Continental shelf records of climate change

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Important advantages

(1) Age of Holocene/postglacial marine deposits is relatively certain cf. terrestrial deposits on land. They are ‘easy’ to identify because they have never been sub-aerially exposed e.g. the calcareous shells are well preserved.

(2) Episodes of sub-aerial exposure of continental shelves during glacial periods are good age markers datable by many methods as well as by countback.

(3) Global climate change is reflected by sea-level changes on stable continental shelves.

Methods of age determinaton

(1) Sequence stratigraphy of marine and terrestrial deposits including by countback

(2) Direct methods of dating –
Radiocarbon (usually reliable if younger than 8.2 ka)
Uranium-series (up to 500 ka)
Luminescence (up to 1000 ka, usually < 250 ka)
Amino acid racemization (up to 2000 ka)

(3) Indirect methods –
isotopic distribution of calcareous organisms
magnetic susceptibility
density and moisture content
correlation with other records e.g. ice cores, loess and deep sea cores

2 types of climate change records

(1) Low resolution ‘long’ record of ~0.5 million years in duration

Example – seafloor sediments off Hong Kong a coastal megacity with 7 million (possess a tectonically ‘stable’ muddy inner shelf)

(2) High resolution ‘short’ record of weekly to daily sensitivity

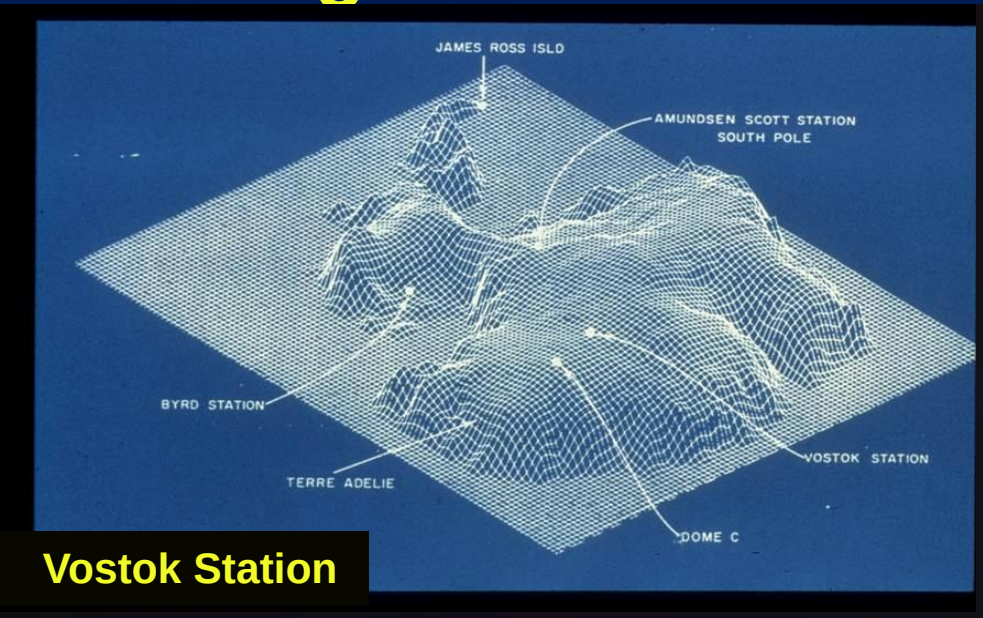
Example – study on a *Porites* sp. coral from Hong Kong for sea-surface temperature

Model of offshore Quaternary sediments in the inner shelf of Hong Kong

Unit	Age	Estimated age (ka)	Marine isotope age	Absolute age confirmed	Maximum thickness (m)
M1	Postglacial	< 8.2	1	√ ^{14}C	21.5
T1	Last glacial	8.2 – 70	2-4	√ OSL	6.5
M2	Last interglacial	90 – 140	5	√ U series	15.7
T2	2nd last glacial	150 – 180	6	-	9.5
M3	2nd last interglacial	190 – 240	7	-	12
T3	3rd last glacial	250 – 300	8	√ T-L	7.3
M4	3rd last interglacial	310 – 340	9	√ U series	14.1
T4	4th last glacial	350 – 370	10	-	6
M5	4th last interglacial	380 – 420	11	√ U series	3.5
T5	5th last glacial	> 440	12	-	7

M – marine; T – terrestrial

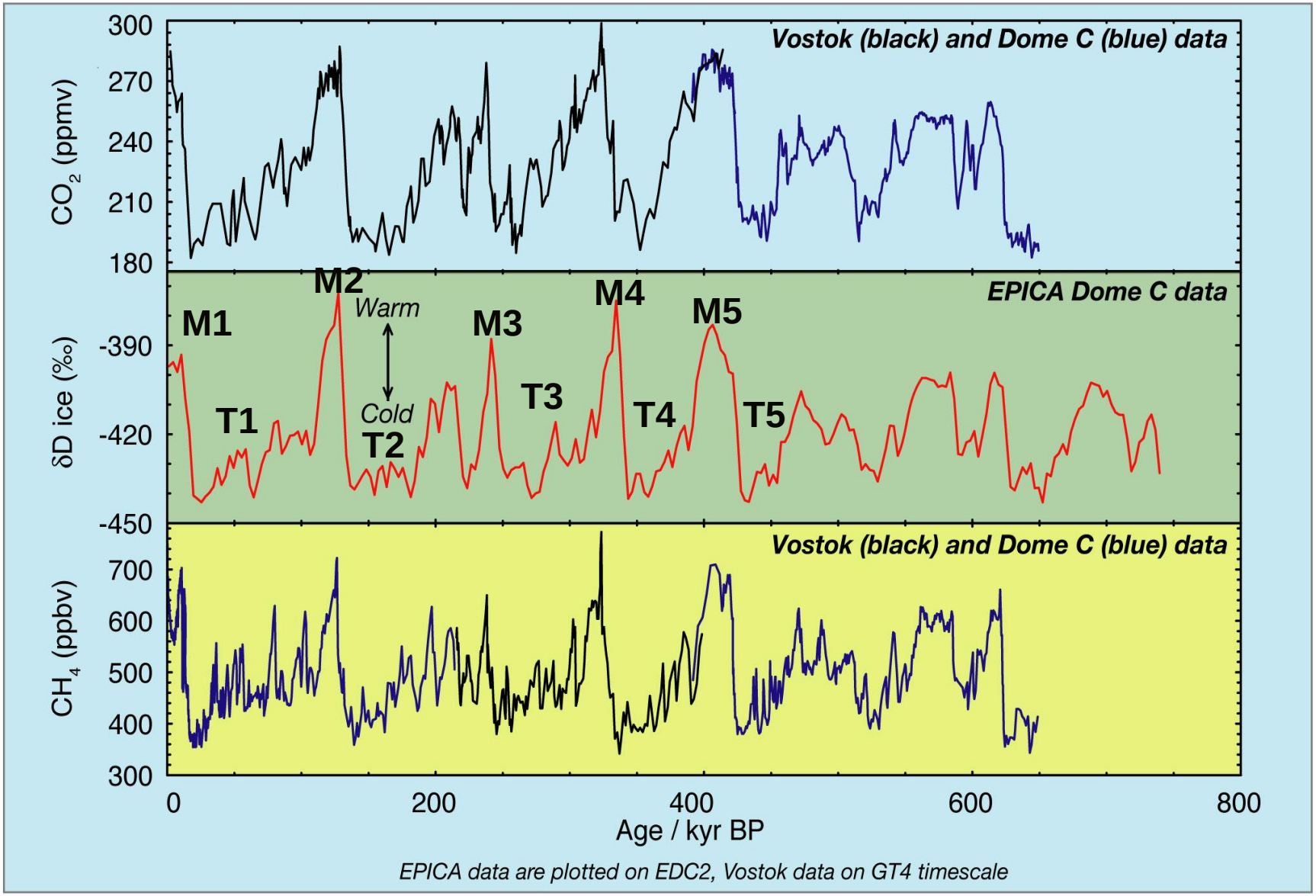
Agreement with ice cores in Antarctica – highest resolution terrestrial record



Vostok Station

Annual layers

Antarctic ice core records: Vostok and EPICA CO_2, CH_4 and δD



GLOBAL CHANGE IGBP

Petit et al., 1999 (Vostok), Siegenthaler et al., 2005 (Dome C - CO_2), Spahni et al., 2005 (Dome C - CH_4), EPICA community members, 2004 (δD)

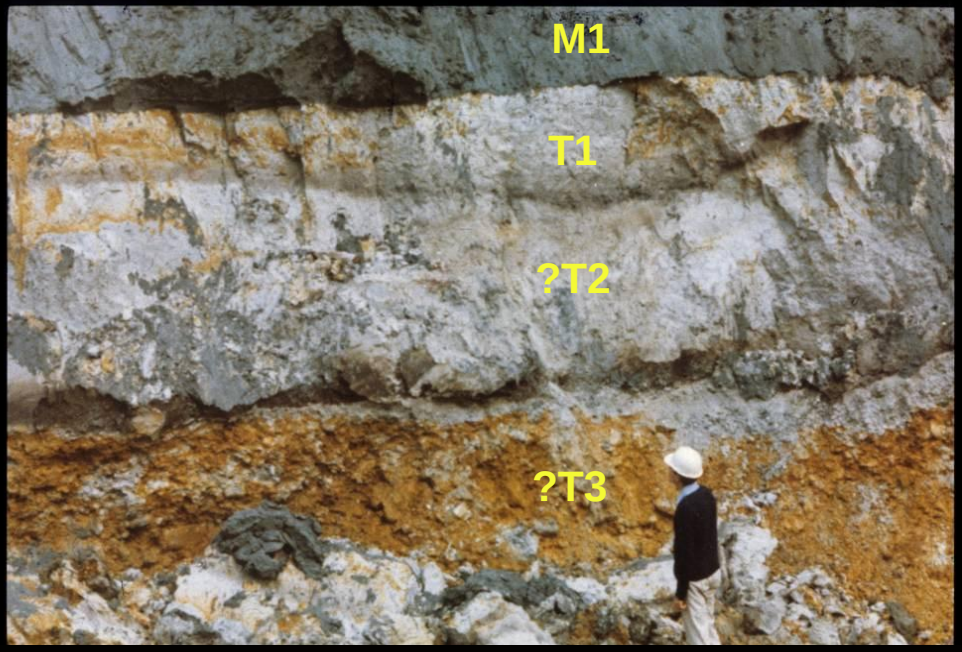
PAGES PAST GLOBAL CHANGES

High Island Reservoir excavation 1970s

Before construction

After construction

During construction



West Dam excavation

Drilling platforms used in Hong Kong

Drilling on a bamboo platform

Drill barge with legs

Jackup platform

Drill barge

Vibrocoring

6-m drill pipe

Moon pool

Vibrocoring

A 6-m core section

A 59-m core

A palaeo-desiccated crust formed by sub-aerial exposure from the new Hong Kong International Airport

South China Morning Post April 27, 1998

Monday April 27 1998

G'S NEW GATEWAY

Big achievement

Airport Authority

The reclamation work for the new airport site at Chek Lap Kok was one of the biggest marine construction projects ever undertaken in the world.

Reclamation project involved 75pc of world's dredging fleet

KEITH WALLIS

Reclamation of the 1,250-hectare site at Chek Lap Kok was one of the largest marine construction projects ever carried out, involving about three-quarters of the world's dredging fleet.

Work on the massive scheme was split into two sections. Stage one involved the award of a $614 million advance works contract to a joint venture between Kumagai Gumi, HAM of Holland and Maeda for the creation of a 29-hectare platform on the original Chek Lap Kok island.

This provided a works area, including site offices for both Airport Authority and contractors staff, from which stage two, the larger reclamation, could be launched.

This was done in November 1992 when a $9,041 million contract, which remains as the second largest deal for work on the airport site, was awarded to Airport Platform Contractors.

The group was a consortium of six international firms – Costain from Britain, Nishimatsu of Japan, Morrison Knudsen from the United States, China Harbour Engineering, Ballast Nedam from Holland and Jan de Nul of Belgium – formed specially to bid for the reclamation contract.

The last two contractors were responsible for all dredging and sand filling, an operation so precise that vessels were fitted with a global positioning system to ensure material was correctly dumped.

Mud removal began in January 1993 when 24 dredgers, 75 per cent of the world's fleet, arrived in Hong Kong to clear 70 million cubic metres of mud from the seabed. This was done to provide a firm foundation for the rock and sand fill and reduce settlement to a minimum.

The Airport Authority was anxious not to have a repeat of the situation at Japan's Kansai International Airport where reclamation was carried out on top of the existing marine mud deposits. Settlement, at alarming rates, was a problem even before the airport opened.

Removal of the mud at Chek Lap Kok was done so quickly that most of the dredgers left nine months ahead of schedule. This cracking pace was maintained during the main reclamation work so that the airport island was finished ahead of the original 41-month contract deadline.

As the mud was being removed, sand and rock was being put in its place.

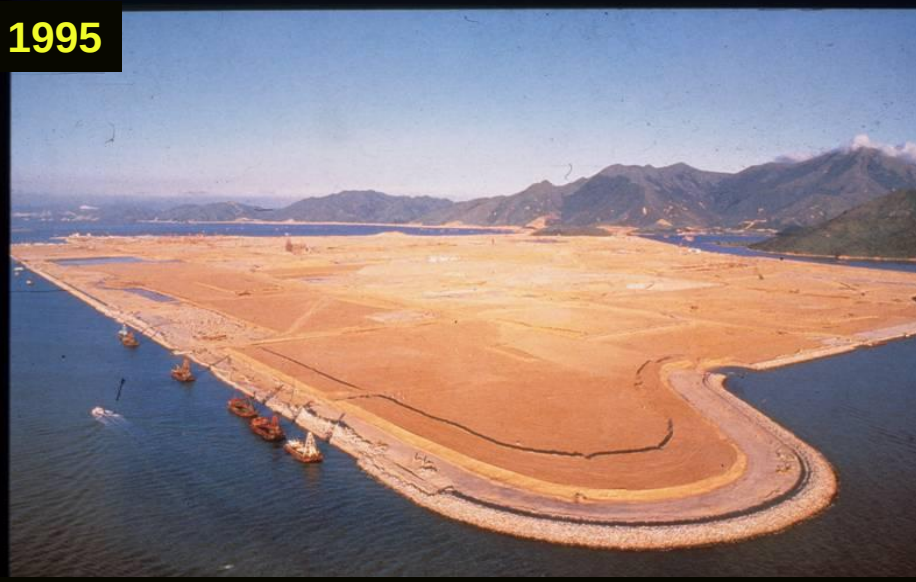
Most of the rock was provided from the original island which was flattened to just six metres above sea level. The same fate befell Lam Chau which was incorporated into the airport site and the Brothers, two islands east of Chek Lap Kok.

The equipment, including trucks, excavators and drilling rigs, was later sold for about $70 million. This was a fraction of what it cost new but, in the three years working at Chek Lap Kok, some of the dump trucks had travelled the equivalent of four times around the world.

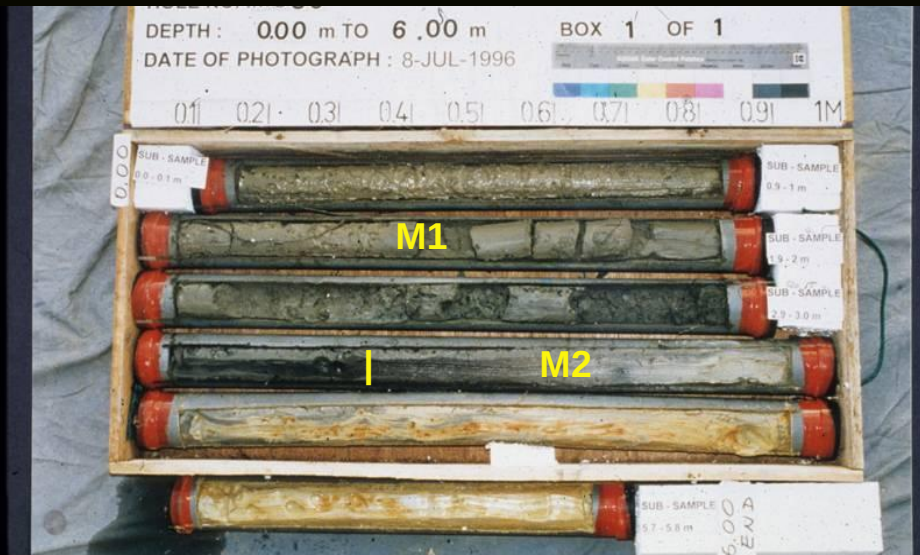
Meanwhile, the pace was no less hectic at sea where, during the busiest periods, enough sand and mud was being shifted to fill an Olympic-sized swimming pool every minute.

Overall, enough sand was pumped and dumped into the Chek Lap Kok site to fill 148 Empire State buildings.

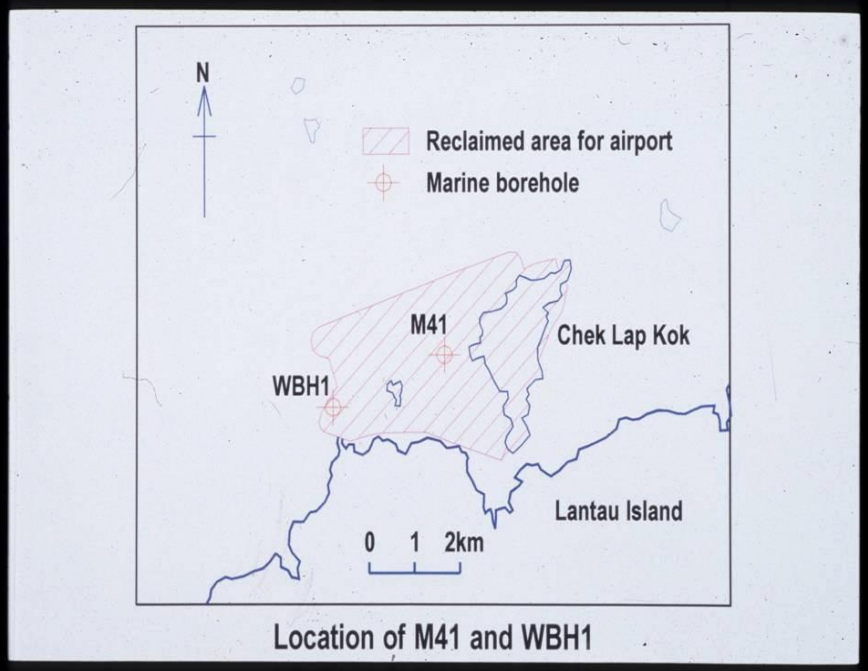
1995



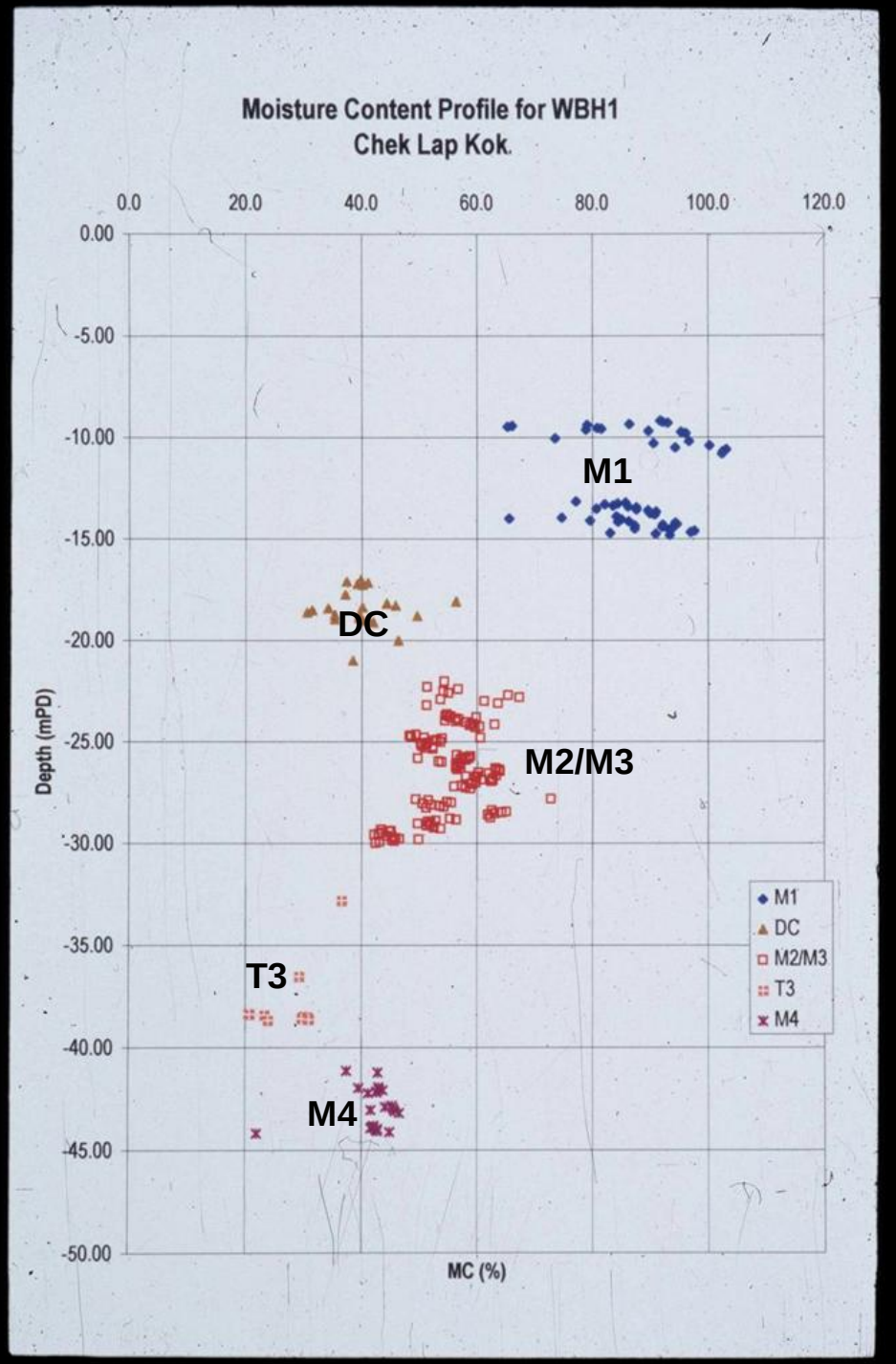
Continuous core showing a palaeo-desiccated crust in the upper part of the M2 unit



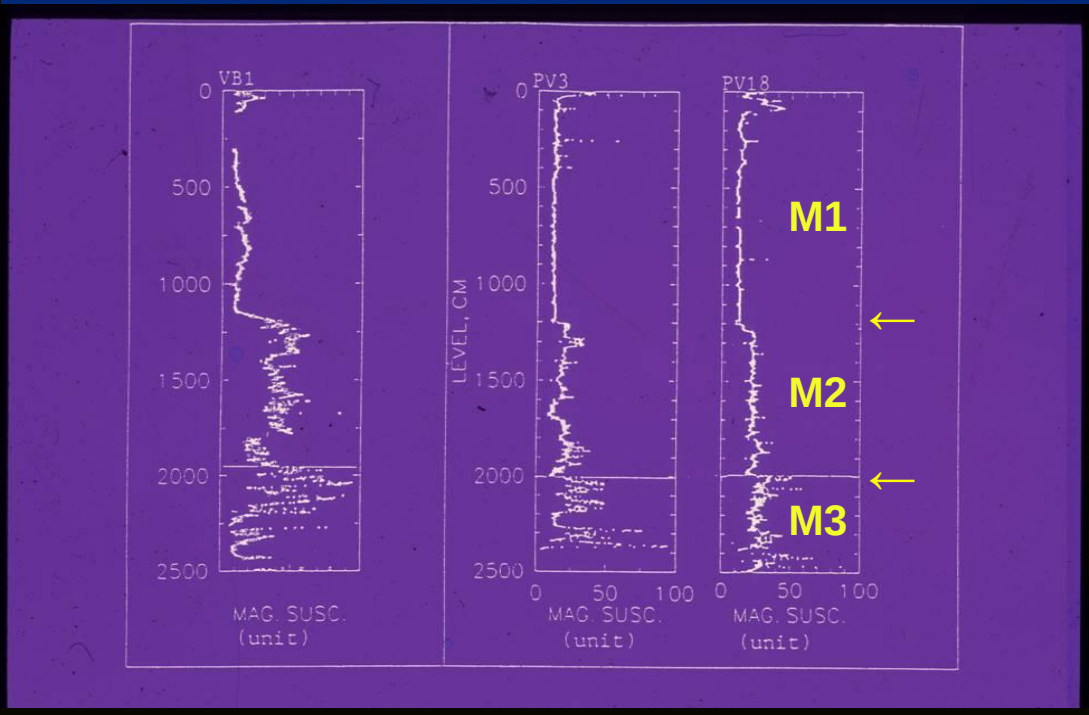
Water content measurements



Location of M41 and WBH1

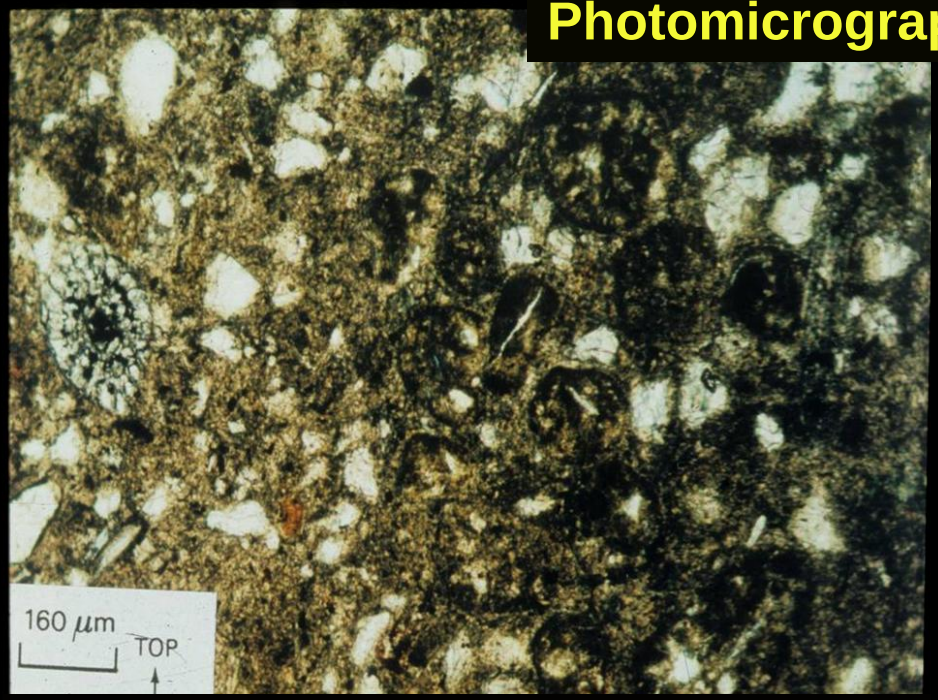


Measurement of magnetic susceptibility

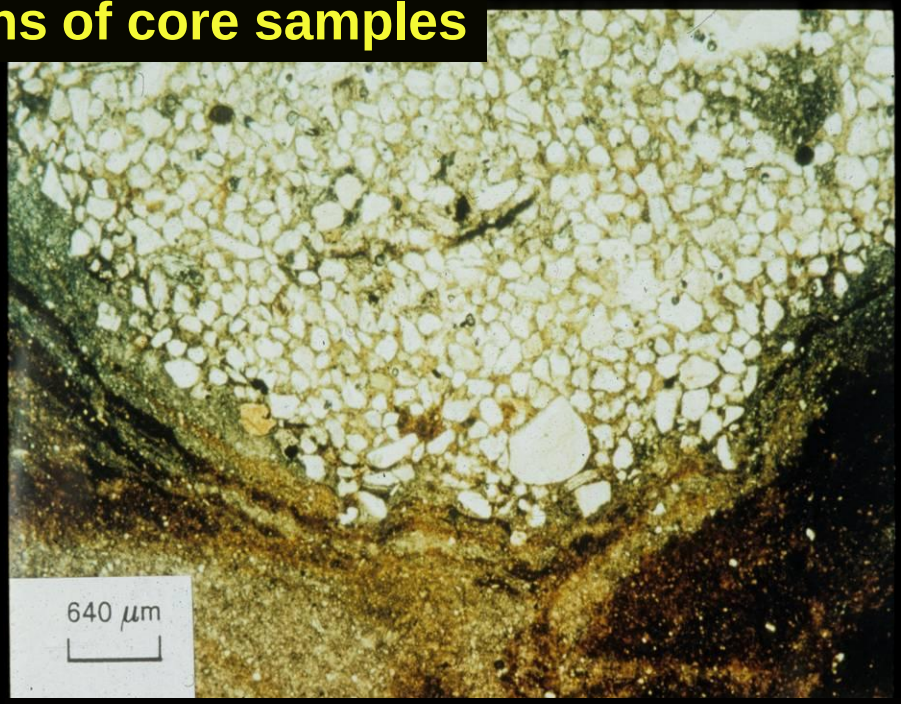


Three continuous vibrocores showing palaeosol development in the upper part of the M2 and M3 units. VB1 is from the new Hong Kong Airport. PV3 and PV18 are from Penny's Bay.

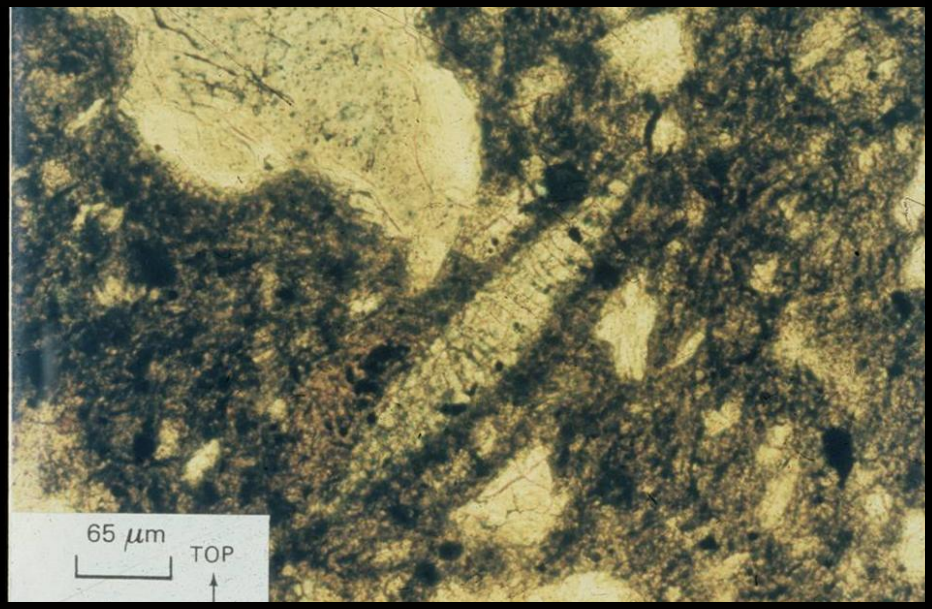
Photomicrographs of core samples



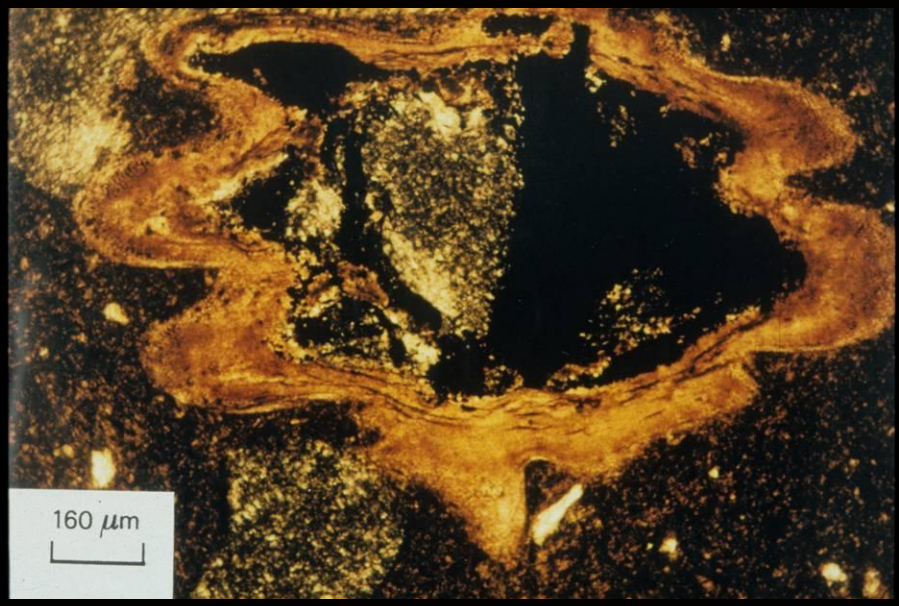
M1 unit with abundant calcareous microfossils



M2 unit showing burrow



M2 unit with diatom preserved



M2 unit a plant rootlet with pyrite framboids

Evidence from vegetation in the past

A mangrove pollen *Sonneratia* sp. occurring within the M2 unit of the New Hong Kong Airport site. This is a good indicator that the surface temperature exceeded the present day by 2-3^{o}C about 130,000 years ago during the last interglacial period.

Example 3 Drillhole in the West Lamma Channel for the Western Harbour Development Study

Samples at about 0.5 m Intervals in Borehole WB7

Borehole WB7

Legend	Depth in m P.D.	Origin	Description
	0.00		Sea level
	-10.20		Sea bed
	-17.20	M1	Very soft, grey clayey silt with shell fragments and subangular gravel in the top metre
	-23.80	M2	Soft to firm, grey clayey silt with occasional shell fragments and large bivalves at the base
	-27.60	T2	Yellow, brown and grey subrounded sand and gravel
	-35.70	M3	Firm; mottled, grey, yellow and brown clayey silt to -31.20 m; dark grey, clayey silt with a little sand and gravel below -31.20 m
	-37.05	T3	Mottled, white and grey silty sand with gravel below -36.85 m
	-51.20	M4	Soft to firm; mottled, grey, yellow and brown clayey silt to -46.13 m ; dark grey and grey clayey silt below -46.13 m
	-53.20	M5	Firm, mottled, grey, yellow and brown clayey silt becoming more grey at the base
	-60.20	T5	Firm to stiff, locally mottled, white,pink and grey clay to sand with occasional gravels
	-70.20	Residual soil	Completely decomposed rock (? granite)

Simplified logsheet

Chemical reactions involved

Pyrite → Ferrous ions + Sulphate ions

Ferrous ions → Ferric ions (oxidation) → Ferrous ions (reduction)

Ferric ions + Water → Limonite (iron cementation)

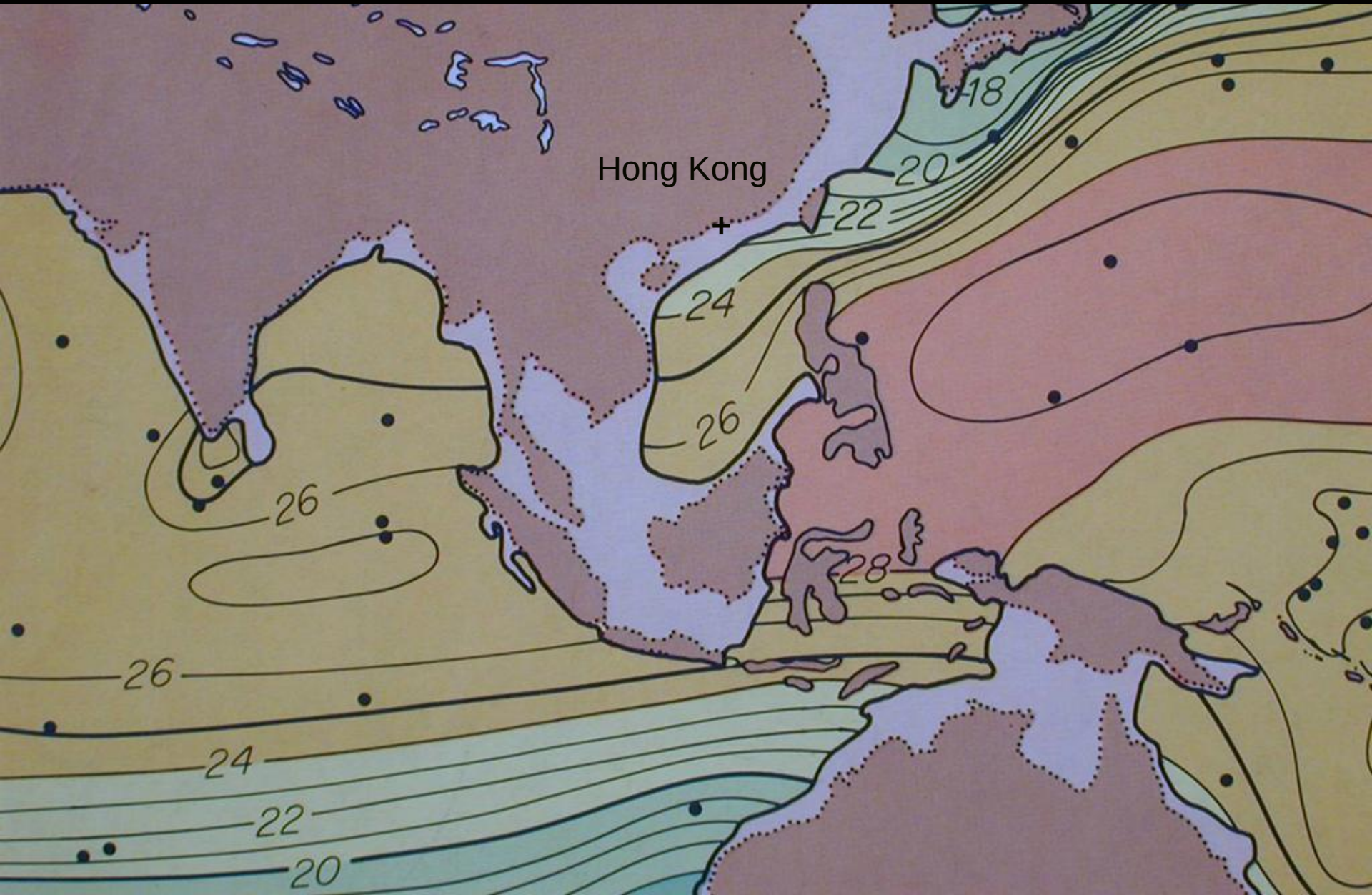
Hydrogen ions + Sulphate ions → Sulphuric acid

Shells + Sulphuric acid → Gypsum + Water + Carbon dioxide

Plant matter → Methane (bacterial action)

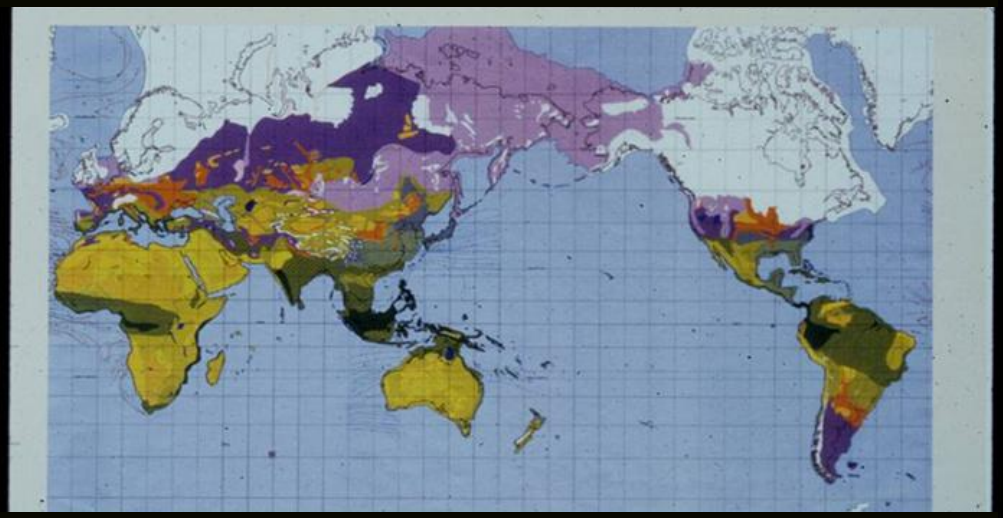
Ferrous ions + Carbonate ions → Siderite

Reconstruction of sea level during the last glacial maximum (CLIMAP 1982)
Isotherms in degrees Centigrade are estimates of August sea-surface temperature using oxygen-isotope stratigraphy of formaminifers



Present/last ice age comparison

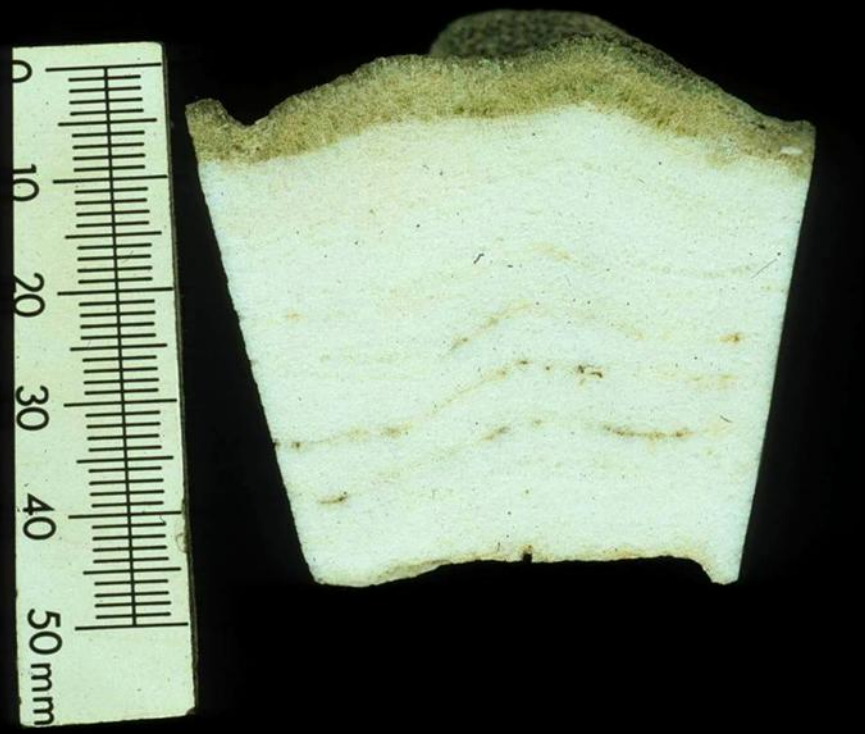
Present



Last ice age ca. 21,000 years ago (after Petit-Maire, 1999)

Knowledge gap – vegetation history during glacial periods

Study on a Hong Kong *Porites* sp. coral head



***Porites* sp. specimen from Little Palm Beach selected for oxygen & carbon isotope analysis**

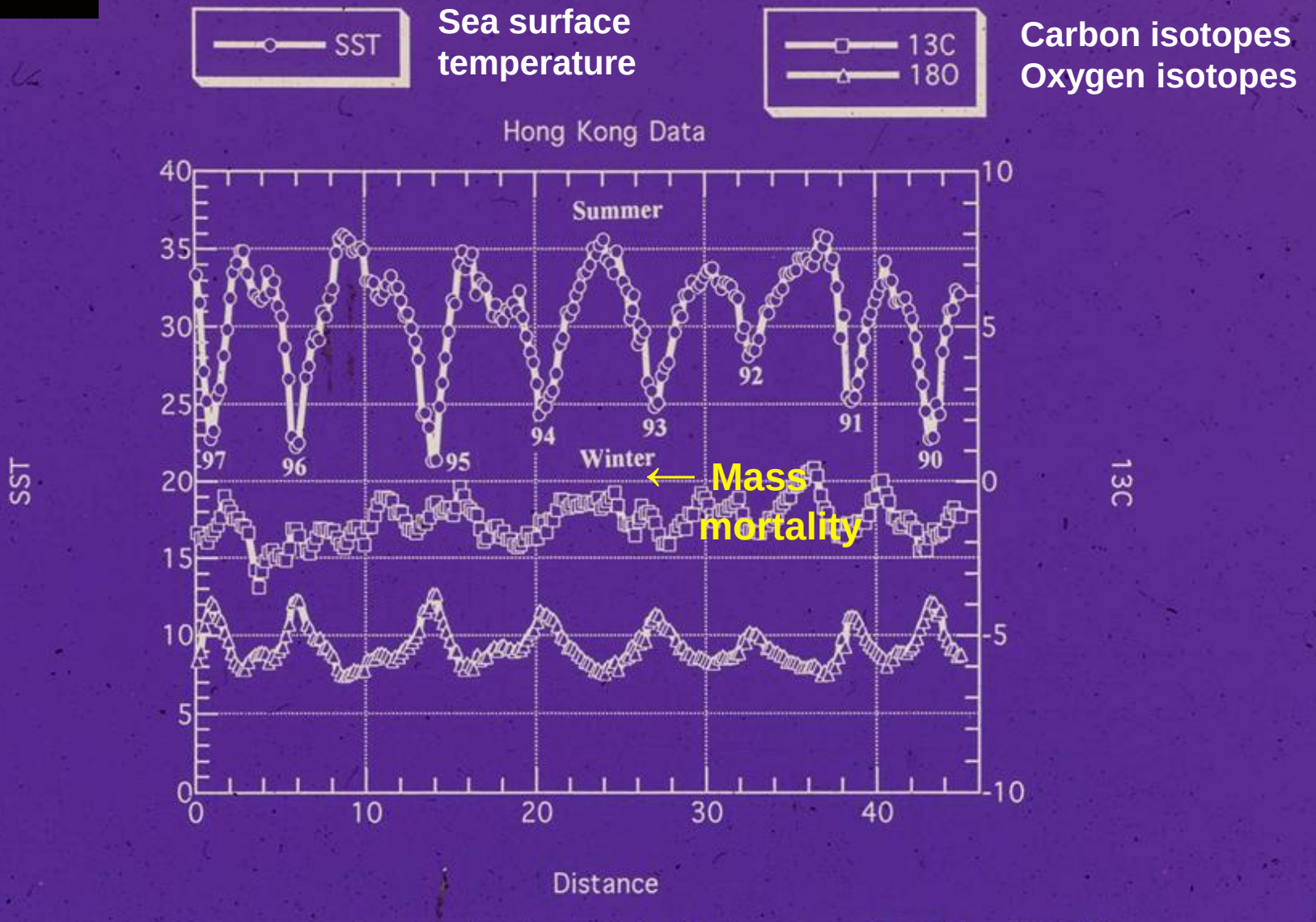
Sample cutting

Sample weighing

Sample holder for batch running

Stable isotope measurements

The results



Distribution of oxygen and carbon isotopic ratios in a *Porites lobata* specimen collected from Little Palm Beach, Sai Kung on 19th May, 1998. The SST is estimated from Great Barrier Reef calibration.

Some conclusions

(1) Continental shelves possess valuable records of climate change.

(2) Low & mid latitudes continental shelves have played an important role in global climate change and sea-level change during glacial periods through the production of greenhouse gases.

(3) High latitude ice sheet growth and the thermohaline circulation mechanism is not mainly responsible for global climatic change.

(4) Further studies are needed on continental shelves particularly on the record of vegetation and the variety of environments during glacial periods.

(5) Other high resolution terrestrial records e.g. fossil wood drowned below present sea level have not been examined.

Thank you