Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

TROPICAL AND TEMPERATE CARBONATE ENVIRONMENTS - THE EFFECTS OF SEA LEVEL, CLIMATE AND TECTONICS ON FACIES DEVELOPMENT.

JOINT BMR/TRC-JNOC PROGRAM

PHASE 1

1991/92 - SOUTHERN QUEENSLAND MARGIN

PRE -CRUISE PROPOSAL

RECORD 1991/88

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TROPICAL AND TEMPERATE CARBONATE ENVIRONMENTS - THE EFFECTS OF SEA LEVEL, CLIMATE AND TECTONICS ON FACIES DEVELOPMENT

EXECUTIVE SUMMARY

A joint BMR/JNOC cruise on Rig Seismic will be conducted between 14 October and 10 November to study the effects of sea level and climate on the temperate carbonates of the continental margin of southern Queensland. The aim of the study is to develop models of carbonate deposition and facies development that can be applied to the interpretation of carbonate rocks in general. This is the first phase of what will be a comprehensive study of both temperate and tropical carbonates, which will compare and contrast these two systems whose basic, but profound, differences are largely related to climate and sea level.

The joint cruise will involve the collection of 600 km of high resolution multichannel watergun data, 300 km of single channel boomer and sidescan data, and some 150 cores on the shelf and upper slope. A detailed seismic and sampling grid will be concentrated within two study areas, one off Noosa Heads and the other off Fraser Island, that have been chosen on the basis of the contrasts that occur between their topography, oceanography and biological associations.

The principal objectives of the cruise will be to define the distribution and geometry of carbonate facies on the shelf and upper slope, and to determine the major factors that have effected this distribution, particularly in relation to sea level change and climate, and to ultimately model these changes in order to understand the differences in processes and products in warm water and cold water limestones.

INTRODUCTION

Carbonate sediments, through their dominantly biological composition are extremely sensitive indicators of the environment in which they have

lived: sea level and climatic changes are faithfully recorded in the coral and algal skeletons which dominate the composition of the sediments deposited in such environments. However, the strongest signals of environmental change will be encapsulated in the sediments deposited in the marginal climatic environments, i.e. in the subtropical and warm-temperate regions. In addition, such thick and widespread carbonate accumulations in many parts of the world have been shown to contain almost 50% of global oil and gas reserves, although almost all research has concentrated on sediments of tropical affinities, ignoring the facies relations, build-ups and potential plays in their subtropical and temperate counterparts. Northeastern Australia , mantled by tropical and temperate sediments, therefore, defines the essential model for exploration applicable to both other parts of Australia and many parts of the world, and is, in addition, a prime focus for understanding the history and mechanisms of climate change in the past half million years.

The passive continental margin of northeast Australia extends for 2500 km from the tropics to temperate latitudes. It comprises the largest area of carbonate sediments deposited on a passive margin anywhere in the world, and includes both the Great Barrier Reef and the lesser known temperate build-ups of southern Queensland and northern New South Wales. It's architecture has been primarily defined by Late Cretaceous rifting and it's sedimentary evolution owes much to the northward plate motion of Australia in the Cainozoic from temperate to tropical latitudes. The Great Barrier Reef represents the major feature on the margin, extending for 2000km and comprised of 2500 individual reefs. It is widest in the central-south area around latitude 21°S where coral reefs and *Halimeda*-rich sediments dominate the outer shelf. To the south the reefs and *Halimeda* packstones diminish, and the sediments on the shelf comprise red algal boundstones, bryozoan/foraminifera grainstones and packstones, and rhodolith dominated buildups, bioclastic in nature and dominated by calcite rather than unstable aragonite. The facies and porosity/permeability attributes clearly reflect the change from tropical warm water to temperate cold water (Marshall and Davies, 1978; Davies and others, 1989). Studies on temperate carbonates in the Australian region are few, in spite of such sediments mantling the shelves surrounding half the continent (Jones and Davies, 1983; Marshall and Davies, 1978; Marshall, 1980; Rao, 1981; Collins, 1988; James and Bone,

1991; Conolly and von der Borch, 1967; Wass and others, 1970; von der Borch, 1970). BMR and JNOC-TRC scientists have visited the coastal outcrops of Tertiary limestones in the Torquay area of Victoria and have collected the principal facies in order to effect a comparison with the offshore facies to be collected off northeast Australia.

PREVIOUS WORK

The main geological features of the region have been deduced from geological (Davies, 1977,1983; Davies and Hopley, 1983; Marshall and Davies, 1978; Marshall, 1977, 1980, Stephenson, 1982) and geophysical studies(Davies and others, 1989; Symonds and others, 1983; Marshall, 1979; Nunn, 1982; and Searle, 1983). Plate tectonics, climate, subsidence, oceanography and sea level have all contributed significantly to the distribution of facies.

Previous studies of the margin between latitudes 20° and 28°S have been fragmentary, covering only parts of the area and only some aspects of the Holocene evolution of the reefs (Davies,1983; Davies and Hopley, 1983), the mapping of surface sediments (Marshall, 1977, 1980), and the intermediate to deep geological structure (Davies and others, 1989, Hill and others, 1989). With the exception of ODP Leg 133 further north, little attempt has been made previously to thoroughly understand the factors affecting the evolution of the sediments or to use the record in the sediments as a library of past environmental change. Only Harris and others (1990) have attempted to relate sediment composition and distribution to causal mechanisms, although much of the ODP related research further north has provided the most important leap in understanding the relevance of the region to studies of climate change and passive margin evolution. The astonishing conclusion that parts of the Great Barrier Reef are less than one million years old and possibly as young as 500,000 years suggests that the environmental record it encapsulates is of the highest known resolution anywhere in the world, and a priceless statement of natural global climate change and the mechanisms driving modern climate change. Further, the extreme youth of the system raises crucial scientific questions about its biological evolution and the dogmas assumed in this evolution, and provides a

priceless asset in model generation for energy exploration elsewhere.

The joint BMR-JNOC program will study the outer shelf and upper slope sedimentary facies of the northeast Australian margin along critical and contrasting latitudinal transects in 1991, 1992 and 1993.

Our summary of previous work concentrates on two aspects, i.e. facies distribution and seismic data. Our literature survey is included in Appendix 1.

Facies Distribution

The bathymetry in the study areas is shown in Figure 1. The distribution of samples previously collected in the area, together with the grain size and calcium carbonate content are shown on the large format maps, not appended to this report.

Very close correlation occurs between the areal distribution of large grain size sediments and the high carbonate content sediments.Those sediments which are relatively coarse and have a high carbonate content are, in general, distributed on the outer shelf and upper slope, whereas relatively finer sediments with low carbonate content tend to be distributed on the inner shelf. As an exception, the shelf between 26°S to 26.5°S shows a reverse distribution , with coarse sediments rich in carbonate on the inner shelf and fine grained sediments low in carbonate content on the outer shelf to upper slope. Corals and coralline algae are documented from the outer shelf, whereas the dominant carbonate grains on the inner shelf sediments are mainly mollusc fragments.

One drill hole occurs in the area off the northern end of Fraser Island (GSQ-Sandy Cape 1-3R), the summary log for which is shown in Figure 2. This shows 420m of late Tertiary and Quaternary sandy marine shelf deposits, 172m of mid-Tertiary interbedded basaltic volcanics, and marine, deltaic and fluvial sediments. These sequences are correlated with the Oligocene and younger rocks in Wreck Island 1, and the Capricorn 1 and Aquarius 1 wells in the Capricorn basin, further to the north.

Distribution of seismic data

The following seismic data has previously been collected in the area under consideration for study:

BMR continental margin data collected in the early 1970s.
BMR shelf mapping sparker data also collected in the early 1970s.
Sonne 15 airgun data collected off Fraser island during 1980.
Gulf and Shell seismic lines collected in the mid 1960s.

The position of previously collected seismic data is shown on the large scale unpublished maps. It is generally poor quality and emphasis on penetration over resolution makes most of the data of minimal use to the present study. Examples of the data are shown and have been used essentially to define gross differences between the two selected study areas.

STUDY TRANSECTS

Two study areas (1 and 2 in Figures 1, 3 and 4) have been chosen for detailed study on the following basis:

1. The distribution of carbonate sediments.

2. The expected distribution of various types of carbonate sedimentary facies in relation to the expected current conditions, water depth, bathymetry,etc In particular the distribution of rhodoliths is relevant because of the importance of this facies in the Ryukyus.

3. Sedimentation rates and outer shelf/upper slope morphology in the way they effect accessibility to the stratigraphic record.

4. The effects of currents on the distribution and characteristics of carbonate sedimentary facies.

The characteristics of each of the two selected study areas are defined below:

Area 1 (northeast of Brisbane) - Figure 3 .

- Carbonate sedimentary facies are expected to extend from the inner shelf to the outer shelf.
- Grainsize distribution patterns show a normal equilibrium condition, i.e a gradient from coarser sediment on the inner shelf to finer sediment on the outer shelf.
- Living coral is documented on a bank in the area. The biological association and the associated development of the carbonate sediments presents an interesting mid-shelf association.
- Planktonic foraminifera dominate the fine sedimentary facies on the outer shelf deeper than 70m, in distinction to the Ryukyus where such facies occur deeper than 200m.
- The change in topography from shelf to upper slope is very gentle: prograding sedimentary patterns are observed in the seismic sections.

Area 2 (east of Fraser Island) - Figure 4.

- In this area, the southward flowing East Australian Current impinges on the outer shelf.
- Biologic generation of substantial carbonate sedimentary facies is expected at the shelf edge.
- Grain size distribution patterns show the reverse pattern to that observed in Area 1, i.e. the coarse sediments occur on the outer shelf.
- The Rhodolith facies, one of the most characteristic carbonate facies in the Ryukyus, is expected to occur in this area.
- The change of topography from shelf to upper slope is very steep and areas of low sedimentation rates and exposure of older formations, through shelf edge erosion, is expected on the shelf/slope. Dredge sampling from such slopes is expected to provide information on the age and sedimentary facies of older formations identified in the seismic sections.

SURVEY TRACKS AND SAMPLING LOCATIONS

Tracks for the collection of water gun, boomer and sidescan data are shown in Figures 3 and 4. These were defined after considering the bathymetry and sedimentary facies distribution. In Area 1, seismic lines traverse the shelf to upper slope from the inner coarse carbonate rich area

to the outer fine carbonate poor area; they also traverse Barwon Bank. In Area 2, the seismic lines traverse the shelf to upper slope from the inner fine carbonate poor area to the outer carbonate rich area; they also traverse the deep water terraces. At the shelf edge region in both areas, we believe that detecting the precise 3-D distribution patterns of sediments controlled by sea level changes will be clarified by boomer surveys.

Grab sampling locations, for the biofacies mapping, have been defined after considering the bathymetry and sedimentary facies distribution. The final coring and dredging locations will be decided on board ship after studying the results of the water gun, boomer and sidescan surveys.

WORK PROGRAM - 1991/92

1.Pre-Cruise Program

- Scientific data analysis:
    - Compile and prepare bathymetric base maps.
    - Collect and synthesize all geophysical data. Prepare maps showing distribution in each transect area, the development of the Quaternary section and specific seismic geometries as a bases for defining seismic acquisition strategies.
    - Collect and synthesize all geological and geochemical data and prepare maps of grain size and facies variations. Hypothesise on the principal factors affecting facies distribution. Define a sampling strategy.
    - Conduct a literature survey of all previous studies (a) in the transect areas and (b) related studies elsewhere.
    - Visit Tertiary outcrops of temperate limestones in Victoria and relate outcrop geology to climate, sea level and likely seismic geometries.
    - Prepare a report defining targets for field studies.
    - Define hypotheses testable by field studies.

-Preparations for Cruise 1.

- Maintenance and testing of the following equipment items - seismic acquisition systems (waterguns and boomer), sidescan-

sonar, vibrocorers, and piston corers.
- Purchase consumables.
- Organise the in-port readiness of RV Rig Seismic.
- Organise the transfer of resources from Canberra to Sydney.
- Prepare and maintain necessary onshore navigation facilities.
- Liaise with all relevant State and Federal organisations. In particular, obtain permission from the GBRMPA for conducting research in the GBR Marine Park if research in the Marine Park is contemplated.

2. Rig Seismic Cruise - 14th October to 10th November

The following data will be collected on the basis of targets defined above in the section on Study Transects:

- 600km of high resolution multichannel watergun data.
- 300km of boomer single channel data.
- 300km of sidescan digital data.
- 150 vibrocores and/or grab/piston/gravity cores.
- Sea bottom photos.
- On board preparation/photography of cores.
- Core description.
- Maintenance and curation of cores.
- Preparation of track charts.

The principal objectives of this cruise will be:

- To define the facies distribution on the shelf and upper slope to a depth of approximately 1000m.
- To define the three dimensional facies geometry.
- To define the principal factors effecting facies distribution:
- To relate facies geometry to the above factors, particularly to sea level change.
- To define both the effect of climate and sea level change on the physical position of the East Australian Current and the chemical fingerprint of this specific watermass in the sediments.
- To understand and model the changes in climate and sea level particularly in the past 500,000 years, and to relate sea level change to facies geometry.
- To understand the post depositional factors affecting the physical make-up of the sediments and in particular to define and

understand the differences in process and products in warm water and cold water carbonates limestones.

3.Post Cruise program

The responsibilities and proposed schedule of the post-cruise program are shown in Tables 1 and 2. The major components of the work program are:

- Seismic data processing and interpretation.
- Navigation data processing.
- Sediment data processing including sampling, description and analysis of cores.
- Preparation of Cruise report for the 1991 Cruise.
- Preparation for second cruise scheduled for October/November 1992.

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APPENDIX 2 - EQUIPMENT LIST

Geophysical and Geological Equipment

FJORD Instruments seismic receiving array: for this survey configured as 6.25 m group lengths with 96 channels and 600 m active streamer length.

Syntron RCL-3 cable levellers; individual remote control and depth readout.

Seismic Systems S-15 and S-80 high resolution water guns.

Air compressor system: 6 x A-300 Price compressors, each providing 300 scfm at 2000 psi (62 litres/min at 14 MPa).

Digital seismic acquisition system designed and built by BMR: up to 320 data channels, special 16 bit floating point, SEG-Y output at 6250 bpi.

Raytheon echo sounders: 3.5 kHz (2 kW), 16 transducer sub-bottom profiler and 12 kHz (2 kW) bathymetric system.

Geometrics G801/803 magnetometer/gradiometer.

Bodenseewerk Geosystem KSS-31 marine gravity meter.

EG&G model 990 sidescan sonar with 1000 m coaxial cable.

EG&G Uniboom sub-tow single channel boomer.

Australian Winch and Haulage deepsea winch with 10 000 m of 18 mm wire rope, and hydrographic winch with 4000 m of 6 mm wire rope.

15 metre A-frame with 12.5 ton load capacity.

Submersible Services (Aust.) vibrocorer; 6 m x 75 mm.

Gravity/piston coring system; <15 m x 75 mm.

Chain bag rock dredges.

20 litre capacity van Veen grabs.

Navigation Equipment

Magnavox T-Set Global Positioning System navigator.

Racal Differential GPS system.

Magnavox MX 1107RS and MX 1142 transit satellite receivers.

Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers.

Sperry, Arma Brown and Robertson gyro-compasses, plus Ben paddle log.

Decca HIFIX-6 radionavigation system, modified for long-range operations.

Motorola high precision radio navigation system.

APPENDIX 3 - CREW LIST

P.J. Davies	Co-chief Scientist
Y. Tsuji	Co-chief Scientist (JNOC)
N. Honda	Scientist (JNOC)
H. Matsuda	Scientist (JNOC)
J. Marshall	Scientist
D. Feary	Scientist
G. Bickford	Scientist
R. Mleczko	Systems Operator
L. Kalinsan	Systems Operator
T. Hunter	Systems Technician
D. Pryce	Systems Technician
D. Wilson	Systems Technician
J. Kossatz	Systems Technician
P. Attenborough	Geological Technician
J. Stratton	Geological Technician
D. Holdway	Electronics Technician
V. Wierzbicki	Electronics Technician
C. Green	Mechanical Technician
R. De Graaf	Mechanical Technician
A. Radley	Mechanical Technician
B. Dickinson	Mechanical Technician
C. Dyke	Mechanical Technician

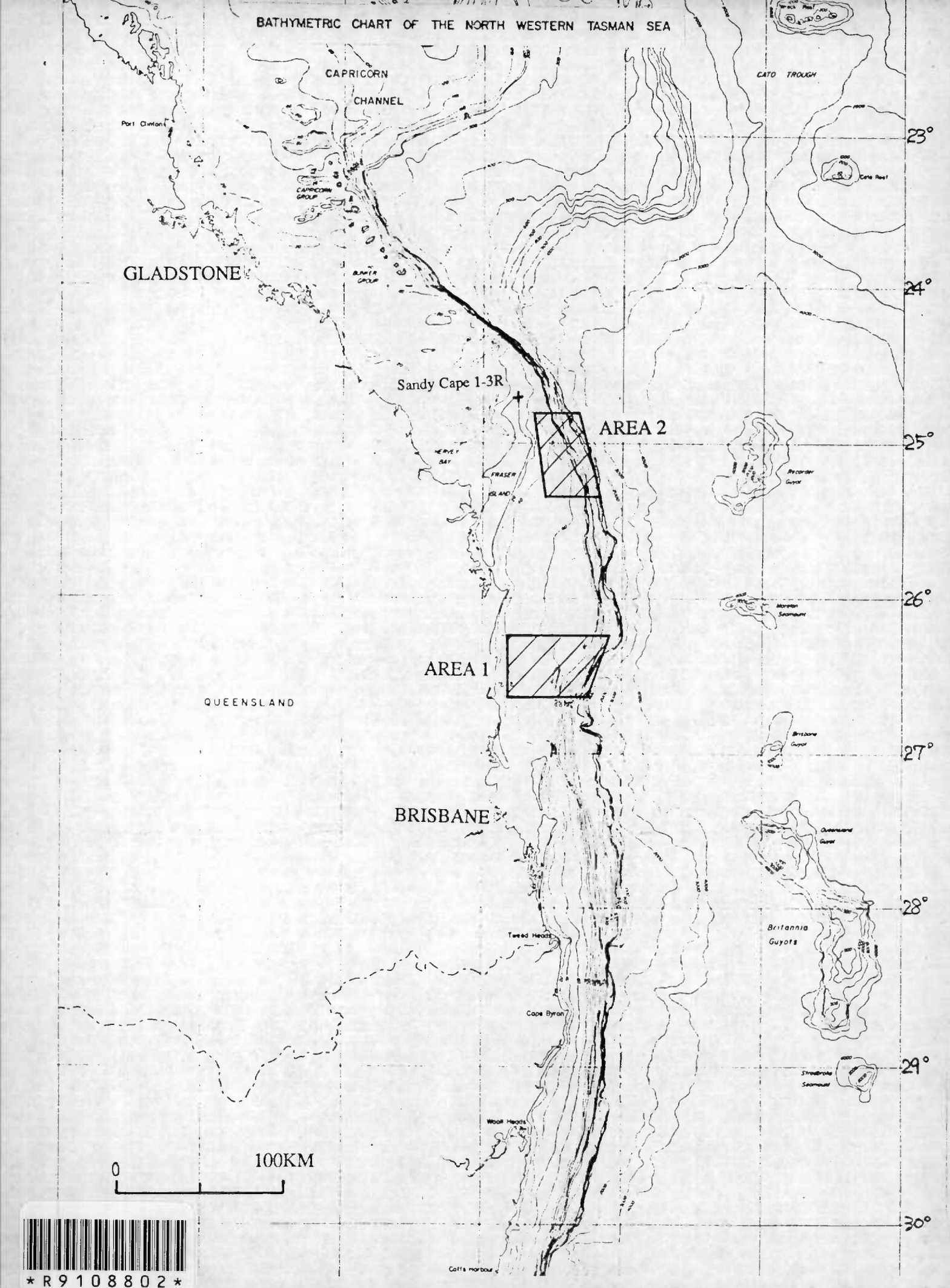

Figure 1. Bathymetry and position of the proposed study areas in southern Queensland.

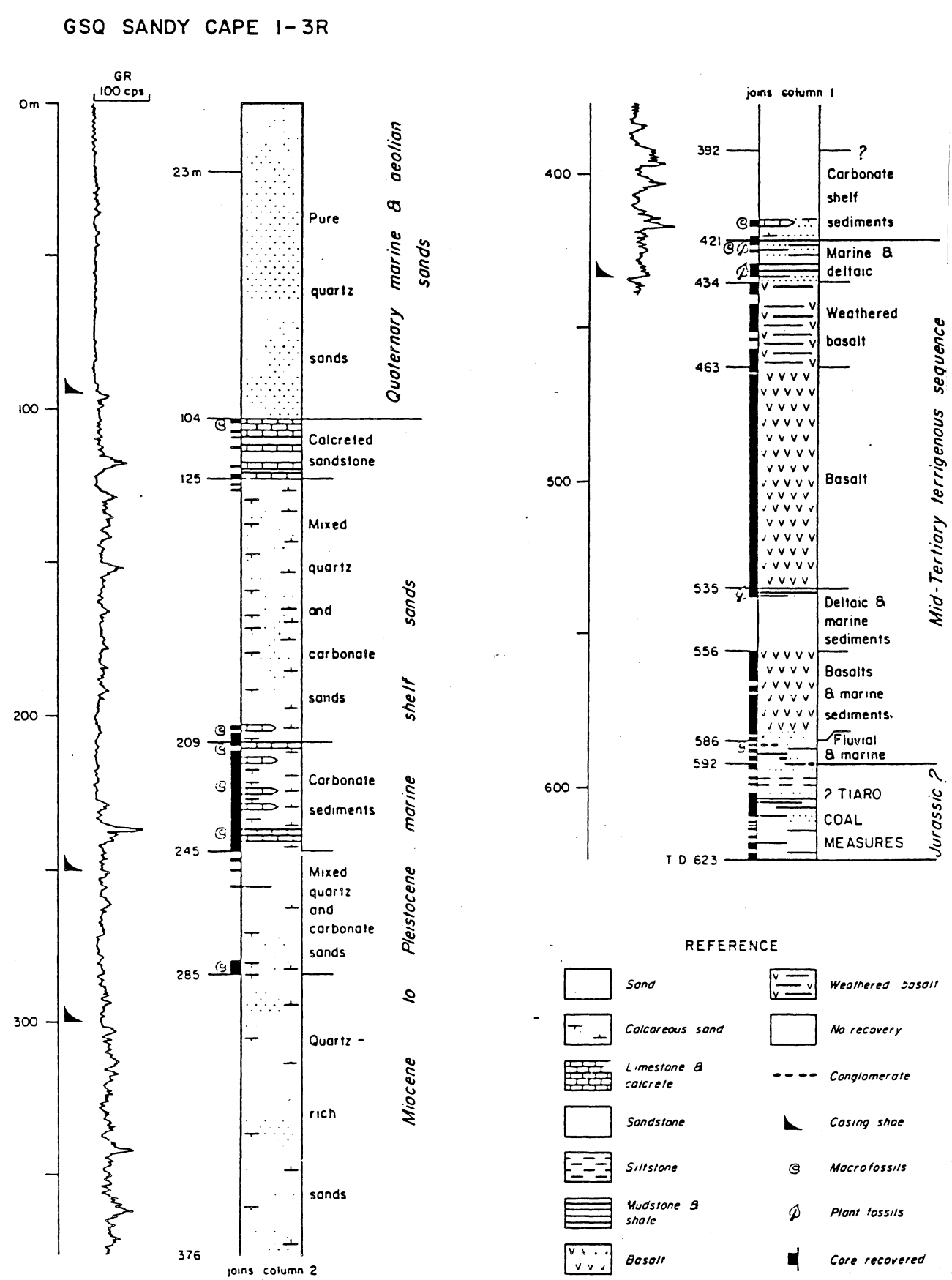

Figure 2. Survey drilling log for Sandy Cape 1-3R.

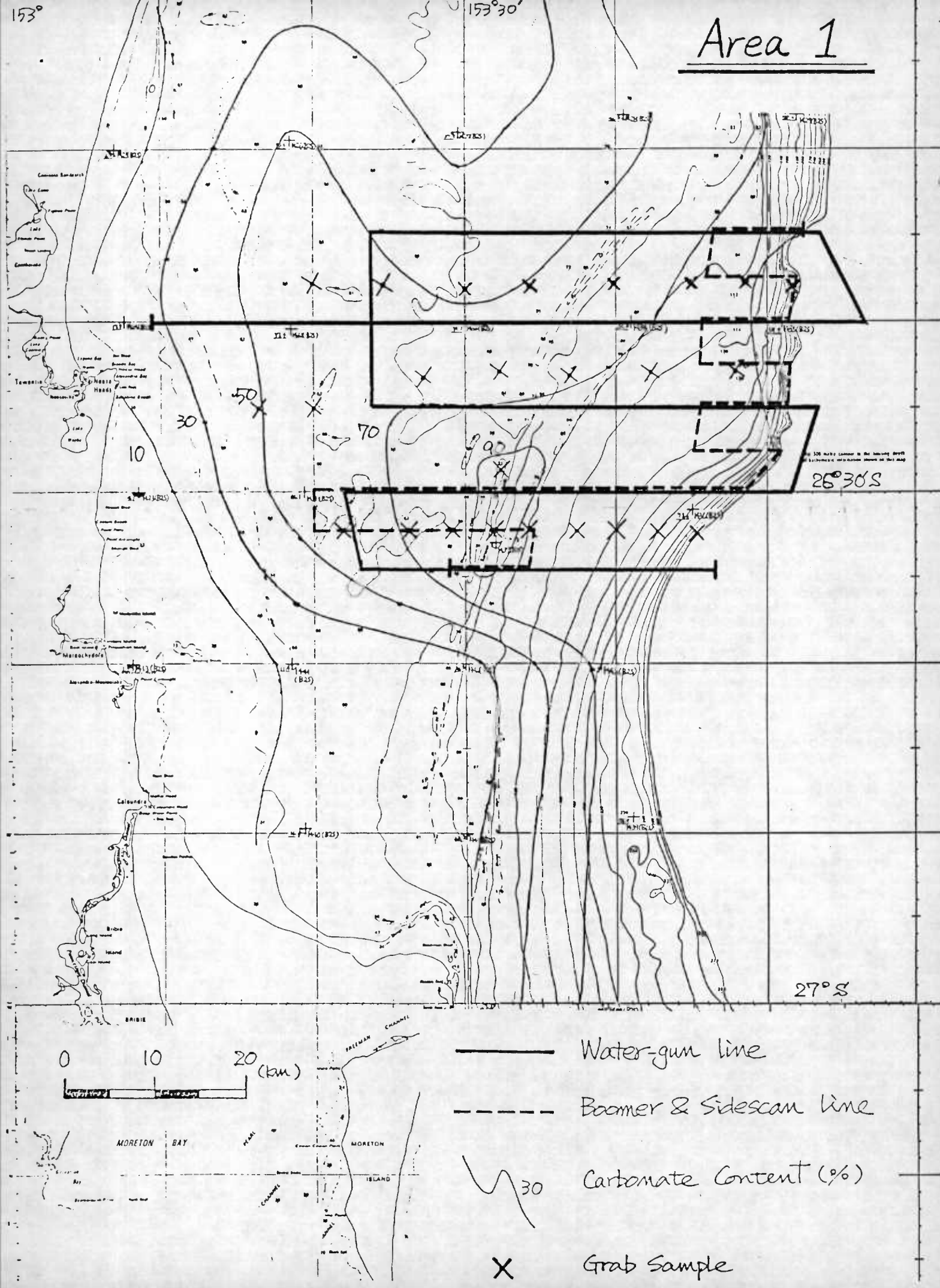

Figure 3. The position of study are No 1, and the proposed distribution of seismic tracks and grab sampling positions.

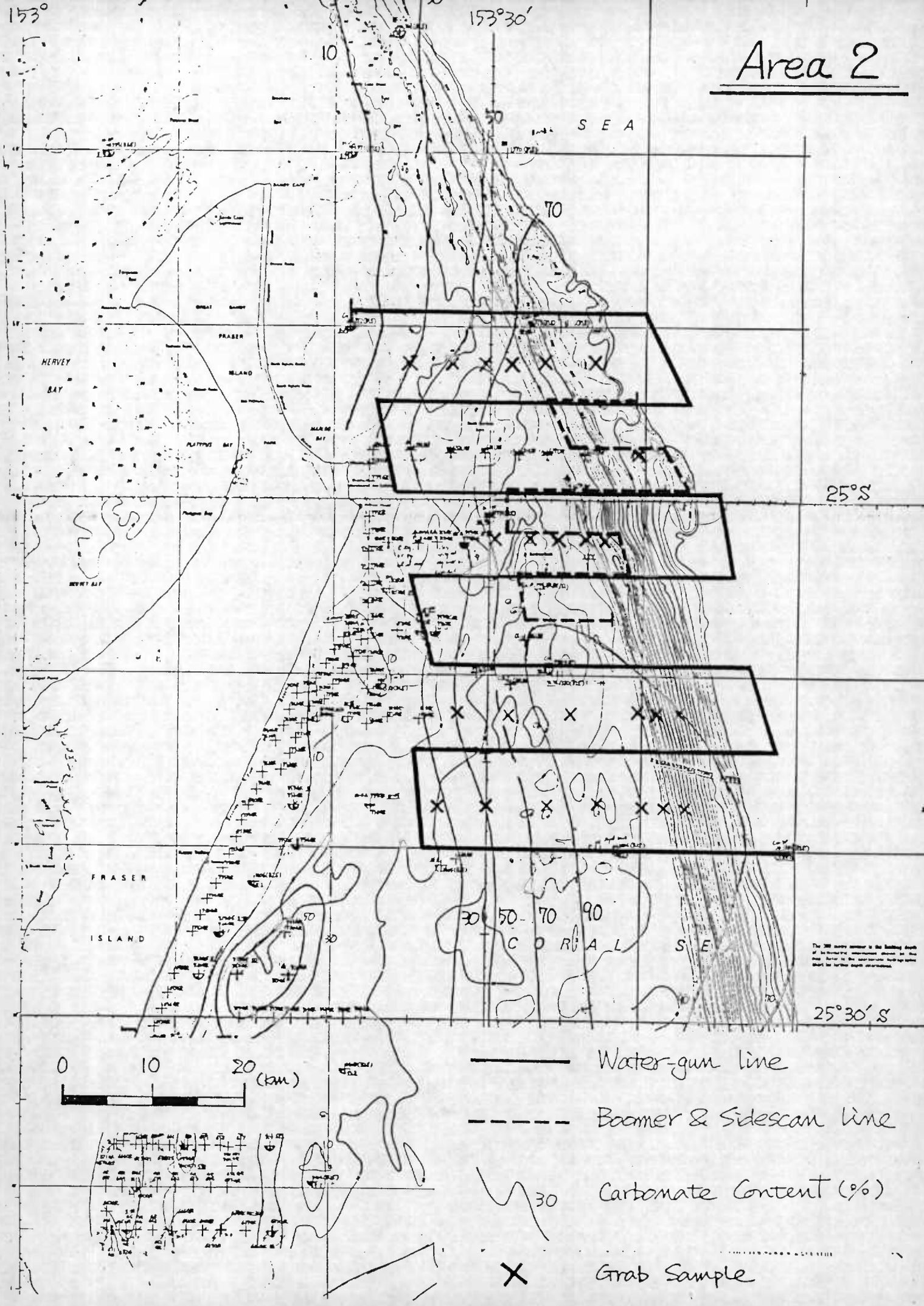

Figure 4. The position of study area No 2, and the proposed distribution of seismic tracks and grab sampling positions.

Job Identification	BMR	U of S	JNOC	Univs.Jap.
1. Describe Cores	*	*	*	
2. X-Ray Cores	*			
3. Sub sample	*	*	*	*
4. Bio-Analysis of cores (Skeletal components)				
Forams		*	*	*
Bryozoans		*		*
Ostrocods		*		
Rhodoliths				*
Other Algae				*
Corals	*	*		*
Nannos			*	
Other Bio	*	*	*	*
Palaeodating of Cores			*	
C14 dating of cores	*			
U/Th dating of cores				*
Magnetic properties of Sediments	*	*		
Stable Isotope Anal of Forams	*	*	*	*
Stable Isotope Anal of Ostrocods	*	*		
Metals in Forams/Ostrocods	*	*	*	
Forams/Nannos in water column		*	*	
Grain size Anal	*	*		
X Ray Diffraction		*	*	
Organics in sediments		*	*	
Diagenesis of Sediments	*		*	
Pore water chemistry			*	*
Organic carbon analysis of cores	*		*	*
Seismic data processing	*			
Seismic data interpretation	*	*	*	
Mapping surface sediments	*	*	*	*
Sidescan interpretation		*	*	
Oceanographic program		*	*	
Metals in Sediments	*		*	
Carbonate/Insols %	*	*		*
Pososity/Permeability			*	

Table 1. Proposed work distribution between participants in the program

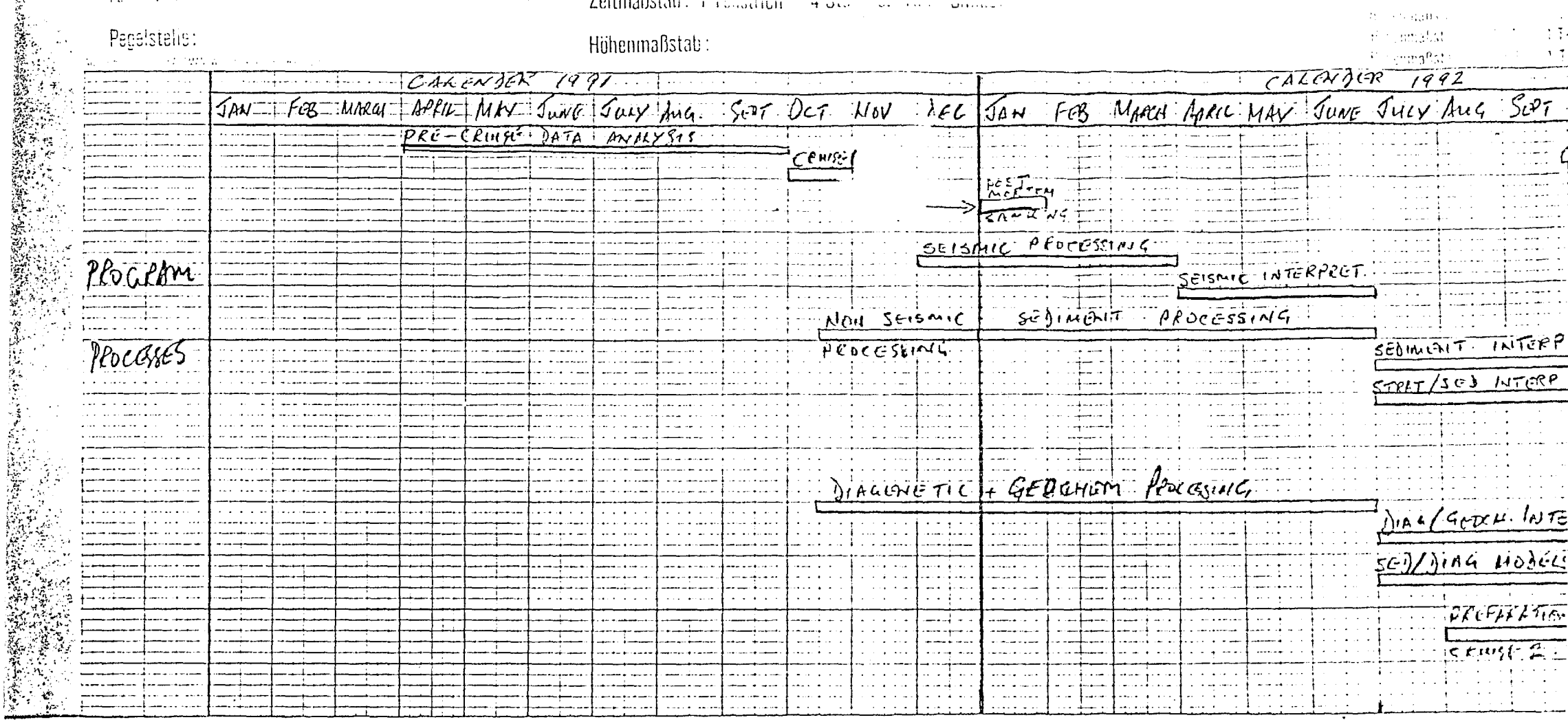

Table 2. Proposed schedule of work by participants in the period 1991-1995.

Istrich △ 4 cm Wasserschwankung
Istrich △ 3 cm Wasserschwankung
Istrich △ 2 cm Wasserschwankung
Istrich △ 1 cm Wasserschwankung

abgelesen: .....

angenommen: .....

Zeitmaßstab: 1 Teilstrich = 4 Std. (32 Tage

Höhenmaßstab:

CALENDER 1993 | CALENDER 1994

OCT | NOV | DEC | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | JAN | FEB | MARCH | APRIL | MAY | JUNE | JULY | AUG | SEPT | O

CRUISE 2

CRUISE 3

P.M. SAMPLING

PORT SAMPLING

PROCESSING OF OCEANOGRAPHIC DATA

SEISMIC PROCESSING

SEISMIC INTERPRET

FINAL SEISMIC PROCESSING

NON-SEISMIC PROCESSING

SEDIMENT PROCESSING

FINAL SEDIMENT PROCESSING

SEDIMENT INTERP.

STRAT/SED INTERP

FINAL DATA COMPILAT

SEDIMENTOLOGY, SEIS

AND GEOCHEMISTR

DIAGENETIC + GEOCHEMICAL PROCESSING

DIAG/GEOCHEM INT.

FINAL DIAG/GEOCHEM PROCESSING

SED/DIAG MODELS

PREPARATION CRUISE 3

maßstab: 1 Teilstrich = 4 Std. (32 Tage Umlauf)

enmaßstab:

CALENDER 1994 | 1995

MARCH APRIL MAY JUNE JULY AUG SEPT OCT NOV DEC | JAN FEB MARCH APRIL

EANOGRAPHIC DATA

INTERP – OCEANOG. DATA.

SSING

PROCESSING

FINAL DATA COMPILATIONS. —
SEDIMENTOLOGY, SEISMICS, DIAGENESIS
AND GEOCHEMISTRY

INTEGRATION OF
OCEANOGRAPHY +
SEDIMENTOLOGY