渤海 黄海 东海

海洋图集

水 文

海 洋 出 版 社

渤海 黄海 东海

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水　文

海洋图集编委会　编

MARINE ATLAS

OF
BOHAI SEA
YELLOW SEA
EAST CHINA SEA

HYDROLOGY

EDITORIAL BOARD FOR MARINE ATLAS

海洋出版社
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《渤海、黄海、东海海洋图集》

《渤海、黄海、东海海洋图集》由海洋地质和地球物理、海洋化学、海洋生物、海洋水文、海洋气候五个专业图册组成。图集覆盖的范围为北纬 21°45′－41°15′ 东经 116°00′－131°30′。编图所用资料主要取自中华人民共和国成立至1987年期间各海洋研究单位和院校调查获得的海洋资料。此外，适当选用了一些其他国家的调查资料。它是中国迄今最完整、最系统的大型基础性海洋图集。

"Marine Atlas of the Bohai Sea, Yellow Sea and East China Sea"

"Marine Atlas of the Bohai Sea, Yellow Sea and East China Sea" consists of five disciplinary atlases: Geology and Geophysics, Chemistry, Biology, Hydrology and Climatology, covering the area between 20° 40′ N —41° 30′ N and 116° 00′ E—131° 30′ E. The data used in compiling the Atlas are taken from the marine data acquired in the surveys conducted by various marine research institutions, and colleges and universities during the period from the founding of the People's Republic of China through 1987. Besides, the survey data from some foreign countries are also used as appropriate. It is the most comprehensive and the most systematic large basic marine atlas in China so far.

渤海黄海东海海洋图集

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《渤海、黄海、东海海洋图集》

前　　言

海洋在我国社会主义现代化建设中具有重要的作用，国家一贯十分重视海洋工作。早在一九五八年即曾组织各方面力量进行了全国性大规模的海洋普查。在此后的三十年间，国家海洋局及各有关部门根据国家经济建设和国防建设的需要，对我国周围海域又陆续进行了大量规模不等、内容广泛的海洋调查、监测和科学研究工作，获得了大量的调查观测资料和丰硕的科学研究成果。随着我国社会主义建设事业的发展，海洋开发活动日益增多，对海洋的管理和保护日趋迫切。根据这种形势，为满足我国海洋科学研究、开发、管理、保护、教学以及维护海洋权益的需要，并反映建国以来各有关部门在海洋调查和科学研究方面的成果，国家海洋局组织编辑出版这套《渤海、黄海、东海海洋图集》，以供各界使用。《南海海洋图集》将于以后组织编辑出版。

《渤海、黄海、东海海洋图集》由《地质及地球物理》、《化学》、《生物》、《水文》和《气候》五本专业图册组成。

为确保本套海洋图集的质量，我们尽可能搜集了国内外现有的海洋观测资料，经过校对、分析、对比和质量控制，按照以国内资料为主、国外资料为辅的原则，进行精心筛选采用。对缺乏资料的海区，国家海洋局组织了必要的海上外业补测。图集所用资料大体上截止至一九八七年底。为提高本套图集的整体性，我们从资料处理、分析、评价的方法与标准到图集的内容、格式、表现方法等方面，均作了统一的规定。要求做到科学性、系统性、实用性的统一，在保证科学性前提下力求美观。

参加本套海洋图集编辑出版工作的有国家海洋局第一海洋研究所、第二海洋研究所、第三海洋研究所、海洋科技情报研究所、海洋环境保护研究所、东海分局、北海分局、海洋环境预报中心、海洋出版社等单位。编辑工作得到中国科学院海洋研究所、南海海洋研究所，青岛海洋大学，地质矿产部石油地质海洋地质局，以及农业、交通、石油等部门和其他高等院校的热情支持和大力协助，特此致以衷心的感谢。对图集中存在的不足，热诚希望给予批评指正。

《渤海、黄海、东海海洋图集》编辑委员会

一九八九年七月

Preface

As the ocean plays an important role in China's socialist modernization drive, the Chinese government has all along attached great importance to the marine undertaking. As early as in 1958, a nationwide, large-scale marine survey was conducted, mustering strength from all walks of life. In the subsequent 30 years, the State Oceanic Administration of China (SOA) and the relevant organizations, in the light of the needs of the national economic construction and the national defence, have successively carried out a large amount of marine survey, marine monitoring and scientific research on various scales and with substantial content in the surrounding waters of China, and obtained great quantities of surveying and observational data, and rich scientific research results. With the development of China's construction, activities of ocean development are growing day by day, which makes the management and protection of the ocean increasingly urgent. In the light of this situation, and, in order to meet the needs in China's marine research, development, management, protection, education as well as safeguarding of rights and interests in marine affairs, SOA sponsored the editing and publishing of this series of "Marine Atlas of the Bohai Sea, Yellow Sea and East China Sea". This series also reflects the achievements in marine surveys and research made by other departments concerned since the founding of the People's Republic of China. The "Marine Atlas of the South China Sea"will come off later.

"Marine Atlas of the Bohai Sea, Yellow Sea and East China Sea" consists of five sub-atlases: "Geology and Geophysics","Chemistry","Biology","Hydrology"and "Climatology".

To ensure the quality of this series, we have collected as far as possible the marine observational data available both at home and abroad, which, through checking, analysis, comparison and quality control, have been carefully selected and adopted, on the principle of relying mainly on the domestic data while making the external data subsidiary. SOA had organized activities to make supplementary observation of the sea regions lacking data . The data used in this Atlas are basically as of the end of 1987 . To achieve the integrity of the series, unified rules have been formulated in terms of the contents, formats and elements description of the Atlas as well as the methods and standards for the data processing, analysis and evaluation. The unity of the Atlas has been required to be scientific, systematic and practical and we have done our best to make it artistic while ensuring its authenticity.

Participants in the work of editing and publishing of the Atlas are the First Institute of Oceanography, the Second Institute of Oceanography, the Third Institute of Oceanography, the Institute of Marine Scientific and Technological Information, the Institute of Marine Environmental Protection, the East Sea Branch, the North Sea Branch, the National Research Center for Marine Environmental Forecasts, the China Ocean Press, etc., of SOA. The editing work has been enthusiastically and energetically supported by the Institute of Oceanology, the South China Sea Institute of Oceanology, of Academia Sinica, the Qingdao Ocean University, and the Bureau of Petroleum and Marine Geology of the Ministry of Geology and Mineral Resources as well as agricultural, transport and petroleum sectors and other related universities. We hereby extend to them our hearty thanks. Comments and criticisms on the shortcomings of the Atlas will be warmly welcome.

Editorial Board
July,1989

说　　明

一、图幅内容和范围

本图册编绘海洋水文图件841幅，内容包括海水温度（简称水温）、盐度、密度、声速、水色、透明度、表层海流、潮汐、潮流、海浪、海冰等要素、是渤海、黄海、东海海区海洋水文基础图册。

本图册采用墨卡托投影，基准纬线30°N(1／350万及1／450万图幅为40°N)。成图比例尺分别为1／350万、1／450万、1／500万、1／700万、1／750万、1／1 000万。基本图幅范围为21°45′～41°15′N，116°00′～131°30′E。

二、资料来源及质量审核

本图册资料来源于国内外的海洋调查资料、沿海海洋台站观测资料和船舶天气观测报资料。

水温、盐度搜集了1907～1986年间调查资料148 779站次，其中1954年以后的资料126 738站次；水色、透明度搜集了1907～1986年间调查资料68 490站次，其中1954年以后的资料54 176站次；表层海流搜集了1900～1986年间调查资料108 918站次，其中1950年以后的资料61 146站次；潮汐共选取调和常数617站次，其中计算值320站次；潮流搜集了约1 800站次；海浪搜集了1968～1982年间船舶天气观测报和海洋调查资料273 678站次；海冰搜集了1962～1987年间10个海洋站海冰观测资料，船舶海冰观测资料及卫星照片资料。

鉴于资料来源不同质量各异，选取资料的原则是优先使用观测记录完整、精度符合要求的观测资料，其它资料有选择地使用。

我们对观测记录做了严格的质量审核。首先进行常规审核。然后，对标有注释的观测记录逐个分析处理，剔除错误记录；对不符合技术细则要求的测站，逐个剔除；通过可行性试验，分析筛选有疑问的观测记录；对一些有疑问又难以判断的记录，在各要素综合分析过程中一起处理，这样既删除影响图册质量的错误记录，又防止丢失宝贵的特殊记录。水温记录经上述审核舍去8 340站次。

三、整编方法

1、水温、盐度、密度、声速、水色、透明度

(1)水温 、盐度、密度、声速、水色、透明度均以0.5°×0.5°经纬度网格，按月分层求其平均值。平面分布图系根据各网格内平均值绘制而成。

水温、盐度、密度平面分布图分表层、10m、20m、30m、50m、100m、200m和底层，共8层。声速平面分布图分表层和底层。

（2）水温、盐度断面分布图是根据各测站的多年资料平均值绘制的。

（3）密度为条件密度异常（γ_t），由水温，盐度算出单站条件密度异常，再求其网格内的平均值。条件密度异常是根据联合国教科文组织海洋科学技术报告（1981）公布的海水状态方程计算的。

海水状态方程：$\rho(S,t,p)=\dfrac{\rho(S,t,0)}{1-p/K(S,t,p)}$

$\gamma=\rho-1\ 000$　　γ单位为kg/m^3

声速则根据Chen和Millero声速公式算出，其平均值由网格内各单站声速值合计后平均而得。

声速公式：$C(S,t,p)=C_w(t,p)+A(t,p)S+B(t,p)S^{\frac{3}{2}}+D(t,p)S^2$

表面声道选取标准是，声速梯度

$\alpha=\dfrac{\Delta C}{C_0\Delta Z}\geqslant 0.10\times10^{-4}m^{-1}$　（$C_0=1500m/s$）

水深（或观测深度）大于10m时，才选取声道。

（4）水温、盐度、密度、声速要素在垂直方向上出现急剧变化，其垂直梯度达到临界值的水层，称为跃层。根据本海区跃层特性，跃层强度临界值分为浅海、深海两种标准。

	浅　海	深　海
水　温	$\dfrac{\Delta t}{\Delta Z}=0.20℃/m$	$\dfrac{\Delta t}{\Delta Z}=0.05℃/m$
盐　度	$\dfrac{\Delta S}{\Delta Z}=0.10m^{-1}$	$\dfrac{\Delta S}{\Delta Z}=0.01m^{-1}$
密　度	$\dfrac{\Delta\gamma_t}{\Delta Z}=0.10kg/m^4$	$\dfrac{\Delta\gamma_t}{\Delta Z}=0.015kg/m^4$
声　速	$\dfrac{\Delta C}{\Delta Z}=0.50s^{-1}$	$\dfrac{\Delta C}{\Delta Z}=0.20s^{-1}$

凡水温、盐度、密度、声速的垂直梯度小于跃层强度临界值的均视为无跃层。图中均以跃层强度临界值的等值线作为跃层的边界线。

（5）水温盐度年变化图、声道特性图、径流量输沙量变化图均采用多年资料平均值绘制。

2.表层海流

表层海流图主要根据 0.5°×0.5°经纬度网格内历年实测表层海流的平均合成流矢绘成。

3.潮汐和潮流

潮汐特征分布图是根据我国沿岸及岛屿附近水位观测资料的潮汐调和常数和部分国外公开发表的潮汐调和常数资料通过计算绘制的。潮流特征分布图是根据我国海流观测资料的潮流调和常数和部分由流体动力学方程用数值计算方法求出调和常数，然后再计算特征值绘制。潮流特征分布图只绘制 5m 层。

（1）潮汐类型计算公式：

当 $0<\frac{H_{K_1}+H_{O_1}}{H_{M_2}}\leqslant 0.5$时，为规则半日潮

$0.5<\frac{H_{K_1}+H_{O_1}}{H_{M_2}}\leqslant 2.0$时，为不规则半日潮

$2.0<\frac{H_{K_1}+H_{O_1}}{H_{M_2}}\leqslant 4.0$时，为不规则全日潮

$4.0<\frac{H_{K_1}+H_{O_1}}{H_{M_2}}$时，为规则全日潮

（2）最大可能潮差计算公式：

对规则半日潮海区，

$2(1.29H_{M_2}+1.23H_{S_2}+H_{K_1}+H_{O_1})$；

对规则全日潮海区，

$2(H_{M_2}+H_{S_2}+1.68H_{K_1}+1.46H_{O_1})$；

对不规则半日潮和不规则全日潮海区，按上述两式分别计算，取其中较大值作为最大可能潮差。

（3）潮流类型计算公式与潮汐相似，仅以 H 换成 W。最大可能潮流计算公式：

对规则半日潮流海区，

$1.29W_{M_2}+1.23W_{S_2}+W_{K_1}+W_{O_1}$；

对规则全日潮流海区，

$W_{M_2}+W_{S_2}+1.68W_{K_1}+1.46W_{O_1}$。

4.风浪和涌浪

风浪和涌浪是采用 2°×2°经纬度网格按月计算其平均值绘制的。在邻近陆地、岛屿以及海峡地区采用不规则网格。

风浪和涌浪的观测记录均为有效波。浪向、涌向指风浪和涌浪的来向。各统计区的最大浪高、最大涌高是指 1968～1982 年间观测到的最大值。

（1）风浪

浪向 分 8 个方位和静稳（无浪）、浪向不定共 10 组统计。方位划分如下：

方位	N	NE	E	SE	S	SW	W	NW
度数	335～24	25～64	65～114	115～154	155～204	205～244	245–294	295–334

浪高 分 6 组统计，其相应的浪级和浪高为：

浪 级	静稳	1～2	3～4	5～6	7	≥8
浪高(m)	≤0.2	0.3～0.7	0.8～2.7	2.8～5.7	5.8～9.7	≥9.8

周期 分 6 组统计，其相应的周期为：

周期(s)	静稳	≤5	6～7	8～9	10～11	≥12

（2）涌浪

涌向 分 10 组统计，分组方法与风浪相同。

涌高 分 4 组统计，其相应的涌级和涌高为：

涌 级	静稳	1～2	3～5	≥6
涌高(m)	≤0.2	0.3～2.2	2.3～4.2	≥4.3

周期 分 6 组统计，分组方法与风浪相同。

5. 海冰

从冰情调查图及卫星照片上量取各海区的结冰范围，按旬求平均，得出各旬结冰范围。冰期根据调查观测资料分析确定。

6. 各要素单位：

水深：m　　水温：℃　　密度：kg/m^3

声速：m/s　　水色：号　　透明度：m

流速：cm/s　　流向、浪向、涌向：度

浪高、涌高：m　　周期：s　　潮差：m

本图册由国家海洋局海洋科技情报研究所负责整编。参加单位有国家海洋局第一海洋研究所、第二海洋研究所、北海分局、东海分局。

本图册在编制声速、声道特性图过程中，曾得到中国船舶工业总公司第七研究院孙琪田同志的指导和帮助。

Introduction

Ⅰ. Contents and Coverage

The Atlas contains 841 sheets of chart, including Sea Water Temperature (abbreviated to Temperature), Salinity, Density, Sound Velocity, Water Colour, Transparency, Surface Current, Tide, Tidal Current, Sea Wave, Sea Ice, etc. It is a basic and comprehensive atlas of marine hydrology for the Bohai Sea, the Yellow Sea and the East China Sea.

Mercator projection is used in the atlas. The standard paralled is 30°N (40°N for the charts on the 1∶3 500 000 and 1∶4 500 000 scales). The final chart scales are 1∶3 500 000, 1∶4 500 000, 1∶5 000 000, 1∶7 000 000, 1∶7 500 000 and 1∶10 000 000. The coverage of the major chart is 21°45′—41°15′N, 116°00′—131°30′E.

Ⅱ. Data Source and Quality Control

The data of the Atlas originate from the marine investigation data both at home and abroad, observations of the coastal ocean stations and ship reports of weather observation. The number of the stations of data collected for each element is: 148 779 stations of data during 1907—1986 for Temperature and Salinity, with 126 738 stations being the data since 1954; 68 490 stations of data during 1907—1986 for Water Colour and Transparency, with 54 176 stations being the data since 1954; 108 918 stations of data during 1900—1986 for Surface Current, of which 61 146 stations are the ones since 1950; 617 stations of harmonic constant selected for Tide, including 320 stations of computed data; about 1 800 stations for Tidal Current; 273 678 stations of ship weather observation report and marine investigation data during 1968—1982 for Sea Wave; and sea-ice observations from 10 ocean stations, ship sea-ice observations and satellite picture data during 1962—1987 for Sea Ice.

As the data vary in their source and quality, the observations with a complete record and the required precision are given priority while other data are optional.

Strict checks have been made on the data quality. First, routine checks were made on the observations, and then, the marked observation data analysed and processed one by one, deleting those wrong records. The stations that are not in conformity with the technical rules were deleted one by one. Following the feasibility test, the doubtful observation records were analysed and picked out. And those which are doubtful but hard to be determined, would be processed during the comprehensive analysis of various elements. In so doing, not only would the wrong records which affect the quality of the Atlas be deleted, but also the special records of value could be retained. For Temperature, 8 340 stations of data have been deleted through the above examination and check.

Ⅲ. Compiling Method

1. Temperature, Salinity, Density, Sound Velocity, Water Colour and Transparency

(1) Temperature, Salinity, Density, Sound Velocity, Water Colour and Transparency are computed in half-degree squares of latitude and longitude (0.5°×0.5°grid) to obtain their monthly means for each layer. The plane distribution charts are plotted according to the mean values in each grid.

The distribution charts of Temperature, Salinity and Density include 8 layers: surface, 10m, 20m, 30m, 50m, 100m, 200m and bottom. The plane distribution charts of Sound Velocity have only the surface and bottom layers.

(2) The sectional distribution charts of Temperature and Salinity are plotted according to the means of the multi-year observation data.

(3) Density is specific density anomaly (γ_t), which is the mean value of specific density anomaly in single stations, computed from temperature and salinity. The specific density anomaly is computed by the seawater condition equation published in the Marine Technical Report of UNESCO(1981).

Seawater Condition Equation:

$$\rho(S,t,p) = \frac{\rho(S,t,0)}{1 - p/K(S,t,p)}$$

$\gamma = \rho - 1\,000$ γ is in kg/m^3

Sound velocity which is computed using Chen and Millero's Sound Velocity Formula, is also the mean value averaged over the various sound velocities in single stations within the grid.

Sound Velocity Formula:

$$C(S,t,p) = C_w(t,p) + A(t,p)S + B(t,p)S^{\frac{3}{2}} + D(t,p)S^2$$

The selection criterion of surface sound channel is sound velocity gradient

$$\alpha = \frac{\Delta C}{C_0 \Delta Z} \geqslant 0.10 \times 10^{-4} m^{-1} (C_0 = 1500 m/s).$$

Sound channels are selected only for the water depth (or observation depth) greater than 10m.

(4) Temperature, salinity, density, and sound velocity change dramatically in the vertical direction and the layer whose vertical gradient reaches the critical value is called spring layer. The critical values of the spring layer intensity are determined following the two criteria for the shallow sea and the deep sea respectively according to the characteristics of the spring layer.

	Shallow Sea	Deep Sea
Thermocline	$\frac{\Delta t}{\Delta Z} = 0.20℃/m$	$\frac{\Delta t}{\Delta Z} = 0.05℃/m$
Halocline	$\frac{\Delta S}{\Delta Z} = 0.10\ m^{-1}$	$\frac{\Delta S}{\Delta Z} = 0.01\ m^{-1}$
Pycnocline	$\frac{\Delta \gamma_t}{\Delta Z} = 0.10\ kg/m^4$	$\frac{\Delta \gamma_t}{\Delta Z} = 0.015\ kg/m^4$
Sound Velocity Spring Layer	$\frac{\Delta C}{\Delta Z} = 0.50\ s^{-1}$	$\frac{\Delta C}{\Delta Z} = 0.20\ s^{-1}$

Layers whose vertical gradients of temperature, salinity, density and sound velocity are smaller than the critical values of the spring layer intensity are considered as without spring layer. Contour lines of spring layer intensity critical values serve as boundaries of the spring layer.

(5) The multi-year mean values are used in the charts of Annual Temperature and Salinity Variation, Characteristics of Sound Channel, Runoff and Bed-Load Transport.

2. Surface Current

Surface Current charts are plotted with the mean resultant current vectors of the observed surface currents in many years in the 0.5°×0.5°grid of latitude and longitude.

3. Tide and Tidal Current

Data computed with the harmonic constants of tide from the water level observations off China's mainland and islands and data published in other countries have been used in plotting the Tide Characteristics Charts.

The characteristic values computed with harmonic constants of tidal current from current observations in China and partly obtained with the fluid dynamics equation using the numerical method are used to plot the Tidal Current Characteristics Charts, which are only for the 5m layer.

(1) Calculation formulas of tide types:

When $0 < \frac{H_{K_1} + H_{O_1}}{H_{M_2}} \leqslant 0.5$,

it is a regular semi-diurnal tide.

When $0.5 < \frac{H_{K_1} + H_{O_1}}{H_{M_2}} \leqslant 2.0$,

it is an irregular semi-diurnal tide.

When $2.0 < \frac{H_{K_1} + H_{O_1}}{H_{M_2}} \leqslant 4.0$,

it is an irregular diurnal tide.

When $4.0 < \frac{H_{K_1} + H_{O_1}}{H_{M_2}}$,

it is a regular diurnal tide.

(2) Calculation formulas of maximum possible tidal range:

Tidal range for the area with regular semi-diurnal tides:

$$2(1.29H_{M_2} + 1.23H_{S_2} + H_{K_1} + H_{O_1});$$

Tidal range for the area with regular diurnal tides:

$2(H_{M_2}+H_{S_2}+1.68H_{K_1}+1.46H_{O_1})$;

For the sea areas with irregular semi - diurnal tides and those with irregular diurnal tides, calculations are done respectively using the formulas above, and the bigger value thus obtained is taken as the maximum possible tidal range.

(3) The calculation formulas of tidal current type are similar to those of the tide types except that H is used instead of W.

The calculation formulas of maximum possible tidal current are:

for the sea areas with regular semi - diurnal tidal current

$1.29W_{M_2}+1.23W_{S_2}+W_{K_1}+W_{O_1}$;

for the sea areas with regular diurnal tidal current

$W_{M_2}+W_{S_2}+1.68W_{K_1}+1.46W_{O_1}$.

4. Sea and Swell

The charts of sea and swell are plotted with mean values computed monthly in 2°×2°grids of latitude and longitude. Irregular grids are adopted for the areas near land, islands and straits.

The observations of sea and the swell used in the Atlas are all effective waves. The coming directions of sea and swell are considered as sea and swell direction. The maximum sea height and maximum swell height in various statistic squares refers to the maximum value observed in the years of 1968—1982.

(1) Sea

Sea Direction: Ten groups including 8 directions, calm sea and undefined sea direction are calculated. The 8 directions are:

Direction	N	NE	E	SE	S	SW	W	NW
Degrees	335—24	25—64	65—114	115—154	155—204	205—244	245—294	295—334

Sea Height: Six groups are used in the sea height statistics. They are:

Sea Level	Calm Sea	1—2	3—4	5—6	7	≥8
Sea Height(m)	≤0.2	0.3—0.7	0.8—2.7	2.8—5.7	5.8—9.7	≥9.8

Period: Six groups are used in the period statistics. They are:

Period(s)	Calm Sea	≤5	6—7	8—9	10—11	≥12

(2) Swell

Swell Direction: The same as those of sea.

Swell Height: Four groups are used in the swell height statistics, with the corresponding levels and heights as follows:

Swell Level	No Swell	1—2	3—5	≥6
Swell Height(m)	≤0.2	0.3—2.3	2.3—4.2	≥4.3

Period: The same as those of sea。

5. Sea Ice

The scope of freezing is taken from the sea ice investigation charts and satellite pictures. The mean value averaged over the ten - day period is the scope of freezing in the ten - day period.

The sea ice period is determined by analysing the observations.

6. The units of various elements:

Depth: m　　Temperature: ℃　　Density: kg/m^3

Sound Velocity: m/s　　Water Colour: Forel—Ule code　　Transparency: m

Current Velocity: cm/s　　Current & Sea and Swell Direction: Degree

Sea and Swell Height: m　　Period: s　　Tidal Range: m

The Atlas is compiled by the Institute of Marine Scientific and Technological Information . The First Institute of Oceanography , the Second Institute of Oceanography, North Sea and East Sea Branches of SOA also took part in the work.

We thank Mr. Sun Qitian from the Seventh Research Institute of the China Ship Industry Corporation for his help and guidence in the compilation of the Sound Channel Characteristics Chart and the Chart of Sound Velocity.

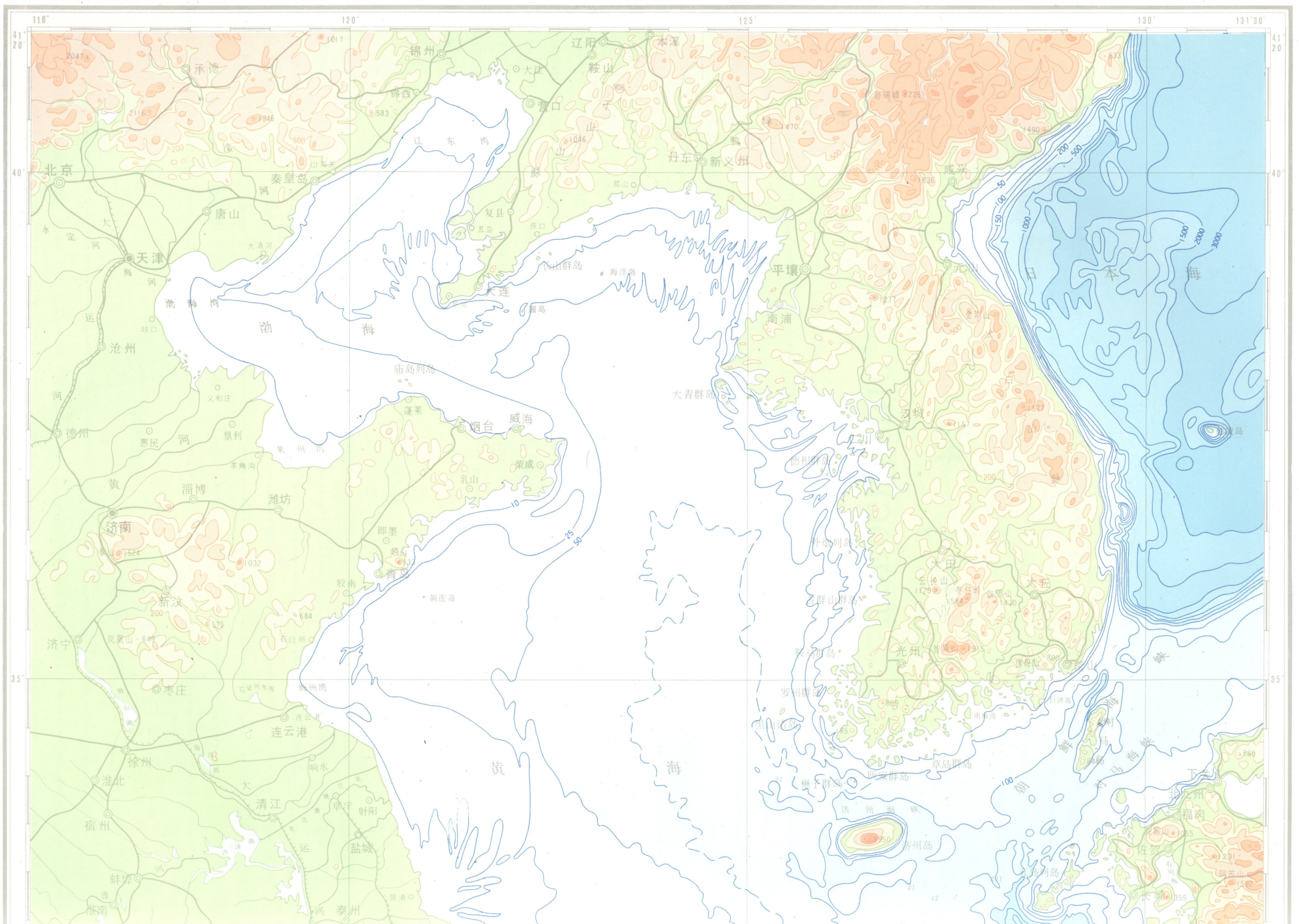
地　　形　　图

TOPOGRAPHIC MAP

1 : 5 000 000

地　　形　　图

Topographic Map



1:5 000 000（基准纬线 30°）