with a thickness of 20-30 metres. Nutalaya & Rau (1981) reported Quaternary deposits in the lower Central Plain as Bangkok Clay of two main deposits; i.e. a basal-stiff clay and an upper soft clay. Dheeradilok et al. (1984) gave a lithological description of the Bangkok Clay which was observed in this locality. A study of the genesis and a paleoecology of these deposits was also carried out, based on the interpretation of the lithostratigraphic and biostratigraphic data. Carbonaceous materials were also dated by the C^{14} dating method. Sangsuwan et al. (1987) and Jarupongsakal (1987) made a palynological study of this locality.

Locality

The type section is exposed in a large sand pit excavated in a rice field of the floodplain of the Chao Phraya river in the southernmost part of the Chao Phraya Central Plain, northeast of Bangkok and about 35 kilometers from the Gulf of Thailand. It lies at 100° 37'E longitude and the 13° 50'N latitude. The site is located in Ban Lat Pla Khao, Amphoe Bang Khen, Bangkok and has an access by a side-street off Phaholyothin road leading to the Senanivate Housing Project (around the 4th kilometer stone). The type section is situated in the south side of an abandoned open pit behind the third project area of the Senanivate Housing complex. The ground elevation of the site is about 2 m above mean sea level.

Geologic identification

The sequence consists of three main units which overlay an erosional surface developed on Pleistocene deposits. The total thickness of this sequence in the type section is 15.5 m. The lowest unit consists of sandy clay with 5 per cent mottling and is developed from 11 to 15.5 m. No shell fragments nor plant remains were observed. But palynological study show an abundance of Gramineae and spore reflecting the open-forest environment. The upper boundary shows a clear contact and is marked by bioturbation consisting of Crustacean burrows filled with iron concretions. These burrow casts are very similar to *Callianassa* sp. burrows which reflect a change in the depositional environment from a paralic marine environment to the marine environment of the upper unit. The lower boundary of this unit is an erosional surface cut into Pleistocene deposits. These Pleistocene deposits can be distinguished by mean of various characters, mainly humic soil horizons with abundant mottling and a stiffness of the sediments. Both characters indicated a long period of being dried out and exposed to the air during Late Pleistocene time.

[1] Geological Survey Division, Department of Mineral Resources, Bangkok, Thailand.

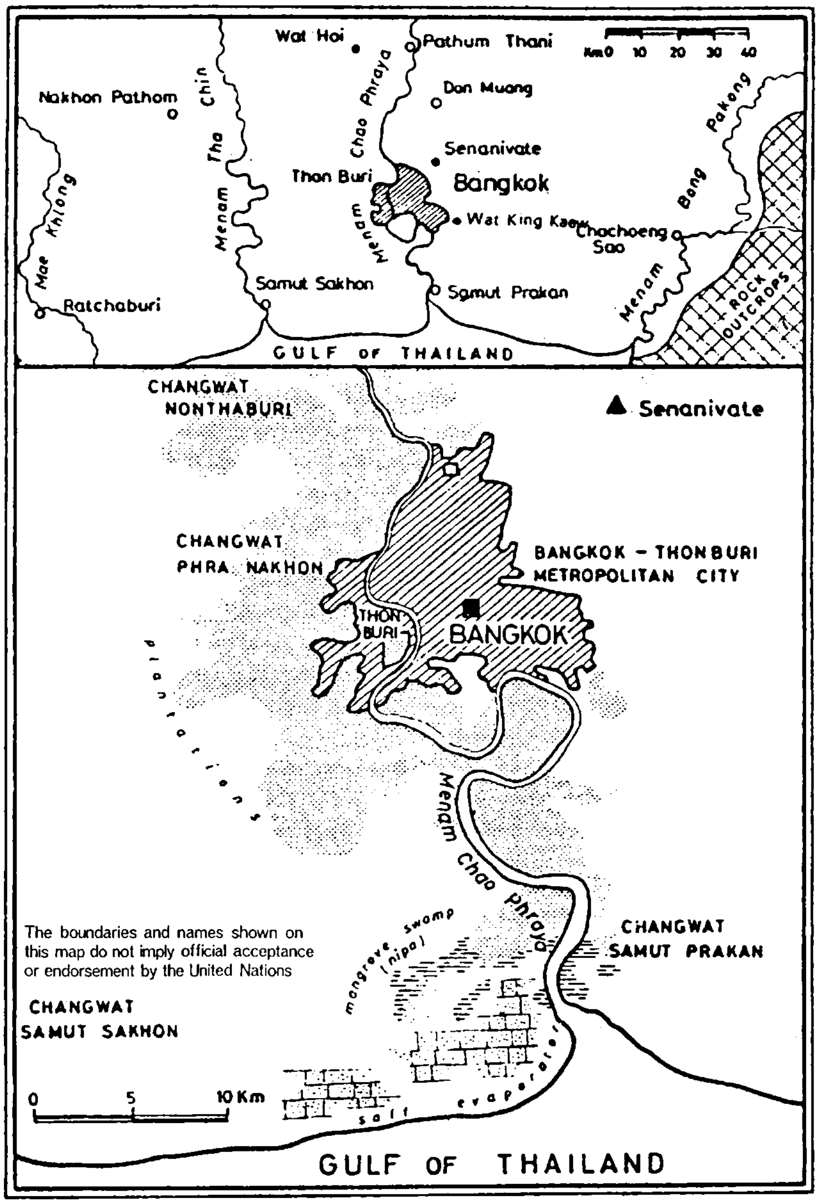


Figure 1. Location map of the Bangkok Clay Formation

The middle unit consists of silty clay with abundant plant remains and peat, extending from 7-11 meters. Scattered bivalve shells were observed in life position. Dense laminations of fine sand occur in the lower part of the unit which reflects the lower part of the intertidal zone. Palynologically, mangrove environments are characterized by an abundance of pollen of *Rhizophoraceae* sp, *Sonneratia* sp, and *Avicinnia* sp.. Peat layers in this unit were dated at about 6,300 yrs. BP.

The uppermost unit of the sequence is also silty clay from a depth of 1 to 5 metres. The unit shows distinct features as a mollusc layer in the lower part and a massive layer in the upper part with the remains of molluscs in living position. *Placuna placenta* which is widely distributed in South-East Asian seas and the eastern Indian ocean, was selected as ecologically significant as an indicator of a shallow sea environment. The molluscs were dated by C^{14} dating methods which gave an age of about 5,200 yrs. BP. In the upper part of the unit, a sand lense with shell fragments was observed and possibly indicates a decreasing of marine influence.

The Senanivate sequence has developed a humic clay as top soil which shows clear pedologic horizons.

Regional aspect and genesis

The genesis, development, and evolution of the Holocene sequence along the coastal area, especially the lower Central Plain of Thailand are well recognized. The Holocene sequence is obviously different from Pleistocene deposits as comparing its marine origin to the fluvial origin of the latter. The marine Holocene deposits of the Senanivate site can be correlated with the Wat Hoi profile (Chonglakmani et al, 1983), located 40 km north-

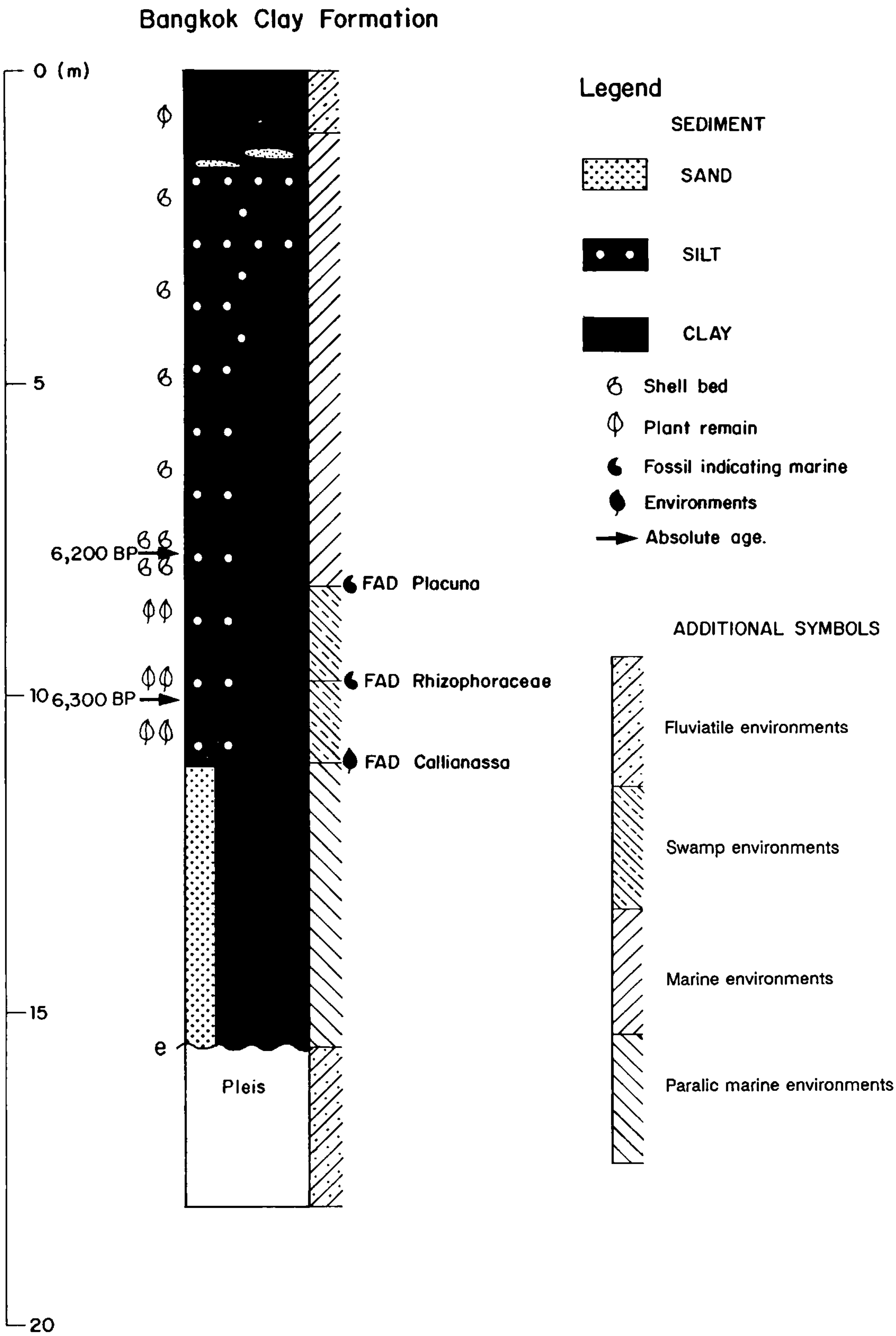


Figure 2. Stratigraphic column of the Bangkok Clay Formation

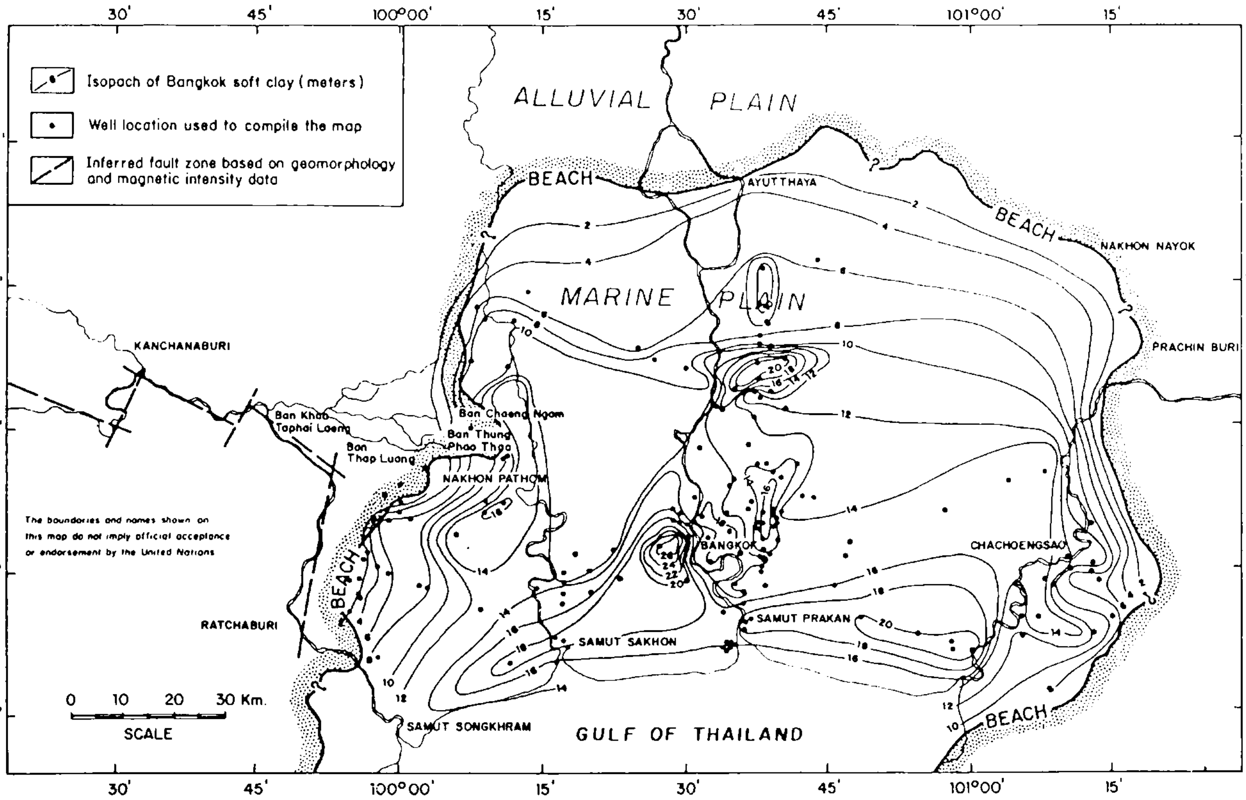


Figure 3. Isopach map of the Bangkok Clay showing the Holocene Bangkok Embayment (Nutalaya and Rau, 1981)

west of Senanivate and the Wat King Kaew profile (Chaimanee et al, forthcoming) situated about 20 km south of Senanivate. The difference between each site is only the thickness of each unit which is thicker towards the present day coast of the Gulf of Thailand.

Nam Mae Chang Formation

Kind & Rank

Lithostratigraphy: basalt and gravel

Chronostratigraphy: Pleistocene

Historical background

DMR, 1981 started to establish the stratigraphic sequences of the deposits in the Lampang basin based on morphological and lithological criteria. Recent alluvial deposits were developed upon Pleistocene basalt and valley-fill deposits. Barr and Macdonald (1978) dated the basalt in this area as ranging of 0.69-0.95 my.

Locality

The Formation is situated in the southern part of the Lampang basin, Northern Thailand, approximatly 900 km from Bangkok. The section is located in a roadcut at the 24.5 kilometer mark of the Lampang-Den Chai highway. The elevation of the section is about +260 metres.

Geological identification

The Formation consists of three main units of Pleistocene deposits which overly Tertiary rock. The lowest unit is composed of thick bedded gravel. The roundness and the variety of parent material such as tuff, rhyolite, andesite, sandstone, and quartzite reflect the fluviatile origin. The structure and fabric of these sediments show an approximately eastern sediment transport direction.

The middle unit consists of olivine nepheline basalt which shows sharp contact with the lower unit. In contrast, the upper boundary of this unit is not clear due to weathering process. The thickness of this unit is about 4 metres. Its radiometric age determination was 0.95 my. at the base of the unit.

The uppermost unit consist of laterite which forms a hardpan in the lower part and a lateritic soil in the upper part. The formation of this laterite is due to the weathering of the basalt unit under hot and dry climatic conditions.

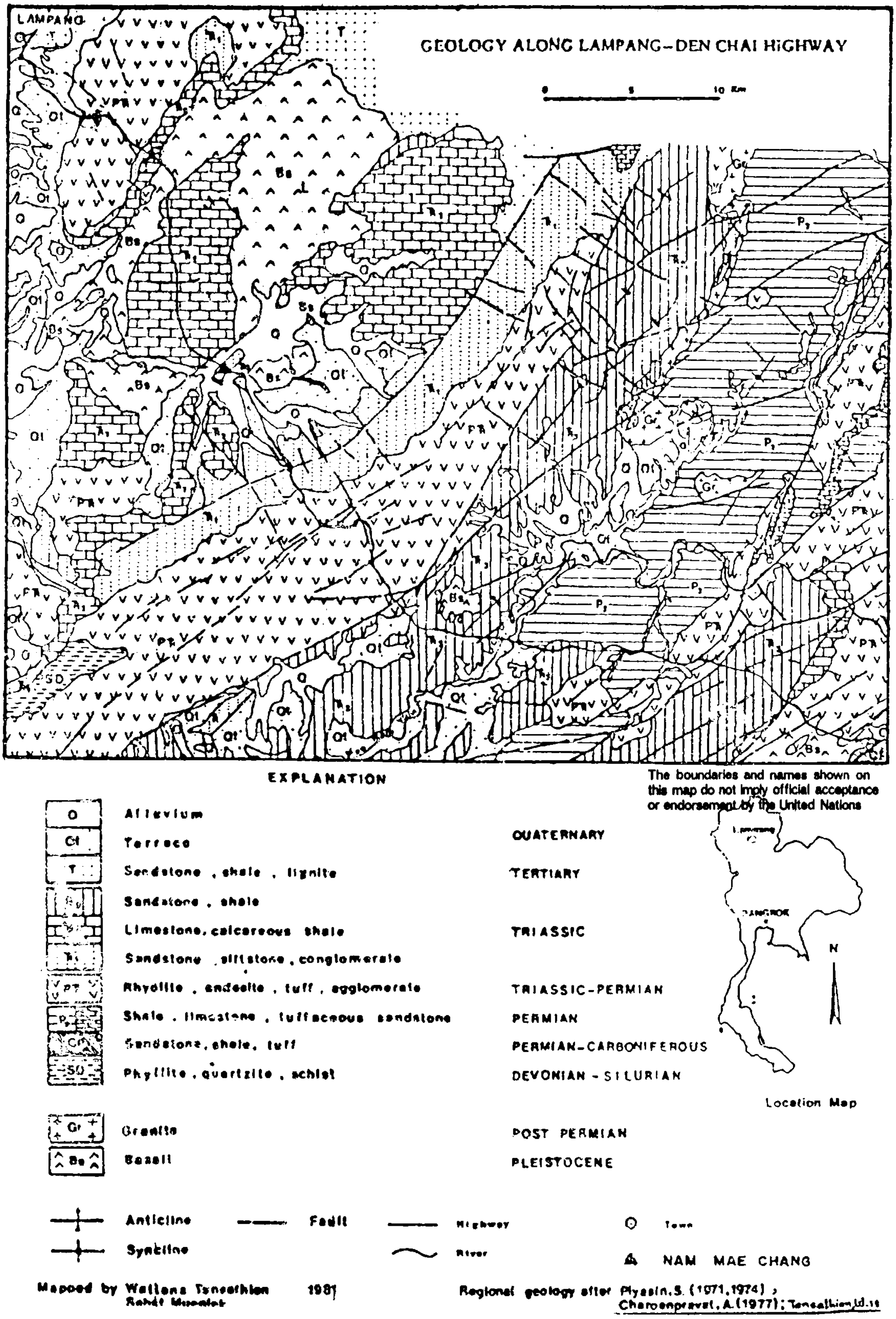


Figure 4. Location map of Nam Mae Chang Formation

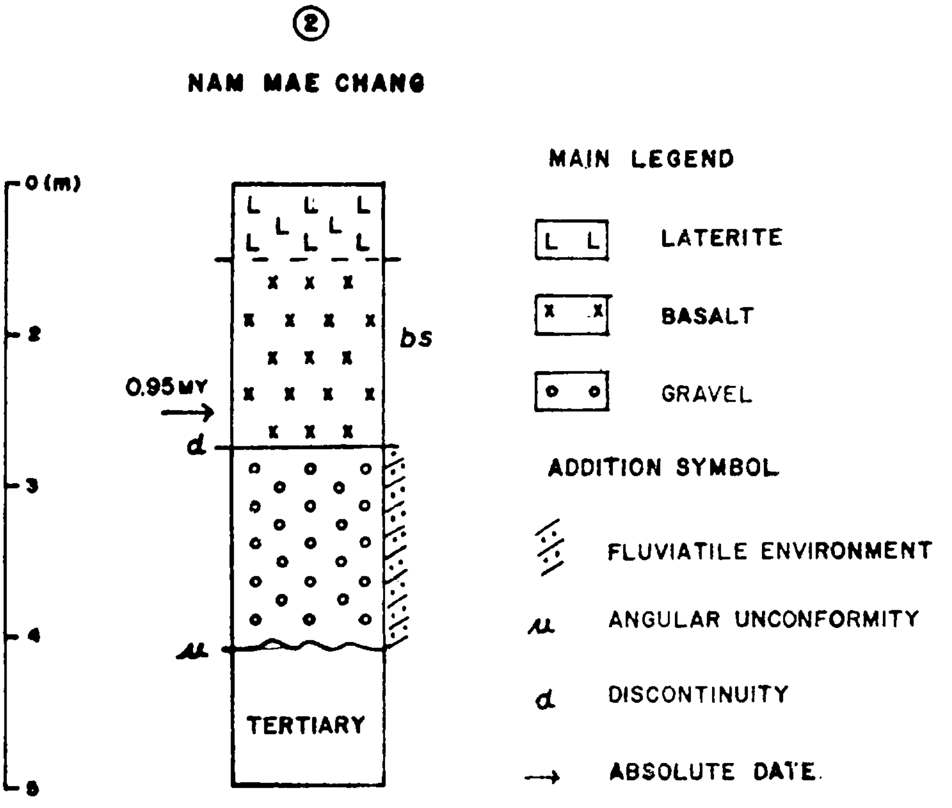


Figure 5. Stratigraphic column of Nam Mae Chang Formation

Regional aspect and genesis

The fluviatile coarse sediment which overlies the Tertiary formed during the Pleistocene as a terrace. This was followed by deep erosion and contemporaneously by a basaltic flow over this gravel bed. By pedogenesis and weathering processes, the upper part of the basalt degenerated and a laterite was formed.

This terrace system can be found all over a single intermontane basin. In this case, the Lampang basin was developed by a main river, the Wang river, which drains from north to south. The system is not necessarily formed by the same process in other basins due to various conditions, mainly parent material, tectonic movement and drainage pattern.

IGCP 296

THE THU DUC LOESS FORMATION, A TYPICAL EOLIAN DEPOSIT OF TROPICAL REGIONS

by

Hoang Ngoc Ky[1]

The type section of the Thu Duc Loess Formation consists of reddish-yellow sandy silt clay containing sharp fragments of charcoal and unconformably overlying various lithologies on gently undulating topography at varying elevations in Viet Nam. It is a coarse loess, deposited in sub-aerial environments of a tropical humid climatic region by monsoonal whirlwinds or dust storms in the hot dry seasons during the last glacial maximum.

The Thu Duc Loess is Late Pleistocene to Holocene in age and may therefore be correlated with the red yellow loess in the Khorat Plateau of northeastern Thailand, the Loam of upland Malaysia, and sandy silt loess in the Punjab of India. It is proposed that loess is not restricted to the high latitudinal regions only, but is distributed widely around the globe. Loess formation is related to global atmospheric circulation and loess may be classified into three types as follows:

1. The coarse-grained loess of tropical (low latitudinal) regions.
2. The medium-grained loess of middle latitudinal regions.
3. The fine-grained loess of high latitudinal regions.

1. Introduction

Loess consists of reddish brownish yellow clay silt of eolian origin. It is distributed over large wide areas of the world including the middle and high latitudes of China's north and northeast, Europe and North America. This paper will introduce a number of red-yellow loess sections in Viet Nam and correlate these with other sections distributed in several lower latitude countries.

The reddish yellow loess in Viet Nam was discovered in 1983 and the loess has now appeared for the first time in the legend of the Viet Nam Quaternary Map at a scale of 1:200,000. The coarse red-yellow loess is found not only in Viet Nam but has been described from India's Punjab by D.N. Wadia and northeast Thailand's Khorat plateau by Montree Boonsener; the surficial loam layer identified in Malaysia's upland by Morgan de Dapper may also be a correlative of this loess.

As well as introducing and describing the loess, this paper will give a new point of view for the formation and global classification of the loess.

2. The Thu Duc Loess Formation (Viet Nam)

Stratotype

The type section is a 3 metre thick red-yellow sandy silt-clay in the Thu Duc District of Ho Chi Minh city on southern Viet Nam's upland. The loess in the type section is of uniform lithology, with no interbeds, and consists of 20-30 per cent sand, 30-40 per cent silt and 30-40 per cent clay; locally it contains sharp fragments of charcoal with radiocarbon ages of 8570 ± 40 BP.

The Thu Duc Loess Formation at the type section overlies unconformably the hard laterite surface of the Chunh Luu Formation (Pliocene). Elsewhere the loess overlies a wide range of different rocks in the low and high hills of south Viet Nam's northeastern upland, at elevations from 10 to 70 m above sealevel (ASL). Black tektites at the boundary between the loess and the underlying hard laterite have K-Ar ages of between 600 and 700 ka BP.

Distribution of the loess in Viet Nam

For some time, the greyish, red yellow sandy silt clay surficial layer that occurs in many places in Viet Nam has been interpreted to be of alluvial, proluvial or eluvial origin. This interpretation is a misunderstanding and is similar to that of considering the sandy silt clay mantle on south Viet Nam's northeastern upland as being of ancient alluvial/proluvial origins. In fact, this reddish yellow sandy silt clay has grain size characteristics, general physical character and, especially, landscape distribution similar to the Thu Duc Loess Formation, strongly indicating that these mantles may be considered to be loess. Typical sections of the loess throughout Viet Nam were compiled. (Atlas Sheet Viet Nam 1).

In the Son Tay (B), Nam Dan (C), Da Nang (D), Dong Nai (K) and Tam Nong (L) sections the loess blan-

[1] Quaternary Division, General Department of Mines and Geology, 200 Ly Chinh Thang District III, Ho Chi Minh City, Viet Nam.

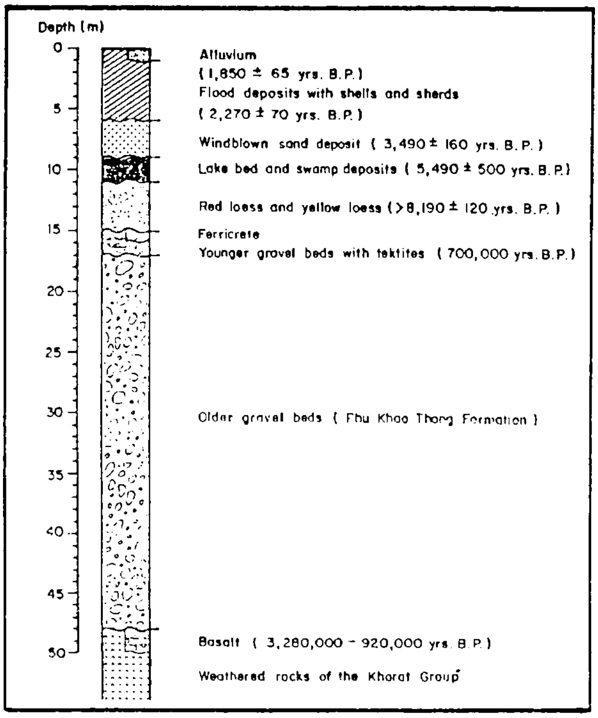


Figure 1. Quaternary stratigraphic section of the Khorat Plateau, Thailand (after Udomchoke, 1989)

kets coastal erosional and depositional terrace surfaces and river terraces at elevations of 10 to 70 m ASL. The Phu Quoc (M) section, on an island off southern Viet Nam, overlies depositional and erosional marine terraces at 5-10 m ASL. The Dak Nong (H) section overlies bauxite derived by weathering of Neogene basalt, the Da Lat (Y) section is on granite, and the Cao Bang (A) section occurs on a variety of rocks and elevations. The latter three sections consist of reddish yellow loess on plateaus having gentle topographies, and elevations of 800-1000 m ASL.

About 8 per cent of Viet Nam's overall area has been blanketed by the reddish yellow coarse grained loess. The soil formed from this has a good spongy grade which makes it suitable for the development of silviculture and agriculture.

Origin and age of the Thu Duc Loess

On the basis of lithological composition, topographic setting, comparison with the characteristics of loess throughout the world, the loess materials described here from Viet Nam cannot be considered to be of alluvial, deluvial, or eluvial origins (Idonov 1970; Hoang Ngoc Ky 1985, 1989a, 1989b). Rather, they are coarse grained loess which has been deposited under eolian conditions in the tropical humid climatic regions, where monsoon and eddy dust storm winds were formerly very active during the hot seasons.

Radiocarbon dates of charcoal fragments from the upper part of the section are between 1 ka and 10 ka BP and the absolute ages of tektite fragments underlying the blanketing loess layers are 700 ka to 800 ka BP. The Moc Hoa Formation of Late Pleistocene age was unconformably overlain by the Thu Duc Loess Formation, demonstrating that the loess in Viet Nam dates from about the Middle (?) to Late Pleistocene, to the Holocene, after the tektite rain.

3. Correlation with loess materials in other Asian countries

The red yellow coarse grained loess has also been recognised in other Asian countries. Coarse sandy clay loess has been described from the upland of northwestern Punjab and on the Salt Range of India by Wadia (1918). This loess covers all levels of the plain's general surface, on the flat plateau top of the Salt Range. According to Wadia, the conditions that favoured the formation and deposition of loess in these areas were general aridity and long drought seasons. The conditions resulted in dust storms of great violence in the hot months preceding the monsoons which mobilised and transported vast clouds of dust and silt from the desiccated plains and dry river basins, depositing dust on any elevated ground.

On northeast Thailand's Khorat Plateau, a red loess, 5-6 m thick, consists of 40-50 per cent sand, 25-30 per cent silt and 20-30 per cent clay, and a yellow loess contains 30-40 per cent sand, 30-35 per cent silt and 30-35 per cent of clay and attains a thickness of 8 m (Boonsener 1987; Dheeradilok 1987; Nutalaya *et al.* 1987). Both types occur at elevations of 150 to 200 m ASL and are of the same age, but they exhibit different degrees of oxidation. The red yellow loess is unconformably overlain by lake and swamp deposits having an age of 5490 ± 50 years BP and itself unconformably overlies ferricrete (laterite) and the younger gravel beds containing tektite fragments 700 ka old (Figure 2). In the red yellow loess of Thailand, as in the Thu Duc Loess Formation, there are sharp charcoal fragments which have yielded an absolute age about 8190 ± 20 years BP.

In Malaysia's upland, cover layers of sandy or silty clay loam have been described by Morgan De Dapper (1987). This loam may be similar to the loess found in Viet Nam and Thailand.

It is proposed here that these various loess deposits in lower latitude (tropical) regions are of the same age. Moreover, they are interpreted to have the same eolian origin. It is suggested, therefore, that loess is found not only in high latitude regions but also in the lower latitude (tropical) zones.

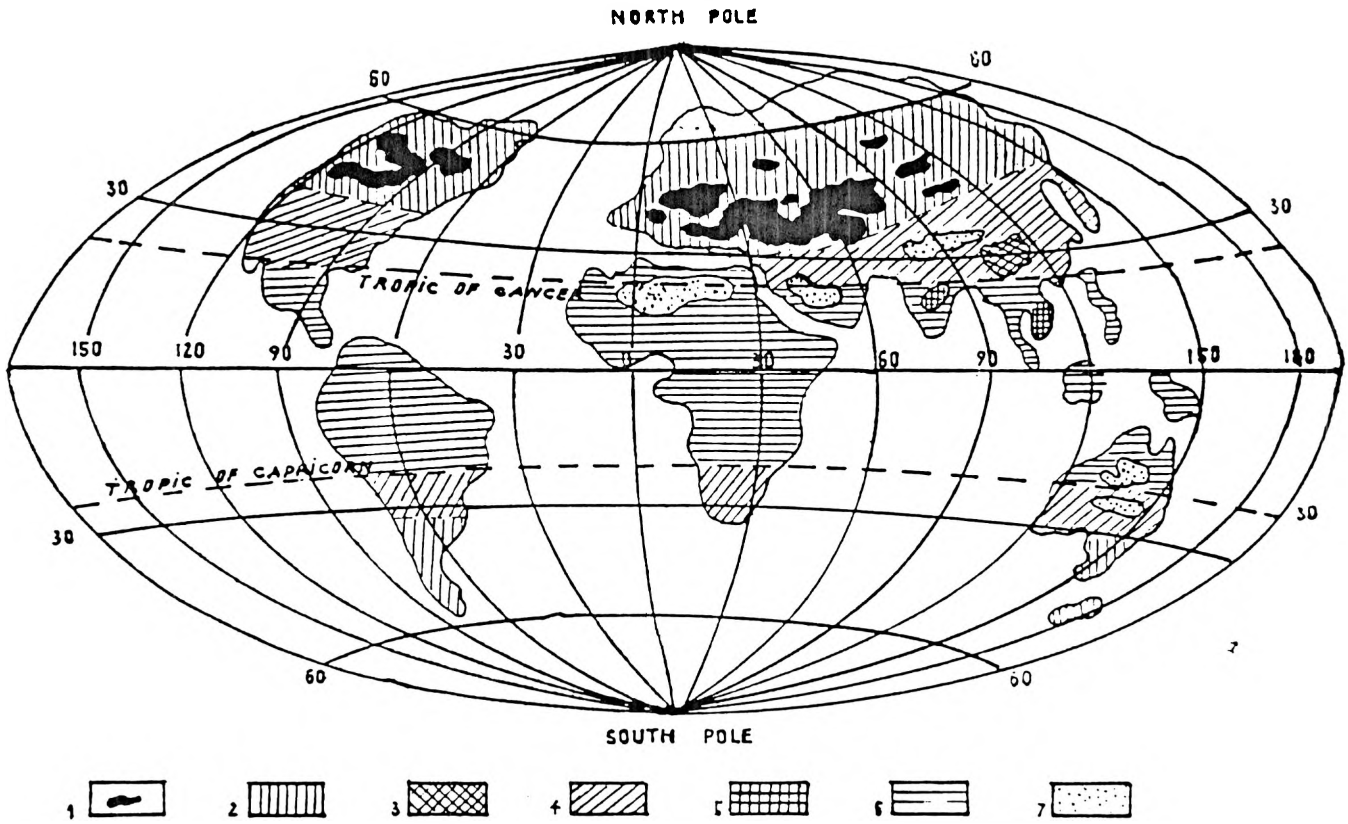


Figure 2. General, schematized distribution of loess throughout the world. 1. Fine-grained loess; 2. Predicted zone of fine-grained loess; 3. Medium-grained loess; 4. Predicted zone of medium-grained loess; 5. Coarse loess; 6. Predicted zone of coarse-grained loess; 7. Sandy desert.

4. A general classification of loess and a global mechanism for its formation

For a considerable time, until recently, loess was understood to have formed in high and middle latitudes only. However, the coarse sandy silt commonly found overlying weathering profiles in the humid hot climate of the tropical zone and interpreted as resulting from the final stage of weathering, lies unconformably on the weathered (lateritic) surface. Its composition does not match the underlying weathered material. That is, the blanketing layer must be sand or silt clay of eolian origin, and is not composed of secondary materials resulting from weathering. The discovery of eolian, coarse-grained red yellow loess in the lower latitudes (intertropical zone) therefore demands a widening of the understanding and general classification of loess in the global context.

Loess formation in Viet Nam and the world

The Earth's passage around the Sun creates an orbit. The Earth's axis deviates from the flat of the orbit, with an angular deviation that has varied throughout Earth history. Currently this tilt is 23°30'. As a consequence of the tilt, the Earth's surface receives perpendicular insolation in a belt between the Tropic of Cancer and the Tropic of Capricorn. The intertropical atmosphere receives maximum heating due to this perpendicular insolation. The air in the troposphere expands and its low density creates whirlwind currents rising up from the Earth's surface into the high atmospheric layer (stratosphere). These whirlwinds mobilise particles of varying grain sizes (sand and dust) and elevate them to the stratosphere. The volume of sandy dust mobilised depends on the wind speed, the dryness of the climatic conditions, soil characteristics and vegetation cover. All of these have been changing in response to changing climates throughout geological time. The coarser fractions of the wind-borne sediment soon return to the surface of the globe under the influence of gravity, whereas the finer fraction moves on up into the stratosphere and towards both Northern and Southern Hemispheres.

In the opposite direction, cold air moving from the poles towards the Equator creates the regular horizontal winds called the Regular Winds or Trade Winds and these carry away the small dusty grains from the surface of glaciers towards the areas equatorwards of the glaciers, forming the fine grained loess of high latitudes. This regular wind also brings fine-grained sediment to the intertropical zone.

These transport mechanisms account for two critical aspects of loess in the global context: i) the production of large amounts of fine-grained sediment in high latitudes during the Quaternary, and its deposition outside its latitude of origin, and ii) the high percentages of both sand and clay found in the loess of the tropical regions. The variations in grain size of loess throughout the world is therefore of atmospheric circulation and it is important to note that loess is found not only in high latitudes but widely on the globe, preservation permitting, of course.

Global distribution and classification of loess

Loess may be classified on the basis of grain size character in conjunction with latitude and wind speed. In this way loess may be divided into three types with global distribution as follows (Figure 2):

Coarse loess: This consist of 20-40 per cent sand, 30-40 per cent silt, and sometimes contain 1-5 per cent gravel. Coarse loess is distributed in lower latitude (intertropical) regions, where a humid tropical climate is characterised by monsoons and vertical whirlwind. Examples include the sandy loess of the Punjab in India, the reddish yellow loess in Thailand's Khorat Plateau, and the Thu Duc Loess in Viet Nam.

Medium loess: This is an intermediate form of loess and is distributed in mid-latitude regions with a warm dry climate. This form of loess has been recognised in northwestern China and the central Asian Republics of the USSR.

Fine loess: This is composed of 60-70 per cent silt, 30-40 per cent clay and a little sand and was formed in cold dry climates in the high latitudinal regions of both the Northern and Southern Hemispheres. Fine-grained loess is found bordering glacial areas that have experienced consistent horizontal winds blowing from both North and South Poles towards the Equator. This loess is commonly found in Europe and North America.

5. Summary and future practical significance

The coarse loess has been described in Viet Nam and other Asia countries. Its significance and economic potential are as follows:

1. The loess has covered a broad area of the whole country's flat and undulating topography. Soils with a good spongy grade suitable for the growth and development of silviculture and agriculture have formed on these loess deposits.

2. The grain size characteristics of the loess make it suitable for the production of unbaked bricks.

3. In Viet Nam, some bauxite and kaolinite deposits that had formed by weathering were covered by the coarse loess. Further research on the correlation between the quality, quantity and economic potential of the weathering profiles, and the character of the blanketing coarse loess is necessary.

4. The world-wide distribution of loess necessitates revision of both our classification schemes for loess and our understanding of the periods and mechanisms of its formation. The inter-tropical coarse loess could occupy an important position in the legend of the Quaternary geological maps of the Asian and Pacific regions, and provide an extremely useful tool for inter-regional correlations.

References

Boonsener, M. 1986. Quaternary geology of Khon Kaen Province, Northeast Thailand. *In*: Thiramongkol, N. (ed.). *Proceedings of the Workshop on Economic Geology, Tectonics, Sedimentary Processes and Environment of the Quaternary in SE Asia*. Department of Geology, Chulalongkorn University, 75-86.

De Dapper, M. 1987. Landform development during the late Quaternary in the upland of peninsular Malaysia. *In*: Wezel, F.W. and Rau, J.L. (eds.). *Progress in Quaternary Geology of East and Southeast Asia*. Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in E and SE Asia During the Last Decade." *CCOP Technical Publication* 18, 109-134.

Dheeradilok, P. 1987. Review of Quaternary geological mapping and research in Thailand. *In*: Wezel, F.W. and Rau, J.L. (eds.). *Progress in Quaternary Geology of East and Southeast Asia*. Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in E and SE Asia During the Last Decade." *CCOP Technical Publication* 18, 141-167.

Dodonov, A.E. 1984. Stratigraphy and correlation of upper Pliocene-Quaternary deposit of central Asia. *Geographical Research Institute Hungarian Academy of Sciences Budapest* 1984, 201-211.

Fontaine, H. and Hoang Thi Than. 1971. Ancient alluvium of central South Viet Nam. *Arch. Geology of Viet Nam* N-14 (Saigon), 40-50.

Hoang Ngoc Ky and others. 1983. Aeolian formed loess distributed in South Viet Nam's eastern upland. *Geology* 168/1985, 35-36.

Hoang Ngoc Ky (ed.). 1985. Geological and mineral reports of Tay-Ninh and Song Be provinces. *Archives of Tay Ninh and Song Be Economic Zoning Planning Committee.*

Hoang Ngoc Key, Nguen Ngoc Men and Le van Cu. 1987. Quaternary geology in northern Viet Nam. *In*: Wezel, F.W. and Rau, J.L. (eds.). *Progress in Quaternary Geology of East and Southeast Asia.* Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in E and SE Asia During the Last Decade." *CCOP Technical Publication* 18, 271-281.

Hoang Ngoc Ky. 1989a. The Quaternary geology of the Mekong lower plain and islands in southern Viet Nam. *In*: Thiramongkol, N. (ed.). *Proceedings of the Workshop on Correlation of Quaternary Successions in South, East and Southeast Asia.* Department of Geology, Chulalongkhorn University, 215-241.

Hoang Ngoc Ky. 1989b. The stratotypes of Thu Duc yellow loess in Viet Nam. Paper delivered at the first meeting of IGCP Project 296; Ipoh, Malaysia, 11-13 September, 1989.

Hoang Ngoc Ky and Dang Duc Nga. 1989. The stratotypes of Quaternary in Red river's lower plain of North Viet Nam. Paper delivered at the first meeting of IGCP Project 296; Ipoh, Malaysia, 11-13 September, 1989.

Idodonov, A.E. 1970. Stratigraphy of the upper Pliocene-Quaternary deposit of Tajikistan (Soviet central Asia). *Acta geologica Academiae Scientiarum Hungaria* 22, 63-79.

Nutalaya, P., Vella, P., Bunopas, S. and Kaewyana, W. 1987. Quaternary Processes in Thailand. *In*: Thiramongkol, N. (ed.). *Proceedings of the Workshop on Economic Geology, Tectonics, Sedimentary Processes and Environment of the Quaternary in SE Asia.* Department of Geology, Chulalongkorn University, 23-33.

Petrov, U.V. 1968. Osnova usevaic o drovnic korax vivetrivania Izdatlistva. *Nedra Moskva* 1986, 235-237.

Udomchoke, V. 1989. Quaternary stratigraphy of the Khorat Plateau, northeastern Thailand. *In*: Thiramongkol, N. (ed.). *Proceedings of the Workshop on Correlation of Quaternary Successions in South, East and Southeast Asia.* Department of Geology, Chulalongkhorn University, 69-94.

Wadia, D.N. 1918. *Geology of India,* New Delhi, 384-385.

Xisorukova,S.S. and Kovalena E.E. 1988. Lithologia i genesis pokrovi otlorenia Viet Nama accosirovonnic tektita. *Aktialinue vaproxi meteoritiki v Xibiri*, 231-238.

Yung Zigeng and Li Shaoquan. 1987. Progress in Quaternary geology in China during the last decade. *In:* Wezel, F.W. and Rau, J.L. (eds.). *Progress in Quaternary Geology of East and Southeast Asia.* Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in E and SE Asia During the Last Decade." *CCOP Technical Publication* 18, 23-31.

IGCP 296

THE QUATERNARY STRATOTYPES IN THE RED RIVER'S LOWER PLAIN OF VIET NAM

by

Hoang Ngoc Ky[1] Nguyen Dich Dy[2] Nguyen Ngoc Men[2] Dang Duc Nga[3]

1. Introduction

The Quaternary geological map on 1:200.000 scale of the Red river's plain was established on the basis of stratigraphic subdivision, sediment age and origin (environment).

The Quaternary period is approximated 1.8-2 million years in length and occurred during the last phase of the geological history.

The stratigraphical units and their corresponding time are divided as follows: Early Pleistocene from 1.8-0.7 million years (m.y.) (prior to tektite fall); Middle Pleistocene from 0.7 to 0.3 m.y.; Late Pleistocene from 0.3 to 0.01 m.y. and Holocene from 0.01 to present.

According to us the Quaternary stratigraphy could be put into the following divisions:

- The Formation: That is local stratigraphic unit or mapping unit which can be correlated using certain petrographic characteristics.

- The Horizon: That is the regional or correlational stratigraphic unit which is used to link Quaternary sediment's divisions in a wide area. Correlated units may have similar or different origins and petrologic compositions but are of the same age.

2. The stratotypes of Red river's lower plain

The Red river's lower plain of thick Quaternary sediments has been studied by mapping on 1:200.000 scale and divided into five stratotypes as follows:

The Thaithuy Formation (F_2). The stratotype of Thaithuy Formation is one section of a borehole in the Thaithuy district of Thaithuy province. This unit extends from a depth of 100 metres to 250 metres and consists of coarse gravels and sands in the lower part and sandy silt with interbedded silty clays of marine origin in the upper part. This formation unconformably covers the Vinhbao Formation of Pliocene age and is overlain by the Hanoi Formation. Thaithuy Formation's age is early Pleistocene (Q_I) the same as the Hoanghoa and Nghixuan Formations distributed along the Ma and Ca rivers and the same as alluvial and marine deposits on the fourth terrace.

The Hanoi Formation (A). The stratotype of the Hanoi Formation is one section of a borehole near Hanoi. This one lies in depth about 40 meters with a thickness of about 40-50 metres. The Hanoi Formation consists of rounded pebble-gravels and having interbedded silty and sandy clays of alluvial origin. Its age is Middle-Early Late Pleistocene (Q_{II-III}^1) as well as of the Nuido culture of the Paleolite. The Hanoi Formation's origin is of the regressional phase.

The Vinhphuc Formation (B). The typical section of Vinhphuc Formation is in the borehole on Vinhphuc province's upper plain with elevation of from 5 meters to 10 meters above the present sea level. Vinhphuc Formation consists of reddish yellow silty clays or brown clayey silts and contains abundant foraminifera of the shallow marine environment. This formation's age is Late Pleistocene (Q_{III}^2). This is the same age as the Sonvi and Hoabinh cultures of the Late Paleolite and earlier than the Phungnguyen culture of the Bronze period.

The Vinhphuc Formation can be correlated to silty-sand deposits of the second marine terrace, with clayey silt on delta and coastal plains along the central part of Viet Nam and to the Mochoa Formation's yellowish silty clay on the Mekong upper plain.

The Vinhphuc Formation's origin was of the transgressional phase in the latest interglacial period.

The Haihung Formation (C). The section of the borehole on Haihung province's middle plain 3 meters above the present sea level is the stratotype of the Haihung Formation. There are two parts: the lower part consists of grey sandy clay with interbedded silt layers and contains abundant foraminifera and the upper part the sudden marine transgressional phase of greenish soft

[1] Quaternary Division, General Department of Mines and Geology, 200 Ly Chinh Thang Str., District III, Ho Chi Minh City, Viet Nam.

[2] National Center for Scientific Research Institute of Earth Sciences. Hanoi Viet Nam.

[3] Department of Geology. Hanoi University.

clay with plants of inland, shoreline and swamp environments. The absolute ages of fragments of plants are 7195 + 85 and 4150 + 50 years ago. The origin of the Haihung Formation was the marine transgressional phase dating from about 10,000 years ago to 3000 years BP.

Haihung Formation can be correlated to the Thieuhoa and Canloc Formation's clayey silts and sandy silts laying on the first marine terrace of the central part of Viet Nam and with the soft clay in the Lower Central Plain of Bangkok, Thailand.

The Thaibinh Formation (D). The typical section of the Thaibinh Formation is from a borehole in Thaibinh province's lower plain. It includes sediments of the greyish darkish marine sands, distributed along the coastline, the eolian yellowish white sandy dunes stretching along seashores and coastal swamps creating peat and black sandy clay layers. Most of these units are of mixed marine-alluvial origin established during the last marine regression from 3000 to 1500 years ago.

3. Conclusion

The five stratotypes of the above mentioned formation's in the Red river's lower plain were studied. They are the units that can be linked stratigraphically with other localities in Viet Nam and also can be correlated with other territories in the Asia/Pacific region (Atlas Sheets Viet Nam 1 and 2).

References

1. Hong Chuong, 1978. On the delimitation between the Anthropogenic system and the Neogene in the Hanoi depression. *Geology* No. 135-I-II/1978, pp. 40-42.

2. Hoang Ngoc Ky, 1976. The Quaternary sediments of North Viet Nam plains. *Geology* N° 126-III-IV/ 1976.

3. Hoang Ngoc Ky (Editor in Chief), 1974. Geology and mineral report of the Quaternary map on a 1:200,000 scale of Red's river plain. *Archive of G.D.M.G*, Hanoi.

4. Hoang Ngoc Ky, 1979. The radioactive carbon dates of Red river Quaternary sediments. *Geology* No. 135-II-III/1979.

5. Hoang Ngoc Ky, NGUYEN NGOC MEN and LE VAN CU, 1987. Quaternary geology in North Viet Nam. "Progress in Quaternary geology of East and Southeast Asia" (J.L. Rau and F.W. Wezel, eds.). Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP), *CCOP Technical Publication 18* Bangkok, Thailand 27-30 October 1986.

6. Hoang Ngoc Ky, 1988. *The Quaternary geology of the Mekong lower plain and islands in South Viet Nam.* Paper presented at the workshop on correlation of Quaternary successions in East and Southeast Asia (IGCP project 218, held in Chulalongkorn University, Bangkok, Thailand 22-24 November 1989.

7. K.V. Nikiforova, 1976. *Status of the boundary between the Pliocene and the Quaternary.* The First International Congress on the Pacific Neogen Stratigraphy, Tokyo 1976.

8. Nguyen Ngoc, 1975. Foraminifera fossils and the Vinhbao Formation's age. *Oil and Gas*, No 4.

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AN INTRODUCTION TO THE QUATERNARY SEDIMENTS OF VIET NAM

by

Nguyen Duc Tam[1] and
Huynh Minh Chinh[2]

In the whole area of the Socialist Republic of Viet Nam there are two regions of distribution of Quaternary deposits: coastal and mountain regions.

In the coastal region Quaternary deposits are composed of four great horizons. Upwards these are:

(i) The first, the lowest horizon, has a narrow distribution at the bottom of the coastal plains and is fully covered, mainly constituted by polymictic pebble, gravel, sand of a continental facies, with the thickness of 20-30 m. Its age may be of Upper Pliocene-Lower Pleistocene (N_2-Q_1).

(ii) The second horizon is composed of 4-5 clay layers with thickness of 10-35 m each, largely distributed at the bottom of the coastal plains, weakly weathered into red-white colour, with a marine facies. In some places of Central Viet Nam there are exposures of peculiar deposits called "red sand." The age of the lower part is Middle Pleistocene (QII).

(iii) The third horizon is the most prevalent coarse-grained horizon, frequently met in the whole of the coastal plains and is the main hydrogeological object. It is composed of polymictic pebble, gravel, sand and has a fluvial facies. In the Mekong River delta this horizon has a more complicated lithology with intercalations of sand and clay. This horizon is generally covered and only crops out in some places at the margins of the coastal plains where it has been identified in fluvial terrace blocks. Its thickness is from 10 to 100 m. The upper part of this horizon is dated as Middle Pleistocene - lower part of Upper Pleistocene (QII-QIII).

(iv) The fourth, the uppermost horizon of the stratigraphic column of the coastal plains, is composed of many suites of fluvial and marine sediments intercalated with thicknesses is of from 10 to 80 m.

The fluvial suites consist of small pebbles, gravel, sand and clay. Marine deposits are of clay, sand and peat. The first three to four marine suites are called "Bimson Layers" (Nguyen Duc Tam, 1974). They are the products of three to four transgression movements ("Bimson transgressions," Nguyen Duc Tam, 1974). The marine suite of the latest transgression of the Late Pleistocene ("Vinh Phuc transgression", Nguyen Duc Tam, 1970) had been called "Vinh Phuc layer" (Nguyen Duc Tam, 1970). The Middle Holocene suite had been called the "Dong Da layer" (Nguyen Duc Tam, 1970) or "Hai Hung Suite" (Hoang Ngoc Ky, 1978).

Along the actual sea coast there is a peculiar type of sediment attributed to marine-wind mixed dune sands.

Beach sand and dunes contain placer deposits in many places. Sometimes these deposits are of high quality and consist of large bodies of titaniferous sand. Other types of mineral resources of the coastal plains are peat, and glass sand.

In the mountain region there are two types of Quaternary deposits: alluvium along the river valleys and deposits of the weathered crust.

Along the river valleys, the main sediments are stream channel deposits, i.e. the lst, the 2nd and the 3rd terraces. The stream bed, as a rule, consists of polymictic pebbles, boulders, gravels, and sand clay with a thickness of 1-7 m. The 1st and the 2nd terraces consist of rather large fragments of pebble, gravel, sand and clay, with a thickness of from 1-2 m to 10-15 m. The 3rd terrace consists of small fragments with a thickness ranging from 2 to 8 m, having as constituents pebbles, gravels, sands and clay. The fragments of the 4th, the 5th terrace etc. can also be distinguished in some places, but they are quite small and thin.

In some places, especially in neotectonic and karst depressions, the Quaternary deposits have a thickness of 80-110 m.

Alluvium of the river valleys contain many important placer deposits, such as tin, gold etc. For instance, Naca is a big tin deposit of Quaternary age which fills a large deep basin of neotectonic origin and also some deep valleys in karst, with a thickness of 1100 m.

[1] Institute of Geology and Mineral Resources, Hanoi.

[2] National Committee for CCOP, Hanoi.

Recently, placer gold has been found everywhere along the large and small river valleys. In some places the bodies are hundreds of kilometres long. The exploitation of placer gold has become a profession of the local people.

The weathering crusts of Viet Nam consist of three types:

(i) Weathering crust on the igneous and effusive rocks. In some places has a thickness of about 30-35 m, and includes some types of mineral resources such as clay and construction materials.

(ii) The weathering crust on limestone leads to the formation of phosphorite, the important mineral for phosphoric fertilizer.

(iii) The weathering crust on Neogene-Quaternary basalt consists of so called "red land." "Red land" mainly has a thickness of 10-4 m and is distributed over thousands of square kilometres. The weathered sediments are suitable for plants such as rubber, coffee, cocoa, black pepper etc. The weathering crust developed on the Pliocene - Lower Pleistocene (N_2-Q_1) basalt bears a peculiar mineral deposit. It is bauxite, which has been found lately in many places and, nowadays, is being investigated.

In brief, the Quaternary sediments of Viet Nam consist of different types, distributed in different regions with different characteristic stratigraphic columns. Some sediments are of economic importance.

The summary above is only a brief outline of the Quaternary sediments of Viet Nam. The study of them is being continued and in the future an annual report will be submitted to the meetings of the IGCP Project 296.

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COASTAL EVOLUTION: CHANGES OF ENVIRONMENT IN COASTAL REGIONS OF VIET NAM AND PROBLEMS OF MANAGEMENT AND EXPLORATION

(The first preliminary recapitulation of 20 years of study)

by

Nguyen Duc Tam[1],

Before 1963 Quaternary geology was not given enough attention. During this time there were only short articles of some authors or summaries on general geological maps. From 1966 to 1967 for the first time this author had an opportunity to take part in the geological investigation of the northern margin of the Red River plain for hydrogeological purposes and to study the marine sediments and transgression – regression movements during Quaternary time (Vinh Phuc layer, Vinh Phuc transgression, Dong Da layer, Dong Da transgression etc.). Beginning in 1970 with the mapping of the Ha Noi sheet (F-48-XXIV) and the Ninh Binh sheet (F-48-XXXIV) at a scale of 1:200,000 it was the start of the study of Quaternary geology in Viet Nam. The author of this paper had an opportunity to take part in this work from the first days. The results of mapping showed the sequence of marine suites and transgressions in the coastal plain region.

1. Neogene-Quaternary sediments of coastal plains

Along the sea coast of Viet Nam, there's a row of coastal plains, which formed at the mouths of the rivers and occupy 1/3 of the whole acrerage of the country. Some of them are rather large, such as Bac Bo plain (at the mouth of Hong River) and Nam Bo (at the mouth of the Mekong River).

Most coastal plains of Viet Nam have been deposited in the Cenozoic tectonic depressions and their downfaulted periferal blocks which are wholly filled by Neogene and Quaternary sediments.

Neogene sediments

The Neogene formations are distributed largely at the bottom of the plains and are mainly covered by Quaternary deposits. They are of two types of accumulation.

1. The first type is the sedimentary formation due to a filling up of tectonic depressions of great size (Ha Noi rift and Cuu Long depression). These sediments consist of intercalated continental and marine deposits, with a thickness of some thousands of metres. These basins are the object of oil exploration activity.

2. The second type is the sedimentary formation filling up small depressions and valleys (Na Duong type) and consisting of continental deposits from 100 to 300 m thick.

Quaternary sediments

Quaternary sediments of the coastal plains of Viet Nam are composed of four great horizons.

Horizon 1

The first, the lowest horizon, was the first discovered by the author in Sam Son region (Thanh Hoa plain, Thanh Hoa province) and was called the "Sam Son horizon" in 1975. It has a narrow distribution at the bottom of the plains and overlies an eroded surface cut into the bedrock and is fully covered. It is mainly constituted by polymictic pebble, gravel, sand of a continental sediment facies. Its age may be of Late Pliocene - Early Pleistocene (N_2-Q_1).

Horizon 2

The second horizon was first discovered by the author in Yen Mo (southern margin of Bac Bo plain in 1974 when compiling the report of the geology of Ninh Binh sheet (Ha Nam Ninh province) and called the "Yen Mo horizon" (and Yen Mo transgression"). It is composed of 3 to 4 clay layers with a thickness of from 5-10 to 35-40 m each and largely distributed at the bottom of plains. Its composition includes clay, clayish aleuvrite, weakly weathered into white-red colour with a marine lithofacies. In the central part of Viet Nam in some places there are exposures of peculiar deposits called "red sand". Red coastal sand occupies a small area distributed from near sealevel to an altitude of 100 m or higher. It is dated as lower Middle Pleistocene (Q^1_{II}).

[1] Institute of Geology and Mineral Resources, Hanoi.

Horizon 3

The third horizon is the most prevalent coarse-grained horizon, frequently met in the whole plain. It is composed of polymictic pebbles, gravels, sands and chiefly has a fluvial lithofacies. In coastal region one can observe an intercalation of marine fossil-bearing clay and sand. In Nam Bo plain (south Viet Nam) this horizon has more complicated composition with the intercalation of sand and clay layers. It is generally covered and only outcrops in some places at the marginal parts of the plains and indentified as fluvial terrace blocks. Its thickness is about 10 to 100 m. The upper part of this horizon is dated as Middle Pleistocene and the lower part as Upper Pleistocene (Q^2_{II}-Q^3_{III}).

Horizon 4

The fourth, the uppermost horizon of the stratigraphic column of the plain sediment, is from 10 to 70-80 m thick. It is composed of many intercalated suites of fluvial and marine sediments. Its composition in the north and central Viet Nam plains is more simple than in Nam Bo (south Viet Nam).

In those sediments we have discovered 3 to 4 suites of fluvial deposits and 5 to 6 marine suites.

Fluvial deposits, formed during the stages of regression, are commonly narrow, thin-banded with gravel sand and clay. In the central and coastal parts of many plains, a great mass of fluvio-marine mixed deposits is exposed with a composition of grey-brown-grey, dark-brown sandly clay.

Marine deposits often are composed of clay, sand, and peat bearing fossils. Along the actual sea coast there's a peculiar type of deposit. It is a marine-wind deposits making a system of sand dunes and big dune ranges. This horizon is dated as upper Upper Pleistocene-Holocene.

2. Marine deposits, transgression, regression

A number of marine deposits had been discovered by the author in 1966 to 1967, but at that time they were not named. In recent years (1970 to 1975) they have been systematically studied further and have been given stratigraphic names such as Vinh Phuc, Dong Da, Bim Son layers etc. and officially symbolized in national geological maps on 1:200,000, etc. scale such as the F-48-XXIV Ha Noi, F-48-XXXIV Ninh Binh sheets etc.

Suite 1

The Middle Pleistocene suits: it is the second great horizon, which is the product of a great transgression during the late part of the Middle Pleistocene called the Yen Mo transgression nowadays. Some deposits of it remain at the altitude of 60 to 100 m.

Suite 2

The marine sediments of Late Pleistocene age occur at the lowermost part of the fourth great clay-sandy horizon and are mainly covered. They are composed of dark-grey sand-clay beds containing plant remains with littoral swampy lithofacies and silt-clay layers weakly weathered in a checkered red white colour of a shallow sea lithofacies. In different depths of some boreholes there are found a complex of fossils as followes: *Ammonia annectens* (Parker et Souce), *A. beccarii* (Lin), *Elphidium hispidulum* (Cushm), *Hauzawaica nipponica* Asano, *Rotalia rolshanseni* (Cushm et Berr.), *Nonion* sp., *Quinquenloculina* sp., etc. Fragments of marine terraces exist at altitudes of from 25 to 40 m.

In 1974, when compiling the report of geology of Ninh Binh sheet, we had called them the "Bim Son layers" and ("Bim Son transgression"). They are the product of 3 or 4 transgressions (Table I.).

Table I. Radiocarbon data of Bim Son layers

Sample Number	Depth (m)	Locality	Age (years before present)
LK 19 – 204	59	Tien Hai (Thai Binh province)	47,000
LK 15 – 204/1	62.5	Kim Son (Ha Nam Ninh province)	37,000
LK 15 – 204/2	100.6		43,390

Suite 3

The latest transgression sediment suite is of Late Pleistocene age. It is similar to the marine sediment suite, having rather large outcrop areas, along the marginal parts of the plains. Fragments of the terrace occur at altitudes of from 15 to 17 m. They are composed of two main beds: the lower is a sandy clay bed, yielding plant remains and has a black to grey colour. It is always covered and occurs in wells at a depth of from 7 to 8 m. In this bed can be found large molluscs such as *Ostrea edulis* Linne etc. The upper is a clayish bed, weakly weathered having a red-white colour and a stable thickness of 5 to 8 m, first discovered by us (1966) in Mao Khe region (Quang Ninh province) and afterwards a rather detailed study was carried out or a large outcrop at Vinh Phuc (Northwest of Ha Noi).

In this bed fossils are: *Ammonia annectens* (Parker et Sones), *Cibicites wuellestorfi*, *Quiqueloculina seminulum, Rotalia rolshanseni* (Cushman et Ber.), *Elphidium ex* gr. *advenum, Noni boucramun, Reussella granulosa* Kuss., *Bolivian* sp., *Nodosaria lepidula, Trachyleberis dicreta* etc. According to E. Saurin a C^{14} sample collected from the 15 m terrace of this transgression (at Ca Na - Thuan Hai province) gave an absolute age of 18,000 ± 150 years before present).

In 1973, when compiling the report of the geology of Ha Noi sheet we had called it the "Vinh Phuc Layer" (and "Vinh Phuc transgression").

Suite 4

The Middle Holocene marine deposit suite occupies the great eastern parts of the surface of plains from 0 to 5 m in absolute altitude. Nowadays the fragments of the terrace of this transgression remain at altitudes of from 3 to 5 m. This suite chiefly constitutes two main units close to each other: the lower is a dark grey sandy clay bed bearing plant remains (or peat at some localities). In the greater parts of the plain, this bed lays at a shallow depth (1 to 2 m) under a thin clay cover and has only small outcrop areas of its peat layers. The lower beds contain a number of fossils, such as *Ostrea edulis* Linne, *Meritrix meretrix* Linne, *Placuna placenta* Linne, *Turritella* sp. etc. and a microfauna. Above this bed there is a fine clay or silty clay bed in typical greyish green colour. Its thickness is only about 1 to 2 m, but quite stable. This bed spreads out all over the "low plain" surface from 0 to an altitude of 5 m.

In 1973, when giving a total account of the Ha Noi sheet the above-discussed beds and the related transgrssion were called by us the "Dong Da layer" and "Dong Da transgression."

In the small plains of Central Viet Nam, in some places during this transgression stage clays did not accumulate and a special type of deposit was formed. It is a littoral sand. It resulted in building up a sandy undulating plain. In the littoral plain sand was drifted continuously to build up sand dunes or big and high sand ranges.

Sediments of the Dong Da transgression (layers) surround the Da But archaeological (Neolithic) site having an absolute age of 6,095 ± 60 years B.P. On the top of these sediments archaeological sites with absolute ages of 4,000 to 4,700 years B.P. up to present can be found. So these sediments and this transgression have an absolute age of from 7,000 to 4,000 years B.P.

In 1970 based on the discovery of the Dong Da transgression the Holocene was divided by the author into 3 subdivisions: lower (12,000 to 7,000 year B.P.), middle (7,000 to 4,400 year B.P.), upper (4,000 year B.P. up to now).

Table II. Some absolute data of Dong Da deposits

Locality	Depth (m)	Age (years before present)	
Pho Noi (Hai Hung province)	2	5,730	60
Pho Noi (Hai Hung province)	3.5	6,800	40
Cong Chanh (Hai Hung province)	3.5	6,360	75
Gia Loc (Hai Hung province)	2	4,145	50
	5	6,000	
	9	7,190	90
Tu Son (Ha Bac province)	2.5	6,790	60

Suite 5

The upper Holocene marine sediment suite is only found in coastal regions, where it forms the 2 m terrace. In the great part of the area a sandy bed with a thickness of from 1 to 3 m forms many small patches of the undulating plain, containing numerous fossils of the littoral zone and elsewhere is represented by the grey or brown greyish clays produced by an "ingression movement" which is called the "Quang Xuong ingression." Fragments of this marine terrace remain at the altitude of from 1.5 to 2.0 m. In Trung Bo (Central Viet Nam) the littoral region is characterised by sand dunes originating from beach sands and gathered by winds to set up high dunes, similar to the bands of Middle Holocene sand dunes.

The Ca Mau Cape, the eastern part of the Mekong River delta, the small delta located in the Southeastern corner of Bac Bo plain from the estuary of the Red River to that of the Day River is composed of grey-brown, grey clays formed during this stage.

3. Some traits in the history of formation of the plains

From the Early Pleistocene to the end of the Middle Pleistocene the coastal plains of Viet Nam had existed in a continental regime. At an early stage of the Middle Pleistocene a great transgression took place and invaded deeply inside the continent covering all the plains. But the Late Pleistocene - Holocene marine transgression still played the main role in forming the coastal plains. All of the transgressions (except the Middle Holocene) reached the foot of the marginal mountains. The sediments of the recent coastal plains of Viet Nam are due to marine accumulation and are cut by a system of marine stepped terraces. The transgression and regression were caused chiefly by the fluctuation of the sealevel. Neotectonic movements led to the deformation of the marine terraces.

4. Model of sediment formation during a transgression – regression cycle

The marine suites generally have their own specific structure. Formed in a transgression-regression cycle, each suite has a succession of sediments, consisting of three sequences deposited in three stages:

Stage 1

The lower sequence consists of two parts: the lower part exists only in some places and is composed of clay and sand containing the remains of a continental forest, sometimes with big roots. The upper part is composed of clay or sandy clay with dark-grey colour, abundant remains of swanpy vegetation and littoral molluscs of big size (such as *Ostrea edulis* Lin. etc.) which prove its littoral-swampy and littoral lithofacies, formed at the first stage (lacustrinization) of a transgression movement.

Stage 2

The middle sequence is a fine clay layer in grey, green greyish colour (which turns to checkered red-white colour due to the weathering process) containing a sparse shallow sea macro- and micro faunas, non-stratified, with massive and compressed structure and has a shallow sea, gulf-lagoon lithofacies. This facies was formed in the new sea.

The change from the black swampy deposits to the shallow sea clay is the first lithofacies change in a transgression - regression cycle, which takes place during the transgression stage of it.

In parallel with the first lithofacies change there also is a change in the biofacies from the littoral zone fossils (fauna of big size and remains of salty vegetation) to the shallow sea (poor oppressed fauna and micro-fauna).

Stage 3

The shallow sea clay sometimes contains a sand layer (sometimes with an undulating surface) rich in a macrofauna (of big size) of the littoral zone formed during the last stage of the transgression-regression cycle; i.e. the regression movement after the transgression.

The change from the fine shallow sea clay to a (coarse-grained) littoral sand is the lithofacies change which takes place during the last stage of the regression. In parallel with the latter there is a second biofacies change, from a poor oppressed shallow sea fauna and microfauna to a rich littoral one (of big size).

5. Actual coastal geodynamic processes

At present, on the whole, the actual coastline can be observed everywhere as a transgression movement.

1. Sea activities are destroying the sandy beaches. The beach deposits in some places contain placer deposits, and, locally, the clayish shoreline of deltas.

2. In most places estuary systems are still being gradually formed and enlarged in proportion to the formation and extension of salt-marshy region (swamp) with mangrove vegetation. Among them the two largest are (i) northeast-ern seashore region from north of the Red river estuary to Mong Cai and (ii) the estuary region of Dong Nai river, east of Hochiminh city.

3. More than one habitation site has been slowly submerged under the sea or destroyed by sea.

Such a prevailing phenomenon of the sea attack may possibly and chiefly be caused by the *actual elevation of sealevel.*

6. Special law of formation, structure, distribution of peat, sand, clay, coastal placer deposits

Results of the study of Quaternary deposits and coastal evolution led to the discovery of the special law of distribution, of peat, clay, sand, and coastal placer deposits.

Peat

In the coastal plain areas many peat localities (peat mines) have been found and are being exploited. They are the outcrop areas of the lower layer (littoral swamp) of the middle transgressive formation, so they have a special distribution – around the Middle Holocene transgressive clayish bed (Dong Da layer), along the former Middle Holocene transgressive shoreline Peat as a rule has a special stratigraphic structure consisting of three parts:

- Lower part contains the remains of continen-tal forest, sometime with big roots, formed during the first stage of the transgression movement – the lacustrinization of the plain.

- Middle part is the swampy, littoral swampy deposits, with the remains of swampy, littoral swampy vegetation, formed during the climax of the transgression when the shoreline reached this climax position and could not move further. The area existed in a swampy condition.

- Upper part is the deposit of the actual fresh water swamp, because after the regression the littoral condition turned into the fresh water swamp, which has existed up to now.

In the direction towards the centre of the plains the middle and lower parts of the peat formation are overlain by marine deposits (clay and sand). In the central parts of the plains in some places there are peat localities but they are not common and are poor in plant remains. Maybe these parts of the plains formed during the first stage of the transgression (lacustrinization) when the peat (swamp) formation mostly had been destroyed by the sea.

Sand

Along the actual sea coast and somewhere inside the plains there are many localities of sands of good quality, formed in special geographic and palaeogeographic conditions. Sands could be used for making glass and for other purposes.

Clay

In the coastal plains marine clays are widely distributed and have been being used for brick, tile and ceramic production.

Coastal placer deposits

Along the actual coastline and inside the plains there are many placer deposit localities.

In the plains placer deposits are the Pleistocene beaches, overlain by recent marine deposits. Along the actual seacoast the placer deposits follow the special "bow-shaped law": the seacoast consists of many bow-shaped parts of different sizes, both large and small. The bow placer deposit are formed and distributed at the northern and southern parts of the plain but mainly in the southern part. This special law is related to the direction of the sea current. Sediment is transported from the North to the South.

Results of the study of Quaternary deposits and coastal evolution led to the discovery of a peculiar law for a special method of archaeological research – the "method of strandline."

The discovery of the history of the plains enables us to derive the following archaeological law as a method of research.

1- On the high alluvial and marine terraces in marginal areas of plains may be relics of many historical stages.

2- On the surfaces of the small fragments of Pleistocene marine plains surrounding the low plains (Northwestern parts of Bac Bo and Nam Bo plains, western parts of Trung Bo plains) we find only the relics of historical stages from 25,000 to 20,000 years up to now.

3- On the surfaces of the large Middle Holocene marine and deltaic plains occupying 8/10 to 9/10 of the plains with the absolute height from 5 m downwards we find only relics of historical stages from 4,500 to 5,000 years up to now.

4- In general the archaeological associations dated later and later in the direction from mountain foot to the sea.

5- On monadnocks of the plains and islands (often connected with continent) there may be relics of different historical stages.

6- The group of Neolithic and Early-Bronze archaeological vestiges in the limestone caves in Ha Long and Bai Tu Long Bays previously formed on shore, now drop into the sea area, which has newly flooded. It is not true that the ancient people inhabited the marine area as we thought.

7- The 'method of strandline' may be employed to determine the ages of different archaeological relics.

Exp. 1: Da But site (Thanh Hoa province) is correlated with the shoreline of the climax of middle Holocene transgression and would have the absolute age of 6,000 years.

Exp. 2: The group of Kjokhmoding Quynhvan (Nghe Tinh province) is correlated with the shoreline during the regression after middle Holocene transgression and would have the age of about 4,500 to 5,000 years.

References

Le Duc An, 1980. Is there a jump in Holocene transgression?. *Geological map.*, N. 47, pp. 69. Hanoi.

Le Duc An, 1982. Main outline of the evolutional history of the coastal zone topography of Thuanhai and Minhhai Provinces. *Sci. Tech. Infor. of Geol.*, N. 11, pp. 18-23. Hanoi.

Hguyen Duc Chinh, 1963. Relief types of the Bacbo plain and relation on topography between the plain and the midland. *Biol. Geogr. Geol. Rev.*, T. II, N. 1, pp. 2-8. Hanoi.

Nguyen Dich Di, Hoang Kim Cuong, 1982. Mollusc fossils– C^{14} geochronology and their significance. *Archaeology*, pp. 65-67. Hanoi.

Fontaine H., 1964. Anciens niveaux marins dans la region de Ninhhoa (Province de Nhatrang). *Arch. Geol. Viet Nam,* N. 6, pp. 13-18. Saigon.

Fontaine H., 1972. Remarque sur des formations littorales quaternaries du centre Viet Nam meridional. *Arch. Geol. Viet Nam,* N. 15, pp. 145-148. Saigon.

Fontaine H., 1973. Anciens niveaux marins du Quaternaire au Viet Nam. *Fourn. Hong Kond Arch. Soc.,* Vol. IV, pp. 29-33. Hong Kong.

Fridland V.M., 1961. The first soil chema of the Democratic Republic of Viet Nam. *Biol. Geogr. Geol. Rav.*, T. III, pp. 16-19. Hanoi.

Nguyen Kim Hoan, Nguyen Duc Tam, Hguyen Tan, Nguyen Minh Loan, 1981. Titaniferous placers on the littoral of Viet Nam. Addi. *Proc. 4th Reg. Conf. Geol. SE Asia,* GDG Viet Nam; *Proc. 4th Reg. Geol. Min. Res. SE Asia,* pp. 649-653. Manila.

Nguyen Duc Tam, 1968. Discussion on the Bacbo plain. *Geol. Rev.*, N. 79-80, 5-8/1968, pp. 6-15.

Nguyen Duc Tam, 1969. Some stages of history related to the activities of Quaternary time and characteristic of archaeological laws of Viet Nam and Southeast Asia. *Hist. Researches,* N. 122. 5/1969.

Nguyen Duc Tam, 1969. General discussion on North Viet Nam's plain. *Geol. Rev.* N. 85-86, 5-8/1969, pp. 6-22.

Nguyen Duc Tam, 1973. Plain soil and cultivation. In *Hung Dynasty in building up the Nation.* Tome IV. Social Science Publishing House. 4/1973, pp. 160-172.

Nguyen Duc Tam, 1974. "Plain archaeology and the problem of Hungvuong time." In *Hung Dynasty in building up the Nation.* Tome IV, Social Sci. Pub. House., 4/1974, pp. 142-150.

Nguyen Duc Tam, 1974. "Condition of economic geography and the problem of Hungvuong time." In *Hung Dynasty in building up the Nation.* Tome IV, Social Sci. Pub. House., 4/1974.

Nguyen Duc Tam, 1976. On the geomorphology of North Viet Nam plains. *Geol. Rev.*, N. 125, 5-6/1976, pp. 14-16.

Nguyen Duc Tam, 1976. Quaternary sediments of plains and the construction. In *The problem of engineering geology.* "Sci. Tech. of Construction Pub. House. 1976, pp. 126-141.

Nguyen Duc Tam, 1980. Cenozoic deposits in Bacbo and Trungbo plains. *Geol. Rev.*, N. 147, 1-2/1980.

Hoang Ngoc Ky, 1978. Results of C^{14} radiometric dating of Quaternary sediments in the Bacbo plain. *Geol. Map.* N. 37, pp. 53-54. Hanoi.

Nguyen Ngoc, 1976. Characteristics of Foraminifera remains from marine deposits of the two meter level at Cana, Thuanhai province. *New Discov. Archaeol 1976,* pp. 68-72. Hanoi.

Nguyen Ngoc, 1981. Foraminiferal assemblages of the Quaternary deposits of the Mekong basin and their stratigraphical significance. *Proc. 4th Reg. Conf. Geol. Min. Res. SE Asia,* pp. 355-361. Manila.

IGCP 296

WELCOMING ADDRESS TO DELEGATIONS ATTENDING IGCP 296 BY GEOLOGICAL SURVEY OF MALAYSIA (IPOH)

by

Foo Khong Yee[1]

Distinguished experts, colleagues and guests, it is a great pleasure for me to welcome you to the first meeting of IGCP Project 296, Quaternary Stratigraphy of the Asia/Pacific Region. The Geological Survey of Malaysia is pleased to host this meeting which has been jointly organized with ESCAP, UNESCO, CCOP and the Association of Geoscientists for International Development. The organising committee has informed me that the purpose of this new five year project is to establish a network of geoscientists interested in Quaternary stratigraphic correlation in this region. Also, this network will promote the use of Quaternary geology for human survival, a major new UNESCO programme. The network will be linked by an Asia/Pacific Newsletter which will carry news items related to the theme "Quaternary Geology for Human Survival," as well as new developments in Quaternary Stratigraphy.

The second objective of the project is to establish a chronologic basis for a firm time-stratigraphic classification of the Quaternary in Asia/Pacific countries and to publish stratotypes from onshore and offshore areas showing appropriate lithologic, biostratigraphic and chronologic data. Quaternary stratigraphy has been the focus of numerous studies in the region, especially during the last 10 years. Yet, most of this work has tended to be country specific and no regional correlation has yet been attempted. Therefore, the proposed objectives of this project focus on a long felt need in the region.

It is appropriate that ESCAP and CCOP are involved in this project as these two organizations have a mandate to undertake regional geological investigations in Asia and the Pacific and to assist their member countries in this regard. The Geological Survey of Malaysia has long cooperated with them on various activities and has benefited from the meetings and training provided by the United Nations system.

At this meeting the countries of Australia, the Peoples Republic of China, Indonesia, Malaysia, New Zealand, the Republic of Korea, Philippines, Thailand and Viet Nam will present papers. This exchange of scientific data should provide a substantial thrust for continued Quaternary activity in this region towards developing a useful framework within which regional correlation can proceed. It is clear that continuing efforts of both Geological Surveys and university researchers will be required to achieve the objectives of the project. The Quaternary stratigraphy of the region is complex, both onshore and offshore and the search for useful key horizons such as volcanic ash beds, loess sequences, zones of paleomagnetic reversals, and paleontologic data will be essential. The laboratory work associated with this work may require substantial resources and expertise not widely available in the region. Therefore, it would be useful if some form of exchange of laboratory services be agreed upon so that geological research laboratories in developed countries could help support the efforts required to obtain the Quaternary analytical data, especially with regard to obtaining absolute dates which are beyond the means of some countries in the region. I believe there are many opportunities for geologists interested in Asia and the Pacific to cooperate in achieving the objectives of IGCP 296.

Finally, let me again thank the organising committee for their efforts to bring together this group of Quaternary stratigraphic experts which we hope will bring into sharp focus the current stratigraphic research in the region, especially with regard to identifying stratotypes of the Quaternary from each of the countries of the region. This is a very important first step.

The Geological Survey of Malaysia is pleased to have played a role in the organization of this meeting, the first of its kind in the region. We intend to actively participate in all of the activities of IGCP project 296 which we believe will fill a gap in Quaternary correlation knowledge.

I hope all of you enjoy your stay in Ipoh and, for those of you that have stayed on for this meeting after the IGCP Project 274 meeting, I wish you continued success in your deliberations.

Thank you.

[1] Director General, Geological Survey of Malaysia (Ipoh Laboratories) Ipoh, Malaysia.

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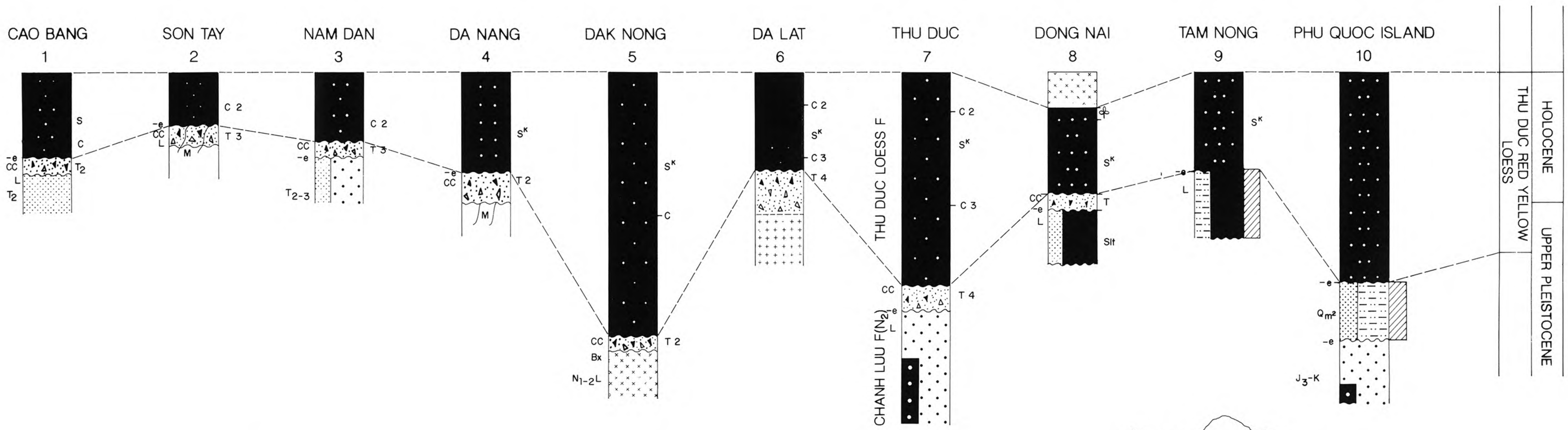
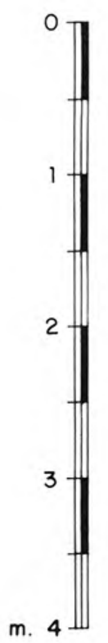
VIET NAM

ESCAP ATLAS OF STRATIGRAPHY

QUATERNARY





VERTICAL SCLAE

LEGEND

CAO BANG (1)
1. ELEVATION OF HIGH PLATEAU 500-700 m
2. K-Ar ABSOLUTE AGE OF TEKTITE 790.000±150.000 YEARS Bp

SON TAY (2)
1. ELEVATION OF LOW HILL 20-30 m
2. C^{14}ABSOLUTE AGE OF CHARCOAL 1435+35 YEARS Bp
3. K-An ABSOLUTE OF TEKTITE 760.000±150.000 YEARS Bp

NAM DAN (3)
1. ELEVATION OF LOW HILL 30-40 m
2. C^{14}ABSOLUTE AGE OF CHARCOAL 1215±110 YEARS Bp
3. K-Ar ABSOLUTE AGE OF TEKTITE 860.000±150.000 YEARS Bp

DA NANG (4)
1. ELEVATION OF MARINE EROSIONAL TERRACE 20-30 m
2. K-Ar ABSOLUTE AGE OF TEKTITE 680.000±150.000 YEARS Bp

DAK NONG (5)
1. ELEVATION OF PLATEAU 300-1000 m
2. K-Ar ABSOLUTE AGE OF TEKTITE 700.000 YEARS Bp

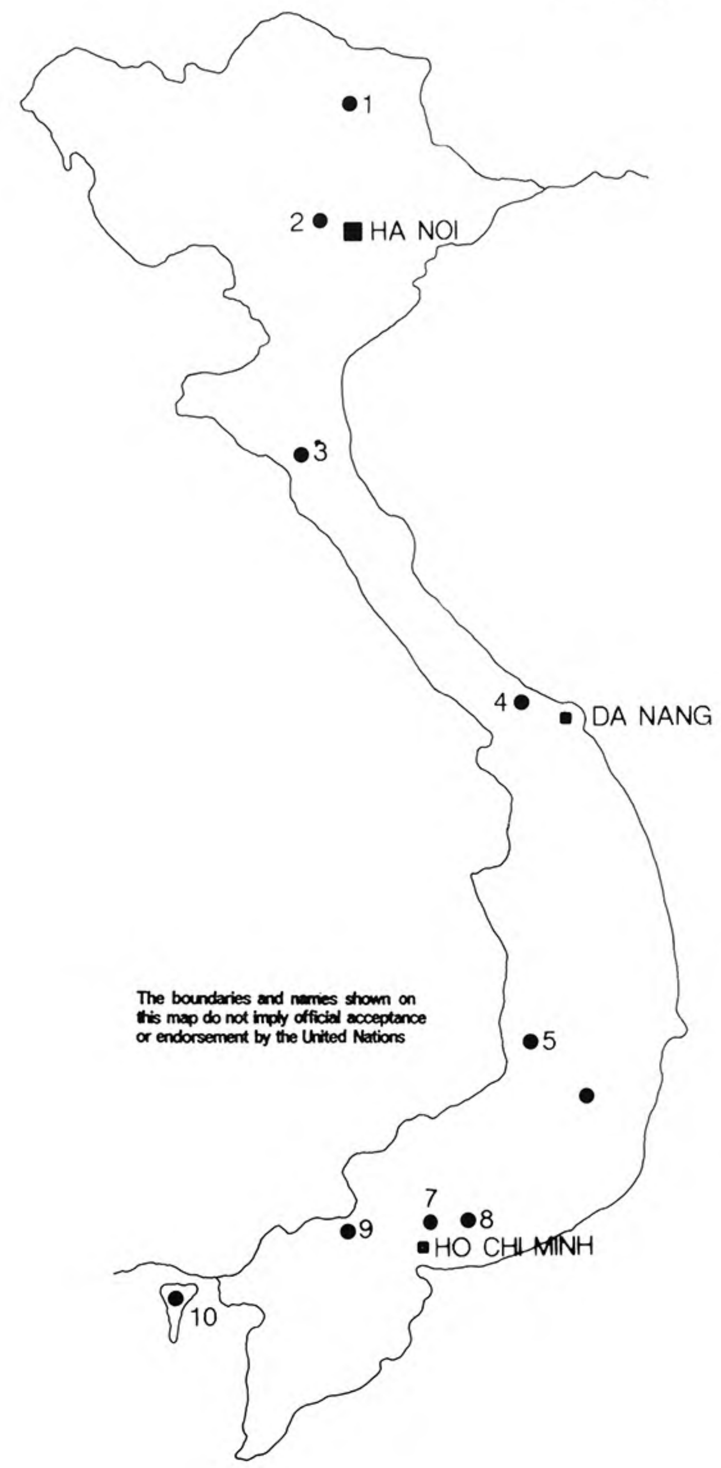
DA LAT (6)
1. ELEVATION OF PLATEAU 1000-1200 m
2. C^{14}ABSOLUTE AGE OF CHARCOAL 3855±45 YEARS
3. C^{14}ABSOLUTE AGE OF CHARCOAL 10210±100 YEARS Bp
4. K-An ABSOLUTE AGE OF TEKTITE 700.000±120.000 YEARS Bp

THU DUC (7)
1. ELEVATION OF LOW HILL 10-40 m
2. C^{14}ABSOLUTE AGE OF CHARCOAL 1080±40 YEARS Bp
3. C^{14}ABSOLUTE AGE OF CHARCOAL 8570±40 YEARS Bp
8770±600 YEARS Bp
4. K-Ar ABSOLUTE AGE OF TEKTITE 670.000 YEARS Bp

DONG NAI (8)
1. ELEVATION OF HIGH HILL 50-70 m
2. C^{14}ABSOLUTE AGE OF WOODY FRAGMENTS 4500 Bp

TAM NONG (9)
1. ELEVATION OF PLAIN 5-10 m

PHU QUOC ISLAND (10)
1. ELEVATION OF EROSIONAL TERRACE 10-40 m



COMPILED BY Dr. HOANG NGOC KY: GENERAL DEPARTMENT OF MINE GEOLOGY OF VIET NAM

VIET NAM

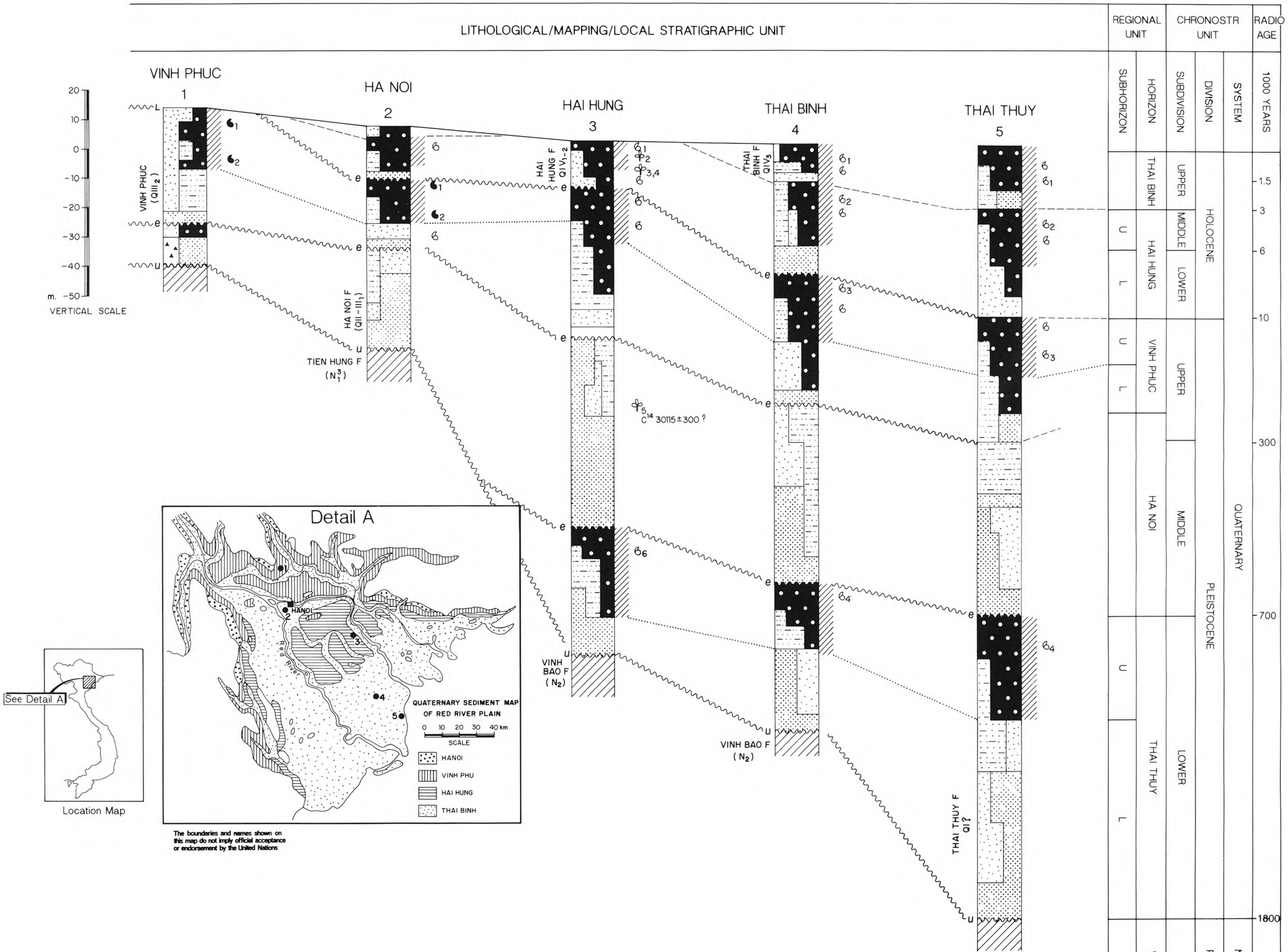
ESCAP ATLAS OF STRATIGRAPHY

QUATERNARY

VINH PHUC
1. FORAMINIFERA
   AMONONIA BECCARRII (LINEAEUS)
   ELPHIDIUM ADVENUM (CUSHMAN)
   SIBICIDES
2. FORAMINIFERA
   AMMONIA BECCARRI (LIN)
   ELPHIDIUM HISPIDULUM (CUSHM)
   QUINQUELOCULINA Sp
   HANZAWAI NIPPONICA ASANO
   NONION Sp

HANOI
1. FORAMINIFERA
   AMMONIA ANNECTENS (PARKER et JONES)
   ELPHIDIUM cf ADVENUM (CUSHM)
   QUINQUELOCULINA SENINULUM (LIN)
2. FORAMINIFERA
   AMMONIA ANNECTENS (PARKER et JONES)
   QUINQUELOCULINA SEMINULUM (LIN)
   VIGULINA PAUCILOCULALA BRADY
   NONION Sp
   CIBICIDES Sp
   BIGENERINA Sp

HAI HUNG
1. FORAMINIFERA
   AMMONIA BECCARRII (LIN)
   QUINQUELOCULINA SEMINULUM (LIN)
   CELANTUS CRATICULATUM
   ELPHIDIUM ADVENUM (CUSH)
2. ABSOLUTE AGE 4145±5 YEARS Bp



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Location Map

Compiled by : Dr. Hoang Ngoc Ky : General Department of Mine-Geology
Dr. Dang Duc Nga : Geo - Geography Department of Ha Noi University
Dr. Nguyen Dich Di
Dr. Nguyen Ngoc Men } Institute for Scientific Research