National Standards of People's Republic of China

GB/T 12763.8—2007

Replace GB/T 13909-1992

Specifications for oceanographic survey—Part 8: Marine geology and geophysics survey

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Preface

GB/T 12763 *Specifications for oceanographic survey* is divided into 11 parts:

——Part 1: General rules

——Part 2: Marine hydrological observation

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——Part 4: Seawater chemical characteristics survey

——Part 5: Marine sound and light characteristics survey

——Part 6: Marine biology survey

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——Part 8: Marine geology and geophysics survey

——Part 9: Guide to marine ecological survey

——Part 10: Seabed topography survey

——Part 11: Marine engineering geological survey

Part 9: Guide to marine ecological survey, Part 10: Seabed topography survey and Part 11: Marine engineering geological survey are add parts compared with GB/T 12763-1991.

This part is the eighth part of GB/T 12763 *Specifications for oceanographic survey* which replaced GB/T 13909-1992 *Specifications for oceanographic survey Marine geology and geophysics survey.*

This part is used together with part1, part7 and part10 of GB/T 12763.

The main changes of this part compared with GB/T 13909-1992 are:

This part uses new structure which divides into chapter, piece and paragraph according to GB/T 1.1 *Standardized working guidelines Part1: Standard structure and work requirements.*

Table 1 in this book has 4 changes compared with that in GB/T 13909-1992:

—— Deleted the differences between "high-seas" and "offshore seas", both areas require the same;

—— Deleted the survey contents of $1:200 \times 10^4$ scale and some projects added the

survey contents of $1{:}10{\times}10^{4}$ scale and $1{:}5{\times}10^{4}$ scale;

—— Deleted " according to the distance (mm) between the corresponding scale" to regulate the navigation positioning accuracy and changed into DGPS positioning;

——The survey accuracy criteria of marine gravity survey and marine geomagnetic survey have been greatly improved. The survey accuracy of marine geomagnetic survey of $1{:}100{\times}10^{4}$ scale and $1{:}50{\times}10^{4}$ scale has changed from 12nT and 8nT to 4nT. The survey accuracy of marine geomagnetic survey of $1{:}20{\times}10^{4}$ scale has changed from 4nT to 2nT.

Because of the massive changes of survey method, Chapter 5 seabed topographic survey was separated into a new standard which is part 10 of GB/T 12763: Seabed topography survey. Chapter 5 in this book quotes this new standard.

There are many changes in the Chapter 6 of this book:

—— 6.1.3.2b) The original requirement for columnar sample length was no less than 50cm and no less than 150cm in offshore area. In this book, the requirement is changed to no less than 150cm and also requires that the sampler weighs 300kg~500kg;

—— 6.3.2.3 The grain size analysis method was changed from Coulter counter to laser particle size analyzer;

—— 6.3.3.2 Added sediment triangulation classification of deep sea sediments in the classification and naming of sediment particle size;

—— 6.3.3.3 The sorting level in table 4 was merged from seven levels to five levels;

—— 6.5 Added penetration strength test and physical and mechanical property test of cobalt-rich crust and rock in the test of physical and mechanical properties of sediments;

—— 6.7 In the chemical determination of sediments, the determination method of 6.7.8 determination of organic carbon, 6.7.10 determination of total nitrogen and 6.7.11 determination of carbonate were all changed to element analyzer.

The original version of the title "shallow submarine structure and surface sediments acoustic detection" of chapter 7 was replaced with "shallow seabed structure detection". The original version of the title " stratigraphic profile detection " of 7.1

was replaced with " towed shallow stratigraphic section detection " and The original version of the title " submarine multi - frequency detection" of 7.2 was replaced with " shipborne shallow stratigraphic section detection ".

 In chapter 9, the word " free space gravity anomaly "was replaced with the word " spatial gravity anomaly ". Paragraph d in the marine gravity abnormal original acceptance criteria "Continuous record loss on one survey line should be less than 10% of total survey line length. Accumulating record loss should be less than 20% of total survey line length. Unqualified survey lines should be less than 10% of total survey lines." was changed to "Continuous record loss on one survey line should be less than 5% of total survey line length. Accumulating record loss should be less than 10% of total survey line length. Unqualified survey lines should be less than 5% of total survey lines."

 The part 6 of chapter 10 " paleomagnetic survey of marine sediments" was adjusted to 6.9 paleomagnetic survey of bottom sediments.

 Appendix A, Appendix B, Appendix C, Appendix D, Appendix E, Appendix F, Appendix G, Appendix H in this part are all normative addenda.

 This part is put forward by the State Oceanic Administration.

 This part is managed by the National Ocean Standard Metrology Center.

 This part is drafted (revised) by the Second Institute of Oceanography of the State Oceanic Administration. Guangzhou Ocean Geological Survey Bureau of Ministry of Land and Resources and State Oceanic Administration First Marine Research Institute has participated in the drafting (revision).

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 The previous versions of the standards that were replaced by this part are:
——GB/T 13909-1992.

Specifications for oceanographic survey

Part 8: Marine geology and geophysics survey

1 Range

Part 8 of GB/T 12763 specified the basic contents, methods and the requirements of data processing and survey results of marine geology and geophysics survey.

This part is applicable for basic environmental factor survey of marine geology and geophysics. This part can also be provided for references in some professional or special surveys.

2 Normative references

Terms in the following documents became the terms of this part through the quotation of part 8 of GB/T 12763. The citated document with date and its later amending list (exclude mistake) or the recision are not situated this standard. However, parties to this arrangement are encouraged to discuss whether to use the latest version of these documents. The latest edition of the citated document without date fit this standard.

GB/T 12763.1 Specifications for oceanographic survey Part 1: General provisions

GB/T 12763.6 Specifications for oceanographic survey Part 6: Marine biology surveys

GB/T 12763.7 Specifications for oceanographic survey Part 7: Oceanographic survey data interchange

GB/T 50123 Standards for geotechnical test methods

3 Terms and definitions

The following terms and definitions are applicable for this part.

3.1 radioactive dating

An analytical method of determining the absolute age of geological bodies according to the law of the decay of some radioactive elements in the natural world.

3.2 submarine heat-flow density

The heat energy in the earth interior flowing outward in the form of heat conductivity through unit submarine surface area in unit time.

3.3 geothermal gradient

The earth temperature difference in unit depth.

3.4 cooling plate model

A theoretical thermal model based on plate kinematics. It assumes that new oceanic crust generates constantly from the mid-ocean ridge and put the oceanic crusts expand on both sides.

3.5 TVG gain trace

The change rules of the voltage of acoustic receiver with time.

4 General provisions

4.1 Technical design

The main contents of technical design should include:

a) The objectives and requirements of the task;

b) Apart from what has required in the task book, the basis of design should include introduction of previous work in the water area observed, basic characteristics of geology and geophysics of the investigation area and its adjacent area, etc;

c) Research vessel, survey instruments, survey scale, survey line and survey network layout, workload and basic method;

d) Technical requirements and measurements;

e) Field operation and indoor operation arrangements and schedule;

f) Expected results and the investigation report;

g) Personnel composition, division of labor and cooperation of the research group;

h) Budgetary estimate.

For more information on the responsibility for compiling the task book and the review process of the task book, see GB/T 12673.1.

4.2 The basic survey methods

4.2.1 The ways of research vessel operation

The ways of research vessel operation can be divided into two categories: stop observation and navigation continuous measurement.

Stop observation items include bottom sediment sampling, submarine photography, submarine heat flow measurement, etc.

navigation continuous measurement items include shallow stratigraphic structure detection, marine gravity survey, marine geomagnetic survey, marine seismic survey, etc.

4.2.2 The basic ways of investigating operations

According to the purpose and task of the survey, different scale of the area survey or route survey should be used. the survey line and survey network layout should be in accordance with survey scales.

4.3 The basic requirements of the survey

The basic requirements of the survey are as follows:

a) A multi-project comprehensive survey should be used in the survey as far as possible.

b) The survey line or network layout should be unified when geological and geophysical survey is carried out in the same survey area in order to make the investigation data confirm each other and comprehensively interpret the data.

c) Researchers should make a field survey for the islands and land in the measured area and its adjacent areas. If there is no such field survey, researchers should widely collect data to infer from land and sea to explain the geological structure of the measured area.

4.4 The accuracy of the survey

The survey line or network of frequently-used scales and the accuracy of navigation positioning and measurement in the environmental basic factors survey are shown in Table 1.

Submarine heat flow measurement and submarine shallow stratigraphic structure detection projects are allowed not to meet the survey line and network density requirements in table 1, but researchers should select the appropriate profile or station based on task requirements and / or other project investigation status.

4.5 The basic requirements of data processing

4.5.1 Acceptance of raw data

Acceptance process of raw data are as follows:

a) The acceptance of raw data should abide by the relevant technical standards of the project. The raw data is generally divided into two levels: qualified and unqualified. The unqualified raw data should be abandoned.

b) The acceptance of the raw data is carried out by the department that issues the survey task or the department that carries out the survey task.

c) The original data acceptance results should be written reviews, signed and sealed by the accepters, which are filed as a part of the final survey results.

4.5.2 Data analysis and processing

The requirements of data analysis and processing are as follows:

a) Liability system should be established when analyzing and calculating data. The analysis and calculation results should be signed by analysts (calculator), check man and the person in charge.

b) The report form of the analysis and calculation results should be filled according to the regulations of Chapter 11, GB/T 12763.7.

c) the compilation of map should contains map title, scale, latitude and longitude coordinates, main features, legend, figure number and the necessary description, the

responsibility table and so on. The responsibility table includes map establishment institutions, map maker, fair drawer, technical director, data resources and the data of compilation and publication.

4.6 Survey results

4.6.1 Samples and original records

Samples and original records include sediment samples, rock samples, biological samples, water samples, site description records, navigation positioning records, modeling records, digital records and various record forms and books, which are the firsthand material and the primary results of the survey.

4.6.2 Basic maps

After the indoor processing, analysis and calculation of the samples and original records obtained from the survey, researchers compile the basic maps of all elements according to the requirements of mapping scale. The basic maps of marine geology and geophysics survey include bottom sediment chart, bottom sediment's physical and chemical elements distribution chart and profile, submarine shallow stratigraphic structure detection profile, spatial gravity anomaly plan and profile, geomagnetic anomaly (ΔT) plan and profile, seismic profile, mineral resources assessment map, regional geological structure map, etc.

4.6.3 Survey report

The contents of survey report include:

a) Preface. This part introduces (1) the source, objective and task of the survey; (2) the scope and location of the measured sea area; (3) the content and the workload of the survey; (4) external and internal working hours and working conditions, etc.

b) Marine survey and data processing. Describing the working methods of the maritime survey, the layout of the survey lines, the performance and indicators of the instrument and equipment system, the selection of the observation system and its working conditions, the navigation positioning system and its accuracy, the quality of the original data, the method of data collation, the accuracy of the results, etc.

c) Data analysis and interpretation. Including the data analysis methods and its basis, the distribution characteristics and regular patterns of each factor and the comprehensive analysis, etc.

d) Geological environment and geological structure analysis and mineral resources evaluation.

e) Conclusions and suggestions

Table 1 The main technical requirements of the survey

Survey project	Scale	Main line spacing/km (cross-line spacing ×Main line spacing)[a]	Navigation and positioning requirements	Line deviation/line spacing%	Accuracy (ε)[b]
Marine bottom sediment survey	1:1,000,000	30×30	DGPS	–	–
	1:500,000	15×15			
	1:200,000	10×10			
	1:100,000	5×5			
	1:50,000	1×1			
Seabed shallow stratigraphic structure detection	1:1,000,000	≤40×(5)	DGPS	<20	–
	1:500,000	≤20×(5)			
	1:200,000	≤10×(5)			
	1:100,000	≤5×(5)			
Marine gravity survey	1:1,000,000	≤20×(2.5~5)	DGPS	<20	≤3×10⁻⁵m/s²
	1:500,000	≤10×(2.5~5)			≤3×10⁻⁵m/s²
	1:200,000	≤5×(2.5~5)			≤2×10⁻⁵m/s²
	1:100,000	≤2.5×(5)			
Marine geomagnetic survey	1:1,000,000	≤20×(2.5~5)	DGPS		≤4nT
	1:500,000	≤10×(2.5~5)			≤4nT
	1:200,000	≤5×(2.5~5)			≤2nT
	1:100,000	≤2.5×(5)			≤2nT
Marine seismic survey	1:1,000,000	≤20×(5)	DGPS	<20	–
	1:500,000	≤10×(5)			
	1:200,000	≤5×(5)			
	1:100,000				
[a] Main line spacing lies before "×", cross-line spacing lies after "×", the number in the brackets represents the mutiples of main line spacing. [b] See the calculation of the value of accuracy (ε) in 5.1, 9.1 and 10.1.					

4.7 Materials filing

Materials that should be filed include:

a) Survey duty book or contract, power of attorney, etc.

b) Project demonstration report, technical design, program report and its approval comments.

c) Project implementation plan, station table, survey line layout map, etc.

d) Original records of investigation, experiment, test and analysis.

e) Data report and the description of the calculation and analysis results.

f) Various charts, illustrations (including base map), photos and text descriptions.

g) Voyage report and thematic summary report.

h) Survey report and the book of results appraisal and deliberation.

i) Tables of subject members and fund settlement.

The above mentioned should be filed both in paper format and electronic format.

The requirements for materials filing, materials quality and results acceptance are specified in GB/T 12763. 1.

5 The benthonic terrain survey

The benthonic terrain survey is mainly carried out by multi-beam sounding system, single-beam echo sounder and side-scan sonar, supplemented by shallow stratigraphic section, single-channel earthquake and geological sampling. The requirements for the technical indexes, instrument detection, maritime survey, data processing and topographic and geomorphic map compilation in submarine topography survey are shown in GB/T 12763.10.

6 Marine bottom sediment survey

6.1 Marine bottom sediment sampling

6.1.1 General requirements

General requirements for marine bottom sediment sampling are as follows:

a) When sampling bottom sediment, researchers should firstly measure the water depth, then take sample of surface sediment, and finally take sample of columnar sediment.

b) When sampling in deep sea, researchers should respectively position twice when the survey vessel reaching the station and the sampler reaching seabed.

c) Researchers should make sample collection meet the required quantity and keep the original state as far as possible.

d) Generally, the collected samples should be timely preserved in cryopreservation.

6.1.2 Bottom sediment surface sampling

6.1.2.1 Sampling method

Sampling bottom sediment samples generally by way of mussel-type sampler, box-type sampler, multi-tube sampler, self-return or trawl sampling methods.

Mussel-type sampler is used under normal circumstances. The ocean may be appropriate to use self-return cableless sampler. The box-type sampler is applicable for samples that have special requirements (such as large, original sample, etc.). Trawl is applicable for samples that are composed of rock, gravel or coarse debris material.

6.1.2.2 Sampling requirements

The samples shall be of a certain quantity, and the sediment shall not be less than 1000g. The station shall be regarded as empty sampling station if the sediment was less than 1000g. The number of empty sampling stations in the survey area shall not exceed 10% of the total number of stations. When using trawl, researchers should increase the strength of the network and the load capacity of the winch rope as much as possible to facilitate access to samples.

6.1.3 Bottom sediment columnar sampling

6.1.3.1 Sampling method

Geological columnar sampling is often carried out using gravity, gravity piston, vibration piston and shallow drilling, etc.

6.1.3.2 Sampling requirements

Sampling requirements are as follows:

a) Columnar sampling is not applicable for bottom sediments composed of bedrock or coarse sediment.

b) Column sampling tube is 300 ~ 600kg in weight. The length of the columnar sample is not less than 150cm.

c) The number of columnar sampling stations in the continental shelf should account for more than 1/10 of the total number of surface sampling stations. The number of columnar sampling stations in the oceanic sea area should account for 1/15 of the number of surface sampling stations.

d) Samples should be marked in different layers the order cannot be reversed up and down.

e) When splitting the sample, researchers should observe the integrity of the sample on the section to prevent contamination and damage to the sample.

6.1.4 Requirements for suspended sediment sampling and analysis

6.1.4.1 Sampling method

Suspended sediment collection is generally carried out by horizontal water sampler, reverse water sampler or Nansen water sampler, etc. The water level is determined according to the water depth or investigation requirements. Generally, three layers are required in offshore area which are divided into surface, middle and bottom.

6.1.4.2 Sample analysis requirements

Sample analysis requirements are as follows:

a) It is required that the water extraction quantity is $2000cm^3$ on the high seas and shall not be less than 1000cm3 offshore and about 500cm3 in the estuary area of high sediment concentration.

b) Filter membranes should be pre-dried, weighed and numbered. Researchers should use the same balance with a sense of 0.0001g in each step needed weighing.

c) Suspension analysis requires the calculation of sediment content per unit volume of seawater.

d) Use an automated particle size analyzer to determine the percentage of

granular fraction of sediment.

e) When the biological or organic matter is to be measured, half of the sample is taken for loss on ignition analysis. Burn the sample at 500 °C for 2 hours to calculate the loss on ignition.

6.2 Field description and process of bottom samples

6.2.1 General requirements

The general requirements for field description and process of bottom samples are as follows:

a) The sample shall be immediately described after being taken from the seabed to the ship's deck;

b) The project and content of sample site description should be straightforward and tabular, and the description record should be written in pencil;

c) When sampling and handling samples, attention should be paid to the hierarchy, structure and representativeness. All samples should be carefully registered, marked and not confused.

6.2.2 Sample site description contents

6.2.2.1 Color, smell, thickness

6.2.2.1.1 Color

Observe and record the color change of the sample surface and profile. The secondary additional color and adjective should be in front of the dominant primary color when giving the color name.

6.2.2.1.2 Smell

After sampling, immediately identify if there is hydrogen sulfide or other odor and its strength.

6.2.2.1.3 Thickness

The depth of the sampling tube inserted into the seabed and the actual sampling length and the stratified thickness are included in the table.

6.2.2.2 Consistency and viscosity

6.2.2.2.1 Consistency classification

The classification of consistency for sediment field description can be divided into the following three categories:

a) Flowing, the sediment can flow;

b) Semi-flowing, the sediment can flow slightly;

c) Soft, sediment cannot flow;

d) Dense, fingers can be inserted with strength;

e) Slightly consolidated, hard to insert with finger but can be cut open with a knife.

6.2.2.2.2 Viscosity classification

The classification of viscosity for sediment field description can be divided into the following three categories:

a) Strong viscosity, easy to stick hand, strong plasticity;

b) Weak viscosity, slightly stick hand, plastic;

c) Non sticky, non stick hand, not plastic.

6.2.2.3 Material composition

a) Make a rough classification of the sorting characteristics of sediment according to the grain size standard (see appendix A simplified method)

Excellent sorting, single advantage grain content of more than 75%;

Good sorting, a single dominant grain content of 50% to 75%;

Poor sorting, a single dominant grain content of 25% to 50%;

Very poor sorting, a single dominant grain content of less than 25%;

b) Name the sediment on-the-spot based on the sediment color and particle size. The color name should be in front of the grain size name when naming the sediment;

c) Debris, gravels, tuberculosis, clumps and biological components should be given special description. Researchers should identify the name of the rock, its shape size, color, roundness (sharp edges and corners, sub-angular, rounded), cemented material composition, as well as biological species, quantity on-the-spot.

6.2.2.4 Sediment structure

The structure of the sediments is described as follows:

a) Characteristics of sediment particle arrangement, cementation and combination;

b) Stratification, interlayer variation and bedding characteristics;

c) Biological activity traces and disturbance status.

6.2.2.5 Others

Typical and special geological phenomenon should be sketched, photographed, exposed or shot X-ray film.

6.2.3 Sample site treatment

6.2.3.1 Sampling analysis

The requirements for sampling analysis are as follows:

a) Researchers should determine the pH value, E_h value, Fe^{3+}/Fe^{2+} ratio, relative density and capacity immediately after the site description;

b) Particle size analysis, mineral identification, physical and mechanical properties determination, paleontology identification, chemical analysis, paleomagnetism and dating should be carried out in the land laboratory;

c) Samples should be taken where there are lithological changes when dividing the columnar samples. Sampling spacing shall be not more than 50cm there is little change in lithology.

d) Trawl samples shall be sampled separately according to lithology or biological type and sent to the laboratory for rock and mineral or biological identification.

6.2.3.2 Sample Registration and Preservation

The following is sample registration and preservation requirements:

a) Labeling the bottle(bag) containing samples, and recording the numbers of sample bottles and boxes into the scene description form, putting the labels on the location of taking samples of sample column, its serial number is same as the bottle(bag).

b) Sealing the samples which has been taken.

6.3 The Grain Size Analysis of Sediment

6.3.1 Technique Index

The following is the main technique requirements of the Grain Size Analysis:

a) The grain grade scale uses Uden-Windward's geometric φ grade scale(see Appendix A);

b) The interval of sieve analysis method is 0.5φ,you can refine if necessary; the interval of precipitation method is 1φ;

c) The sediment coarse part need to be sieved to insure the mass fraction of initial grain grade is less than 1%(except big gravel);

d) Adopting Focke-Worde grade parameter formulation(1,2,3,4) to calculate the grade parameters;

e) Calculating each grade mass fraction of grade parameters, and reading them from the cumulative relative frequency curve;

f) Sediment classification and name adopt Shepard's triangle graphic method of sediment particle size(see Appendix D, Figure D.1) or Focke-Worde classification and name method; Deep-sea sediment classification and name adopt triangle graphic method of deep-sea sediment(see Appendix D, Figure D.2).

6.3.2 Analysis Methods

In general, the analysis of sediment grain size use sieve analysis method and precipitation method(pipette method), that is the synthesis method. The sieve analysis method is suitable for the ones whose grain size is small than 0.063mm, and the precipitation method is suitable for the others. When the matter whose grain size is big than 0.063mm is more than 85% or the matter whose grain size is small than 0.063mm is more than 99%, you can choose sieve analysis method or precipitation method alone. Before you use Automated particle size analyzer(laser particle size analyzer) to analysis sediment grain size, you must compare its results with results obtained from the synthesis method, the sieve analysis method and the precipitation method and the comparison is up to standard.

6.3.2.1 The Sieve Analysis Method

The following is the procedure:

a) Stirring the samples uniformly, taking samples according to quartering, and the sample mass is estimated on the basis of Table 2;

b) Putting the analysis samples three hours at 105℃ in dry oven after drying, then putting it in dryer for 15-20 minutes, then weighing on the scales with sensitive quality 0.001g.

c) Immigrating the samples into glass cup and add into distilled water, then add into $20cm^3$ $[NaPO_3]_6(0.5mol/dm^3)$. Soaking 12 hours to make the sample fully dispersed;

d) Pouring the analysis samples into small sifter(0.063mm), Repeated washing with distilled water, making material(<0.063mm) completely flushed into the measuring cylinder, and doing sieve analysis of the material(>0.063mm) after drying and weighting;

e) Fine sieving for 15 minutes using sifter with 0.5φ's aperture interval according to top-down process, drying each grain grade and weighing them on the scales with sensitive quality 0.0001g , calculating their mass fraction.

Table 2 The Sampling Quality Estimating Table of Grain Size Analysis

Max grain diameter/mm	Min sampling amount/kg	Max grain diameter/mm	Min sampling amount/kg
25	10	6	0.5
19	5	5	0.25
13	2.5	3	0.1
9	1	0.07	0.01

6.3.2.2 The Precipitation Method

The following is the procedure:

a) Washing d) of the sieve analysis method into the measuring cylinder and attenuating the material(<0.063mm) to 1000 cm^3, and reading the suspension temperature before suction fluid;

b) Stirring(60r/min) uniformly using stirrer for 1 minutes, lifting the stirrer

gently in the final seconds, the setting is starting to calculate from this moment, you can depth and time of the suction fluid from Appendix C;

c) 15 seconds before suction fluid, placing the tube slightly in specific depth of suspension, you should suck 25 cm^3 suspension fluid uniformly and accurately in 20 seconds.

d) Weigh and dry the sucked suspension in small beaker, and calibrate the mass fraction of each grain grade.

6.3.2.3 Laser method

The steps of laser method are as follows:

a) Take a few grams of sediment samples and place them in a glass, add pure water and 5 cm^3 [NaPO$_3$]$_6$ of 0.5mol/dm^3.

b) Soak the sample for 24h and stir gently every 8h to allow the sample to be fully dispersed.

c) Pour all the soaked samples into the laser sample tank, add ultrasonic vibration and high-speed centrifugal to make the sample fully dispersed again.

d) Calibrate the mass fraction of each particle size.

e) The error of the analysis result should be less than 3, and the opacity should be less than 30.

f) Calculate particle-size parameters.

6.3.2.4 Error testing of particle size analysis

The index of error testing of particle size analysis is shown in Table 3.

Table 3 The allowable error range of particle size analysis

analysis method	internal examination proportion/%	correction factor	average particle size(Mz)	sorting coefficient(σ_i)
comprehensive method	20~30	0.95~1.05	0.40φ	0.3φ
sieve method	10~20	0.99~1.01	0.15φ	0.1φ
sedimentation method	20~30	0.95~1.05	0.40φ	0.3φ
laser method	5~10	0.99~1.01	0.15φ	0.1φ

When a few samples are not in compliance with the index in Table 3, the sample should be redone.

6.3.3 Materials compilation

6.3.3.1 Particle size standard

The Uden-Wentworth grain size scale is adopted in this book. The exchange relation between grain size and value φ is shown in appendix B (φ-millimeter conversion table).

6.3.3.2 Classification and naming of sediment particle size

Shepard's classification of clastic sediments is generally adopted in sediment classification and naming (see appendix D, Figure D.1). Besides, Folk-Walker classification of clastic sediments is also applicable in this book. A small amount of gravel, shell, coral, nodules, and clumps which are not involved in particle size analysis, should be described in words or be marked with the corresponding symbols when compiling the sediments type map.

For the classification and naming of sediments in deep-sea areas, triangulation classification can be used (see appendix D, Figure D.2). Triangulation classification divides the deep sea sediments into 26 kinds. The specific content indexes of clay, calcareous organisms, siliceous organisms of various sediments are shown in Appendix D, Figure D.2.

6.3.3.3 Grain size parameter calculation

Grain size parameters are calculated using the Folk and Ward formula:

$$M_z = \frac{\varphi_{16} + \varphi_{50} + \varphi_{84}}{3} \quad\quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(1)$$

In the formula:

M_z—— average grain size, measured in mm;

φ_{16}、 $\varphi_{50}\cdots\cdots$—— the value φ corresponding to the 16%, 50%$\cdots\cdots$on the probability cumulative curve, measured in mm.

$$\sigma_i = \frac{\varphi_{84} - \varphi_{16}}{4} + \frac{\varphi_{95} - \varphi_5}{6.6} \quad\quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(2)$$

In the formula:

σ_i—— sorting coefficient

φ_{16}、 $\varphi_{84}\cdots\cdots$—— the value φ corresponding to the 16%, 84%$\cdots\cdots$on the probability cumulative curve, measured in mm.

$$S_{ki} = \frac{\varphi_{16} + \varphi_{84} - 2\varphi_{50}}{2(\varphi_{84} - \varphi_{16})} + \frac{\varphi_5 + \varphi_{95} - 2\varphi_{50}}{2(\varphi_{95} - \varphi_5)} \quad\quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots(3)$$

In the formula:

S_{ki}—— eccentric atate

φ_{16}、φ_{50}······—— the value φ corresponding to the 16%, 50%······on the probability cumulative curve, measured in mm.

$$K_g = \frac{\varphi_{95} - \varphi_5}{2.44(\varphi_{75} - \varphi_{25})} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(4)$$

In the formula:

K_g—— kurtosis

φ_{16}、φ_{50}······—— the value φ corresponding to the 16%, 50%······on the probability cumulative curve, measured in mm.

Determining the degree of grain size sorting according to the results from formula (1) and formula (2) and classifying the grain size sorting degree according to Table 4.

Table 4 grain size sorting degree

sorting degree	σ_i
excellent sorting	<0.35φ
good sorting	0.35φ~0.71φ
middle sorting	0.71φ~1.00φ
poor sorting	1.00φ~4.00φ
extremely poor sorting	>4.00φ

6.4 Identification of bottom sediment minerals

6.4.1 Technical index

The main technical indexes of identification of bottom sediment minerals are as follows:

a) Grain size ranges from 0.25mm~0.125mm or 0.125mm~0.063mm is suitable for detrital minerals qualitative and quantitative identification.

b) The number of detrital mineral particles counted in the quantitative calculation shall not be less than 300, and the mass fraction of the mineral should be calculated.

c) When the valuable minerals account for more than 1/4 of the heavy placer mineral cutoff grade, researchers should attach great importance and circle the abnormal point.

d) 0.002mm is generally used when the particle size of clay minerals is less than 0.004mm. Semi-quantitative analysis requires that identification reaches to family and double sampling error should be less than 20%.

e) When collected gravel or bedrock samples, researchers should choose the representative sample for thin section identification to identify the name of the rock except for the naked eye identification.

6.4.2 Detrital mineral identification

6.4.2.1 Sample preparation

When identifying the detrital mineral of bottom sediment, researchers generally directly choose the needed grain size to prepare the sample after the grain size identification.

6.4.2.1.1 Sample separation

The steps of sample separation are as follows:

a) Sample separation is carried out by heavy liquid method or dishwashing method.

b) If the surface of the mineral particles carries with iron or clay film, researchers should put the sample and into the triangle beaker and keep boiling for 1h with sodium oxalate solution [ρ ($Na_2C_2O_4$) = 2 g/ dm^3].

6.4.2.1.2 Requirements for sample separation

Requirements for sample separation are as follows:

a) The sample is separated and weighed using a balance with sensitivity of 0.001g.

b) The amount of the separated sample is generally not less than 10 g, and if it is more than 10 g, reduction of the sample should be performed.

c) If the light and heavy minerals do not meet the minimum requirements for mineral quantification (300 tablets) after separation of the sample, researchers should take again the sample of the same grain size for separation.

d) After the separation of minerals, it is required that there is no heavy minerals in light minerals and light minerals account for no more than 10% in heavy minerals.

6.4.2.2 Analysis and identification

6.4.2.2.1 Qualitative analysis of minerals

The requirements for the qualitative analysis of minerals are as follows:

a) If the sample weight is less than 0.4g, the whole sample should be observed and identified. If more than 0.4g, reduction of the sample should be performed with quartation method or band piecewise method.

b) Name the minerals and describe the color, crystallinity, size, shape, structure, transparency, roundness, inclusions and weathering of the minerals.

c) When the minerals cannot be identified using binocular steroscope, it is applicable to use oil immersion method, trace mineral chemical identification method, light, spectrum, X-ray and electron probe method, etc.

d) The identification results are debited in the detrital mineral identification table.

6.4.2.2.2 Quantitative analysis of minerals

The requirements for the quantitative analysis of minerals are as follows:

a) After qualitative analysis of minerals, quantitative calculation is carried out using striped particle counting or visual method under binoculars or polarizers.

b) When doing quantitative analysis, light minerals and heavy minerals should be counted 300 ~ 500 particles respectively. In the quantitative determination of light minerals, potassium feldspar and plagioclase should be separately counted. Carbonate calcite, aragonite and shell particles should be counted separately as well.

c) Calculate the mass fraction of each mineral in light and heavy minerals. The formula is:

$$\eta = \frac{R}{Q} \times 100 \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5)$$

In the formula:

η ——mineral particle mass fraction, %;

R—— the number of mineral particles;

Q—— the total number of calculated mineral particles.

6.4.2.3 Materials collation

The requirements for materials collation are as follows:

a) Separately collate the records, tables and calculation results of the qualitative and quantitative analysis of the minerals and compile detrital mineral identification report.

b) Compile the light and heavy mineral mass fraction distribution map, single mineral mass fraction distribution map, mineral combination zoning map, sample station map according to the requirements.

c) Compile the identification report.

6.4.3 Identification of clay minerals

6.4.3.1 Sample preparation

6.4.3.1.1 Sample separation and purification

The requirements for sample separation and purification are as follows:

a) Weigh 50 ~ 100g sediment samples, add distilled water and stir into 1000cm^3 suspension, according to Stokes settlement law, take the desired particle size with a straw and repeat several times until get 5g ~ 7g dry clay.

b) Samples for X-ray diffraction, differential thermal, and electron microscope analysis were dried in water bath with 50 °C. Samples for infrared absorption spectrum and chemical element analysis should be dried in an oven below 150 °C.

6.4.3.1.2 Sample processing and thin section making.

6.4.3.1.2.1 The processing and section making of samples for X-ray diffraction

The batch of samples for X-ray diffraction analysis are required to be made three different kinds of oriented thin sections.

a) Take 35mg ~ 40mg from each sample and remove iron and organic matter and make oriented thin sections after magnesium-glycerol saturation processing or ethanol saturation processing.

b) Take 10% of the number of samples, each take 35mg ~ 40mg and remove iron and organic matter and make natural oriented sections.

c) Take another 10% of the number of samples, each take 35mg ~ 40mg and remove iron and organic matter. Soak the sample with 6mol/dm^3 HCl solution and heat it to 80℃ for 30 min.

The slide of the oriented sections is 3.3cm×4.3cm glass or ceramic chip. Dry the section naturally and place it in a desiccator stored in calcium nitrate and test after 24h.

6.4.3.1.2.2 The processing and section making of samples for Infrared absorption
spectrum analysis

Weigh 1mg ~ 1.5mg dry clay and 200mg potassium bromide (KBr) and mix and press them

into section and test immediately on the machine.

6.4.3.2 Sample identification

6.4.3.2.1 Qualitative analysis

The qualitative analysis method for clay minerals are as follows:

a) X-ray diffraction analysis is the main method for qualitative analysis. Differential thermal, infrared absorption spectroscopy, electron microscopy and can energy spectrum analysis can also be used if appropriately sampled to improve the accuracy of qualitative analysis.

b) The same batch of samples should be tested under the same conditions.

c) Compare the scanning map obtained from the analysis with the relevant data to determine the name of the clay mineral and the non-clay mineral components at the same time.

6.4.3.2.2 Semi-quantitative analysis

The semi-quantitative analysis method for clay minerals are as follows:

a) Determine the "weight factor": Montmorillonite(doo_1) is 4; Illite (doo_1) is 1; Chlorite (doo_4) is 1.75; Kaolinite (doo_2) is 1.75. The average weight factor value of the composition is used when it is mixed layer clay mineral.

b) The amount of each clay mineral peak height intensity (peak to the background line distance) is measured based on the X ray diffraction spectra processed by magnesium – glycerol. The reciprocal of the weight factor is by the percentage of the peak high intensity value, and the sum of the high intensity values of the weighted peak, corresponding to the mass fraction of the mineral.

c) The formula for calculating the sum of the weighted peaks of clay minerals in the sample is:

$$w = \frac{1}{4}h_m + h_i + \frac{1}{2.5}h_{(c+k)} + \frac{1}{2.5}h_{(m+i)} + \frac{1}{2.5}h_{(c+i)} + \cdots \qquad \cdots\cdots\cdots\cdots\cdots(6)$$

In the formula:

ω —— the sum of the weighted peaks of several clay minerals in the sample, measured in cm;

h_m—— the peak height of montmorillonite, measured in cm;

h_i—— the peak height of illite, measured in cm;

$h_{(c+k)}$——the compound peak height of chlorite and kaolinite, measured in cm;

$h_{(c+i)}$——the compound peak height of chlorite and illite, measured in cm;

$h_{(m+i)}$——the compound peak height of montmorillonite and illite, measured in cm;

The percentage of the each item of the right side of formula(6) with ω represents the mass fraction of the corresponding mineral.

d) 1/4 min slow scanning must be carried out to get the peak height of chlorite(doo_4) and kaolinite(doo_2) to calculate the mass fraction of chlorite and kaolinite. The formula for calculating the mass fraction is as follows:

$$H_{(c+k)} = h_k + \frac{1}{1.75}h_c \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (7)$$

In the formula:

$H_{(c+k)}$——the sum of weighted peak height of chlorite(doo_4) and kaolinite(doo_2), measured in cm;

h_k—— the peak height of kaolinite, measured in cm;

h_c—— the peak height of chlorite, measured in cm.

$$w_k = \frac{h_k}{H_{(c+k)}} \times w_{(c+k)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (8)$$

In the formula:

ω_k—— the mass fraction of kaolinite, %.

H_k—— the peak height of kaolinite, measured in cm;

$H_{(c+k)}$——the sum of weighted peak height of chlorite(doo_4) and kaolinite(doo_2), measured in cm;

$\omega_{(c+k)}$——the sum of the mass fraction of chlorite(doo_4) and kaolinite(doo_2);

$$w_c = w_{(c+k)} - w_k \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (9)$$

In the formula:

ω_c—— the mass fraction of chlorite, %;

$\omega_{(c+k)}$——the sum of the mass fraction of chlorite and kaolinite;

ω_k—— the mass fraction of kaolinite, %.

6.4.3.3 Data collation

The requirements for the data collation are as follows:

a) Combine the original data into one volume;

b) Fill in the clay mineral analysis report;

c) Draw the station map, single mineral mass fraction distribution map, clay mineral mass fraction combination histogram, clay mineral combination zoning map, clay mineral columnar distribution map in accordance with the requirements.

d) Compile the clay mineral identification analysis report.

6.5 Testing of physical and mechanical properties of sediments

6.5.1 Technical indexes

The main technical indexes of the testing of physical and mechanical properties of sediments are as follows:

a) The tested soil samples must be undisturbed and have no water loss.

b) A set of samples are about 25cm-30cm in length and 6cm-8cm in diameter.

c) Water content, the relative density of undisturbed soil, cross shear strength and natural adhesion should be tested in the field determination as far as possible.

6.5.2 Water content test

6.5.2.1 Test method

The test method for water content is:

a) Take 15g-30g of the representative sample and put it into the weighing box. Weigh the sample with a balance with sense of 0.01g after covering the lid.

b) Unpack the lid and put the sample into the oven with the box and dry to constant weight at a temperature of 100 ℃ ~ 105 ℃.

c) After drying the sample, put it into the dryer to cool to constant temperature, then cover the lid and weigh.

6.5.2.2 The formula for calculating the water content

$$w = \left(\frac{m_{\mathrm{w}}}{m_{\mathrm{d}}} - 1 \right) \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (10)$$

In the formula:

ω—— water content, %；

m_w—— mass of wet (undisturbed) soil, measured in g;

m_d—— mass of dry soil, measured in g.

6.5.3 Test of relative density of undisturbed soil

6.5.3.1 Test method

The test method for the relative density of undisturbed soil is:

a) Cut the original soil samples to 0.3cm ~ 0.5cm thicker than the height of the ring knife. The ring knife is coated thin layer of Vaseline and is put on the soil samples. The center of the knife should be aimed at the center of the soil sample;

b) Press the ring knife vertically and cut off external soil samples with steel wire saw while pressing until the soil sample extends out of the ring knife. Scrap the redundant soil at the both ends of the knife wipe the knife clean. Weigh the soil sample with a balance with a sense of 0.01g.

c) Choose the representative sample to determine the water content.

6.5.3.2 The formula for calculating the undisturbed soil density and dry undisturbed soil density

$$\rho = \frac{m_w}{V} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (11)$$

In the formula:

ρ—— undisturbed soil density, measured in g/cm^3;

m_w—— the mass of the wet soil, measured in g;

V——ring knife volume, %.

$$\rho_d = \frac{\rho}{1 + 0.01w} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (12)$$

In the formula:

ρ_d—— dry undisturbed soil density, measured in g/cm^3;

ρ—— undisturbed soil density, measured in g/cm^3;

ω——water content, %.

6.5.4 Test of the relative density of the soil sample

The relative density of the soil is the ratio of the mass of the soil particles dried to constant weight at 100 °C to 105 °C and the mass of pure water at the same volume of 4 °C.

6.5.4.1 Test method

The test method for the relative density of the soil sample is:

a) Grind and disperse the dried soil sample and sieve it with sieve of 2mm ~ 5mm diameter. Take 15g of the representative sample and put it into the drying pomp and cool the sample in the dryer cooling and finally weight the sample.

b) Add a neutral solution into the pycnometer to the half and put it into the vacuum cylinder for about 1h to 2h until no bubbles escape from the suspension.

c) Add neutral liquid with a dropper to the proportion of the bottle after the suspension is cleared. Cover the lid to let the excess neutral solution escape from the cork capillary. Measure the neutral solution temperature in the bottle after drying and weighing.

6.5.4.2 The formula for calculating the relative density

$$G_{\mathrm{s}} = \frac{m_{\mathrm{d}}}{m_1 + m_{\mathrm{d}} - m_2} G_{kt^\circ} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (13)$$

In the formula:

G_s—— the relative density of soil

M_d—— the mass of dry soil, measured in g;

M_1—— the total mass of neutral solution and bottle, measured in g;

M_2—— the total mass of neutral solution, bottle and soil, measured in g;

G_{kt°—— the relative density of t℃ neutral solution (The relative density of the neutral solution is pre-drawn with temperature changes).

6.5.5 Adhesion test

6.5.5.1 The test method for natural adhesion

The test method for natural adhesion is:

a) Cut the homogeneous soil sample into a cuboid which is 5cm×5cm×5cm and put it on the base of the adhesive meter after leveling the sample surface.

b) Adjust the meter base to make the sample contact with stick hammer. Add the appropriate amount of pressure to make the stick hammer and the sample in full contact, then gently remove the pressure (to avoid touching the sticky hammer).

c) Adjust the adhesion meter to balance both ends and carefully add the steel ball or

weight to the other end of the adhesive meter until the stick hammer leaves the sample.

d) Weigh the mass of the steel balls using a balance with a sense of 0.01g and determine the water content of the sample.

6.5.5.2 The test method for the maximum adhesion

The test method for the maximum adhesion is:

a) Dry and grind the soil sample and sieve it with sieve of 0.5mm diameter. Take 200g of the sieved sample and put a small amount of distilled water in the soil, stir evenly, cover the wet cloth and stand 12h.

b) Mix the soil thoroughly with soil knife and test whether the soil sample sticking soil knife, if not, add a small amount of distilled water and mix thoroughly until the soil samples began to stick the soil knife.

c) Take part of the sample densely fill the test cup, and gently tap on the table to exclude the air in the sample. Flatten the sample surface and put it on the instrument base and measure the adhesion and water content according to the measurement step b), c), d) of natural adhesion.

d) Drain the soil in the test cup and mix it with the soil samples in the soil plate. Add $2cm^3 \sim 3cm^3$ distilled water to stir and repeatedly determine the adhesion and water content until the required adhesion changes from small $\rightarrow$ large $\rightarrow$ small, about 5 or more adhesive data.

6.5.5.3 The calculation of natural adhesion and the determination of maximum adhesion

a) The formula for calculating the natural adhesion is:

$$f_0 = \frac{mg}{10A} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (14)$$

In the formula:

f_0—— natural adhesion, the unit is kPa;

m—— the mass of steel balls, the unit is kg;

A—— the area of stick hammer, the unit is cm^2;

g—— local gravity acceleration, the unit is m/s^2.

b) The determination of maximum adhesion

According to the natural adhesion calculation method, the viscous force of soil under different water content is calculated. Take the water content as the abscissa and take the adhesion as the ordinate to build the relation between them. The highest point of the curve is the maximum adhesion f and its corresponding water content W_f.

6.5.6 Determination of compressive strength

6.5.6.1 Compressive test

The method is:

a) Cut the soil sample with a ring cutter on the compression apparatus (see the process on the determination of the density of the undisturbed soil) and determine the undisturbed soil density and water content.

b) Put a wet filter paper up and down the sample and put the knife together on the permeable stone which is in the compressed container and carefully install the retaining ring, permeable stone and pressure plate and put the compression container in the center of the pressurized cabinet.

c) Adjust the scale so that the pointer reading is a certain value.

d) Load compression step-by-step for 24h, the compression stability for the last 1h does not exceed 0.05mm and then multiplied by the next load. the general compression test is to 0.4kPa so far and high-pressure compression test is to 3.2kPa so far.

e) At the end of the compression test, the water content of the compressed sample is measured.

6.5.6.2 Calculation of the relative indexes of compressive strength

a) The calculation of the parameters of compressive strength sees appendix E.

b) Take the pressure p as the abscissa and take the settlement s or the porosity ratio e as the ordinate to draw the relation curve between unit settlement and pressure or the relation curve between porosity ratio and pressure.

c) Draw the e-log$p$ curve and find the initial consolidation pressure P_c.

6.5.7 Penetration strength determination

6.5.7.1 Small penetration strength test

a) Choose the appropriate penetration probe according to the hardness of the soil and connect it with the penetration meter.

b) Align the penetration probe with the center of the soil sample press slowly into the sample until the probe is deeply into the soil sample; and record the maximum penetration.

c) Determine the penetration strength every 2 cm of the soil sample.

6.5.7.2 The equation to compute the strength of penetration

$$P_a = \frac{p}{A} \times 10 \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (15)$$

In the formula:

P_a---- the strength of penetration, the unit is kPa;

p----- the reading in the penetrometer, the unit is N;

A---- the sectional area of the probe of the penetration, the unit is cm^3.

Using the strength of penetration as horizontal axis, and the depth of soil sample as vertical axis, to plot the curve of changing intensity of penetration with the change of depth.

6.5.8 Measurement of shear strength

6.5.8.1 Quick shear test

The method of quick shear test is as follows:

Following the requirement of measuring undisturbed soil density, using the instrument of loop knife to cut four undisturbed soil samples as one group, and measuring the density of undisturbed soil and water content;

Putting one piece of plastic thin film on the top and bottom of four samples, separately, with the same diameter as the loop knife. Then, push the samples into porous stones of box, and add porous stone, cover clamp, steel ball and stress frame;

Roll the hand wheel, make the front end of stress-measuring ring and steel ball of the shear box contact each other, adjust the reading of stress-measuring ring to zero, (if vertical deformation is needed, install the vertical scale);

Put vertical pressure; vertical pressures on four samples are 0.05kPa, 0.1kPa, 0.2kPa and 0.4kPa, separately. The pressure can be forced in one time, or in several time until

the required pressure;

After the pressure, unplug the fixed plug of shear box, switch on the stopwatch, roll the hand wheel with an even pace of 4r/min-12r/min until the sample get damaged in 3min-5min. Every round of the wheel finished, write down the reading of stress-measuring ring, until the damage. Take out the samples immediately after the damage, and measure the water content of the shear surface.

6.5.8.2 Solidified the fast shear test

The method of solidified fast shear test is as followed:

Processes of a), b), c) in 6.5.8.1 are needed. In addition, plastic thin film used in b) need to replaced by wet filter paper. Push the four samples into four shear boxes to solidify them, separately.

Force vertical pressure to solidify. The process is same as compression experiment, but vertical pressure of every samples need to reach 0.05kPa, 0.1kPa, 0.2kPa and 0.4kPa in the end, separately. Vertical deformation of no more than 0.05mm per hour is defined as stable solidification. Then, exert horizontal shear force to shear.

If the samples are solidified on the preloading device, the stable solidification per hour still need deformation of no more than 0.05mm to do the shear after moving the samples to shear device.

6.5.8.3 Compute the strength of fast shear and solidified fast shear

The strength of fast shear and solidified fast shear are computed as followed:

Shear stress and displacement measured by directly strain-controlled shear device are calculated by the following formula:

$$\tau_i = CR \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots（16）$$

In the formula:

τ_i ------ shear stress, the unit is kPa;

C ------ calibration coefficient of stress-measuring ring, the unit is kPa/mm;

R ------the reading of stress-measuring ring, the unit is mm.

$$\Delta L = nl - R \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots（17）$$

In the formula:

ΔL ----- shear displacement, the unit is mm;

l ----- distance of shear displacement for one round of rolling hand wheel, the unit is mm, l=20∗0.01mm;

R ----- the reading of stress-measuring ring, the unit is mm;

n ----- number of revolution.

Take the shear stress as horizontal axis, and shear displacement as vertical axis, to plot four curves of relationship between τ_i and ΔL. And take the peak point of shear stress or stable value as the intensity of shearing resistance τ;

Take the intensity of shearing resistance τ as vertical axis, and vertical pressure as horizontal axis, to plot τ-P curve. This curve should be a straight line, and the dip angle is internal friction angle of soil φ, and the intercept of the straight line on the vertical axis is cohesion C.

6.5.8.4 Measurement of small size vane shear strength

6.5.8.4.1 Test of small size vane shear strength

The method of test of small size vane shear strength is as followed:

Use the knife cutting soil to cut soil sample to have a flat surface. Based on the degree of hardness of soli, choose the head of vane, and connect it with vane shear device.

Make the vane aim at the centre of soil sample. Softly force the sample into the vane until the bottom of the vane head touch the sample. Slowly turn the vane shear device, and shear the soil sample within 0.5-1min. Record the shear value on the shear device, and measure the water content and undisturbed density of soil.

6.5.8.4.2 Formula of computing vane shear strength

$$C_a = KR \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots（18）$$

In the formula:

C_a ----- vane shear strength, the unit is kPa;

K ----- calibration coefficient of head of vane, the unit is kPa;

R ----- the reading of vane shear device.

Take the vane shear strength as horizontal axis, and the depth of soli sample as vertical axis, to plot the curve of changing vane shear strength with the change of depth.

6.5.9 Co-rich encrustation and physical-mechanical properties of rock

6.5.9.1 Technical requirements

Technical requirements are as followed:

Sample of encrustation must be disturbed. The sample can be got from drilling in encrustation and the rock (samples from trawl), or be grinded into cylinder-shape. In the process of drilling and grinding, sample with man-made crevice is not allowed;

Drilled sample must have the diameter between 48-54mm, and the depth-to-diameter between 2.0-2.5. The errors of depth and diameter are no more than 0.3mm. The error of unflatness of end face is no more than 0.05mm. the end face should be perpendicular to sample axis with deviation no more than 0.25 °;

The number of samples for compressive strength and strength of extension test are 3 in one group, shear strength test are 5 in one group, and point loading strength test are 5-10in one group.

In point loading strength test, cylinder-shape sample are no less than 5 in one group. In diametral test, the length-to-diameter ratio of sample is no less than 1.0, and in axial test, the distance of two loaded points to diameter ratio should better be 0.3-1.0. The numbers of samples with cube-shape and irregular body should be no less than 10. The length of sample should be no smaller than the distance of two loaded points;

Basically, the test of encrustation and physical-mechanical properties of rock are consistent with test of sediment, and parallel test is needed. In addition, test for relative density (specific gravity) should use the pulverizer to smash the encrustation and rock. After the smash , the encrustation and rock must go through the sieve pore with 0.25mm.

6.5.9.2 Measurement of compressive strength of encrustation and rock

6.5.9.2.1 Test for compressive strength

The method of test for compressive strength is as followed:

Put cylinder-shape sample on the center of pressure board of the test machine. Adjust the spherical seat to make the two end faces of sample and pressure board contact each other equably;

Load pressure as speed of 0.5MPa-1.0MPa on the sample until the sample get

ruptured. Record the changing status of samples during loading, and describe the shape of damage in the test.

6.5.9.2.2 Formula to compute compressive strength

$$R = \frac{P}{A} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (19)$$

In the formula:

R ---- compressive strength of the encrustation or rock, the unit is MPa;

P ---- loaded pressure value to damage the sample, the unit is N;

A ---- sectional area of sample, the unit is mm^2.

6.5.9.3 Measurement of shear strength of encrustation or rock

6.5.9.3.1 Test for shear strength

The method to test the shear strength is as followed:

Put cylinder- shape sample into shear box of test machine. Fill the gap between sample sand shear box using padding. Make sure shearing surface in the middle of gap of shearing box. The normal load and shear load should pass through the center of predetermined shearing surface. Measuring devices of the normal displacement and shear displacement should be set up symmetrically, and the number of measuring device should be no less than 2;

Load different normal stress on every sample. The maximal normal stress loaded should no less than predetermined normal stress. Read the normal displacement immediately after the load of normal stress. Read again after 5min. Then, shearing stress should be loaded.

Based on the estimated maximal shear load, load the shear stress from level 8 to level 12, and read the shear displacement and normal displacement after every load. After 5 min, read again and load next level load, until the shear failure. When the change of shear displacement is big, the level of load can be narrowed.

Make the shear load back to zero, and end the test. Describe the condition of damage of shear surface, and distribution, direction and length of striation. Measure area and fluctuation difference of shear surface, and plot the variation curve of the depth of fracture surface following shear direction.

6.5.9.3.2 Compute shear strength

The requirement for computing shear strength is as followed:

Compute the normal stress and shear stress using following formulas:

$$\sigma = \frac{P}{A} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(20)$$

In the formula:

σ ----- normal stress on shear surface, the unit is MPa;

P ----- total normal load on shear surface, the unit is N;

A ----- shear area of sample, the unit is mm^2.

$$\tau = \frac{Q}{A} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(21)$$

In the formula:

τ----- shear stress on shear surface, the unit is MPa;

Q ----- total shear load on shear surface, the unit is N;

A ----- shear area of sample, the unit is mm^2.

Plot curve of shear stress changed with the shear displacement and normal displacement. Based on the curve, record the shear stress on every stage of shear.

Based on shear stress and normal stress of every stage, plot the relation curve, and determine the shear stress parameter using coulomb formula.

6.5.9.4 Measurement of strength of extension of encrustation and rock

6.5.9.4.1 Test of strength of extension

The method for strength of extension is as followed:

Following the direction of axis, plot two loaded parallel base line through two ends of diameter of sample. Following loaded base line, use two filler strips to fix two ends of sample. (filler strip should better be the electrician veneer, which has ratio of width to diameter is within 0.08-0.1.

Put sample on the center of pressure board of the test machine. Adjust the spherical seat to make sample be loaded equably, and make sure the filler strip and sample on the same loading axis.

Load on the sample as speed of 0.3 MPa-0.5 MPa per second until the damage. Record the load of damage and phenomenon during loading, and describe condition

of damaged sample.

6.5.9.4.2 Formula to compute the strength of extension

$$\sigma_\tau = \frac{2P}{\pi Dh} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (22)$$

In the formula:

σ_τ ----- Strength of extension of Co-rich encrustation or rock, the unit is MPa;

P ------ The load of damage, the unit is N;

D ----- The diameter of sample, the unit is mm;

h----- The thickness（length）of sample, the unit is mm.

6.5.9.5 Measurement of the point-loading strength of Co-rich encrustation or rock

6.5.9.5.1 Test of point-loading strength

The method to test point-loading strength is as followed:

When doing radial test on cylindrical sample, put the sample in the circular cone of the end of the point-loading device ball. Make the up and down of cone end closely contact with two ends of diameter of sample, and measure distance between two loaded points. The minimum distance between the contact point and free end of sample should be no less than 0.5 time of distance between two loaded points;

When doing axial test on cylindrical sample, put the sample well as required above. Then, measure distance between two loaded points and width of sample perpendicular to loaded direction;

In test of cube-shape and irregular body, choose the direction of minimum size as loading direction. Put the sample well as required above, and measure distance between two loaded points and width (or average width) of minimum cross section though two loaded points. Distance from contact point to free end of sample should be no less than 0.5 time of distance between two loaded points;

Make the load stable, and break the sample in 60s. Record the breaking load, and describe the condition of breaking sample. The breaking surface should go through the whole sample and two loaded points, which can be defined as valid test.

6.5.9.5.2 Compute point- loading strength

The requirement for computing point- loading strength is as followed:

Using followed formula to compute point- loading strength:

$$I_s = \frac{P}{D_e{}^2} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (23)$$

In the formula:

I_s ----- Unrevised point- loading strength of Co-rich encrustation and rock, the unit is MPa;

P ----- Breaking load of sample, the unit is N;

D_e----- equivalence of sample diameter, the unit is mm.

In radial test, equivalence of sample diameter D_e should be computed as followed formula:

$$D_e{}^2 = D^2 \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (24)$$

In the equation:

D_e----- Equivalence of sample diameter, the unit is mm;

D ----- Separation distance between loaded points, the unit is mm.

$$D_e{}^2 = DD' \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (25)$$

In the equation:

D_e----- equivalence of sample diameter, the unit is mm;

D ----- Separation distance between loaded points, the unit is mm;

D' ----- After the penetration into the up and down of cone, the separation distance at momentary break of sample, the unit is mm.

In the axis direction of cube-shape or irregular body test, using followed formula to compute point- loading strength:

$$D_e{}^2 = \frac{4WD}{\pi} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (26)$$

In the equation:

D_e-----Equivalence of sample diameter, the unit is mm;

D ----- Separation distance between loaded points, the unit is mm;

W ----- Width (or average width) of minimum cross section though two loaded points, the unit is mm.

$$D_e{}^2 = \frac{4WD'}{\pi} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{(27)}$$

In the equation:

D_e-----Equivalence of sample diameter, the unit is mm;

D' ----- After the penetration into the up and down of cone, the separation distance at momentary break of sample, the unit is mm;

W ----- Width (or average width) of minimum cross section though two loaded points, the unit is mm.

When separation distance between loaded points is not 50mm, the computed value should be revised. When the test data are too many, and equivalence diameter have many sizes in one group, plot relation curve of $D_e{}^2$-P based on the test results. Search corresponding P_{50} value when $D_e{}^2$=2500mm^2, and use followed formula to compute point-loading strength:

$$I_{s(50)} = \frac{P_{50}}{2\,500} \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{(28)}$$

In the equation:

$I_{s(50)}$ ----- point-loading strength of sample after the size correction, the unit is MPa;

P_{50} ----- according to the relation curve of D_e—P, value of P (breaking load) when $D_e{}^2$ is 2500mm^2, the unit is MPa.

When separation distance between loaded points is not 50mm, and test data is little, method above should not be used to revise. Followed formula should be used to compute point-load strength:

$$I_{s(50)} = FI_s \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{(29)}$$

In the equation:

$I_{s(50)}$ ----- point-loading strength of sample After the size correction, the unit is MPa;

F ----- correction factor;

I_s ----- point-loading strength of Co-rich encrustation and rock without the size correction, the unit is MPa;

$$F = \left[\frac{D_e}{50}\right]^m \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{(30)}$$

In the equation:

F ----- correction factor;

D_e ----- Equivalence of sample diameter, the unit is mm;

M ----- correction index, which is determined by empirical value of same kind of Co-rich encrustation and rock. Correction index m=2(1-n), in which n is slope of relation curve of log*P* –log $D_e{}^2$.

6.5.10 data compilation

6.5.10.1 partition of engineering geological unit

Based on characteristic of mechanical property of sediment in survey area, and combining geomorphology, material composition, and structure and tectonics, divide stratum or soil which have similar characteristic as engineering geological unit and soil element.

6.5.10.2 Index statistic of physical and mechanical property

For one engineering geological unit, measured indexes of every parameter need to be counted, statistical table and scatter diagram need to be plotted, which reflect the various range of indexes. The index value can be computed directly from scatter diagram.

6.5.10.3 Measurement report

The measurement report of physical and mechanical property of sediment include aim and task, measuring item and workload, vertical and horizontal rule of physical and mechanical property of sediment in survey area, and evaluation on engineering geological condition and so on.

6.6 paleontology identification of sediment

6.6.1 Technical index

Technical index is as followed:

Base on the task, be sure the category of identification, quantitative or qualitative identification, and taxonomic unit;

Gathered samples should not be contaminated and polluted;

When handling and preparing sample, fossil should be totally separated and highly

gathered. In addition, fossil needs to have clean surface, and clear structure and ornamentation, in case fossil being damaged;

In quantitative identification, weigh should be correct, division be equal, and statistic be accurate;

The clean and soak of sample should all be used through filtered water and distilled water.

6.6.2 Analyze sporopollen

6.2.2.1 Prepare the sample

The requirement for preparing sample is as followed:

Using acid-alkali method and hydrofluoric acid washing approach and so on, to remove the calcium-material and other impurities in the sediment; using heavy-fluid which has relative density of 2.2 to centrifugalize cleaned sample at least two times. After this, weigh the sample.

After total flotation, make the sample into active piece and fixed piece.

The preparation of sample should be record. The record should include original number, laboratory number, lithology, source of sample, and location, depth, wet weight, dry wet ratio, dry weight of the sample, weight after centrifugalizing, weight of every piece of sample, and handling method and so on. Followed preparation of the sample should be recorded using same requirement above.

6.6.2.2 Identification and analysis

When doing statistics on sporopollen, the magnification times should be 250-300, and be 600 when observing micro-structure. oil immersion lens should use magnification time of 1000 above. Identical numbers should be more than 200 on every sample.

During identification, mind distinguishing mixed modern re—depositional sporopollen.

The result of identification and analysis should be recorded based on number, classified name, size fraction, particle number and mass fraction.

6.6.3 Analysis on foraminifer

6.6.3.1 Preparation for sample

Firstly, measure the wet and dry ration on sample. Then, weigh and soak. Sifting after

total dispersion. The mesh size is 0.063mm. Drying and weigh part of sample on sifter for identification.

6.6.3.2 Identification and analysis

The requirement for identification and analysis is as followed:

After the division of sample, choose one part of samples to do the identification and statistics, including every sample. Usually, the number of benthic foraminifera should no less than 100, and planktonic foraminifera should no less than 300;

Except from identification and analysis, observe the condition of abrasion, break and corrosion;

As required, when doing micro-structure observation and chemical component analysis of shell, choosing representative sample to do scanning electronic micrography and photomicrography is needed.

6.6.4 Analysis of diatom

6.6.4.1 Preparing for sample

The requirement for preparing sample is as followed:

The weight of sample often is 10g, which can be more if sediment has large sand content and can be less if sediment has large silt or more lighter material.

Weigh the wet sample after drying, and compute the dry-wet ratio. Then, soak the sample again.

Remove the calcium through adding diluted hydrochloric acid. Remove organic matter through adding 30% hydrogen peroxide (or concentrated sulfuric acid.

Centrifuge the cleaned water to remove water, and add heavy-fluid of relative density 2.4 and double volume than sample's. Centrifuge for 20min as speed of 1500r/min.

Use water to dilute enriched diatom and add several drops of glacial acetic acid, and wash off the heavy-fluid.

Use sucker suck up suspension liquid of diatom already being mixed well. Put them on cover glass evenly and use Canada balsam to fix the glass.

6.6.4.2 Identification and analysis

Identify the species of diatom. Observe and describe the size, breaking condition, dissolved characteristic, compaction degree of shell, and filled minerals in shell and

so on.

The number of fossil in one sample should no less than 200. And the integrated degrees of shell should more than 1/2.

6.6.5 Analysis of radiolarian

6.5.5.1 Preparing sample

Same as preparation of diatom, such as soaking, removing calcium and organic matter and so on. Use aperture of 0.06mm to filtrate prepared sample. Dry and weigh the sample of fail to pass filtration. Method of flaking is same as diatom. Samples on every flaking need to weigh and be even without bubble.

6.5.5.2 Identification and analysis

The requirement for identification is same as 6.6.4.2.

6.6.6 Analysis of Calcareous nannofossils

6.6.6.1 Preparing samples

The requirement for preparing sample is as followed:

The sample need to identify must have size fraction of sediment less than 0.035mm;

Fetch 1g to soak. The pH of conditioning fluid need to be no less than 9.4. Add 30% H_2O_2 if removing organic matter is needed;

If the sample need to be identified under the light microscope, the preparation of flaking need to stir the dispersed sample into mud, and fetch several drops of sample onto the cover glass, and dry them by alcohol lamp or electric hot plate, and reverse the cover glass to cover on the glass slide with mounting medium;

Smear method also can be used:

Put little sample onto the glass slide using clean toothpick. Add distilled water and use toothpick stir thoroughly. Then, remove the coarse deposits and make the suspension liquid with fine-grained sediment evenly distributed on the glass slide

Dry the glass slide on the agitating heater. Use Neutral balsam to glue the cover glass onto the glass slide. Fixed slice is made.

If the sample need to be analyzed under scanning electron microscope, the fossil need to further enrich through repeatedly centrifugation, method of breaker, Method of pipette or filter paper method. In the end, mix the fossils well to get the final slice.

6.6.6.2 Identification and analysis

Use 1000 time of polariscope to identify, and at least 10 fields of vision to analyze are needed on one slice.

Use 2000 time of scanning electron microscope to identify, and classification and micro-structure are needed.

6.6.7 Analysis of ostracoda

Preparation of sample, identification and analysis are same as 6.6.3.

6.6.8 Other identification of micropaleontology

Preparation of sample, identification and analysis of Pteropoda and other mollusc micro-fossil, ichthyoliths, fish otoliths, stonewort, coral and bryozoan are same as 6.6.3.

Preparation of sample, identification and analysis of dinoflagellates are same as 6.6.2.

Preparation of sample, identification and analysis of silicoflagellate and chitinozoa are same as 6.6.4.

Preparation of sample, identification and analysis of spongy spicule are same as 6.6.5.

6.6.9 Identification of macrofauna

The identification and statistic method of mollusc and crustacean can be seen in GB/T 1273.6.

Coral, calcareous alga and bryozoan et al need to be cut into slices, and made into optical sections or slices to identify.

6.6.10 organization of data

The requirement for organization of data is as followed:

Organize the identification form, and compute relative and absolute water content;

Make position map, distribution figure of number, composite partition figure, vertical distribution figure of classification units, curve figure et al.

Write identification report.

6.7 Chemical determination of sediment

This standard only list regular measuring items and its requirement in chemical determination of sediment. Under the condition of ensuring the accuracy of analysis, the methods can be chosen

freely.

6.7.1 Technical index

Technical index is as followed:

a) The main items for chemical determination of sediment include:

In situ measurement: E_b, pH, Fe^{3+}/Fe^{2+} et al;

Indoor measurement: organic carbon, total nitrogen, carbonate, SiO_2, Al2O_3, Fe_2O_3, MgO, CaO, Na_2O, TiO_2, P_2O_5, MnO_2 and cauterant decrease et al;

b) The requirement for quality of analysis need to use standard sample method, which is inserting two or two more standard samples (domestic first level or second level) during analysis of samples. Permissibleanalytical error range can be seen in Table 5;

c) Indoor analysis should use sampling inspection, and random choose 30% samples to repeat the analysis. If more than 70% double-sample are in the permissible error range (showed in Table 5), the analysis of whole sample is qualified.

Table 5 permissible error range in chemical measurement of sediment

component	mass fraction / %	permissible error / %	component	mass fraction / %	permissible error / %
SiO₂	>50	0.7	P₂O₃	>1	0.3
	<50	0.6		0.5~1	0.2
Al₂O₃	>20	0.7		<0.5	0.1
	<20	0.5	cauterant decrease		0.5
Fe₂O₃	>5	0.5	pH		±0.3
	<5	0.3			
MgO	>10	0.6	Eₕ		10 mV
	5~10	0.5	Fe³⁺/Fe²⁺		0.2
	<5	0.4			
CaO	>10	0.6	dissolved silicon (SiO₂)	>5	0.5
	5~10	0.5		1~5	0.4
	<5	0.4		<1	0.2
K₂O	>10	0.7	carbonate (CaCO₃)	>15	1.00
	5~10	0.5		5~15	0.75
	<5	0.3		<1	0.5
Na₂O	>10	0.7	organic carbon	>5	0.5
	5~10	0.5		1~5	0.4
	<5	0.3		<1	0.3
MnO	>1	0.3	total nitrogen	>0.5	0.1
	0.5~1	0.2		<0.5	0.05
	<0.5	0.1	Cl		0.2
TiO₂	>1	0.2	FeO		0.5
	<1	0.1			

Attention: Use (A-B)/(A+B)*100%≤50% to measure the composite of less than 0.1%. A, B are two repeatedly analyzed data, seperately

6.7.2 Measurement for pH (potentiometry)
6.7.2.1 Main device

Main devices include:

a) pH meter or inometer with accuracy of 0.01;

b) glass electrode and matched saturated calomel electrode.

6.7.2.2 Reagent

Reagents include:

standard buffered solution

a) potassium biphthalate [1]$[c(KHC_8H_4O_4)=0.05\ mol/dm^3](25℃,pHs=4.003)$;

monopotassium phosphate $[c(KH_2PO_4)=0.025\ mol/dm^3]$, dipotassium phosphate $[c(Na_2HPO_4)=0.025mol/dm^3]$ (25℃,pHs=6.864);

sodium tetraborate decahydrate $|[c(Na_2B_4O_7 \cdot 10H_2O)=0.01mol/dm^3](25℃,pHs-9.182)$;

b）To make standard solution, use distilled water to boil and add 20cm^3 to cool down the solution. It also need to have electric conductivity of less than 2*10-6s/cm, and pH better within 5.6~6.0.

6.7.2.3 Main points of analysis

Main points of analysis are as followed:

a) Preheat, adjust temperature compensated, adjust zero point of device by rule. Standard buffered solution for orientation need to close to the pH of tested sediment;

b) Weigh about 20g representative fresh wet samples. Put them into 50cm^3 beaker. Add 20cm^3 distilled water, and remove hard substance, and stir into paste. Do the measurement in 30min.

c) Wash clean the electrode, use filter paper to suck up water, insert well stirred sample （soaking all bulb part of glass electrode into sample, and higher than ceramic core end of calomel electrode), read after 30min's balance, repeat until same read for the last two times, and the error should be no more than 0.01~0.02.

6.7.3 Measurement for Eh (oxidation-reduction titration)
6.7.3.1 Main device

Main devices include:

a) platinum electrode and calomel electrode;

b) other apparatuses are same as measurement for pH.

6.7.3.2 Reagent

Saturated buffer solution of quinhydrone ($C_{12}H_{10}O_4$): pH is 4.00 or 4.01.

6.7.3.3 Main points of analysis

Main points of analysis are as followed:

a) Check and revise electrode

   Use cleaned platinum electrode as indicator electrode "+", and saturated calomel electrode as reference electrode "-". Soak electrode into saturated buffer solution of quinhydrone, and measure E_h. If the difference value between measured value and theoretical value more than 5mV, platinum electrode should be changed;

b) Take 20g fresh wet sample. Simultaneously insert two pairs of electrodes which can be platinum electrode- saturated calomel electrode, or two platinum electrodes and one saturated calomel electrode (distance between two electrodes no more than 1cm) into sample. Read after balance (normally 30min), and repeat the measurement. Two close readings should be no more than 2mV~3mV, and choose average value;

c) Compute and temperature revision

   Electric potential value read from device is potential difference between E_h and calomel electrode. E_h can be computed using followed equation:

$$E_h = E_a + E_b \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(31)$$

   In the equation:

   E_b ----- Electric potential value measured from device, the unit is mV;

   E_a ----- Electric potential of saturated calomel electrode, the unit is mV, which change with temperature. Its value is 243mV at 25℃, and lower 6mV~7mV if increase the temperature for 10℃. Considering the minimum read error of E_h is 5mV, no need to revise E_h if the change of temperature is not too obvious.

6.7.4 Measurement for Fe3+/Fe2+ value (EDTA volumetric method)
6.7.4.1 Main device

Main devices include:

a) Burette, 25cm^3;

b) Transfer pipette, 15cm^3.

6.7.4.2 Reagent

Reagents include:

a) 5% (volume fraction) hydrochloric acid solution (HCl);

b) sodium acetate solution $[c(CH_3COONa \cdot 3H_2O)=3 \text{ mol}/\text{dm}^3]$;

c) sodium bicarbonate ($NaHCO_3$ solid);

d) $500g/dm^3$ ammonium persulfate solution $[(CH_4)_2S_2O_8]$;

e) $100g/dm^3$ salicylic acid solution ($C_7H_5O_3Na$);

f) EDTA disodium salt solution $[c(C_{10}H_{14}N_2O_8Na_2 \cdot H_2O)=0.01 \text{ mol}/\text{dm}^3]$.

6.7.4.3 Main processes of analysis

Main points of analysis are as followed:

a) Weigh 2g fresh wet sample, put them into 150 cm^3 conical flask, add 0.5g. Put them into 150cm^3 conical flask. Add 0.5g c) sodium bicarbonate, 60~80 cm^3 5% (volume fraction) hydrochloric acid solution, and quickly plug rubber plug with S-shape glass tube. Disperse evenly the sample, heat it under low temperature, and stay slightly boiling for 10min (strictly control the temperature). Then, cool down and clarify the sample;

b) take 15cm^3 upper clear liquid into 50cm^3 conical flask, and add sodium acetate solution to make pH= 1.5~2.5. Add 2~3 drops of salicylic acid solution indicator, and heat to 50~60℃. Then , use 0.01mol/dm^3 EDTA solution to titrate to the totally fading of grape color, and the end point is yellow color.

c) Add 3~4 drops of ammonium persulfate solution into the solution, and shake evenly to the grape color (if not, no Fe^{2+} existed). Quietly placing it for 3-5min. Heat solution of grape color showed again to 50-60℃. Then, use EDTA solution to titrate to the end point.

d) Computational formula is:

$$Fe^{3+}/Fe^{2+} = A/B \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(32^{'})$$

In the equation:

A ----- volume of consumed EDTA solution to titrate high valence iron, the unit is cm^3;

B ----- volume of consumed EDTA solution to titrate low valence iron, the unit is cm^3.

6.7.5 Measurement for silicon dioxide (alkali fusion- potassium fluosilicate volumetric method)
6.7.5.1 Main devices

Main devices include:

a) silver crucible;

b) high temperature box resistance furnace:1000-1600℃;

c) alkali burette: 25cm^3.

6.7.5.2 Reagent

Reagent include:

a) Solid potassium hydroxide (KOH);

b) 300g/dm^3 potassium chloride solution (KCl);

c) 200 g/dm^3 potassium fluoride solution (KF 2H$_2$O);

d) 50% (volume fraction) ethyl alcohol (alcohol) washing liquor, use potassium chloride to saturate;

e) Standard potassium hydroxide solution $[c(\mathrm{NaOH})=0.200 \ \mathrm{mol/dm^3}]$.

6.7.5.3 Main processes of analysis

Main points of analysis are as followed:

a) Weigh 0.1g (to the accuracy of 0.0005g) sample into silver crucible;

b) Add 2g potassium hydroxide, put it into high temperature box resistance furnace, increase the temperature to 650-700℃ for 15-30min, take it out, quickly soak it into 10cm^3 boiled hot water, add 10cm^3 concentrated nitric acid and 10cm^3 potassium chloride solution with stirring, cool down to the indoor temperature, add a little paper pulp, add 10cm^3 potassium fluoride solution to mix thoroughly, and stay for 5-10min (depend on the temperature during depositing, no more than 20min);

c) Use qualitative filter paper to filter, use ethyl alcohol (alcohol) washing liquor to wash the beaker and deposit for 3-4 times, wash away most impurities, such as dissociative acid, icon, aluminum, manganese. Put precipitate and filter paper into 200cm^3 beaker, add 10 cm^3 alcohol washing liquor, 1-2 drops of methyl red indicator, and triturate filer paper;

d) Use 50 cm^3 potassium hydroxide to neutralize quantity of dissociative acid, and use 0.1mol/dm^3 potassium chloride and potassium hydroxide to repeatedly neutralize. Add 50 cm^3 boiled water pre- neutralized, add 1 cm^3 phenolphthalein

indicator. Use standard potassium hydroxide solution to titrate until slight red color showed, at the same time, test the blank reagent;

e) Computational formula is:

$$\varpi_{SiO_2} = \frac{c_{(NaOH)}(V - V_0) \cdot F}{m} \times 100 \qquad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(33)$$

In the equation:

ϖ_{SiO2} ----- weight ratio of SiO_2 in sediment, the unit is %;

$c_{(NaOH)}$ ----- density of standard potassium hydroxide solution, the unit is mol/dm^3;

V ----- volume of consumed potassium hydroxide solution to titrate, the unit is cm^3;

V_0 ----- volume of consumed potassium hydroxide solution of blank beaker, the unit is cm^3;

F ----- 0.015, proportionable weight of SiO_2 when consume $1cm^3$ potassium hydroxide with density of 1 mol/dm^3, the unit is g.

m ----- Weight of sample, the unit is g.

6.7.6 Measurement for Al, Ca, Mg, Fe, Ti and Mn (ICP-AES method)

6.7.6.1 Main devices

Main devices include:

a) high-frequency plasma generator;

b) spectrograph;

c) microdensitometer;

d) spectrum projector.

6.7.6.2 reagent (all use analytic reagent and the second deionized water)

Standard series: make sponge iron, manganese metal, aluminum, calcium carbonate, magnesium oxide and titanium oxide into $1mg/cm^3$ solution, make mixed standard series using step by step dilution method, which can be seen in Table 6, and this series all have 2% (volume fraction) hydrochloric acid.

Table 6 Standard series   the unit is $\mu g/cm^3$

measured element	series number						
	1	2	3	4	5	6	7
Mn	0.125	0.250	0.500	0.750	1.000	2.000	3.000
Al	2.50	5.00	7.50	10.00	25.00	50.00	75.00
Mg	2.50	5.00	7.50	10.00	20.00	30.00	40.00
Ca	2.50	5.00	7.50	10.00	20.00	30.00	40.00
Ti	0.50	0.75	1.000	2.000	3.000	4.000	5.000

6.7.6.3 Main points of analysis

Main points of analysis are as followed:

a) Prepare the sample solution, use acid fusion system of hydrofluoric acid- nitric acid- perchloric acid, remove all fluorinion, no desolvation, and make 2% (volume fraction) hydrochloric acid and solution with sample density of 1mg/cm^3.

f) Based on already chosen measuring condition, do spectrography, color development, photographic fixing. Measure pure blackness value of spectral lines, and search element content on standard curve. Computational formula is:

$$w(x) = \frac{\rho(x) \cdot f(x)}{\rho_0} \times 100\% \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(34)$$

In the equation:

$\varpi(x)$ ----- weight ratio of certain element, the unit is %;

$\rho(x)$ ----- density of certain element search on working curve, the unit is $\mu g/cm^3$;

$f(x)$ ----- coefficient of oxide conversed from certain element;

ρ_0 ----- sample density, the unit is $\mu g/cm^3$.

6.7.7 Measurement for K and Na (flame atomic absorption spectroscopy method)
6.7.7.1 Main device and working condition

The main devices and working condition are as followed:

a) atomic absorption spectrophotometer;

b) K and Na hollow cathode lamp;

c) lamp current 2mA;

d) The monochromator bandpass 0.2nm;

e) Air-acetylene flame;

f) Absorb position: clear and un-bright oxidizing flame.

6.7.7.2 Reagent

Reagents include:

a) K - standard solution $[\rho_{(K_2O)} = 100 \ \mu g/cm^3]$;

b) Na - standard solution $[\rho_{(Na_2O)} = 100\ \mu g/cm^3]$;

c) Cesium chloride solution $[\rho_{(CsCl)} = 100\ mg/cm^3]$;

d) 2% (volume fraction) hydrochloric acid solution (HCl).

6.7.7.3 Synopsis of analysis

Synopsis of analysis include:

a) Prepare the sample solution: same as 6.7.6.3a;

b) Standard series: take 0, 1.0, 1.5, 2.0, 2.5, 3.0 cm^3 standard solution of $100\mu g/cm^3$ Na_2O (K_2O) into 25 cm^3 volumetric flask, separately. Then, add 1.5 cm^3 $10\mu g/cm^3$ cesium chloride, and use 2% hydrochloric acid to dilute to the scale;

c) Take 2 cm^3 1 mg/cm^3 sample solution into $10cm^3$ colorimetric tube, add 0.5 cm^3 10 mg/cm^3 cesium chloride, and use 2% hydrochloric acid to dilute to the scale;

d) Use flame atomic absorption spectroscopy method to measure sample solution and standard series solution at the same time. K_2O: $\lambda = 766.5nm$, when K content is high, use 404.4 nm absorb line to measure; Na_2O: $\lambda = 589.0nm$, when Na content is high, use 330.2nm absorb line to measure

e) Computational formula is:

$$w(Na_2O\ 或\ K_2O) = \frac{\rho}{\rho_0} \times 100 \qquad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(35)$$

In the equation:

ϖ(Na_2O or K_2O) ----- mass fraction of Na2O or K2O in sample, the unit is %;

ρ ----- searched density on working curve, the unit is $\mu g/cm^3$;

ρ_0 ----- sample density, the unit is $\mu g/cm^3$.

6.7.8 Measurement for organic carbon (elemental analyzer analysis)
6.7.8.1 Main devices

Main devices include:

a) CNH elemental analyzer;

b) ultrasonic water bath;

c) drying oven;

d) scale (accuracy is 0.1mg);

e) 20mL glass bottle (test tube or small glass bottle).

6.7.8.2 Reagent

Reagents include:

a) 1N no-carbon (or low-carbon) HCl solution:

b) Standard : choose acetanilide, light acids, sulfanilamide as standard, in which the content range of C and TN are 500 μg -800 μg, 5 μg -100 μg, separately.

6.7.8.3 Synopsis of analysis

Synopsis of analysis include:

a) Dry the sample of sediment; grind it into powder, quantitatively weigh 10mg~20mg, and use CNH elemental analyzer to measure total carbon (TC) content;

b) According to the organic carbon content in sample, weigh 50mg~100mg of one sample (Wo) into 20mL glass bottle (weigh the glass bottle with accuracy of 0.1mg), add excessive (≥2mL) 1N HCl into glass bottle. Put this acidized sample into ultrasonic water bath to vibrate for 5min and take out, and dry it under 50℃ dryer for a night;

c) Take out dry sample, and place it in the air for at least 24h until its weight up to the balance. Weigh the sample and remove the weight of glass bottle to get the final weight of sample (W_f). Grind the sample to homogenization, weigh quantitative sample and use CHN elemental analyzer to measure.

d) Compute.

Computational formula for mass fraction of organic carbon is:

$$w(Corg) = (Corg/M_1) \times (W_f/W_o) \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots(36)$$

In the equation:

ϖ(Corg) ----- mass fraction of organic carbon in sample, the unit is %；

$Corg$ ----- measured organic content, the unit is mg;

M_1 ----- weight of input sample, the unit is mg;

W_f ----- processed final weight of sample, the unit is mg;

Wo ----- initial weight of sample, the unit is mg.

Computational formula for mass fraction of total nitrogen is:

$$w(TN) = (TN/M_1) \times (W_f/W_o) \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots(37)$$

In the equation:

ϖ(TN) ----- mass fraction of total nitrogen in sample, the unit is %;

TN ----- measured total nitrogen content, the unit is mg;

M_1 ----- weight of input sample, the unit is mg;

W_f ----- processed final weight of sample, the unit is mg;

Wo ----- initial weight of sample, the unit is mg.

Computational formula for mass fraction of carbonate is:

$$w\,(CaCO_3) = \frac{(TC - Corg) \times 8.33}{W_f} \times 100 \qquad\qquad\qquad (38)$$

In the equation:

ϖ(CaCO$_3$) ----- mass fraction of carbonate (computed as CaCO$_3$) in sample, the unit is %;

Corg ----- measured organic content, the unit is mg;

TC ----- measured total carbon content, the unit is mg;

W_f ----- processed final weight of sample, the unit is mg.

6.7.9 Measurement for phosphorus (P-V-Mo yellow colorimetric method)
6.7.9.1 Main device

Main devices include:

a) Spectrophotometer;

b) Platinum crucible or teflon crucible.

6.7.9.2 Reagent

Reagents include:

a) hydrofluoric acid (HF);

b) 1:1 (volume fraction) sulfuric acid (H_2SO_4);

c) 5mol/dm^3 nitric acid (HNO_3);

d) Active carbon powder;

e) nitric acid, boiled with no dissociative nitrogen oxide, and no color;

f) color developing agent of ammonium vanadate (NH_4VO_3)- ammonium molybdate [$(NH_4)_6Mo_7O_{24}$ 4H$_2$O] ;

g) 10% (volume fraction) sulfuric acid- color developing agent mixed solution[3:2(volume fraction)];

h) Phosphorus-standard solution: 100 μg/cm^3 P$_2$O$_5$ standard solution and 10μg/cm^3

P$_2$O$_5$ standard solution.

6.7.9.3 Synopsis of analysis

Synopsis of analysis include:

a) Preparation of analyzed solution

Weigh 0.2g sample, put it into platinum crucible, moist it using some distilled water, add 1cm^3 1:1 sulfuric acid and 5~6 cm^3 hydrofluoric acid, heat and dissolve under middle temperature, shake the crucible. When being totally dissolved and have white smoke for 10min, take it down and cool it down. Wash the wall of crucible using distilled water, heat again until the white smoke totally gone, take it down and cool it down. Add 3cm^3 5mol/dm^3 nitric acid, heat to make salt dissolve (control volume be no less than 1.5cm^3), add water up to more than half volume of crucible, heat again until the white salt totally dissolved. When the color of solution is yellow, take down the crucible, ass little active carbon to fade while the sample is still hot (if organic substance and sulfide content are high, sample should be put into high temperature furnace to fire under 600~700℃ after weighing. Then, do acid fusion to resolve). After the cooling down of solution, move sample into 50cm^3 volumetric flask to dilute with water, and filter using dense filter paper;

b) Plot standard curve

Take 0, 10, 20, 30, 40, 50, ```, 100μg P$_2$O$_5$ standard solution into 50cm^3 volumetric flask, add 2cm^3 concentrated nitric acid, dilute to about 30cm^3 with distilled water, add 10cm^3 color developing agent, shake to equalization, dilute with water. After 20min (after 4min, color will change under indoor temperature), use 2cm spectrophotometer-cell to colorimetric analyze at 450nm wave length;

c) Measurement for sample

Transfer 5cm^3 analyzed solution into 25cm^3 dry beaker, add 5cm^3 sulfuric acid-color developing agent mixed solution, stir to equalization. After 20min, use 2cm spectrophotometer-cell to colorimetric analyze at 450nm wave length;

d) Computational formula

$$w(\mathrm{P_2O_5}) = \frac{c \times 0.2 \times 10^{-6}}{m} \times 100 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(39)$$

In the equation:

$\varpi(P_2O_5)$ ----- mass fraction of P_2O_5 in sample, the unit is %;

c ----- Weight P_2O_5 looked up on standard curve, the unit is μg;

m ----- weight of separate sample, the unit is g;

$0.2*10^{-6}$ ----- coefficient.

6.7.10 Measurement for total nitrogen ((elemental analyzer analysis)

Same as 6.7.8.

6.7.11 Measurement for carbonate ((elemental analyzer analysis)

Same **as 6.7.8.**

6.8 Radiocarbon dating of substrate

6.8.1 General requirement

General requirements are as followed:

a) The laboratory should have good ventilation, necessary security and monitor device;

b) The trace indicator and modern carbon standard the lab used should be the standard supported by uranium series group of Chinese mineral, lithogeochemistry Association, isotope geochemistry Association and C-14 discipline group of China Association for Quatemary Research;

c) Try best to reduce the loss of sample during preparation, improve chemical recovery rate (recovery rate more than 75%);

d) Measured relative error is less than 1%, total number of counting for radiation is more than 10000. substrate

In research on marine substrate, several dating methods often used and relative dating range can be seen in Table 7, in which uranium disequilibrium dating method, ionium dating method, radiocarbon and ^{210}Pb are the most maturely and used broadly.

6.8.2 Uranium disequilibrium dating method

6.8.2.1 Requirement for sample

Requirement for sample is as followed:

a) The collected sample should be in a close system ([234]U and [238]U had no transfer after generated).

b) Original generated sample had no ^{234}U;

c) The quantity of sample depends on U content, generally 10g~20g dry sample.

Table 7 Several dating methods often used and relative dating range in

research on marine substrate

method	decayed nuclear	radioactive half-life (a)	Dating range (a)	Adaptive sample to measure
radioactive beryllium	^{10}Be	$1.5*10^6$	$2.5*10^4$~$1.5*10^7$	Oceanic mud sediment, manganese nodule, et al
uranium disequilibrium dating method	^{234}U	$2.48*10^5$	$5*10^4$~$1*10^6$	Coral, stalactite, shell, at al
ionium dating method	^{230}Th	$7.52*10^4$	$3*10^4$~$4*10^5$	Coral, mud sediment in lake and sea, fossil bone, concretion, et al
protactinium dating method	^{231}Pa	$3.28*10^6$	$3*10^4$~$1.5*10^5$	Coral, mud sediment in lake and sea, fossil bone, concretion, et al
radioactive carbon	^{14}C	5730	＜70000	Plant, peat, shell, fossil bone, carbonate, et al
radium dating method	^{226}Ra	1600	＜10000	Mud sediment in lake, adjacent sea, continental shelf
^{210}Pb	^{210}Pb	22.3	＜150	Mud sediment in lake, adjacent sea, continental shelf

6.8.2.2 Preparation of sample

The requirements for preparation of sample are as followed:

a) Weigh sample (accuracy of 0.0001g);

b) Add ^{232}U - ^{226}U indicator;

c) Add acid to dissolve sample;

d) Use ion exchange resin to separate and purify U and Th;

e) TTA extraction;

f) Make points of U and Th radiative source on stainless steel sheet.

6.8.2.3 Measurement of sample

The requirements for measuring sample are as followed:

a) Use α detector and pulsed height analyzer to measure α-particle of U and Th radiative source, and do energy spectrum analysis;

b) The resolution ratio of device should be more than 50keV, and device should have good stability. Displacement should be no more than 2 branches when the device do measurement in the whole process.

6.8.2.4 Data analysis

The requirements for data analysis are as followed:

a) Measured data must be corrected by background, decay of daughter nuclide after separated from parental nuclide and the effect to lower energy peak from nearby high energy peak.

b) calculate the geological age of the sample and the error.

6.8.3 Dating by Einsteinium

6.8.3.1 Sample requirement

Sample should be:

a) undeformed, unstirred original sample.

b) sliced in 3-5cm and record the detailed character of sample, such as grain size, structure.

c) sample amount: mud sediment should be 10-20 g, manganese nodule should be 0.1-0.2g.

6.8.3.2 Sample preparation

See 6.8.2.2

6.8.3.3 Sample measurement

See 6.8.2.3

6.8.3.4 Data analyze

See 6.8.2.4

6.8.4 Radiocarbon dating

Conventional liquid scintillation counter can measure 40 thousand years. The new accelerator mass spectrometry technique can date the age to 70 thousand years.

6.8.4.1 Sample requirement

Sample should:

a) have clear position relationship and be uncontaminated;

b) regard the carbon content and measuring technique to determine the sample amount. Conventional technique regularly needs 5-10g pure carbon, while AMS technique requires more than 100mg carbon.

6.8.4.2 Sample preparation

a) To produce carbon dioxide, organic carbon use combustion method, inorganic carbon use acid dissolution method;

b) Purify carbon dioxide by copper sulfate solution, drikold cold trap,etc;

c) Add metallic lithium or calcium and react with carbon dioxide to generate carbide;

d) Add water to react with carbide and generate ethyne(C_2H_2);

e) Use drikold or liquid nitrogen cold trap to purify ethyne;

f) Under the effect of catalyzer, ethyne polymerize into benzene(C_6H_6), the vacuum degree of benzene formation reactor should be higher than 1×10^{-4}hPa.

6.8.4.3 Sample measurement

Requirements:

a) When use the double channel liquid scintillation counter to measure the βray of ^{14}C, the instrument should have relatively high detect efficiency and low background count,besides its quality factor should be larger than 800;

b) Before and after the measurement, modern carbon and background count should be measured for more than 24h.

6.8.4.4 Data analyze

Requirements:

a) Calculate the ^{14}C age and measurement error of the sample according to measured sample counting and modern carbon counting;

b) 14C age younger than 7000 years should be corrected by dendrochronology;

c) The age of marine inorganic carbonate is usually older so that older carbon should be corrected.

6.8.5 ^{210}Pb dating

^{210}Pb age can be acquired by measuring the second daughter nuclide ^{210}Po usually.

6.8.5.1 Sample requirement

See 6.8.3.1

6.8.5.2 Sample preparation

Requirements:

a) Sample weighs 10-20g (accurate to 0.001g);

b) Add tracer ^{208}Po;

c) Add acid to digest the sample;

d) Centrifuge the sample and extract the clear liquid;

e) Add ions to exclude interference;

f) Prepare homogeneous and moderate-thick Po radioactive source on the silver slice.

6.8.5.3 Sample measurement

See 6.8.2.3

6.8.5.4 Data analyze

Requirements:

a) Background correction. Daughter nuclide will decay after separated from parental nuclide. Measure the effect from the long tail of ^{210}Po peak to ^{208}Po peak.

b) ^{210}Pb background is usually determined by the measured ^{226}Ra of same sample, which can also be replaced by the basically constant ^{210}Pb under certain depth in the sediment core.

c) Mixing effect should be corrected.

6.9 Sediment paleomagnetism measurement

6.9.1 Sample collection

Sample collecting areas should be deposited continuously. Sample collector should be lined with low-magnetic plastic tube, which can keep the state sample was collected. The tube should be sealed at both ends and kept at shaddy, cool place, avoiding knock and vibration. Sample measurement requires the use of undisturbed

part from the central of the core and continuous collecting, pay attention to maintain the original sedimentary structure. The remanent magnetism of the sample box should be less than the instrument accuracy.

The sediment core measuring paleomagnetism requires orientation, relative orientation is also required if no orientation system is established.

Bedrock sample should be unweathered rock.

6.9.2 Measure instrument

Measuring instrument and demagnetization system should be determined according to measure requirement. Measuring instrument includes spinner magnetometer, superconducting rock magnetometer and susceptibility meter. Demagnetization system includes thermal demagnetizer and alternative current demagnetizer.

6.9.2.1 Measurement environment requirement and calibration

Requirements:

a) Working environment requires: steady magnetic field gradient, constant temperature, dustproof, moistureproof, keep quiet within 100m;

b) Before measurement, the precision and orthogonality of instrument should be calibrated and achieve its provisions.

6.9.2.2 Demagnetizer working environment requirement and calibration

Requirements:

a）Workshop should be ventilated;

b）The magnetic shield effect of the thermal demagnetizer's heating room should be less than 100nT, while cooling room should be less than 5nT. The temperature difference between indicating temperature from demagnetization peak and measured heating temperature should be less than 5℃;

c）The shield effect of alternating magnetic shield system and non-magnetic region in demagnetization should be less than 5nT. Magnetic field peak center should be well-distributed and the magnetic field space should be larger than the volume of 3 measured sample. The magnetic peak difference

between indicative and measured value should be less than 0.5nT. The magnetic peak value should decrease to zero at a constant speed. Alternative magnetic field in demagnetizer should be strictly symmetric sinusoidal wave;

d）After demagnetization, the sample should be taken out immediately and kept in magnetic shielding box. Only take out the sample when measuring. Do not keep it at places without magnetic shielding device. The shield effect of the magnetic shielding box's center should be less than 5nT.

6.9.3 Measure method and data analyze

6.9.3.1 Measure method

a) First measure the natural remanent magnetism and magnetic susceptibility of each sample. Systematic demagnetize and measure the typical sample according to different type and generation condition of the measured natural remanent magnetism. Make a chart of stability test of the remanent magnetism, choose best peak area of demagnetization and determine the original remanent magnetism. More than 10% of total sample should be systematic demagnetized. Finally demagnetize all the samples which have measured the natural remanent magnetism and measure the original remanent magnetism parameter according to the chosen best peak area of demagnetization.

b) Test the stability of remanent magnetism, choose the method, magnetization intensity attenuation curve method, stereo projection, vector analysis according to the systematic demagnetization data. Distinguish the original and secondary part of the magnetism.

6.9.3.2 Measurement and calculation of remanent magnetism parameter

Each sample should measure four groups of three orthogonal component X,Y,Z. Calculate the average value of XYZ, remanent magnetization intensity(J) and magnetism parameter such as magnetic declination(D), magnetic inclination(I) magnetization direction dispersion(ID) and standard deviation of remanent magnetization intensity. Basic formula see appendix G.

6.9.3.3 Measurement and calculation of magnetic susceptibility

Measurement procedure see appendix H.

6.9.3.4 Stability test of remanent magnetism

Requirements:

a) Organize the calculation of each demagnetization sample measurement according to table 8;

b) Analyze the best demagnetization result:

1)magnetization intensity attenuation curve method: Divide natural remanent magnetization intensity by the remanent magnetization intensity after each demagnetization. Plot the correlation curve of demagnetization. Take the corresponding magnetic peak or heating temperature of the curve's flat part tagged along the sudden change as best demagnetization value.

2)Stereo projection: Draw the magnetization direction change with demagnetization on a stereographic chart. The best demagnetization value is at constant magnetization direction. The stereographic projection should be centered at polar or equator, avoiding the circumference where vector distortion is severe. Vector in upper hemisphere represents positive with solid dots, while lower hemisphere represents negative with hollow dots.

3)Vector analysis: Draw magnetic vector on scenograph with solid dots representing horizontal projection and hollow dots representing vertical projection. The best demagnetization value is where the curve start to straighten and converge to origin.

Table 8   Systemic demagnetization magnetic parameter record

station number		sediment core number		sample number		demagnetization method				
peak value	parameter									NOTE
	X	X/X_0	Y	Y/Y_0	Z	Z/Z_0	J	J/J_0	D	I	
time			recorder				checker				

6.9.3.5 Data organization of remanent magnetism parameter measurement

Measured and calculated magnetic parameter of each sample should be recorded in magnetic parameter measurement table (table 9) and organized systematically.

6.9.3.6 Organization of measured magnetic susceptibility's magnetic fabric

characteristic parameter

Measured and calculated magnetic fabric characteristic parameter of each sample should be recorded in magnetic fabric characteristic parameter table(table 10) and organized systematically.

6.9.4 Result figures

a) Curve of total magnetic susceptibility K's change;

b) Plot for direction change of the maximum magnetic susceptibility's principal axis;

c) Plot for long term change of the geomagnetic field, made by long-term change of magnetic declination, magnetic inclination whose variation period is about one thousand years;

d) Plot for stability test of remanent magnetism;

e) Profile for polarity of magnetic strata, made by polarity zone and polarity transition zone whose variation period is about 10^3-10^7 years.

Table 9 magnetic parameter measurement table

station number			position φ/λ			water depth		core length					
sample		magnetic parameter											
number	depth	natural remanent magnetism						original remanent magnetism					
		X_N	Y_N	Z_N	J_N	D_N	I_N	X	Y	Z	J	D	I
time			recorder				checker						

Table 10 magnetic fabric characteristic parameter table

station number		position φ/λ		water depth		core length		
sample		K	K_{max}	K_{int}	K_{min}	direction of K_{max}		
number	depth						D	I
time		recorder			checker			

6.10 Survey result

6.10.1 Result figures

a) Survey line position map;

b) Sediment type figure;

c) Distribution of clastic minerals;

d) Distribution of clay minerals;

e) Distribution of suspended sediment concentration;

f) Distribution of biogenic shells (including foraminifera, diatom, radiolarian, nannofossils, macrofaunal, etc.)

g) Distribution of sediment's physical and mechanical parameters;

h) Distribution of major element concentration;

i) Chemical environment partition.

6.10.2 Data table

a) Positon table(including water depth);

b) Survey results table;

c) Results identification table;

d) Professional analysis table(including geology, chemistry, biology, etc.)

Other data should be presented in tables and figures as much as possible.

6.10.3 Survey report

Content and requirement of survey report see 4.6.3.

7 Seabed subbottom detection

7.1 Towed subbottom profile detection

7.1.1 Technique index

7.1.1.1 Shallow water subbottom profiler

Working depth: less than 100m

Detection depth: 30-50m below seabottom(vertical);

Recording resolution:20-30cm.

7.1.1.2 Deep water subbottom profiler

Working depth: less than 6000m

Detection depth: 200m below seabottom(vertical);

Recording resolution:3-5m.

7.1.1.3 The recorded strata reflection signal and time mark signal of profile should be clear and continuous.

7.1.1.4 Measuring scale and survey line setting

Usually strata profile detection is selective. Measuring scale, survey line and survey web setting of area investigation see Table1.

The direction of main survey line should be perpendicular to the trend of isobath or regional geologic structure and the liaison line should be perpendicular to main survey line.

7.1.2 Measure instrument

Towed subbottom profiler consists of three parts, sound source, transducer array and receiver and recorder.

7.1.2.1 Sound source

Source level of shallow water subbottom profiler is 86dB-90dB(relm,1Pa),its frequency spectrum 250Hz-14kHz; source level of deep water subbottom profiler is 90dB-97dB(relm,1Pa),its frequency spectrum40Hz-1kHz.

7.1.2.2 Receiving transducer

a) Technique index of shallow water subbottom profiler hydrophone:

sensitivity -100dB/V/Pa~-104 dB/V/Pa

receiving bandwidth 100Hz~10kHz

b) Technique index of deep water subbottom profiler hydrophone:

sensitivity -80dB/V/Pa~-84 dB/V/Pa

receiving bandwidth 20Hz~1.5kHz

7.1.2.3 Receiver and recorder

Requirements:

a) Filter whose central frequency and bandwidth can change within the receiving frequency is required;

b) TVG gain adjust is required;

c) Total gain, contrast ratio and threshold adjustment is required;

d) Before working, the recorder should be adjusted using signal generator so that the lines on the record paper are evenly dark with at least ten gray scales.

7.1.2.4 Instrument installation

The instrument is usually towed at the stern during work. Shallow water subbottom profiler can be hanged at one side of the middle of the ship or aft.

Source and hydrophone should be well grounded. Recorder should be set at the laboratory at the stern.

7.1.3 Measurement on board

7.1.3.1 Navigation requirements

Research vessel should sail in straight line at a constant speed and not stop randomly. When switching survey lines, do not take small turns. The speed of vessel should not exceed 6kn when shallow water subbottom profiler are working;3 kn for deep water subbottom profiler.

7.1.3.2 Detection record

a) Before starting survey line detection, total gain, TVG and receiving frequency of receiver should be adjusted to the best penetration rate and resolution of the profile. During the work of towed profiler, the angle of transducer entering water should be as little as possible and keep the towed array stable.

b) Proflie record should include survey line number, the start and end time of detection, time mark, water depth and brief description of special occasion.

c) Work shift record should include worker's name, work area, sea conditions, speed, survey line detection condition, surrounding environment and response of special occasion.

7.1.4

7.1.4.1 Identification of interference signal

Background noise induced by sea condition, marine organism, wake flow and propeller cavitation is wideband and appears as uniform snowflake on the record. Electronic noise produced by mechanical vibration and poorly grounded is narrow band and appears as special stripes.

Backscatter of sound emission related to emission frequency and scanning frequency can produce reverberation noise. It often appears when high power source are working in shallow water and causes the blurred echo and low resolution.

7.1.4.2 Explanation of strata profile

7.1.4.2.1 Explanation content

Explanation of strata profile includes tracking reflection interface, partition of the reflection sequences, analysis of the reflection sequences' characteristic and explain according to geology.

7.1.4.2.2 Principle for strata profile reflection partition

a) The reflection of same sequence should be continuous, clear and can be tracked regionally.

b) The reflection structure, shape, energy and frequency within sequence should be similar and that should be quite different from a neighboring sequence.

c) The reflection interface of same sequence from main line profile and liaison line should be closed.

7.1.4.2.3 Profile explanation

Requirements:

a) Strong regional reflection interface, obviously different from neighboring sequence, is usually the interface of different type of sediment or sedimentary discontinuity surface.

b) The displacement or distortion of sequence or sequence interface is usually caused by strata traction fault or tectonic movement.

c) Shielding effect within sequence and transparent bright spot in chaotic reflection often indicates the existence of aeration zone.

d) The sequence interface moves up and down, below which the reflection is blurred. This is usually defined as acoustic base.

e) Hyperbolic reflection often indicates subsurface pipeline or large extraordinary item such as shipwreck.

f) Accurate explanation of strata profile should integrate the drilling data.

7.2 Shipboard subbottom profile detection

7.2.1 Technical index

7.2.1.1 Main technical index

Main technical index of shallow water subbottom profiler see 7.1.1.1 and 7.1.2.2a),

deep water subbottom profiler:

a) Working depth: less than 6000m

detection depth:30m~150m below seabed(vertically)

b) Working frequency: linear frequency modulation scan high frequency 15kHz~10kHz, low frequency 2.2kHz~6.6kHz

c) Output power of transducer array: maximum 3kW

d) Computer control can manage to combine low frequency profile window, high frequency profile window, sonar parameter and vessel position information window.

e) Capable of recording real-time digital data and post processing of recorded data.

7.2.1.2 Measuring scale and survey line setting

Ship board subbottom profile detection is also selective. Measuring scale, survey line and survey web setting of area investigation see Table1.The direction of main survey line should be perpendicular to the trend of isobath or regional geologic structure and the liaison line should be perpendicular to main survey line.

7.2.2 Measuring instrument

Ship board subbottom profile detection system is mainly aimed at deep water strata profile detection with subordinate water depth measurement. Hardware equipment includes mainframe and two sets of transducer array with connecting cable installed at the bottom of the vessel. Mainframe consists of computer workstation, monitor, digital recorder, transmitting receiver and linear power amplifier.

7.2.3 System adjustment

7.2.3.1 Start the system program

7.2.3.2 Choose the transmitting power according to water depth range and set linear power amplifier on(use full transmitting power when water depth is deeper than 4000m)

7.2.3.3 Connect the peripheral equipment printer and make sure it can function properly

7.2.4 Measurement on board

7.2.4.1 Navigation requirements

Research vessel should sail in survey line at a constant speed less than 10kn, deviation less than 100m. When entering and leaving survey line, instrument operation team should be informed of stop and change of speed.

7.2.4.2 Seabed detection

7.2.4.2.1 Parameters set up

Requirements:

a) Measure the water depth within survey area and import the measurement to detection system

b) Before entering survey line, adjust transmitting power and receiving gain and do not change during the whole cruise, quantifying transmission and receiving.

7.2.4.2.2 System supervise

After entering survey line, watchman should start the digital recorder and set up a named file firstly. Supervise the detection system track down seabed through monitor. If the detection system cannot track the seabed due to some reason, it will automatically expand the search gate until tracking seabed, which usually takes little time. On extraordinary occasion when automatic search time is long, paper record is required so that this record can be deleted during signal replay processing. If the system cannot search seabed automatically, set up the parameters again see 7.2.4.2.1.

7.2.4.3 Detection record

a) Record print. Print the information of time, water depth, vessel position on real-time profile every 10~15 min.

b) Shift log. Record sea area, survey line number, time, vessel position, sea condition, instrument working condition, adjustment and response of special occasion.

7.2.5 Data organization

See 7.1.4.

7.3 Seabed subbottom detection results

7.3.1 Results figure drawing

Results figure of seabed subbottom detection is geological explanation figure of strata profile. Data of bottom sediment distribution and its sound velocity, density in the survey area should be collected before figure drawing. Choose suitable vertical and horizontal scale and draw geological explanation figure of strata profile according to data organization results in 7.1.4.

7.3.2 Survey report

Content and requirements of seabed subbottom detection see 4.6.3.

8 Seabed heat flow measurement

8.1 Technical index

8.1.1 Measurement station setting

Measurement stations of heat flow should be set according to geological mission.

Before measurement station setting, seismic profile survey or related data collection should be done in order to acquire information about sediment depth and water depth. Measurement stations should be set at areas with loose and thick sediment. Do not set station where sediment depth is less than 200m or bedrock is exposed. Sea bottom water temperature data should be collected for data processing when water depth at the measuring area is less than 1000m, if no history data is found, continuous bottom water temperature change should be observed for two months before measurement.

8.1.2 Survey line and web setting of profile measurement

Requirements:

a) Heat flow measurement profile should be perpendicular to geological structure trend and close to other geophysics profile as much as possible. Space between two station on one survey line is usually 3~5km. In flat area with thick sediment the

space can be up to 5~10km, while areas with complicated terrain and change in sediment thickness, the space should be intensified to 1~2km. Sediment core should be collected to measure thermal conductivity every 30~50km on profile. Heat flow measurement profile should be set along the trend of geological structure in special area such as mid ocean ridge, trench and fault.

b) Grid size for large area average heat flow measurement is usually 1×1 or 5×5 with 3~4 station in one grid and at least one station for thermal conductivity measurement.

c) Block size for elaborated measurement is 20n mile $\times$ 20n mile. Survey line sets at every 2 n mile~3 n mile within each block. 3~4 stations should be set on each survey line. At least two sediment cores should be collected and measured for thermal conductivity within each block.

8.2 Measure instrument

Device measuring heat flow includes two parts, one measuring geothermal gradient, the other thermal conductivity. Geothermal gradient can be measured directly. Thermal conductivity can be acquired directly or through sediment core indoor measurement.

8.2.1 Digital geothermal probe

Requirements:

a) thermosensitive element:

temperature measuring range:-1~5 ℃

resolution higher than1×10^{-3} ℃

resistance drift less than 5%

b) probe

The press thermosensitive element installed in the stainless-steel probe bear should be more than 100Mpa. Tube wall should be as thin as possible so that thermal balance with surrounding sediment can be reached within 90s. Outer diameter should be less than 3mm.

c) The length of sample-containing tubes should be longer than 5m and at least 5 probes are installed with a space of 1m or 1.5m.

d) Geothermal measurement and sample collection are simultaneously performed. Probes can be installed on the outer wall of sample collect tube which weighs 300~600 kg.

8.2.2 Instantaneous thermal conductivity probe

Requirements:

a) Fine heating metal wire and thermosensitive element should be installed in the probe.

b) Resistance of heating wire should be 50Ω and the power of heater strip should be 0.5~1.0W.

8.2.3 Acoustic telemetry seabed heat flow probe

Requirements:

a) Probe system consists of 14 thermosensitive elements and one heating metal wire, which are installed in tube longer than 5m. The stress tube wall bear should be more than 5MPa. Space between thermosensitive resistors should be 3.5×10^{-1}m

b) Heating pulse should initiate 7.5min after probe inserting sediment. The voltage of heating pulse is set at 16V DC. The resistance of heating metal wire is 0.4652Ω/m, heating pulse of which lasts 15s with power of 500 W per meter.

c) Total weight of probe system should be more than 340kg.

8.2.4 Depth supervise system

Depth supervise system includes:

a) Acoustic generator:

acoustic wave frequency 12kHz

acoustic pulse repeat rate 1 or 2s^{-1}

b) Acoustic generator should be installed on the steel wire 30m above the instrument.

8.2.5 Research vessel requirements

Requirements:

a) Propeller with variable pitch should be installed at the stern in order to sail

slowly at 1kn~2kn

b) Steel wire length of the winch on the deck should be 1×10^4m. Load at the end should exceed 5t. winch speed should be variable with maximum descending speed more than 2.5m/s.

8.3 Measurement on board

8.3.1 Positioning requirement

Research vessel should stop at the station for heat flow measurement. Vessel should be located every 10~15min. During work, vessel should stay above the station with deviation less than 10% of water depth.

8.3.2 Seabed geothermal measurement

8.3.2.1 Measuring method

a) Set the zero resistance and reference resistance according to known or estimated bottom water temperature and make sure the measured geothermal value is in the measurement scale.

b) After the instrument enters water, measure the bottom water temperature 100m above seabed. Then release the steel wire immediately and insert the steel tube into seabed sediment. Measure a set of geothermal values after probe reaches thermal equilibrium with surrounding sediment.

c) During geothermal measurement, the probe should be inserted in sediment with no disturbance.

d) After the probe enters water, extra steel wire of 30~50m should be released according to current and sea condition.

e) Sediment cores should be collected at the same time of seabed geothermal measurement. Sediment cores should be taken out and kept in the laboratory immediately after retrieving the sediment corer tube.

8.3.2.2 Data collection and recording

Digital geothermal system collects a data every 0.5s including seven parameters, bottom water temperature, sediment temperature (5) and tube tilt. All data is

recorded on cassette and sent back to vessel through acoustic pulse.

8.3.2.3 Log of original data

Log of supervision record and other instrument data should be done during geothermal measurement. See table 11.

8.3.3 Seabed thermal conductivity measurement

8.3.3.1 Measuring method

Seabed geothermal conductivity measurement can be performed in two ways, on scene measurement and indoor(laboratory) measurement. On scene measurement takes place at the same time of geothermal gradient measurement.

8.3.3.2 On scene geothermal conductivity measurement

a) After instrument inserting into sediment, according its working process, firstly measure geothermal gradient for 7.5min, then measure sediment geothermal conductivity for 15min.

b) Sampling space of geothermal gradient measurement is 15s. Each sample takes 15s and collects 16 data points including time code, reference number and 14 thermosensitive resistance. After 7.5 min, collect data of sediment geothermal conductivity. All data is recorded on cassette and sent back to vessel through acoustic pulse.

c) Data collected after probe reaches thermal equilibrium with surrounding sediment is reliable and calculate the geothermal gradient using last sets of data(last 3 or 5 sets).

d) After the measurement of geothermal gradient, heat the metal wire with pulse current to generate heat pulse. The power of heat pulse conduct to sediment and measure sediment geothermal conductivity by the decay of heat pulse.

e) Relationship between geothermal conductivity and real time sediment temperature:

$$K = \frac{Q}{4\pi T_a t} \quad (40)$$

In the formula:

K-sediment geothermal conductivity, unit in W/(m·℃)

Q-total energy heat pulse released per length, unit in J/m

Ta-sediment temperature at measuring time (t), unit in ℃

t-measuring time, unit in s

geothermal conductivity of same station should be measured three times repeatedly.

Table 11   original record of seabed gradient measurement

station	date	coordinate (latitude/longitude)	water depth /m	time of reaching bottom	time of lifting	tube tilt/(°)	probe N	bottom water temperature /℃	probe temperature $T_1 T_2 T_3 T_4 T_5$	average geothermal gradient/(℃/m)
time				recorder			checker			

8.3.3.3 Indoor geothermal conductivity measurement

Method:

a) Sediment cores collected from seabed should be kept at constant temperature laboratory with no distortion. Keep the water in sediment. Before measuring geothermal conductivity, internal temperature of sediment core should be uniform. Measurement error should be less than ±0.1

b) Insert the probe into sediment core, after metal wire start heating, measure the temperature of surrounding sediment and calculate the geothermal conductivity, using formula:

$$K_0 = \frac{P}{4\pi\Delta T}\ln\frac{t_2}{t_1} \quad (41)$$

In the formula:

K_0-geothermal conductivity, unit in W/(m·℃)

P-power per length, unit in W/m

ΔT- $\Delta T=T_2-T_1$, T_1, T_2 represents the instant temperature at time t_1,t_2.

c) Table 12 lists data that should be logged at one location. In the work, change location along sediment core to collect geothermal conductivity data and calculate the suitable average geothermal conductivity using the least square method.

Table 12 Geothermal conductivity data table

time t/s		60	120	180	240	300	360	420
thermosensitive resistance/Ω								
corresponding sediment temperature T/℃								
geothermal conductivity/W/(m·℃)								
time		recorder			checker			

8.4 Data organization

8.4.1 Data organization

8.4.1.1 Cassette record processing

Extract the original data on computer and save the data to magnetic medium with file number. Edit the extracted data and delete data which is obviously interfered. Delete data with average deviation more than 1.5 times standard deviation during statistic process. Adopt different processing method according to mission requirement. The easy processing method is calculating geothermal gradient, geothermal conductivity and heat flow density. More complicated way is to consider non-ideal probe structure, the interference effect of original geothermal field on measured data when inserting probe into sediment, the insertion is not completed instantaneously should also be considered.

Data process results include relationship between sediment temperature and depth, geothermal conductivity and depth, temperature and Brad depth, regional geothermal gradient and depth, heat resistance and depth, regional heat flow density and depth, average heat flow density of all station, etc.

8.4.1.2 average geothermal gradient calculation

During digital geothermal detection, average geothermal gradient should be calculated as quickly as possible, using least square method to get the slope of the curve, which is average geothermal gradient.

8.4.1.3 Correction of geothermal conductivity

A difference exists between the sediment geothermal conductivity measured on scene and indoor. Indoor results need to be corrected for temperature and pressure difference.

formula for temperature difference correction:

$$\Delta K_t = \frac{T_0 - T}{400} \quad (42)$$

In the formula:

ΔK_t-temperature difference correction of geothermal conductivity, unit in [W/(m·℃)]

T_0 and T-temperature of geothermal conductivity measured indoor and on scene, unit in ℃

formula for pressure difference correction:

$$\Delta K_p = \frac{D}{183\,000} \quad (43)$$

In the formula:

ΔK_p-Pressure difference correction, unit in [W/(m·℃)]

D-water depth at station, unit in m

8.4.1.4 Geothermal conductivity calculation

After temperature and pressure difference correction, geothermal conductivity K:

$$K = \left(1 - \Delta K_t + \Delta K_p\right) \cdot K_0 \quad (44)$$

In the formula:

K_0-geothermal conductivity measured indoor, unit in [W/(m·℃)]

$\Delta K_t, K_p$ use absolute value

8.4.1.5 Average heat flow density calculation

Average heat flow density calculation formula:

$$q = -K\nabla T \quad (45)$$

In the formula:

q-heat flow value, unit in mW/m^2

K- average geothermal conductivity, unit in [W/(m·℃)]

T-average geothermal gradient, unit in ℃/m

'-' represents up

8.4.1.6 Log of heat flow data

Heat flow data should be logged in heat flow data table.

8.4.1.7 Quality assessment of heat flow data

a) Grade 1, completely reliable, all probes are inserted into sediment with no disturbance. Two or more than two sets of measured geothermal gradient are the same. The accuracy of geothermal conductivity measurement is also high.

b) Grade 2, relatively reliable, all (or part of) probes are inserted into sediment. A couple sets of measured geothermal gradient are relatively approximate. The accuracy of geothermal conductivity measurement is high.

c) Grade 3, poor credibility, only one probe is inserted into sediment. Calculated geothermal gradient is approximate with expected value. Heat flow data is usable with geothermal conductivity data.

d) Grade 4, heat flow density data is unusable.

e) Topography of sea bottom is complicated with extremely thin sediment cover. Measurement of heat flow density is not accurate with low credibility. Data should be degraded and abandoned.

8.4.2 Drawing of basic figures

8.4.2.1 Temperature-depth plot

Method:

a) Set seabed as origin, Y axis above origin represents water depth, below represents depth probe inserted, X axis represents water or sediment temperature.

b) Plot water temperature and water depth above the X axis, sediment temperature and probe inserting depth below X axis.

c) If sediment core is also collected during measurement, histogram of sediment core should be plotted on the right bottom of the figure.

8.4.2.2 Geothermal conductivity -depth plot

Method:

Set geothermal conductivity as X axis, depth as Y axis and plot the measured geothermal conductivity on the figure. Calculate the average geothermal conductivity by least square method.

8.4.2.3 Heat flow profile plot

Method:

a) Set distance as X axis, as heat flow density Y axis and plot heat flow profile.

b) On the profile, right represents east or south, left represents west or north.

c) Water depth, seismic profile or other integrated geophysics profile should be added to the figure.

d) Figure name, scale, legend and necessary explanation should be added.

8.4.2.4 Heat flow distribution plot

Method:

a) For vast regional heat flow measurement, mark the heat flow density on figure of certain scale with dots or contour line to show the distribution of heat flow.

b) Figure name, scale, legend and necessary explanation should be added.

8.5 Geological explanation of heat flow data

8.5.1 Preparation work

Requirements:

a) Collect geological data of detection area and surrounding area, especially data on topography, sediment thickness, fault, magma activity and crust structure.

b) Collect physical property data of detection area and surrounding area, such as geothermal conductivity, density and susceptibility.

c) Collect temperature data from drilling in detection area and surrounding area.

d) Collect gravity, magnetic and seismic data in detection area and surrounding area.

8.5.2 Qualitative explanation of heat flow data

8.5.2.1 Classification of all types of heat flow area

Classify the average heat flow density of different geological structure unit in detection area according to following standard.

a) Extra high heat flow density area: heat flow density $>120 \text{mW/m}^2$

b) High heat flow density area: heat flow density $90\sim120 \text{ mW/m}^2$

c) Relatively high heat flow density area: heat flow density $70\sim90 \text{ mW/m}^2$

d) Ordinary heat flow density area: heat flow density $55\sim70 \text{ mW/m}^2$

e) Relatively low heat flow density area: heat flow density $40\sim55 \text{ mW/m}^2$

f) Low heat flow density area: heat flow density <40 mW/m^2

8.5.2.2 Heat flow anomaly explanation

Principle for heat flow anomaly explanation:

Explain the geological factor causing heat flow anomaly and explore heat origin mechanism of high heat flow anomaly and possible reason for low heat flow anomaly. Special attention should be paid to heat flow anomaly induced by magma activity, fault and regional liquid cycle. Come up with suitable heat flow anomaly relationship (relationship between heat flow and age or cooling plate, instantaneous prolong)

9 Ocean gravity measurement

9.1 Technical index

9.1.1 Measurement accuracy

Requirement:

a) Ocean gravity measurement accuracy is assessed by root mean square calculated by the measurement difference at cross station between main survey line and liaison line.

b) For gravity measurement with scale less than or equal to 1:500 000, root mean square of space anomaly should be less than 3×10^{-5}m/s^2; for gravity measurement with scale larger than 1:500 000, root mean square of space anomaly should be less than 2×10^{-5}m/s^2.

9.1.2 Measurement scale and survey web setting

9.1.2.1 Measurement scale and survey web setting requirements

Requirements:

a) Set measurement scale according to mission and condition, survey web density of different scale see table1.

b) Main survey line (profile) should be perpendicular to geological structure trend and the liaison line should be perpendicular to main survey line.

c) Conjunct part of different figure, cruise or measure instrument should set check survey line or repeat survey line

9.1.2.2 Check workload setting

Requirement:

a) Check workload is the repeat measurement amount of cross station between main survey line and liaison line. No matter what scale the map use, one station should be set on main survey line every 1cm on map, cross station should be more than 5% of total station which should be more than 30.

b) Route survey should set some repeat survey line as check workload circumstantially.

9.1.2.3 Base setting

a) Base of gravity measurement is used to control zero drift and deliver absolute gravity.

b) Gravity base should be set at coastal port and fixed port of island with secure mark and join in 85 national gravity base net. When pulling in foreign port, join in IGSN(1971) base net. Each time comparing gravity base, instrument relative elevation to base should be measured. Gravity base comparison error should be less than $0.5 \times 10^{-5} \mathrm{m/s^2}$.

9.2 Measure instrument

9.2.1 Instrument installation and adjustment

a) Instrument should be installed at stable cabin middle of vessel where mechanic vibration effect is little.

b) The vertical axis of gravimeter should be along the vessel's fore and aft. Panel and platform adjust device should face aft.

c) Instrument cabin should be moistureproof, at constant temperature, whose variation range is within the instrument requirement.

d) Static observation test includes: repeated test of instrument set up; instrument static zero drift observation, more than 7d and 3d continuous observation is

required before and after on board measurement annually to acquire the linearity of zero drift.

e) Dynamic observation test, test the instrument dynamic linearity of zero drift before measurement.

f) Instrument adjustment should follow the operation procedure strictly.

Gravimeter can only be used for measurement when its zero drift is long-term stable (according to static test if without dynamic test data), monthly drift should be less than $3.0 \times 10^{-5} \text{m/s}^2$.

9.2.2 Measurement and calibration of instrument constant

Every 1~2 years instrument constant should be measured; relative error of instrument constant should be less than 0.1%.

9.3 Measurement on board

9.3.1 Navigation requirements

a) Research vessel should sail straight at a constant speed. During one survey line or segment, the speed deviation on latitude direction should be less than ±0.2kn, heading deviation on longitude direction should be less than ±1 °

b) When vessel deviates from survey line, instantaneous but slow amendment is required, amendment rate should be less than 0.5 °/s

c) 20 min before reaching first station on each survey line, vessel should head to the survey line direction accurately. Vessel can veer 5min after the measurement of last station of survey line.

d) For area measurement, deviation between navigation line and planned survey line should be less than one fifth of spacing of survey lines. For gravity measurement of scale larger than 1:500 000, navigation speed should be less than 15kn

e) Navigation department should inform measurement watchman of veering and change of speed.

9.3.2 Measurement

9.3.2.1 Preparation before measurement

Requirements:

a) Before measurement, instrument should be kept at constant temperature for more than 72h. Open gyro platform system 1h before measurement.

b) Before set off, data about gravity base should be collected: base elevation and absolute gravity, readings after instrument stabilized (more than 30 min), water depth, elevation between instrument and sea surface, elevation between sea surface and base, horizontal distance and direction between instrument and port base, which should be briefly plotted.

c) Adjust the measure range of gravity according to gravity variation of measured area.

9.3.2.2 Instrument check and management

Instrument check and management include:

a) Daily check:

Central alarm system

Battery system

Thermostat function

Consistency of digital and analog record

Platform function

Levelling function of platform tube level gauge

Position of upper gauge spindle

Consistency of time standard between gravimeter and other measurement

b) When collision with platform or gravimeter happens, come back to check with the station just measured or nearby station, make sure the instrument function well then continue measuring.

c) During measurement, if the gravimeter range adjusting knob and thermostat knob was turned but unclear about the time of change, measurement of this cruise should be abandoned. Return to the base immediately for adjustment.

d) Encountering the following condition, one should stop measurement immediately: power off, collision avoidance, platform pitch and roll angle larger

than 20 °, malfunction.

9.3.2.3 Measure shift

Requirement

a) Time standard for ocean gravity measurement record is usually Beijing time standard or Greenwich time. Time standard within one survey area should be uniform.

b) Watchman should operate according to operation procedure or instrument instruction, write shift log carefully, including: survey area, survey line, bearing , speed, direction, instrument condition and operation.

9.3.3 Rock density measurement

Method:

a) Collect different age and type of rock from survey area seabed or surrounding land and measure its density.

b) Collect rock density data of survey area seabed or surrounding land to supplement or replace measured data.

c) Make histogram of strata and rock density in the order of geologic time, divide the density interface.

9.3.4 Quality control of on scene data

Requirement:

a) During on board measurement, technical director should often check the data quality condition.

b) On scene data quality supervise includes: record feature, instrument working condition, existence of drift, analysis on the reason for gravity anomaly and great gradient, calculate the measurement difference of cross station.

c) On finding problems, provide advice on resurvey or supplementary survey immediately.

9.4 Data organization

9.4.1 Acceptance and access of original data

9.4.1.1 Original data

Original data includes：

Survey line setting map, absolute gravity at base, elevation between instrument and base/sea surface, instrument static/dynamic test data, analog record paper, digital record, navigation and location record, water depth data, shift log,etc.

9.4.1.2 Standard for acceptance and access of original data

Standard for accepted original data should be as followed:

a) Survey line setting should be reasonable and can represent the gravity morphology of survey are. Measurement accuracy meets the requirement of provision.

b) Instrument functions well and data collected is complete and satisfactory.

c) Original record is complete and clear. Problems are handled immediately with explanatory note.

d) Continuous record loss on one survey line should be less than 5% of total survey line length. Accumulating record loss should be less than 10% of total survey line length. Unqualified survey lines should be less than 5% of total survey lines.

Any survey line below qualification standard should be marked disqualification.

9.4.1.3 Principle of number fetching

On the results map of various scales, number spacing of in-line and cross-line must not exceed 5 mm.

The characteristic points of analog curves should be infilled.

9.4.2 Data calculation and correction

9.4.2.1 Normal gravity calculations

Adopting the 1985 international normal gravity formula:

$$r_0 = 978\ 032.667\ 14 \times \frac{1+0.001\ 931\ 851\ 3\ 8639\sin^2\varphi}{\sqrt{1-0.006\ 694\ 379\ 9\ 013\sin^2\varphi}} \quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots（46）$$

r_0——normal gravity (10^{-5}m/s^2)

φ——measuring point dimension (°)

9.4.2.2 Gravity base system

The absolute gravity value of marine gravity measurement starting point adopts

IGSN (1971) system.

9.4.2.3 Formula for calculating Eotvos correction

$$\delta_{ge}=7.499 \times V \times \sin A \ \cos\varphi+0.004V^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots（47）$$

A——true azimuth (°)

V——speed (m/h)

φ——Measuring point dimension (°)

Also:

$$\delta_{ge}=7.50 \ \frac{\lambda'-\lambda}{t'-t} \ \cos^2\varphi \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots（48）$$

λ'&λ——longitude of measurement points (°)

t'&t——observation time of measurement points (sec)

φ——measuring point dimension (°)

9.4.2.4 Formula for calculating spatial correction

$$\delta_{gf}=0.3086H' \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots（49）$$

H'——the height difference between the elastic system of gravity meter and the
average sea level (m)

When the vessel draft changes within one metre before and after sea, calculate on average of vessel draught. Over one meter, calculate segmented; Tidal correction should be done offshore; Space correction error should be less than $0.2 \times 10^{-5} m/s^2$.

9.4.2.5 Formula for calculating Bouguer correction

$$\delta_{gb}=0.0419(\sigma-1.03)H \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots（50）$$

σ——formation density , $\sigma=2.67\times10^{-3}(kg/cm^3)$ in basic survey.

H——depth of measuring point (m), calculation according to average sea level.

9.4.2.6 Calculation of outliers

The calculation method of outliers is as follows:

a) Calculating formulas of space gravity anomalies:

$$\Delta g_f=g+\delta_{gf} -r_0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots（51）$$

$g=g_0+C\Delta s +\delta_R +\delta_{ge}$

g——Absolute gravity value of the measured point $(10^{-5}m/s^2)$

δ_{gf}——Space correction $(10^{-5}m/s^2)$

r_0——Normal gravity field value (10^{-5}m/s^2)

g_0——Absolute gravity value of base point (10^{-5}m/s^2)

C——Gravity meter constant

Δs——reading difference of Gravity meter between measured point and base point (10^{-5}m/s^2)

δ_R——zero drift correction (10^{-5}m/s^2)

δ_{ge}——Eotvos correction (10^{-5}m/s^2)

b) Calculating formulas of Bouguer gravity anomalies:

$$\Delta g_b=\Delta g_f+\delta_{gb} \ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \ \cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad （52）$$

Δg_b——Bouguer gravity anomalies (10^{-5}m/s^2)

Δg_f——space gravity anomalies (10^{-5}m/s^2)

δ_{gb}——Bouguer correction (10^{-5}m/s^2)

9.4.2.7 Comprehensive survey

The comprehensive survey method is as follows:

a) After various corrections, system error of measuring value on different line can be eliminated by comprehensive investigation methods.

b) The comprehensive survey is based on the difference value of repeated measure of in-line and cross-line intersection point, and the in-line and cross-line are adjusted in turn, until the whole area is flattened.

9.4.3 Measurement accuracy

9.4.3.1 Sources of marine gravity measurements error

The sources of marine gravity measurements error is as follows:

a) Error in the measuring process of marine gravity meter ε_i. Including the inherent error of instrument, measurement error caused by external disturbance, correction error of temperature coefficient, constant measurement error and correction error of zero drift. This type of error should not be greater than $\pm 1 \times 10^{-5}$m/s^2;

b) The error caused by the gravity base ε_s, including error of measurement and comparison of basic point, should not be greater than $\pm 0.5 \times 10^{-5}$m/s^2;

c) The error caused by incomplete Eotvos correction ε_e, Including speed, heading and latitude errors due to positioning errors, should not be greater than $\pm 1.5 \times 10^{-5} \text{m/s}^2$; at 1:200,000 scale, should not be greater than $\pm 1 \times 10^{-5} \text{m/s}^2$;

d) Correction error of normal field ε_r, mainly is the latitude error caused by positioning error, should not be greater than $\pm 0.1 \times 10^{-5} \text{m/s}^2$;

e) Space correction error ε_f, mainly caused by the height error between the elastic system of gravity meter and the average sea level, should not be greater than $\pm 0.2 \times 10^{-5} \text{m/s}^2$;

f) Bouguer correction error ε_b, mainly caused by the incomplete Bouguer correction due to sounding error.

9.4.3.2 Calculation of marine gravity measurement error

The calculation method of marine gravity measurements error is as follows:

a) External fitting accuracy formula:

$$\varepsilon = \pm \sqrt{\frac{\sum_{i=1}^{n} \delta_i^2}{2n}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{（53）}$$

δ_i——difference of measurement value of two instruments at the same point (10^{-5}m/s^2)

n——number of measuring points

b) Internal fitting accuracy formula:

$$\varepsilon = \pm \sqrt{\frac{\sum_{i=1}^{n} \delta_{il}^2}{2n}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{（54）}$$

δ_{i1}——difference of measurement value of same instrument at the same point (10^{-5}m/s^2)

n——number of measuring points

c) Internal fitting accuracy formula (after comprehensive survey):

$$\varepsilon = \pm \sqrt{\frac{\sum_{i=1}^{nm} \delta_{i2}^2}{2(n-1)(m-1)}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{（55）}$$

δ_{i2}——difference of measurement value of same instrument at the same point after comprehensive adjustment (10^{-5}m/s^2)

n、m——number of in-line and cross-line

d) When calculating the measurement error, allow to abandon a few special values, but the rate should not be greater than 3%.

e) When using multiple instrument with equal precision in the same voyage, calculate error with formula (53), single instrument (or multiple instrument with unequal precision), calculate error with formula (54), all that through the comprehensive adjustment, use formula (55).

9.5 Measuring results

9.5.1 Results report content

Results report content includes:

a) Measured point observation time, latitude and longitude, absolute observation value, corrected depth value, space anomaly value, Bouguer anomaly value; The header includes measuring sea area, measuring vessel, observing date, measuring line number, observing instrument used, constant of the instrument, gravity base point used, and measuring line comprehensive adjustment value etc.

b) In the results report, the measured point position unit is the second, the depth unit is meter, and the gravity value unit is $0.1 \times 10\text{-}5\text{m}/s^2$

9.5.2 Results map plotting

The results map includes: actual material graph, space gravity anomaly plane profile, space gravity anomaly contour map. Bouguer gravity anomaly plane profile, Bouguer gravity anomaly contour map can be appended according to the task requirements.

9.5.2.1 Plotting of actual material graphs

Requirements are as follows:

a) The actual material graph can be plotted by checking the data of gravity measurement.

b) Icon：

National base po　⊚

Base point　⊙

Measuring point　·

c) The line number is labeled at both ends of the measuring line, each ten gravity observations are marked with a horizontal line, the point number is labeled on the line, and the abnormal value is labeled below.

9.5.2.2 Plotting of gravity anomaly plane profile

Method is as follows:

a) The abscissa of plan profile graph is based on the survey results map scale. Ordinate is based on the gravity anomaly and observational accuracy;

b) The right and top of plan profile graph is positive, the lower and left is negative, red stand for positive, and blue stand for negative.

c) In addition to planar profiles, small scale profile location map should be appended.

9.5.2.3 Plotting of gravity anomaly contour map

Method is as follows:

a) Gravity anomaly contour map is plotted on the basis of the actual material graph, gravity anomaly contour map only need delineate contour line, and the isoline spacing shall not be less than twice times ~2.5 times of the measuring accuracy. Curve should be slick, where the data is insufficient, the dotted line replaces.

b) Legend must include normal gravity formula, absolute gravity system, Bouguer gravity anomaly map should indicate the average density value of intermediate layer.

c) Gravity anomaly contour map shall be coloured, red stand for positive, and blue stand for negative. The depth of the color represents the strength of gravity anomaly.

9.5.3 Geological interpretation of gravity anomaly

a) Information on the geological, geophysical, drilling and rock density of the measurement area and surrounding areas should be collected and understood.

b) Geological interpretation is mainly through the method of forward and inversion, suppressing interference, highlighting and enhancing target anomalies, to reveal the inherent relation between the distribution regularity of

gravity anomaly field and geological factors, and explain the characteristics of geological structure and crustal structure.

c) Small scale marine gravity measurements based on qualitative interpretation.

d) In comprehensive geophysical survey, the interpretation of gravity anomalies is combined with other geophysical data.

9.5.4 Survey results

9.5.4.1 Results Information and drawings

Including：

a) Original record (see 9.4.1)

b) In-line and cross-line intersection measurement difference statistic calculation table

c) Gravity Measurement Results Table

d) Gravity Anomaly Basic maps

e) Acceptance opinion of marine gravity surveying data

9.5.4.2 Survey Report

See 4.6.3

10 Marine geomagnetic measurements

10.1 Technical Requirements

10.1.1 Measurement accuracy

Requirements are as follows:

a) The accuracy of marine geomagnetic measurement is dominated by root-mean-square of Difference of measured values of intersection point of in-line and cross-line.

b) Measurement accuracy of different survey scales see Table 1.

10.1.2 Measurement error distribution

The error of marine geomagnetic measurement is the synthetical error of many factors, including instrument error, navigation positioning error, ship magnetism

influence, geomagnetic diurnal variation correction and the error of geomagnetic normal field correction. See Table 13.

Table 13 Offshore geomagnetic survey error distribution table unit: nT

Scale	Root mean square error	Instrument	Navigational positioning	Ship magnetism influence	Diurnal correction	Normal field correction
$1{:}100{\times}10^4$	≤4	≤2	≤2	≤1	≤2	≤1
$1{:}50{\times}10^4$	≤4	≤1	≤2	≤1	≤2	≤1
$1{:}20{\times}10^4$	≤2	≤1	≤1	≤1	≤1	≤0.5
$1{:}10{\times}10^4$	≤2	≤1	≤1	≤1	≤1	≤0.5

10.1.3 Survey scale and requirement of surveying net layout

10.1.3.1 Requirements of survey scale and surveying net layout

Requirements of survey scale and surveying net are as follows:

a) According to the investigation tasks and conditions to determine the scale, the survey scale of different network density see table 1

b) The in-line is perpendicular to the regional geological tectonic direction, the cross-line is perpendicular to the in-line, when doing oceanic magnetic seamount measuring, and the seamount can be selected as the center of radial measurement.

10.1.3.2 Check workload layout

Requirements of check workload layout are as follows:

a) The number of repeated measurements with Intersection point of in-line and cross-line as a check workload

b) The number of intersections should not be less than 5% of the total number of points measured, the total number of intersections must not be less than 30

c) At the low latitude sea area measurements, in the condition of the geomagnetic station, one or two duplicate lines should be laid to verify the correction effect and eliminate the geomagnetic diurnal variation.

10.2 Measuring instruments

Marine geomagnetic measurement instruments include proton precession magnetometer, optical pumping magnetometer, magnetic gradiometer etc.

10.2.1 Instrument Commissioning

The instruments should be debugged and tested before measurements.

10.2.1.1 Main technical indicators of instrumentation

Digital record: 0.25nT, 0.5nT, 1nT, 2nT, 4nT. Sensitivity Self-calibration reading error is not greater than ±2.

Jitter is not much less than ±2nT

10.2.1.2 Debugging of Crystal Oscillator

For stability determination, if frequency drift, should be adjusted to live replacement

10.2.1.3 Debugging of sensor harmonic coordination

The measurement of the sensor matching harmonic frequency amplifier each of the central frequency, not meet the technical specifications, should be replaced

10.2.1.4 Measurement and requirement of signal-to-noise ratio in static apparatus

The signal level value and the noise level value of the instrument are measured after debugging, and the Snr should be not less than 50, otherwise the debugging should continue.

10.2.1.5 The Stability test of instrument system

After commissioning the instrument system should carry on the continuous working state test, the test duration 2d~3d, the instrument system should remain stable state.

10.2.2 Influence test of ship's magnetic azimuth

The test method for the influence of ship's magnetic azimuth is as follows:

a) On the geomagnetic calm day, in the vicinity of the survey area or the survey sea, select a magnetic field calm zone (gradient less than 6 nT/km), leaving a fixed non-magnetic buoy. Investigation ship along eight directions (0°,225°,90°,315°,180°,45°,270°,135°)The bow, stern, towed sensors three points into a straight line through the buoy, the sensor and buoy distance to be less than 20m, the measured value by the diurnal correction, as the azimuth curve, the magnetic impact of the ship correction;

b) When the magnetic azimuth influence test is done, the sensor towing distance test is carried out, and the optimum cable towing length is selected.

c) In the survey of different latitudes, the magnetic impact tests of ships are required, the same sea area, the use of different investigation ships, must have their respective magnetic azimuth impact correction curves

d) The geomagnetic apparatus room should be equipped with navigation display equipment synchronized with the navigation room

10.3 Offshore measurements

10.3.1 Navigational requirements

Navigational requirements are as follows:

a) The survey vessel should be along the laying of the line of uniform speed, straight sailing;

b) The survey vessel should be 3 min in advance, so that the bow, aft and tow sensors are three points in a straight line into the measurement, the measurement of the end of the survey vessel should be delayed 3 min turn;

c) Measurement of the survey, the vessel shall not be large steering, variable speed or stop vessel, in case of special circumstances necessary to stop the ship, steering or speed, should promptly notify the measurement of the duty room, take emergency measures;

d) The geomagnetic apparatus room should be equipped with navigational display equipment synchronized with the navigation room.

10.3.2 Measurements and records

10.3.2.1 Instrument working status

The choice of the instrument working condition is as follows:

a) Check the power supply polarity and voltage selector switch is correct;

b) Check the frequency meter self-correcting reading;

c) Adjusting the frequency selection and the sensor harmonic, so that the signal level reaches the maximum, the lowest noise level;

d) Analog record as a monitoring record, should check and debug recorder, record pen full bias and the complex zero position should be accurate, flexible, the speed of the paper should be uniform correct;

e) Digital records and analog records should be kept in sync, time, data should be consistent;

f) The instrument room temperature should be kept below 25 ℃, and the instrument's quartz crystal oscillator blow cooling.

10.3.2.2 Instrument Management and Instrumentation inspection

Instrumentation management and inspection requirements are as follows:

a) On duty personnel should pay attention to observe instrument monitors and listen to magnetization chirp, find abnormal, timely debugging or inspection maintenance;

b) Note the measurement record, the occurrence of modulus mismatch or jump large number, should be timely debugging;

c) The hourly mark and the measured value are recorded on the analog recording paper, usually with the standard time of Beijing, the Ocean is standard with Greenwich mean times;

d) Towing cables to take protective measures to detect distortion or damage to timely treatment.

10.3.3 Observation on diurnal geomagnetic variation

10.3.3.1 Observation instrument and site selection of geomagnetic diurnal variation

The geomagnetic diurnal observation instrument and site selection requirements are as follows:

a) In addition to the magnetic gradient instrument, the geomagnetic diurnal variation Observatory should be established by using the other magnetometer, and the geomagnetic   diurnal variation is observed at the same time measurement.

b) The geomagnetic diurnal observation instrument should be identical with the maritime magnetic measuring instrument.

c) The effective control radius of the geomagnetic diurnal variation observatory for 300 km~500 1km, the observatory should control the whole area of surveying, the area of the survey is large, and should be set up more than two geomagnetic daily-change observatory, simultaneous observation;

d) The geomagnetic diurnal variation observatory must be away from the alternating magnetic disturbance zone, such as power supply line, telephone line, broadcast line, and the magnetic field gradient change is less than 1 nT/m in the 20m radius of observatory.

10.3.3.2 Observational records and geomagnetic storms and magnetic disturbance processing

observational records and geomagnetic storms, magnetic disturbance processing methods are as follows:

a) Diurnal variation observation every 2 min---5 min Three consecutive readings, averaging as the value of the magnetic field;

b) Daily change station timing with Beijing standard time, clock error must not exceed 1 min daily;

c) The continuous 24 h observations of the geomagnetic calm day were chosen as the base value of the diurnal variation, and the geomagnetic curves were plotted daily.

d) Diurnal observation, when the storm, magnetic disturbance day, must accurately record the initial movement, continued, disappear time, and promptly notify the investigation vessel.

10.3.4 Determination of magnetic parameters of rocks

The determination methods of magnetic parameters of rocks are as follows:

a) Collecting fresh rocks of different ages and different types in the surveying area or adjacent land, and determining the magnetization rate and residual magnetization intensity;

b) Collecting the magnetic data of the rocks in the surveying area and the surrounding area, sorted by the time, rock and magnetic strength list.

10.4 Data collation

10.4.1 Acceptance of original record data

10.4.1.1 Data acceptance

Original records include: analog recording paper volumes, Digital records (floppy disk, CD-ROM), navigation and positioning records, geomagnetic diurnal observation records, on duty records. The eligibility criteria for the original record data are: analog recording curve jitter not exceeding ± 1 NT records accounted for more than 70%% of all records, jitter degree in ± 1 nT~ ± 2 NT record not exceeding 25% of all records; The abnormal record produced by the instrument debugging or maintenance does not exceed 5% of all records; The original records are complete and clear.

Records of substandard.

After the maritime survey, the Investigation task execution unit carries on the acceptance to the original record data, the appraisal rank, gives the textual comment.

10.4.1.2 Number Spacing

On the results map of various scales, the number of the main line and the contact line must not be greater than 5 mm.

The characteristic points of the analog curves should be infilled.

10.4.2 Data collation and correction

10.4.2.1 Geomagnetic normal field

Calculation of the normal field of marine geomagnetic measurements the International geomagnetic reference field IGRF, which was published by the International High altitude Physics and Geomagnetic Association (IAGA), was used for five years (see Appendix F)

10.4.2.2Correction of geomagnetic diurnal variation

The correction method of geomagnetic diurnal variation is as follows:

a) According to diurnal variation curves drawn from the synchronous measurements of geomagnetic stations near the substation or survey area, it is found that the magnetic field value can be adjusted when the field level is high

or low, the base value of the magnetic field graph equals the daily variable base value plus added value;

b) When two or more date changes are used in the same measurement area, the diurnal variation of the base value is unified to a certain station.

c) The change amplitude is less than 100 nT magnetic disturbance Day Change record, can be used for daily change correction, the diurnal variation correction of magnetic disturbance day is divided into two steps: First use the place to calm day (the magnetic disturbance before and after the three days of the average curve) change value correction; then use the world when the magnetic disturbance correction, the magnetic disturbance correction value is measured by the diurnal variation minus the average magnetic calm day change value.

10.4.2.3 Magnetic impact correction of ships

The measured value minus the actual heading of the investigation vessel corresponds to the magnetic influence azimuth curve value.

10.4.2.4 Calculation of geomagnetic anomaly

The calculation formula of geomagnetic anomaly is:

$$\Delta T = T - T_d - T_s - T_0 \quad\quad\quad (46)$$

ΔT——The geomagnetic anomaly value (nT)

T——The total magnetic field measurement of the geomagnetic field (nT)

T_0——The Geomagnetic normal field value (nT)

T_d——The diurnal variation of geomagnetic deviation (nT)

T_s——The deviation value of the magnet influence of the ship (nT)

10.4.2.5 Measurement accuracy Calculation

The calculation formula of measurement accuracy is:

$$\varepsilon = \pm\sqrt{\frac{\sum_{i=1}^{n} \delta_i^2}{2n}} \quad\quad\quad (57)$$

$\delta_i = \Delta T$ (in-line) $-\Delta T$ (cross-line), (nT)

n——The number of Total checkpoints.

The strong magnetic anomaly area of the intersection is very large, cannot participate in the calculation of accuracy, but the number of discards cannot exceed the total number of points of 3%.

As the normal distribution curve of magnetic measurement error, if not normal distribution, the statistical data should be inspected, and the obvious system error section is separated separately.

10.5 Measuring results

10.5.1 Results Report

Results report content: The table should be measured sea area, measuring vessel, measuring date, measuring instrument and line number, etc. the contents of the table should include: ordinal, time, latitude and longitude, total t value, normal field value, ship magnetic azimuth correction value, geomagnetic diurnal variation andΔT value.

10.5.2 Results drawings and compilation requirements

10.5.2.1 Results map

The results map includes:

a) Actual material drawings;

b) Geomagnetic anomaly (t) planar profile;

c) Geomagnetic anomaly (t) contour map;

d) The total strength of the geomagnetic field T-contour map.

10.5.2.2 Plotting

The diagram compilation includes:

a) Actual material map

Preparation of methodologies and requirements see 9.5.2.1;

b) Geomagnetic anomaly (t) planar profile

According to the actual material graph, the starting point of the measuring line is the linear horizontal coordinate, the measuring points of the line are projected vertically to the horizontal axis, and the NT value of the measuring points is the ordinate drawing section. When (ΔT) the planar cross-section

graph is not coordinated, the zero line can be adjusted, so that the positive and negative anomalies are about half of the area; (ΔT) the longitudinal scale of the planar profile drawings represents 50 nT~100 nT per centimeter;

c) Geomagnetic anomaly (ΔT) contour map

(ΔT) isoline spacing should not be less than 2.5 times the accuracy of the measurement; delineation contour Map To reference geological data and other geophysical data;

d) The total strength of magnetic field T Contour map

T isoline spacing and drawing requirements are identical to (ΔT) isoline graphs.

10.5.3 Data processing and geological interpretation of geomagnetic anomalies

10.5.3.1 Preparation before interpreting

The preparation requirements before interpretation are as follows:

a) Collecting data from surveying area and adjacent land, including geological, regional geological structure, drilling and other information, especially magmatic activity, rupture activity and crystalline basement characteristics;

b) Collecting material of rock density and magnetism;

c) Collecting the gravity, geomagnetic, seismic and geothermal data of the surveying area and adjacent areas.

10.5.3.2 Classification and zoning of geomagnetic anomalies

According to the abnormal axial, shape, arrangement characteristics and strength can be divided into strip anomaly, linear anomaly, isometric anomalies, abnormal ladder bands, etc., according to the combination of abnormal relations can be divided into the calm magnetic field, strip magnetic field and disorderly magnetic field.

10.5.3.3 Data processing

The minimum burial depth of magnetic body and its geometrical parameters and magnetic parameters can be calculated by using the tangent method of "the inclined magnetization" and the conventional data processing method. The conventional methods of data processing include: magnetization direction transformation (polar); bit field analytic continuation (upward continuation, downward continuation),

magnetic field directional derivative computation (derivation); Gravity anomaly computation (pseudo gravity anomaly) and magnetic basement inversion calculation.

10.5.3.4 Magnetic Anomaly calculations

The forward fitting computation of the strip magnetic anomaly in the oceanic and marginal basins (such as the two-dimensional rectangular strip-plate composite model), compared with the international geomagnetic polar chronology, can determine the rate of the seafloor dilation and the age of formation. The identification of stripe magnetic anomaly should be combined with seismic, gravity, geothermal and deep-sea drilling.

10.5.3.5 Geological interpretation of geomagnetic anomalies

The geological explanations include: the thickness variation of sedimentary rocks, rock lithology and morphology, basement structure and fracture characteristics, magmatic activity, regional geological structure characteristics, etc.

10.5.4 Survey Report

The content requirements of the investigation report see 4.6, the report should be annexed to the results map.

11 Marine seismic Survey

11.1 Technical Specifications

11.1.1 Main technical indicators of investigation quality

The main technical indicators of the investigation quality are as follows:

a) The total capacity of the combination air gun is not lower than the 80 rings, the sound pressure is not less than 90 write, the whole line test the empty gun rate is less than 6%;

b) The abnormal work road does not exceed the total number of 1/24;

c) The timing lines of the monitoring record are clear, and the road is evenly spaced, and the breakpoints of the air gun sync signal and the excitation signal (TB) are clear.

11.1.2 Survey scale and surveying line laying

Survey scale and surveying line layout requirements are as follows:

a) According to the task and working conditions, the scale of investigation is determined, and the requirement of surveying line layout of different survey scales is shown in table 1.

b) The in-line is perpendicular to the direction of regional geological structure, and the cross-line is perpendicular to the in-line, and the surveying line is arranged not equidistant from the specific situation.

c) Seismic lines should be consistent with other geophysical lines as far as possible, especially by drilling wells or sonar buoy measurements.

11.2 Investigative instruments

11.2.1 Technical index of digital seismograph system

In the current environmental basic survey, the 48 digital seismograph system, which is commonly used as an example, puts forward technical indicators:

a) Consistency ahead

Amplitude difference: -2%~2%

phase difference: ±1ms

b) Noise and drift

Noise: when gain equals 2^8, Noise is not greater than 0.13 μV

When gain equals 2^6, Noise is not greater than 0.19 μV

When gain equals 2^4, Noise is not greater than 0.66 μV

drift: 0±1 μV

c) Main Gain Step

Average stair accuracy requirements：

1~4: -0.06%~0.06%

5: -0.08%~0.08%

6: -0.20%~0.20%

7: -0.60%~0.60%

Accuracy requirements for single step stairs

1~4: -0.1%~0.1%

5: -0.15%~0.15%

6: -0.30%~0.30%

7: -1%~1%

d) Crosstalk

When the primary gain is 1FP, the crosstalk is less than 78 dB

When the main amplifier gain is 2FP, the crosstalk is less than 72 dB

e) Distortion

Distortion is not greater than 0.06%

f) Trapping waves

Attenuation of any path is not less than 40 dB

g) The purity of A/D converter

Linear error is not greater than 0.02%

h) Dynamic Range

Dynamic range is greater than 78 dB

i) Pulse response

Amplitude difference in -2%~2%

Phase difference is 2 ms

j) Leakage Rate

The total "I" code test requires leakage rate is not greater than 1×10^{-6}

k) Tape drive

Distortion must not exceed 0.25% of a row of group time

Reading amplitude Error in -10%~10%

Instantaneous change of belt speed in -2%~2%

l) System timing

Should be precise to 1×10^{-4}.

11.2.2 Technical requirements of electrostatic monitoring recorder

The technical requirements of electrostatic monitoring recorder are as follows:

a) Optical components

The detector and optical components are cleaned once a year to ensure that the paper records are clear.

b) Timing Line

Monthly check the timing line, the top and bottom of the error should be less than 0.5ms (paper);

The accuracy of the timing line is inspected annually, and the error requirements are not greater than ±1ms

c) Constant speed of the paper

Every six months to test the speed of the paper, the linear error per hundred meters should be less than 2%

d) Check Flow meter

Use a set of public pulses to detect;

The phase difference between the Tao is not greater than ±1ms.

Amplitude consistency is not greater than ±10%.

11.2.3 Air gun Source

The technical requirements of the air gun focal are as follows:

a) Single gun start-up stability requirement ±1ms;

b) The combination of the gun should synchronize the work, the start-up error remains within 2%；

c) The air gun capacity is not less than the design of 80%, sound pressure is not less than the design of 90%；

d) Peak peak ratio not less than 6.

11.2.4 Cable

Cable technical requirements are as follows:

a) Full cable insulation resistance (before launching) should be greater than 10 m;

b) Cable crosstalk greater than 60 dB;

c) Cable towing noise is less than 0.1 Pa;

d) The phase difference between each channel is less than 1 ms;

e) The amplitude of each passage varies within 15%；

f) The cable is controllable range 3m ~ 30m.

11.2.5 Instrument inspection

11.2.5.1 Daily check

Daily work before admission index oscillator record one.

11.2.5.2 Monthly check

The monthly inspection requirements are as follows:

a) A/D converter, main release, pre-DC drift 0;

b) Pre-release gain adjustment;

c) Computer Test Project: Pre-release consistency, noise and drift, gain step accuracy, crosstalk, distortion, trapping, A/D converter linear, dynamic range, impulse response, leakage rate;

d) Analog test Project: main amplifier regulator 0, the main right clock timing allowance, A/D converter clock timing allowance, system timing, AGC function, the first segment of the solution bias.

11.2.5.3 Annual inspection

Complete the whole month check project and do the following:

a) Comprehensive maintenance equipment, focusing on cleaning the tape drive, test the tape drive read amplitude, distortion and speed error;

b) Repairing or replacing the mechanical and electronic components with poor performance or hidden dangers;

c) Complete calibration of testing equipment to achieve the factory target;

d) Check the playback system.

11.2.6 The use and maintenance of seismic instruments

The use and maintenance of seismic instrumentation are as follows:

a) Set up the instrument file, record the malfunction and the processing method of the instrument in the process;

b) The use of the instrument shall abide by the relevant regulations of the operating rules and instruments;

c) Instrument room to keep clean, dry, dustproof, when the humidity outside the 40%~80%, and temperature above 30 ℃, or below 5 ℃, should not use the instrument;

d) The instrument room should place CO_2 (dry ice) fire extinguishing machine to ensure the safety of the apparatus;

e) The instrument is not used for a long time, to frequent power, periodically to the instrument standby Board charging;

f) The instrument must obtain a qualified yearly and monthly inspection record before it can be used for investigation, and the daily inspection record shall be obtained before working.

11.3 Offshore measurements

11.3.1 Navigational requirements

Navigational requirements are as follows:

a) Ship speed and heading should be stable, speed requirements at about 5 km, ship deviation from the survey line beyond the prescribed scope, timely correction, the correction rate should not be greater than 2 ‰km;

b) Reaching the beginning of the line 2 km before the cable should be straightened, reaching the end of the line, the vessel should continue to work along the heading, the continuation distance should be equal to half an arrangement length, enter the line or the end of the line to have a qualified satellite navigation positioning point;

c) In seismic measurements, the positioning system is usually controlled by the focal excitation, such as distance or time blasting, and the locating gun should correspond to the seismic file number.

d) Route deviation design line must not be greater than the line spacing of 1/5;

e) When the vessel must deviate from the original heading or deceleration, the earthquake duty officer should be notified beforehand, and the ship should be amended as soon as possible to return the vessel to the design line;

f) Motorists should always monitor the source and cables of towing, and when they are found to be through the water of the cable, the sinking cable should be done in advance.

11.3.2 Measuring method

The Reflection seismic survey generally uses the horizontal superposition (common depth point) method, covering the superposition number and arrangement length according to geological task.

Some special problems can be solved by SAP, ESP, sonar buoy method or three-dimensional seismic method, high-resolution seismic method.

11.3.3 Measurement requirements

The measurement requirements are as follows:

a) The Instrument inspection project, time, method and technical index should conform to the specification and operation rules;

b) Recording the noise of cables under normal working conditions before the daily (or every line of surveying) can be recorded on the production tape;

c) Before the earthquake cables each work, all seismic road, auxiliary road should be in the normal working state, the water fault signal should be recorded normal;

d) In the construction of the measurement of the interruption of the line, should be made in the voyage, the measurement line is connected, to the gun point continuous, the reverse connection to repeat the observation of one arrangement (the gun point to the farthest detector distance) length;

e) The monthly inspection is limited to 30 days, the longest not exceeding 37 days;

f) According to the different tasks, the instrument inspection should be done before the seismic prospecting, to select the optimum instrument parameters.

11.3.4 Monitoring records

The monitoring record requirements are as follows:

a) Every 40 cannon should be played back with a monitoring record in the first and aft point measurements of each line, and the monitoring record should be replayed in a special case.

b) A record of an air gun is taken every 40 cannon in the first cannon and measurements, and the breakdown of the focal faults should be recorded in a timely manner and detailed in the report.

c) Select a record to make a single-track monitoring section, the monitoring record of the timing line should be clear, the Tao also evenly, air gun synchronous signal and excitation signal (TB) breakpoints clear;

d) The phase and amplitude of the reference signal are stable, the error of the time standard is ±1 ms;

e) Monitoring records stamped on both ends of the login chapter, fill in the content;

f) In measuring the sudden change of sea or ship acceleration, the noise level should be recorded in time, the noise levels exceed the standard, and the operation should be stopped.

11.3.5 Seismic logbook

The seismic logbook request is as follows:

a) The first, the last shot number. And every 40 shot truthfully complete the data according to the request;

b) The shot number and the file number shall correspond to the correct;

c) Record the factors influencing quality in measurement; mark the scrap gun, file number, the Taoist of Bad road, by time blasting, should indicate the time interval of firing;

d) The class newspaper is filled with pencils, and should not be rubbed with eraser, and the original record should be rewritten as amended.

11.4 Data collation

11.4.1 Raw Material Acceptance

11.4.1.1 Data Acceptance Project

Data acceptance projects include:

a) Test data: Cable noise, source energy and sink depth, instrument receiver factor selection, equipment replacement and working methods change;

b) Original record data: Digital seismic tape data, digital seismic surveillance records, single-track record, digital Seismograph, daily and monthly inspection data, air gun printing records, navigation and positioning information and records and hand books.

11.4.1.2 Raw Material Acceptance criteria

Qualifying records and line measurements:

a) Instrument daily and monthly inspection records.

b) The instrument factor or method conforms to the design requirement;

c) The abnormal working path (dead Road, disorderly road, and inverse-channel sensitivity below 6 db of adjacent road, the noise exceeding the index of the earthquake road) does not exceed the total number of 1/24;

d) The cable towing noise is not greater than 3 MPA, the depth error of sinking is less than 2.sm, the tail mark deviates from 15 ;

e) The total capacity of the combined air gun is not lower than the specified value of 80 writes, the sound pressure is not less than 90%;

f) The gun spacing error is less than the 50Om range, the empty gun rate of the whole line is less than 6%;

g) N-time covering of continuous artillery points not exceeding n/2 in empty, waste cannon;

h) Single-track surveillance records are basically complete and clear.

All those who do not meet the above-mentioned requirements are unqualified records and lines.

11.4.2 Data processing requirements

11.4.2.1 Process Design Book Content

The content of the design book includes:

a) Geological tasks;

b) Maritime work and original quality analysis;

c) Analysis of existing processing data;

d) Process tasks and projects;

e) Trial processing and bulk processing;

f) Data processing and planning;

g) The submission of processing results.

11.4.2.2 Requirements of velocity spectra and spectral drawings

The requirements of velocity spectra and spectral drawings are as follows:

a) Each velocity spectrum and spectrum should print the line number, the CDP (total depth point) number, the spectral category, the processing date, the Analysis window, etc.

b) The parameter of the width of velocity spectrum should be consistent with the parameters provided by the design book.

c) The speed spectrum display and the track set motion correction display should be clear;

d) The range of velocity spectra can contain the actual velocity value;

e) The point of velocity spectrum is reasonable and its density meets the requirements of processing and interpretation.

11.4.2.3 Requirements for electrostatic profiles

The requirements for electrostatic profiles are as follows:

a) Electrostatic display graph of ink uniformity, waveform clear, the ratio of the appropriate gain;

b) The header name is identical to the corresponding job wide line name, which includes: the unit of operation, the measuring area, the line number, the main collecting factor, the main parameters of the processing flow, the section scale, the processing date, the line position graph, etc.

c) The two sides of the time section should be marked with a depth callout on both sides of the depth profile;

d) The cross section should be measured at the top of the line, the CDP number and the corresponding gun points.

11.4.2.4 Requirements for photographic profiles

The requirements for photographic profiles are as follows:

a) Each section should be head, content with electrostatic section;

b) The cross section should be measured at the top of the line direction, the CDP number and the actual test line gun point, intersection line callout, superposition speed data, water depth and cable deflection angle;

c) There is no waveform distortion in the cross-section, no obvious oscillation noise and induction phenomena, gain and scale match, enter the direction of the right, step distance evenly;

d) Good washing, clear and clean surface, no light leak, no creases, fingerprints, tear, color uniformity, film transparency.

11.4.2.5 Scale of section

Select the appropriate scale according to the geological task. There are two kinds of regular scales:

Normal scale: Time scale 10cm/s, transverse scale 1.5mm~2mm/road;

Narrowing scale: Time proportional 5cm/s, transverse scale 0.75mm~1mm/road room

11.4.2.6 X-Y drawing, the need for the correct head, complete picture, drawing lines clear, no disconnect, displacement, tear, fouling and other defects. Scale size and parameter selection is appropriate.

11.4.2.7 Quality evaluation of processing results

The results of the submission of inspection should be intact and complete in the form. The eligibility criteria for data processing are:

a) Because of the loss of transcription, the waste cannon is not greater than the total number of 1%; the deep-level signal distortion is less than the total number of 2%, any 100 CDP channel, not normal, not greater than 4;

b) The cannon or the incomplete data of the gun is less than 2% 3% of the total gun number;

c) The processing scheme and the parameters, coding and the task book are basically consistent, the main modules and parameters have no errors, individual minor modules or parameters are used incorrectly, but do not affect the quality of the results section;

d) The machine is functioning correctly, the program is running correctly, the total CDP road number is correct, the abnormal path appearing is less than 2% of the total CDP road;

e) Processing task book, processing notebook, wide list of ranks and all the intermediate surveillance basic complete;

f) The results section, the washing phase and the graph head show neat, complete;

g) Waveform is basically no distortion, no oscillation noise and induction phenomena;

h) The change area is suitable, the gray order conforms to the requirement, the film transparency is good;

i) The direction of the inlet is correct, distance and the time line dislocation is not greater than 4 ms;

j) The results section can achieve the geological effect of the treatment plan.

Failure to meet the eligibility criteria is unqualified.

11.4.3 Seismic Data Interpretation

11.4.3.1 Basic Data collection

Before interpreting seismic data, the following information should be collected:

a) Water depth map, surveying line position map;

b) Speed data and related data;

c) Data and information formed in the process of collecting and processing;

d) Relevant geological, drilling and other geophysical data.

11.4.3.2 Wave contrast and reflection sequence partitioning

The comparison of waves and the division of Reflection sequences are as follows:

a) Comprehensive analysis section structure and wave group characteristics, recognizing the normal reflection, lateral waves, cross-section waves, rotating waves, diffraction waves and various disturbances, combined with the seismic stratigraphic symbols in contrast;

b) Analyzing the regional geology, drilling and other geophysical data, dividing the reflecting sequence, confirming the correspondence relation with the geological stratum;

c) Shallow, medium and deeper overall contrast, focusing on the main purpose layer to prevent the cascade;

d) According to the interruption of wave group system, the occurrence of mutation, cross-section wave, diffraction wave and so on, combining the analysis of offset cross-section, judging breakpoints;

e) The contrast interpretation of waves should be repeated, and the reliability of the contrast interpretation should be verified by the time profiles handled by various methods.

11.4.3.3 Speed data analysis

The speed data analysis requirements are as follows:

a) Mean square root velocity: distinguish the velocity information of the effective reflection wave and other jamming waves, extract the RMS velocity of the effective wave;

b) Average Speed: A comprehensive analysis of the velocity data obtained by different methods, the average velocity suitable for the time-depth conversion is extracted, and the velocity data obtained by velocity spectra should be corrected and converted;

c) Layer Velocity: Using a variety of speed data, to provide different levels of the strata of the layers of the layer velocity;

d) Comparing the transverse variation regularity of average speed and layer velocity, the relevant sectional drawings and planar drawings reflecting the lateral variation of velocity are plotted, and the conversion and further explanation are provided for the time-depth.

e) In the process of interpreting, the fault of reflecting waves on the time section, the mutation (number and shape) of the same phase axes, the bifurcation, merging, distortion, strong phase conversion of the reflecting waves, and the special waves appearing, should be repeatedly contrasted and analyzed to obtain geological explanations.

11.5 Survey results

11.5.1 Results map

11.5.1.1 Depth Profile Drawing

The depth profile drawing is as follows:

a) A depth profile should be drawn by the regional long line, or through the main lines of the construction and drilling wells.

b) The depth profiles represent the reliability of the reflective interface, respectively, with solid and dashed lines, and T0 values in the appropriate locations of different interfaces, such as endpoints, highs, lows, and points of intersection.

11.5.1.2 Drawing of a planar graph (such as t0 or structure)

Floor plan (wait T.) The drawing method is as follows:

a) Selecting the geological significance, the reflective energy is strong, and can be traced continuously, reflecting shallow, medium and deep tectonic formations of different layers, as a planar graph;

b) The breakpoint of the same wave group on each section is plotted on the planar graph, and the breakpoint on the same fault is connected;

c) When the breakpoint combination is carried out on the planar graph, it is necessary to analyze the sectional characteristics, fault properties, fracture layer, cross-section formation, fault-spacing variation and intersection measurement of the line in the same direction, and the main faults with large fault spacing and long extension are connected.

d) The reliability of faults is marked by different symbols, and the various faults in the same area are classified according to the uniform standard, and the same fault should be numbered or named uniformly on the planar graphs of different layers;

e) The construction drawing is required for space correction, waiting for T. The spatial correction of the graph is also necessary for fault correction.

f) The plan should correspond to the actual material graph.

11.5.2 Results Report

For the results report, see 4.6.3, the main figures of the report include:

a) Seismic line location map;

b) Comprehensive interpretation section of regional line or main line of surveying;

c) Hierarchical structure diagrams (such as T0 graphs or equal depth charts);

d) Equal thickness chart;

e) Other drawings.

Appendix A

Isobaric particle size classification table

See the isobaric particle size classification in table A.1.

Table A.1 Isobaric particle size classification table

grain fraction type	grain size name		grain size range		$\varphi=-\log_2 d$		code
	Simplified method	Subdivision method	mm	μm	d	φ	
rock block(R)	rock block(boulder)	rock block	>256		256	-8	R
gravel(G)	gravel	coarse gravel	256~128		128	-7	CG
			128~64		64	-6	MG
		medium-size gravel	64~32		32	-5	MG
			32~16		16	-4	MG
			16~8		8	-3	MG
		fine gravel	8~4		4	-2	FG
			4~2		2	-1	FG
sand(S)	coarse sand	very coarse sand	2~1	2000~1000	1	0	VCS
		coarse sand	1~0.5	1000~500	1/2	1	CS
	medium-sized sand	medium-sized sand	0.5~0.25	500~250	1/4	2	MS
	fine sand	fine sand	0.25~0.125	250~125	1/8	3	FS
		very fine sand	0.125~0.063	125~63	1/16	4	VFS
silt(T)	coarse silt	coarse silt	0.063~0.032	63~32	1/32	5	CT
		medium-sized silt	0.032~0.016	32~16	1/64	6	MT
	fine silt	fine silt	0.016~0.008	16~8	1/128	7	FT
		very fine silt	0.008~0.004	8~4	1/256	8	VFT
clay(mud)(Y)	clay	coarse clay	0.004~0.002	4~2	1/512	9	CY
			0.002~0.001	2~1	1/1024	10	CY
		fine clay	<0.001	<1		>1	FY

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Appendix B

(Normative appendix)

φ-millimeter conversion table

See theφ-millimeter conversion table in table B.1.

Table B.1 φ-millimeter conversion table

φ值	(+φ) mm	(-φ) mm	φ值	(+φ) mm	(-φ) mm	φ值	(+φ) mm	(-φ) mm	φ值	(+φ) mm	(-φ) mm
0.00	1.0000	1.0000	0.50	0.7071	1.4142	1.00	0.5000	2.0000	1.50	0.3536	2.8284
01	0.9931	0070	51	7022	4241	01	4965	0139	51	3511	8481
02	9862	0140	52	6974	4340	02	4931	0279	52	3487	8679
03	9794	0210	53	6926	4439	03	4897	0420	53	3463	8879
04	9718	0285	54	6877	4540	04	4863	0562	54	3439	9079
05	9659	0355	55	6830	4641	05	4841	0705	55	3415	9282
06	9593	0425	56	6783	4743	06	4796	0849	56	3392	9485
07	9526	0498	57	6736	4845	07	4763	0994	57	3368	9690
08	9461	0570	58	6690	4948	08	4730	1140	58	3345	9897
09	9395	0644	59	6643	5052	09	4697	1287	59	3322	3.0105
0.10	9330	0718	0.60	6598	5157	1.10	4665	1435	1.60	3299	0314
11	9266	0792	61	6552	5263	11	4633	1585	61	3276	0525
12	9202	0867	62	6507	5369	12	4601	1735	62	3253	0737
13	9138	0943	63	6462	5476	13	4569	1886	63	3231	0951
14	9075	1019	64	6417	5583	14	4538	2038	64	3209	1166
15	9013	1096	65	6373	5692	15	4506	2191	65	3186	1383
16	8950	1173	66	6329	5801	16	4475	2346	66	3164	1602
17	8890	1251	67	6285	5911	17	4444	2501	67	3143	1821
18	8827	1329	68	6242	6021	18	4414	2658	68	3121	2043
19	8766	1408	69	6199	6133	19	4383	2815	69	3099	2266
0.20	8705	1487	0.70	6156	6245	1.20	4353	2974	1.70	3078	2490
21	8645	1567	71	6113	6358	21	4323	3134	71	3057	2716
22	8586	1647	72	6071	6472	22	4293	3295	72	3035	2944
23	8526	1728	73	6029	6586	23	4263	3457	73	3015	3173
24	8468	1810	74	5987	6702	24	4234	3620	74	2994	3404
25	8409	1892	75	5946	6818	25	4204	3784	75	2973	3636
26	8351	1975	76	5905	6935	26	4175	3950	76	2952	3870
27	8293	2058	77	5864	7053	27	4147	4116	77	2932	4105
28	8236	2142	78	5824	7171	28	4118	4284	78	2912	4343
29	8179	2226	79	5783	7291	29	4090	4453	79	2892	4581

φ值	(+φ) mm	(-φ) mm	φ值	(+φ) mm	(-φ) mm	φ值	(+φ) mm	(-φ) mm	φ值	(+φ) mm	(-φ) mm
0.30	8123	2311	0.80	5743	7411	1.30	4061	4623	1.80	2872	4822
31	8066	2397	81	5704	7532	31	4033	4794	81	2852	5064
32	8011	2483	82	5664	7654	32	4005	4967	82	2832	5308
33	7955	2570	83	5625	7777	33	3978	5140	83	2813	5554
34	7900	2658	84	5586	7901	34	3950	5315	84	2793	5801
35	7846	2746	85	5548	8025	35	3923	5491	85	2774	6050
36	7792	2834	86	5510	8150	36	3896	5669	86	2755	6301
37	7738	2924	87	5471	8276	37	3869	5847	87	2736	6553
38	7684	3014	88	5434	8404	38	3842	6027	88	2717	6808
39	7631	3104	.89	5396	8532	39	3816	6208	89	2698	7064
0.40	7579	3195	0.90	5359	8661	1.40	3789	6390	1.90	2679	7321
41	7526	3287	91	5322	8790	41	3763	6574	91	2661	7581
42	7474	3379	92	5285	8921	42	3729	6759	92	2643	7842
43	7423	3472	93	5249	9053	43	3711	6945	93	2624	8106
44	7371	3566	94	5212	9185	44	3686	7132	94	2606	8371
45	7321	3660	95	5176	9319	45	3660	7321	95	2588	8637
46	7270	3755	96	5141	9453	46	3635	7511	96	2570	8906
47	7220	3851	97	5105	9588	47	3610	7702	97	2553	9177
48	7170	3948	98	5070	9725	48	3585	7895	98	2535	9449
49	7120	4044	99	5035	9862	49	3560	8089	99	2517	9724
2.00	0.2500	4.0000	2.50	0.1768	5.6569	3.00	0.1250	8.0000	3.50	0.0884	11.314
01	2483	0278	51	1756	6962	01	1241	0556	51	0878	392
02	2466	0558	52	1743	7358	02	1233	1117	52	0872	472
03	2449	0840	53	1731	7757	03	1224	1681	53	0866	551
04	2432	1125	54	1719	8159	04	1216	2249	54	0860	632
05	2415	1411	55	1708	8563	05	1207	2821	55	0854	713
06	2398	1699	56	1696	8971	06	1199	3397	56	0848	794
07	2382	1989	57	1684	9381	07	1191	3977	57	0842	876
08	2365	2281	58	1672	9794	08	1183	4561	58	0836	959
09	2349	2575	59	1661	6.0210	09	1174	5150	59	0830	12.042

Table B.1 (Continued)

φ值	(+φ) mm	(−φ) mm	φ值	(+φ) mm	(−φ) mm	φ值	(+φ) mm	(−φ) mm	φ值	(+φ) mm	(−φ) mm
2.10	2333	2871	2.60	1649	0629	3.10	1166	5742	3.60	0825	126
11	2316	3169	61	1638	1050	11	1158	6338	61	0819	210
12	2300	3469	62	1627	1475	12	1150	6939	62	0813	295
13	2285	3772	63	1615	1903	13	1142	7544	63	0808	381
14	2269	4076	64	1604	2333	14	1134	8152	64	0802	467
15	2253	4383	65	1593	2767	15	1127	8766	65	0797	553
16	2238	4691	66	1582	3203	16	1119	9383	66	0791	641
17	2222	5002	67	1571	3643	17	1111	9.0005	67	0786	729
18	2207	5315	68	1560	4086	18	1103	0631	68	0780	817
19	2192	5631	69	1550	4532	19	1096	1261	69	0775	906
2.20	2176	5948	2.70	1539	4980	3.20	1088	1896	3.70	0769	996
21	2161	6268	71	1528	5432	21	1081	2535	71	0764	13.086
22	2146	6589	72	1518	5887	22	1073	3179	72	0759	178
23	2132	6913	73	1507	6346	23	1066	3827	73	0754	269
24	2117	7240	74	1497	6807	24	1058	4479	74	0748	361
25	2102	7568	75	1487	7272	25	1051	5137	75	0743	454
26	2088	7899	76	1476	7740	26	1044	5798	76	0738	548
27	2073	8232	77	1466	8211	27	1037	6465	77	0733	642
28	2059	8568	78	1456	8685	28	1029	7136	78	0728	737
29	2045	8906	79	1446	9163	29	1022	7811	79	0723	833
2.30	2031	9246	2.80	1436	9644	3.30	1015	8492	3.80	0718	929
31	2017	9588	81	1426	7.0128	31	1008	9177	81	0713	14.026
32	2003	9933	82	1416	0616	32	1001	9866	82	0708	123
33	1989	5.0281	83	1406	1107	33	0994	10.0561	83	0703	221
34	1975	0631	84	1397	1602	34	0988	1261	84	0698	320
35	1961	0983	85	1387	2100	35	0981	1965	85	0693	420
36	1948	1337	86	1377	2602	36	0974	2674	86	0689	520
37	1934	1694	87	1368	3107	37	0967	3388	87	0684	621
38	1921	2054	88	1358	3615	38	0960	4107	88	0679	723
39	1908	2416	89	1350	4110	39	0954	4831	89	0675	825

Table B.1 (Continued)

φ值	(+φ) mm	(−φ) mm	φ值	(+φ) mm	(−φ) mm	φ值	(+φ) mm	(−φ) mm	φ值	(+φ) mm	(−φ) mm
2.40	1895	2780	2.90	1340	4643	3.40	0947	5561	390	0670	929
41	1882	3147	91	1330	5162	41	0941	6295	91	0665	15.032
42	1869	3517	92	1321	5685	42	0934	7037	92	0661	137
43	1856	3889	93	1312	6211	43	0928	7779	93	0656	242
44	1843	4264	94	1303	6741	44	0921	8528	94	0652	348
45	1830	4642	95	1294	7275	45	0915	9283	95	0647	455
46	1817	5022	96	1285	7812	46	0909	11.0043	96	0643	562
47	1805	5404	97	1276	8354	47	0902	0809	97	0638	671
48	1792	5790	98	1267	8899	48	0896	1579	98	0634	780
49	1780	6178	99	1259	9447	49	0890	2356	99	0629	889
4.00	0.0625	16.000	4.50	0.0442	22.627	5.00	0.0313	32.000	5.50	0.0221	45.255
01	0621	111	51	0439	785	01	0310	223	51	0219	570
02	0616	223	52	0436	943	02	0308	447	52	0218	886
03	0612	336	53	0433	23.103	03	0306	672	53	0216	46.206
04	0608	450	54	0430	264	04	0304	900	54	0215	527
05	0604	564	55	0427	425	05	0302	33.128	55	0213	851
06	0600	679	56	0424	588	06	0300	359	56	0212	47.177
07	0595	795	57	0421	752	07	0298	591	57	0211	505
08	0591	912	58	0418	918	08	0296	825	58	0209	835
09	0587	17.030	59	0415	24.084	09	0294	34.060	59	0208	48.168
4.10	0583	148	4.60	0412	251	5.10	0292	297	5.60	0206	503
11	0579	268	61	0409	420	11	0290	535	61	0205	840
12	0575	388	62	0407	590	12	0288	776	62	0203	49.180
13	0571	509	63	0404	761	13	0286	35.017	63	0202	522
14	0567	630	64	0401	933	14	0284	261	64	0201	867
15	0563	753	65	0398	25.107	15	0282	506	65	0199	50.213
16	0559	877	66	0396	281	16	0280	753	66	0198	563
17	0556	18.001	67	0393	457	17	0278	36.002	67	0196	914
18	0552	126	68	0390	634	18	0276	252	68	0195	268
19	0548	252	69	0387	813	19	0274	504	69	0194	625

Table B.1 (continued)

value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm
4.20	0544	379	4.70	0385	992	5.20	0272	758	5.70	0192	984
21	0540	507	71	0382	26.173	21	0270	37.014	71	0191	52.346
22	0537	635	72	0379	355	22	0268	271	72	0190	710
23	0533	765	73	0377	538	23	0266	531	73	0188	53.076
24	0529	896	74	0374	723	24	0265	792	74	0187	446
25	0526	19.027	75	0372	909	25	0263	38.055	75	0186	817
26	0522	160	76	0369	27.096	26	0261	319	76	0185	54.192
27	0518	293	77	0367	284	27	0259	586	77	0183	569
28	0515	427	78	0364	474	28	0257	854	78	0182	948
29	0511	562	79	0361	665	29	0256	39.124	79	0181	55.330
4.30	0508	698	4.80	0359	858	5.30	0254	397	5.80	0179	715
31	0504	835	81	0356	28.051	31	0252	671	81	0178	56.103
32	0501	973	82	0354	246	32	0250	947	82	0177	493
33	0497	20.112	83	0352	443	33	0249	40.224	83	0176	886
34	0494	252	84	0349	641	34	0247	504	84	0175	57.282
35	0490	393	85	0347	840	35	0245	786	85	0173	680
36	0487	535	86	0344	29.041	36	0243	41.070	86	0172	58.081
37	0484	678	87	0342	243	37	0242	355	87	0171	185
38	0480	821	88	0340	446	38	0240	643	88	0170	892
39	0477	966	89	0337	651	39	0238	933	89	0169	59.302
4.40	0474	21.112	4.90	0335	857	5.40	0237	42.224	5.90	0167	714
41	0470	259	91	0333	30.065	41	0235	518	91	0166	60.129
42	0467	407	92	0330	274	42	0234	814	92	0165	548
43	0464	556	93	0328	484	43	0232	43.111	93	0164	969
44	0461	706	94	0326	696	44	0230	411	94	0163	61.393
45	0458	857	95	0324	910	45	0229	713	95	0162	820
46	0454	22.009	96	0321	31.125	46	0227	44.017	96	0161	62.250
47	0451	162	97	0319	341	47	0226	426	97	0160	683
48	0448	316	98	0317	559	48	0224	632	98	0158	63.119
49	0445	471	99	0315	779	49	0223	942	99	0157	558

Table B.1 (continued)

value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm
6.00	0.0156	64.000	6.50	0.0110	90.510	7.00	0.0078		7.50	0.0055	
01	0155	445	51	0110	91.139	01	0078		51	0055	
02	0154	893	52	0109	773	02	0077		52	0055	
03	0153	65.345	53	0108	92.411	03	0077		53	0054	
04	0152	799	54	0107	93.054	04	0076		54	0054	
05	0151	66.257	55	0107	701	05	0076		55	0053	
06	0150	718	56	0106	94.353	06	0075		56	0053	
07	0149	67.182	57	0105	95.010	07	0074		57	0053	
08	0148	649	58	0105	670	08	0074		58	0052	
09	0147	68.120	59	0104	96.336	09	0073		59	0052	
6.10	0146	594	6.60	0103	97.006	7.10	0073		7.60	0052	
11	0145	69.071	61	0102	681	11	0072		61	0051	
12	0144	551	62	0102	98.360	12	0072		62	0051	
13	0143	70.035	63	0101	99.044	13	0071		63	0051	
14	0142	522	64	0100	733	14	0071		64	0050	
15	0141	71.012	65	0100	100.427	15	0070		65	0050	
16	0140	506	66	0099		16	0070		66	0049	
17	0139	72.004	67	0098		17	0069		67	0049	
18	0138	505	68	0098		18	0069		68	0049	
19	0137	73.009	69	0097		19	0069		69	0048	
6.20	0136	517	6.70	0096		7.20	0068		7.70	0048	
21	0135	74.028	71	0096		21	0068		71	0048	
22	0134	543	72	0095		22	0067		72	0047	
23	0133	75.061	73	0094		23	0067		73	0047	
24	0132	584	74	0094		24	0066		74	0047	
25	0131	76.109	75	0093		25	0066		75	0047	
26	0130	639	76	0092		26	0065		76	0046	
27	0130	77.172	77	0092		27	0065		77	0046	
28	0129	708	78	0091		28	0064		78	0046	
29	0128	78.249	79	0090		29	0064		79	0045	

Table B.1 (continued)

value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm	value φ	(+φ) mm	(−φ) mm
6.30	0127	793	6.80	0090		7.30	0064		7.80	0045	
31	0126	79.341	81	0089		31	0063		81	0045	
32	0125	893	82	0089		32	0063		82	0044	
33	0124	80.449	83	0088		33	0062		83	0044	
34	0123	81.008	84	0087		34	0062		84	0044	
35	0123	572	85	0087		35	0061		85	0043	
36	0122	82.139	86	0086		36	0061		86	0043	
37	0121	711	87	0086		37	0061		87	0043	
38	0120	83.286	88	0085		38	0060		88	0043	
39	0119	865	89	0084		39	0060		89	0042	
6.40	0118	84.449	6.90	0084		7.40	0059		7.90	0042	
41	0118	85.036	91	0083		41	0059		91	0042	
42	0117	627	92	0083		42	0058		92	0041	
43	0116	86.223	93	0082		43	0058		93	0041	
44	0115	823	94	0081		44	0058		94	0041	
45	0114	87.427	95	0081		45	0057		95	0040	
46	0114	88.035	96	0080		46	0057		96	0040	
47	0113	647	97	0080		47	0056		97	0040	
48	0112	89.264	98	0079		48	0056		98	0040	
49	0111	884	99	0079		49	0056		99	0039	
8.00		0.0039	8.50		0.0028	9.00		0.0020	9.50		0.0014
01			51			01			51		
02		0039	52		0027	02		0019	52		0014
03		0039	53		0027	03		0019	53		0014
04		0038	54		0027	04		0019	54		0014
05		0038	55		0027	05		0019	55		0013
06		0038	56		0027	06		0019	56		0013
07		0038	57		0027	07		0019	57		0013
08		0037	58		0026	08		0019	58		0013
09		0037	59		0026	09		0019	59		0013
		0037			0026			0018			0013

value φ	$(+\varphi)$ mm	value φ	$(+\varphi)$ mm	value φ	$(+\varphi)$ mm	value φ	$(+\varphi)$ mm
8.10	0036	8.60	0026	9.10	0018	9.60	0013
11	0036	61	0026	11	0018	61	0013
12	0036	62	0025	12	0018	62	0013
13	0036	63	0025	13	0018	63	0013
14	0035	64	0025	14	0018	64	0013
15	0035	65	0025	15	0018	65	0012
16	0035	66	0025	16	0018	66	0012
17	0035	67	0025	17	0017	67	0012
18	0035	68	0024	18	0017	68	0012
19	0034	69	0024	19	0017	69	0012
8.20	0034	8.70	0024	9.20	0017	9.70	0012
21	0034	71	0024	21	0017	71	0012
22	0034	72	0024	22	0017	72	0012
23	0033	73	0024	23	0017	73	0012
24	0033	74	0023	24	0017	74	0012
25	0033	75	0023	25	0016	75	0012
26	0033	76	0023	26	0016	76	0012
27	0032	77	0023	27	0016	77	0012
28	0032	78	0023	28	0016	78	0011
29	0032	79	0023	29	0016	79	0011
8.30	0032	8.80	0022	9.30	0016	9.80	0011
31	0032	81	0022	31	0016	81	0011
32	0031	82	0022	32	0016	82	0011
33	0031	83	0022	33	0016	83	0011
34	0031	84	0022	34	0015	84	0011
35	0031	85	0022	35	0015	85	0011
36	0030	86	0022	36	0015	86	0011
37	0030	87	0021	37	0015	87	0011
38	0030	88	0021	38	0015	88	0011
39	0030	89	0021	39	0015	89	0011

Table B.1 (continued)

value φ	$(+\varphi)$ mm	value φ	$(+\varphi)$ mm	value φ	$(+\varphi)$ mm	value φ	$(+\varphi)$ mm
8.40	0030	8.90	0021	9.40	0015	9.90	0011
41	0029	91	0021	41	0015	91	0010
42	0029	92	0021	42	0015	92	0010
43	0029	93	0021	43	0015	93	0010
44	0029	94	0020	44	0014	94	0010
45	0029	95	0020	45	0014	95	0010
46	0028	96	0020	46	0014	96	0010
47	0028	97	0020	47	0014	97	0010
48	0028	98	0020	48	0014	98	00099
49	0028	99	0020	49	0014	99	00098
						10.00	00098

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Appendix C

(the specification appendix)
Table of sample depth and sedimentation time using precipitation method (pipette method)

Table of sample depth and sedimentation time using precipitation method (pipette method) can be seen in Table C.1.

Table C.1 Table of sample depth and sedimentation time using precipitation method (pipette method)

grain size /mm	0.063		0.032		0.016		0.008		0.004				0.002				0.001			
depth /cm	15	10	10		10		10		10		5		5		3		5		3	
t °C	s	s	min	s	min	s	min	s	h	min	min	s	h	min	h	min	h	min	h	min
10	56	37	2	30	9	58	39	53	2	40	79	47	5	19	3	11	21	3	12	38
11	55	36	2	25	9	41	38	46	2	36	77	31	5	10	3	6	20	28	12	17
12	53	35	2	21	9	26	37	42	2	31	75	23	5	2	3	1	19	54	11	57
13	52	34	2	18	9	10	36	41	2	27	73	22	4	53	2	56	19	22	11	37
14	50	33	2	14	8	56	35	42	2	23	71	25	4	46	2	51	18	51	11	19
15	49	33	2	10	8	42	34	47	2	19	69	32	4	38	2	47	18	22	11	1
16	48	32	2	7	8	28	33	53	2	16	67	46	4	31	2	43	17	53	10	44
17	46	31	2	4	8	15	33	1	2	12	66	3	4	24	2	39	17	26	10	28
18	45	30	2	1	8	3	32	12	2	9	64	25	4	18	2	35	17	0	10	12
19	44	29	1	58	7	51	31	24	2	6	62	49	4	11	2	31	16	35	9	57
20	43	29	1	55	7	40	30	39	2	3	61	18	4	5	2	27	16	11	9	42
21	42	28	1	52	7	29	29	55	1	59	59	50	3	59	2	24	15	48	9	29
22	41	27	1	50	7	18	29	13	1	57	58	26	3	54	2	20	15	25	9	15
23	40	27	1	47	7	8	28	32	1	54	57	5	3	43	2	17	15	4	9	3
24	39	26	1	45	6	58	27	53	1	52	55	46	3	43	2	14	14	43	8	49
25	38	25	1	42	6	49	27	15	1	49	54	31	3	38	2	11	14	23	8	38
26	37	25	1	40	6	40	26	39	1	47	53	18	3	33	2	8	14	4	8	26
27	37	24	1	38	6	31	26	4	1	44	52	7	3	28	2	5	13	45	8	15
28	36	24	1	36	6	22	25	30	1	42	51	0	3	24	2	2	13	28	8	5
29	35	23	1	34	6	14	24	57	1	40	49	54	3	20	2	0	13	10	7	54
30	34	23	1	32	6	6	24	25	1	38	48	50	3	15	1	57	12	53	7	44
31	34	22	1	30	5	59	23	55	1	36	47	49	3	11	1	55	12	37	7	34
32	33	22	1	28	5	51	23	25	1	34	46	50	3	7	1	52	12	22	7	25
33	32	21	1	26	5	44	22	57	1	32	45	53	3	4	1	50	12	7	7	16
34	32	21	1	24	5	37	22	29	1	30	44	57	3	0	1	48	11	52	7	7
35	31	21	1	23	5	30	22	2	1	28	44	4	2	56	1	46	11	38	6	59
36	30	20	1	21	5	24	21	36	1	26	43	13	2	53	1	44	11	24	6	51
37	30	20	1	19	5	18	21	11	1	25	42	22	2	49	1	42	11	11	6	43
38	29	19	1	18	5	12	20	47	1	23	41	34	2	46	1	40	10	58	6	35
39	29	19	1	16	5	6	20	23	1	22	40	46	2	43	1	38	10	46	6	27

Annotation: This table assume that all grain are spherical, which have 2.65 relative density, and the medium is water.

Appendix D

(normative appendix)
Sediment grain size triangular classification figure

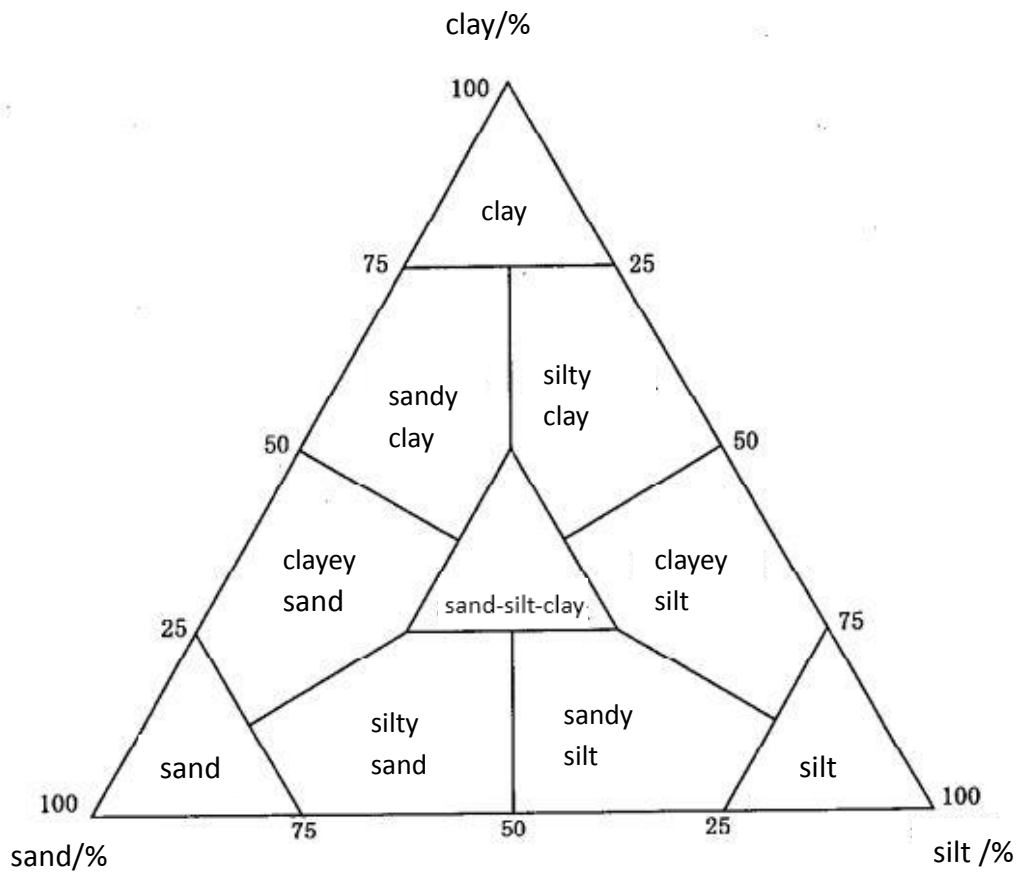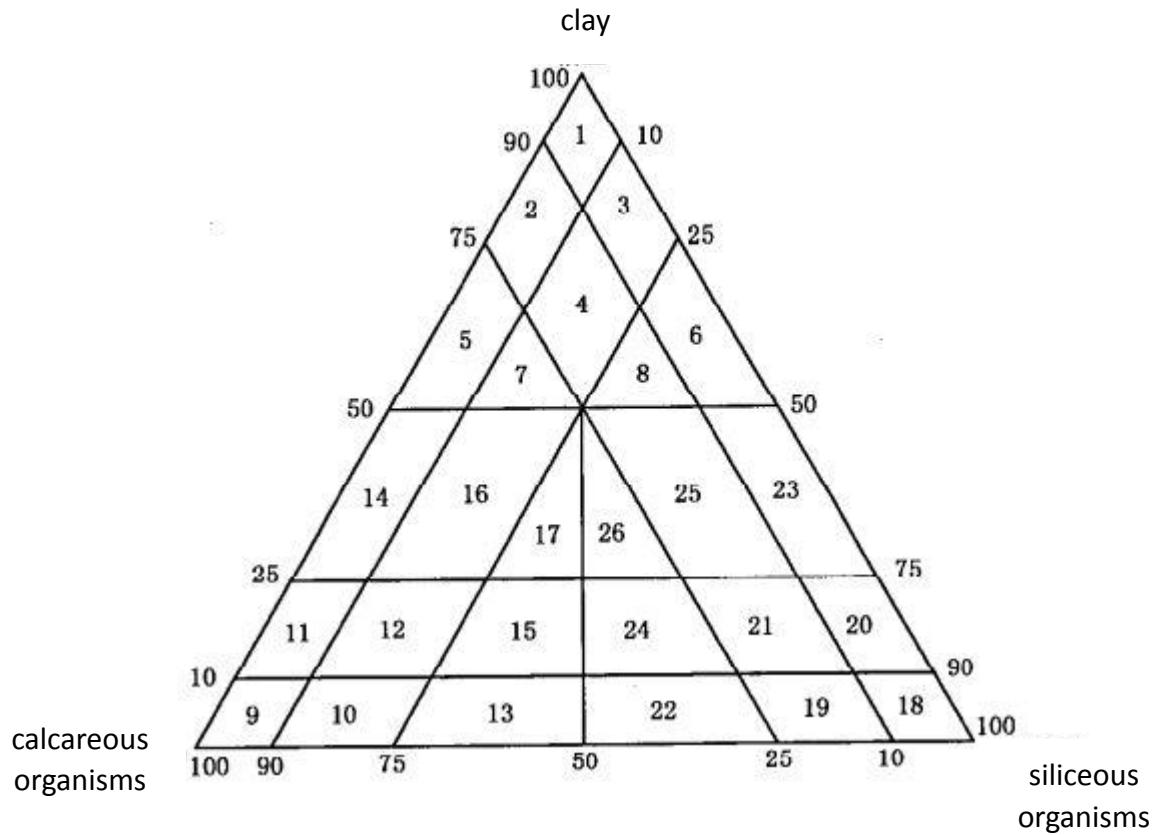Figure D.1 sediment grain size triangular classification figure

Figure D.2 deep sea sediment grain size equilateral triangular classification figure

1. Clay
2. Clay containing calcium
3. Clay containing silicon
4. Clay containing calcium and silicon
5. Calcareous clay
6. Siliceous clay
7. Calcareous clay containing silicon
8. Siliceous clay containing calcium
9. Calcareous ooze
10. Calcareous ooze containing silicon
11. Calcareous ooze containing clay
12. Calcareous ooze containing clay and silicon
13. Siliceous calcareous ooze
14. Clayey calcareous ooze
15. Siliceous calcareous ooze containing clay
16. Clayey calcareous ooze containing silicon
17. Clayey siliceous calcareous ooze
18. Siliceous ooze
19. Siliceous ooze containing calcium

20. Siliceous ooze containing clay
21. Siliceous ooze containing clay and calcium
22. Calcareous siliceous ooze
23. Clayey siliceous ooze
24. Calcareous siliceous ooze containing clay
25. Clayey siliceous ooze containing calcium
26. Clayey calcareous siliceous ooze

Appendix E

(normative appendix)
Parameter calculation of compressive strength

E.1 Initial void ratio

formula:

$$e_0 = \frac{r_w \cdot G_s \cdot (1 + 0.01 w_0)}{r_0} - 1 \quad (E.1)$$

e_0- initial void ratio

r_w-relative density of water, unit in g/cm3

G_s- relative density of soil particles

r_0-sample initial relative density, unit in g/cm3

w_0- sample initial water content (weight percentage), unit in%

E.2 Unit settlement under each load

formula:

$$S_i = \frac{\sum \Delta h_i}{h_0} \times 1\,000 \quad (E.2)$$

S_i- Unit settlement under each load, unit in 10^{-3}

Δh_i- stable total deformation quantity after sample compression of certain load,unit in mm

h_0-initial height of sample, unit in mm

E.3 Void ratio under each load

formula:

$$e_i = e_0 - (1 + e_0) \frac{S_i}{1000} \quad (E.3)$$

e_i- void ratio under each load

e_0- initial void ratio

S_i- Unit settlement under each load, unit in 10^{-3}

E.4 Compression coefficient under certain load range

formula:

$$a_v = \frac{e_i - e_{(i+1)}}{P_{(i+1)} - P_i} \quad (E.4)$$

a_v- Compression coefficient under certain load range, unit in kPa^{-1}

e_i- void ratio under each load

P_i- certain load, unit in kPa

E.5 Modulus of compression under certain load range

formula:

$$E_s = \frac{P_{(i+1)} - P_i}{S_{(i+1)} - S_i} \times 1\,000 \quad (E.5)$$

E_s- Modulus of compression under certain load range, unit in kPa

P_i- certain load, unit in kPa

S_i- Unit settlement under each load, unit in 10^{-3}

E.6 Volume compressibility under certain load range

formula:

$$m_v = \frac{1}{E_s} \cong \frac{m_v}{1+e_i} \quad \text{(E.6)}$$

m_v- Volume compressibility under certain load range, unit in kPa^{-1}

E_s- Modulus of compression under certain load range, unit in kPa

e_i- void ratio under each load

E.7 Compression index

formula:

$$C_c = \frac{e_i - e_{(i+1)}}{\log P_{(i+1)} - \log P_i} \quad \text{(E.7)}$$

C_c- Compression index

e_i- void ratio under each load

P_i- certain load, unit in kPa, take absolute value in calculation

E.8 Consolidation coefficient

formula:

$$C_v = \frac{0.848h^2}{t_{90}} \quad \text{(E.8)}$$

C_v- Consolidation coefficient, unit in cm^2/s

h-under certain load, half the average of sample initial height and ending height, unit in cm

t_{90}- compression time needed for 90% of consolidation under each load, unit in s

Appendix F

(normative appendix)
Normal magnetic field formula and parameter

F.1 International magnetic field

International magnetic field reference consider the international ellipsoid which was declared by International Union of Geodesy and Geophysics in1971, its parameter:

equatorial radius:A=6 378.160km

polar radius:B=6 356.775 km

eccentricity: f=$\frac{A-B}{A}$=$\frac{1}{298.25}$

International magnetic field reference is conducted by real spherical harmonic series and its derivative on earth center spherical coordinates.

F.2 Geomagnetic potential

$$U = a \sum_{n=1}^{n=10} \sum_{m=0}^{m=n} \left(\frac{a}{r}\right)^{n+1} [g_n^m \cos m\lambda + h_n^m \sin m\lambda] P_n^m(\cos \theta) \quad \text{(F.1)}$$

F.3 Three component of geomagnetic field total intensity module

$$X = \frac{1}{r}\frac{\partial u}{\partial \theta} = \sum_{n=1}^{n=10} \sum_{m=0}^{m=n} \left(\frac{a}{r}\right)^{n+2} [g_n^m \cos m\lambda + h_n^m \sin m\lambda] \frac{d}{d\theta} P_n^m(\cos \theta)$$

$$Y = \frac{-1}{r \sin \theta}\frac{\partial u}{\partial \lambda} = \sum_{n=1}^{n=10} \sum_{m=0}^{m=n} \left(\frac{a}{r}\right)^{n+2} \cdot \frac{m}{\sin \theta} [g_n^m \cos m\lambda - h_n^m \sin m\lambda] P_n^m(\cos \theta)$$

$$Z = \frac{\partial u}{\partial r} = \sum_{n=1}^{n=10} \sum_{m=0}^{m=n} -(n+1) \cdot \left(\frac{a}{r}\right)^{n+2} [g_n^m \cos m\lambda + h_n^m \sin m\lambda] P_n^m(\cos \theta)$$

$$\text{(F.2)}$$

X, Y, Z represents north, east, vertical component of geomagnetic field total intensity on earth center spherical coordinates respectively.

F.4 Module of geomagnetic field total intensity

$$|T| = (x^2 + y^2 + z^2)^{1/2} \quad \text{(F.3)}$$

In the formula (F.1, F.2, F.3):

a- average radius of reference ellipsoid (6 371.12km)

r- radius distance from the center of reference ellipsoid

θ- colatitude

λ- longitude start from Greenwich

$P_n^m(\cos \theta)$- n order m times Schmidt orthogonal Legendre function

g_n^m and h_n^m - spherical harmonic coefficient

$$P_n^m(u) = \frac{1}{2^n n!} \left[\frac{\varepsilon_m (n-m)!(1-u^2)^m}{(n+m)!}\right]^{1/2} \cdot \frac{d^{m+n}(u^2-1)^n}{du^{m+n}} \quad \text{(F.4)}$$

In the formula:

u=cos θ; when m=0, $\varepsilon_m = 1$; when m≥ 1, $\varepsilon_m = 2$

Relationship between time and spherical harmonic coefficient:

$$C_n^m(t) = C_n^m(t_0) + C_n^m \cdot (t - t_0) \quad \text{(F.5)}$$

In the formula:

$C_n^m(t)$,$C_n^m(t_0)$- basic field coefficient

C_n^m-Annual variation coefficient, unit in nT/a.

u=cosθ; when m=0, ε_m=1; when m≥1, ε_m=2.

The relationship between time and the value of spherical harmonic coefficients:

C_n^m(t)= C_n^m(t_0)+ C_n^m ·(t-t_0) ···(F.5)

C_n^m(t), C_n^m(t_0)——basic field coefficients;

$\quad\quad C_n^m$——annual variable coefficient, unit is nT/a.

Appendix G

(Standard Appendix)
Calculating Formulas of Remanent Magnetism Parameters

As follows:

$$X=\sum x, \ Y=\sum y, \ Z=\sum z$$

$$\left. \begin{array}{l} J=\sqrt{x^2+y^2+z^2} \\[2mm] D=tg^{-1}\dfrac{Y}{X} \\[4mm] I=\sin^{-1}\dfrac{Z}{J} \end{array} \right\} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad （G.1）$$

X,Y,Z——the north, east and vertical component of residual magnetization(A/m);

　J——residual magnetization(A/m);

　D——declination of remenantmagnetization（°);

　I——inclination of remenantmagnetization（°).

Appendix H

(Standard Appendix)
Measurement and Calculating Formulas of Magnetic Susceptibility

H.1 Measurement of isometric samples

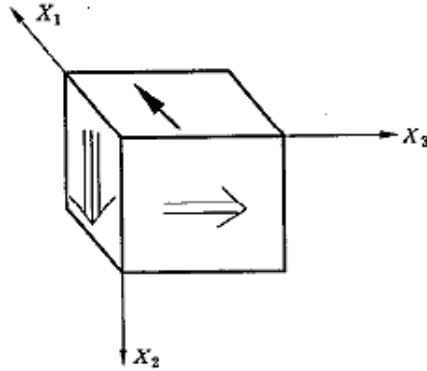The measurement order of isometric samples as shown in H.1,H.2:

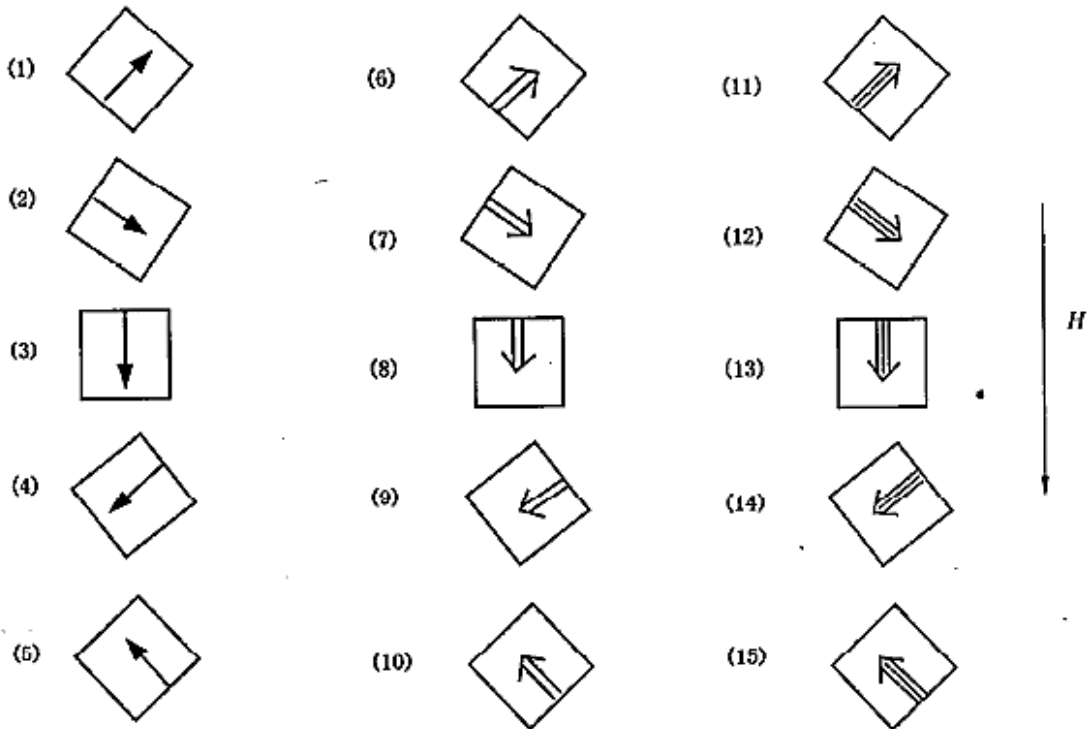Figure H.1 Measurement diagram of cube samples in all directions

Figure H.2 Rotation measurement diagram in 15 measuring directions

The measuring directions of cube samples are relevant to the magnetic field vector H,i,e and the direction of cooling shaft.

H.2 Basic equations of principal susceptibilities value

$$\vec{J} = K\,\vec{H} = K_\lambda\,\vec{H} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{（H.1）}$$

$\vec{J}$——induced magnetization (A/m);

K——magnetic susceptibility;

$\vec{H}$——magnetic field intensity (A/m).

λ=1,2,3 is respectively represent three principal susceptibilities value. Suppose $\vec{H}$ is along one of the λ spindle direction, $\vec{J}$ is parallel to $\vec{H}$.

（H.1）, K_λ is scalar, whose interpretation is magnetized along the λ spindle direction; $\vec{H}$ is vector, means the direction cosine between λ spindle direction and coordinate axis X_1, X_2, X_3 respectively is I_1, I_2, I_3; Make（H.1）as a matrix operation, matrix equation is:

$$\begin{bmatrix} J_1 \\ J_2 \\ J_3 \end{bmatrix} = \begin{bmatrix} K_{11} & K_{12} & K_{13} \\ K_{12} & K_{22} & K_{23} \\ K_{13} & K_{23} & K_{33} \end{bmatrix} \begin{bmatrix} H_1 \\ H_2 \\ H_3 \end{bmatrix} = K_\lambda \begin{bmatrix} H_1 \\ H_2 \\ H_3 \end{bmatrix} \quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{（H.2）}$$

Order：

$a=K_{11}, b=K_{22}, c=K_{33}, f=K_{23}, g=K_{13}, h=K_{12}$;

$q=1/3(a+b+c)^2-(bc+ca+ab-f^2-g^2-h^2)$

$r=2/27(a+b+c)^3-1/3(a+b+c)(bc+ca+ab-f^2-g^2-h^2)+(abc+2fgh-af^2-bg^2-ch^2)$

Do matrix operations, the final total magnetic susceptibility is :

$$K=1/3(K_{11}+K_{22}+K_{23})=1/3(K_1+K_2+K_3) \quad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{（H.3）}$$

$$K_1=K+2\sqrt{\frac{q}{3}}\cos\varphi, \quad \lambda=1, \quad s=0;$$

$$K_2=K-2\sqrt{\frac{q}{3}}\cos(60°-\varphi), \quad \lambda=2, \quad s=2;$$

$$K_3=K-2\sqrt{\frac{q}{3}}\cos(60°+\varphi), \quad \lambda=3, \quad s=4;$$

$$\varphi=\frac{1}{3}\cos^{-1}\frac{r}{2}\sqrt{\frac{27}{q^3}}, \cos^{-1}\frac{r}{2}\sqrt{\frac{27}{q^3}} \text{ take primary value in calculation ,so } \varphi \leq 1/3 \pi =60°;$$

So, $K_2<K_3$, $K_1>K_3$, K_1, K_3, K_2 is respectively represent K_{max}, K_{int} and K_{min}.

H.3 Basic formula of main magnetization axis direction

Order:

$$\left\{ \begin{array}{l} m=\dfrac{I_1}{I_3}=\dfrac{h_0 g-fh}{h^2-a_0 h_0} \\[2mm] n=\dfrac{I_2}{I_3}=\dfrac{C_0 h-fg}{h_0 g-fh} \end{array} \right.$$

$$I_1=\cos (K_\lambda, X_1), I_2=\cos (K_\lambda, X_2),$$
$$I_3=\cos (K_\lambda, X_3);$$

So：

$$I_1=\frac{m}{\sqrt{m^2+n^2+1}} \quad I_2=\frac{n}{\sqrt{m^2+n^2+1}}$$

$$I_3=\frac{1}{\sqrt{m^2+n^2+1}}, \quad D=tg^{-1}\frac{n}{m};$$

I: The direction cosine (inclination of magnetization spindle) of K_λ,(°);

D: The azimuth angle (declination of magnetization spindle) of K_λ,(°).

The calculation formula of the main magnetization spindle of K_{max}, K_{int} and K_{min}:

$$D= \left\{ \begin{array}{l} arctg\dfrac{n}{m}, m>0 \\[3mm] \\ \end{array} \right. \qquad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\text{（H.4）}$$

$$\text{arctg}\frac{n}{m}+180°\quad,m<0$$

$$I=\text{arcsin}\frac{1}{\sqrt{m^2+n^2+1}}\qquad\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots（H.5）$$