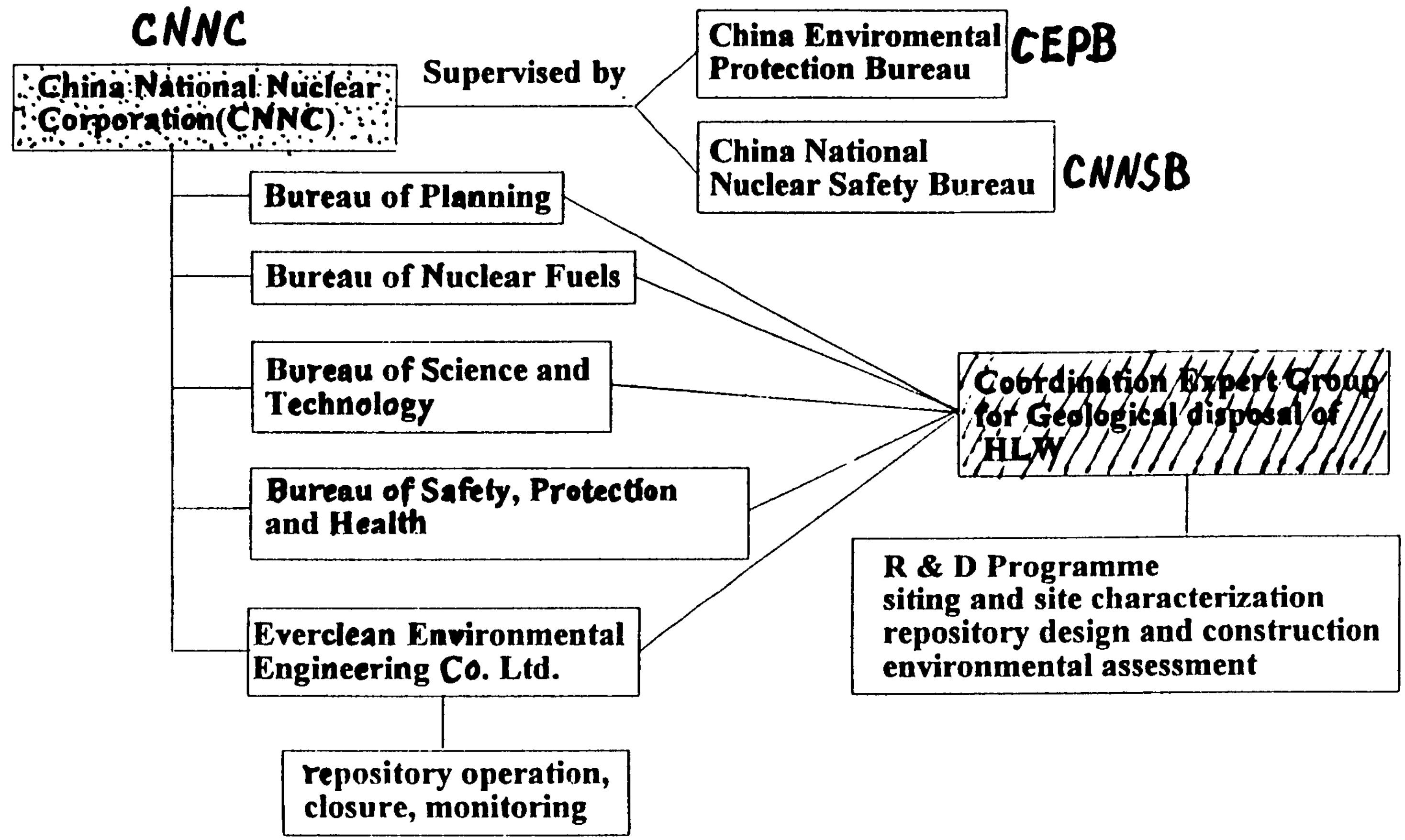

Fig. 2 China's organization structure for the disposal of high level radioactive waste

Table 1. China's NPPs and their capacity

	Name of NPP	Province	Capacity (MW)	remarks
1	✓ Qinshan	Zhejiang	300 × 3	in operation
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Deep Geological Disposal of High Level Radioactive Waste in China

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- Introduction
- Organizational Structure
- DGD Program
- Progress in site selection
- Beishan area, Gansu province, NW China
- Other studies conducted
- Summary

DGD program

Phase 1: 1985–2025 site Selection and Site Characterization

(1)1985–1986 nationwide screening

(2)1986–1988 regional screening

(3)1989–2010 district screening and preliminary site characterization

(4)2011–2015 pre-feasibility study of the pre-selected district

(5)2015–2017 licensing for site characterization

(6)2017–2023 site characterization and suitability study

(7)2023–2025 licensing for the site

Phase 2: 2025–2029 Repository Design

Phase 3: 2041–2050 Repository Construction

Phase 4: 2051– Repository Operation

Siting Criteria

4.1.1 Social Factors

—the distribution of nuclear industry in China;

—the animal and plant resources, the potential mineral resources;

—the attitude of the public and the local government;

—the requirement of national environmental protection laws;

—the feasibility for construction and operation of the repository.

4.1.2 Natural Factors

—natural geography, including topography, climate, hydrology etc.;

geology, including crustal stability(earthquakes, active faults, etc.);

engineering geology.

crustal stress, crustal thermal flow, host rock type, hydrogeology and

Progress in Site Selection

4.2.1 Nationwide Screening (1985-1986)

4.2.2 Regional Screening (1986-1988)

1). SW China

2). Guangdong Area

3). Inner Mongolia

4). East China

5). NW China

4.2.3 District Screening (1989-present)

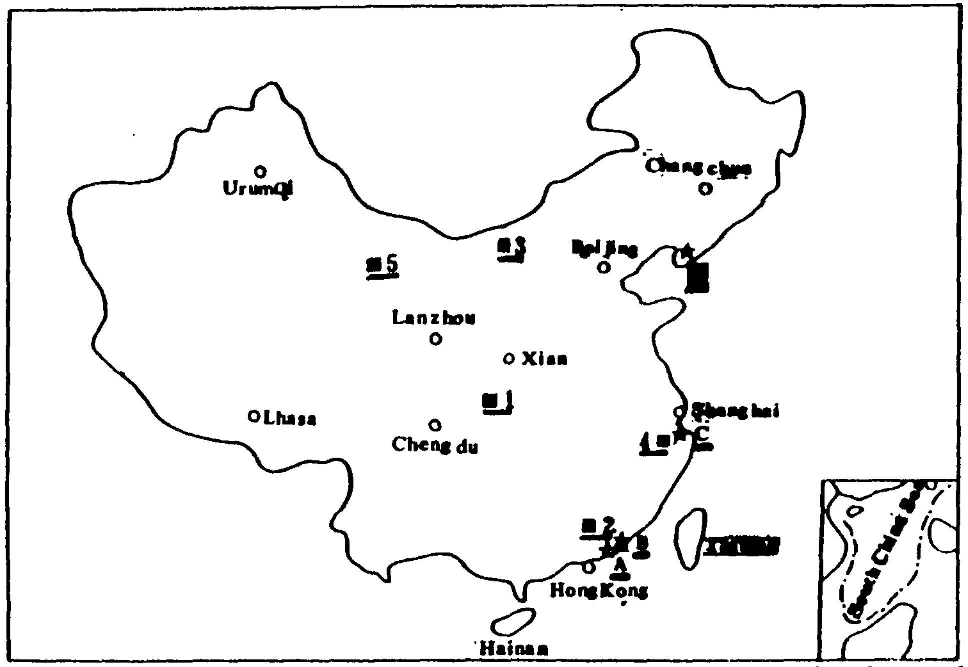
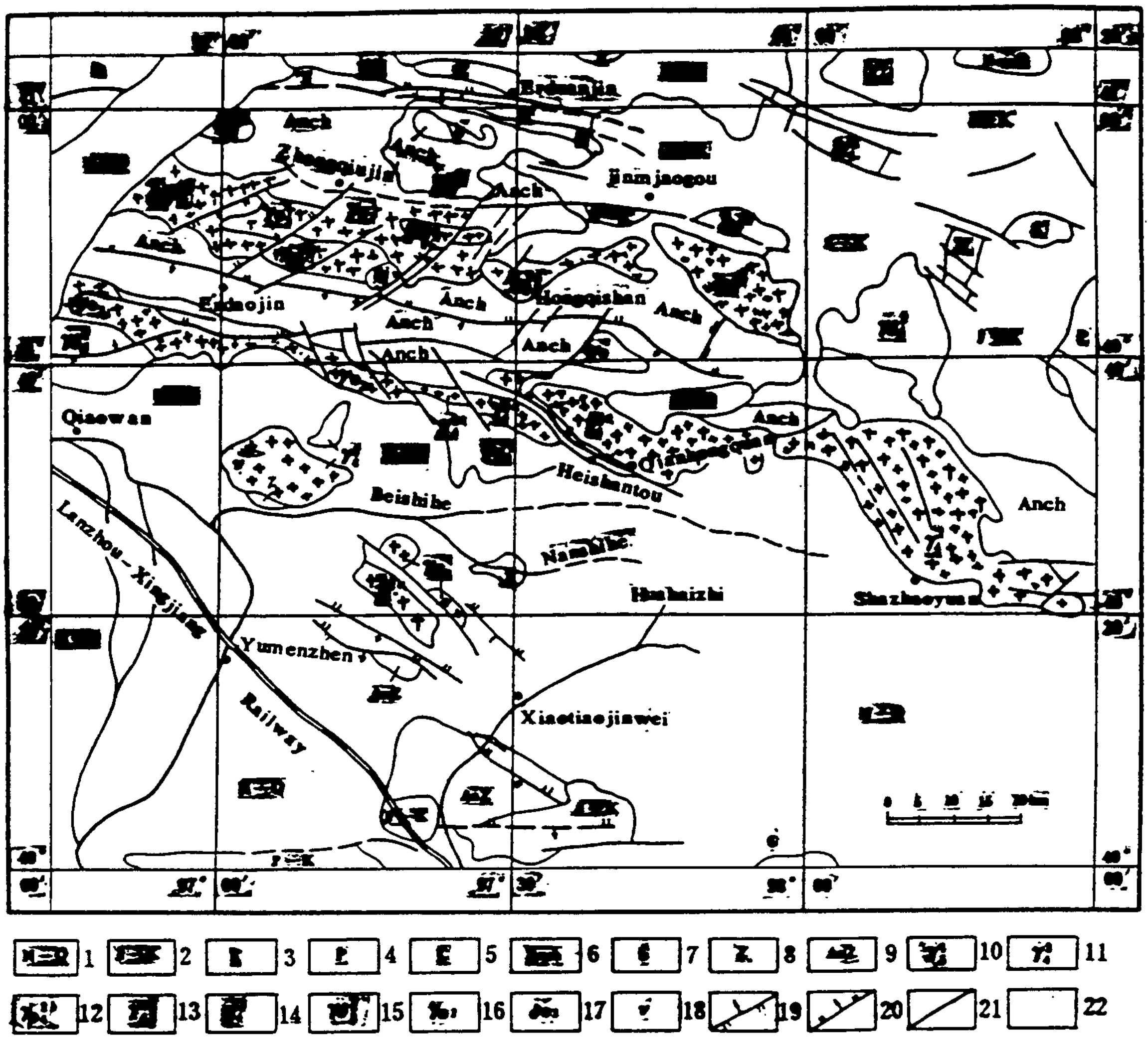


Fig. 1: Map showing the distribution of Nuclear Power Plants (NPPs) on the Chinese mailand and the pre-selected regions for China's HLW repository.

1. SW China (granite, shale); 2. Guandong area(granite); 3. Inner Mongolia (granite) 4. East China (granite, tuff); 5. NW China (mudstone, shale, granite); A. Daya Bay NPP; B. Lin'ao NPP; C. Qinshan NPPs (phase 1, 2 and 3); D. Liaoning NPP.



g. 3 Geological sketch map of the Beishan area, Gansu Province, NW China—t pre-selected area for China's high level radioactive waste repository

1.Tertiary and Quaternary sediment; 2-Cretaceous and Jurassic sandstone, shale a sandstone; 3-Triassic conglomerate and pebbly sandstone; 4-Permian System; 5Carboniferous System; 6-Pre-Changchengian schist, gneiss, marble and migmatite; 7Cambrian System; 8-Sinian System; 9-Pre-Sinian System; 10-Yanshanian granite; 1 Heicynian granite; 12-Heicynian plagioclase granite; 13-Heicynian orthoclase grani Heicynian Plagioclase granite and two-mica granite; 15-Heicynian granite diorit 1 Caledonian plagioclase granite; 17-Caledonian quartz diorite; 18-gabbro vein; 19-norm fault; 20-reverse fault; 21-fault

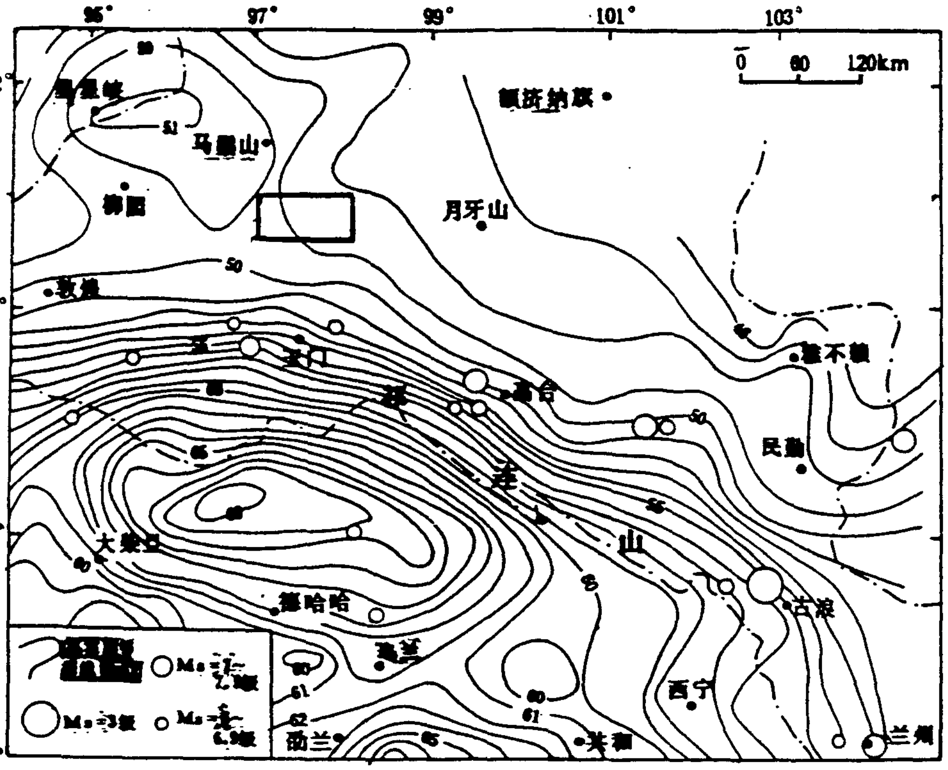


Fig. 7 Moho discontinuity iso-depth contour map of NW Gansu, China

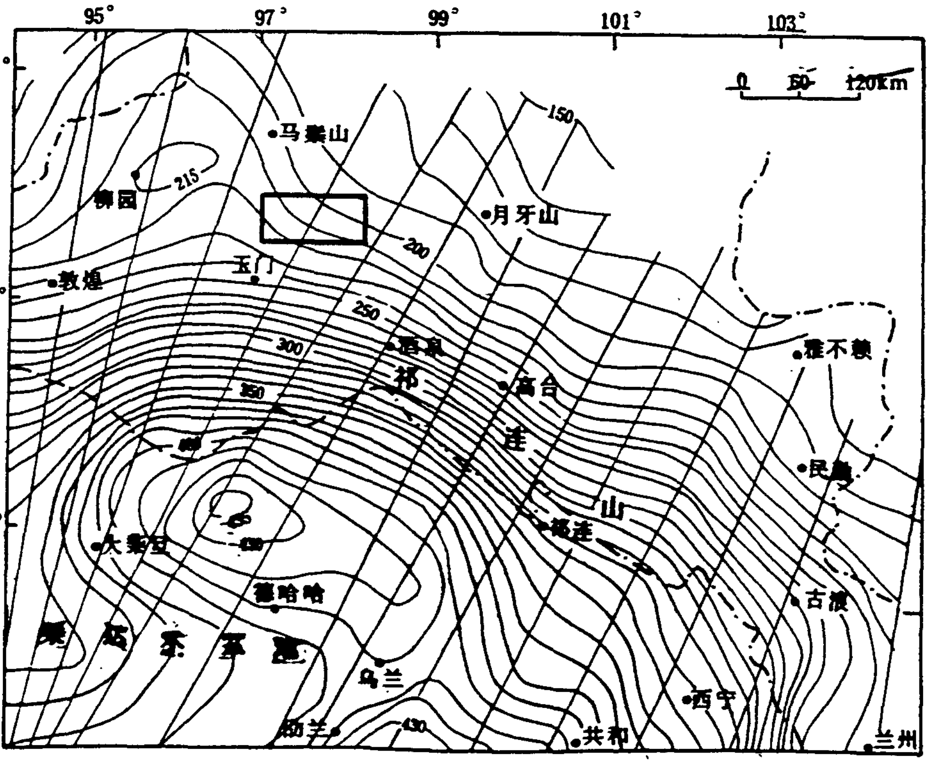


Fig. 8 Regional magnetic anomaly map of NW Gansu, China

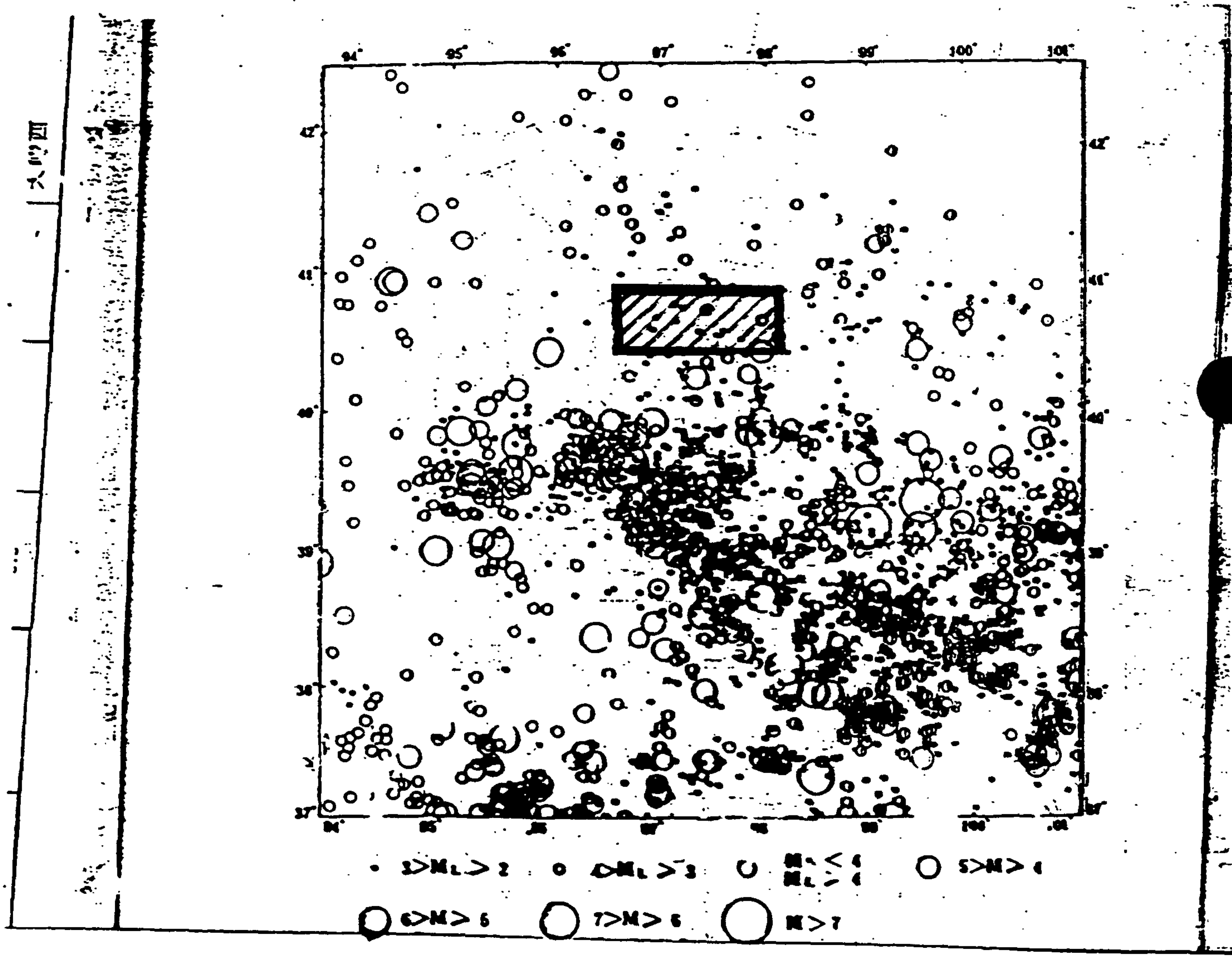


Fig.6 Distribution of seismic center in NW Gansu province, China

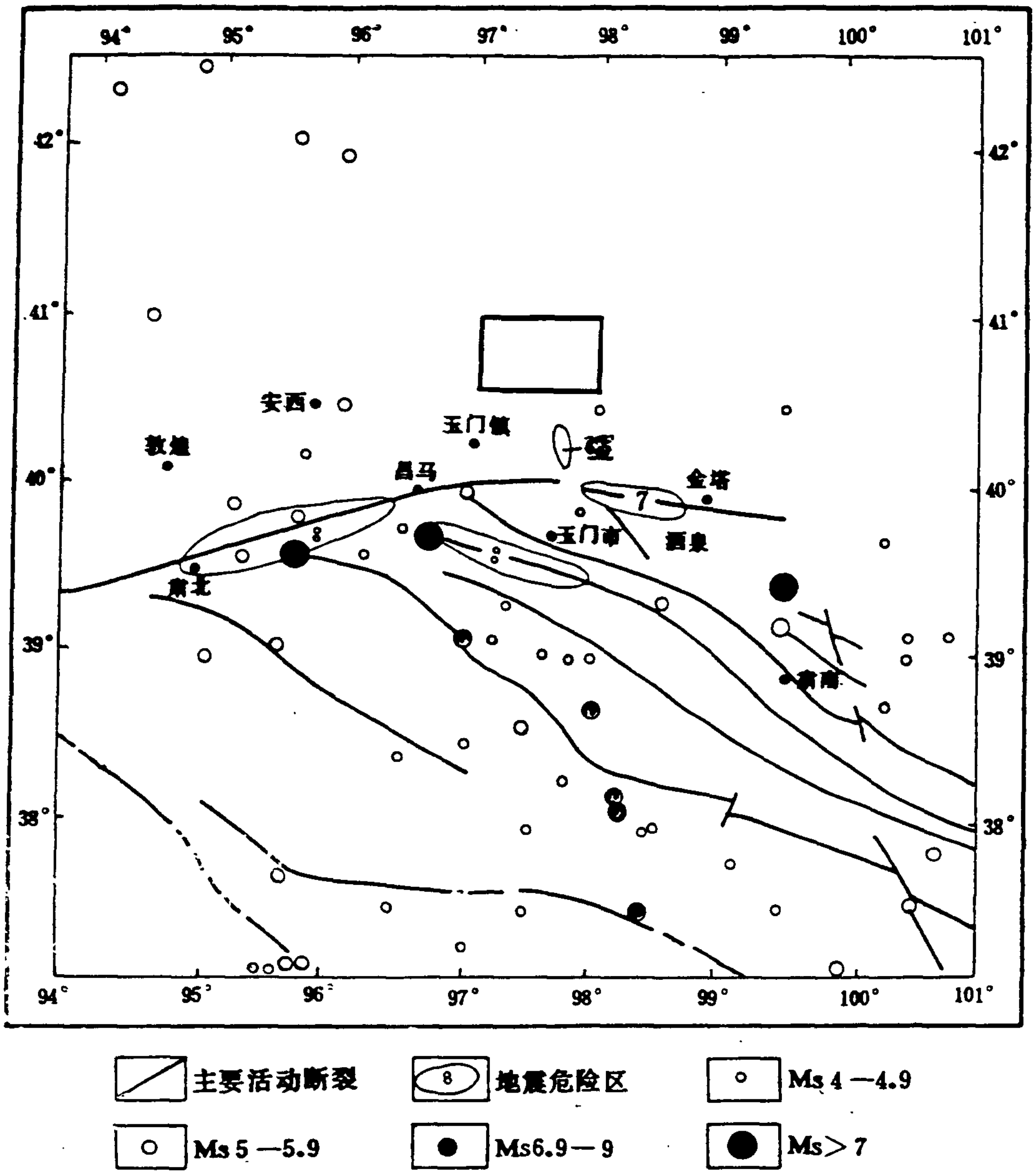


Fig. 9 Seismic risk zoning of NW Gansu, China

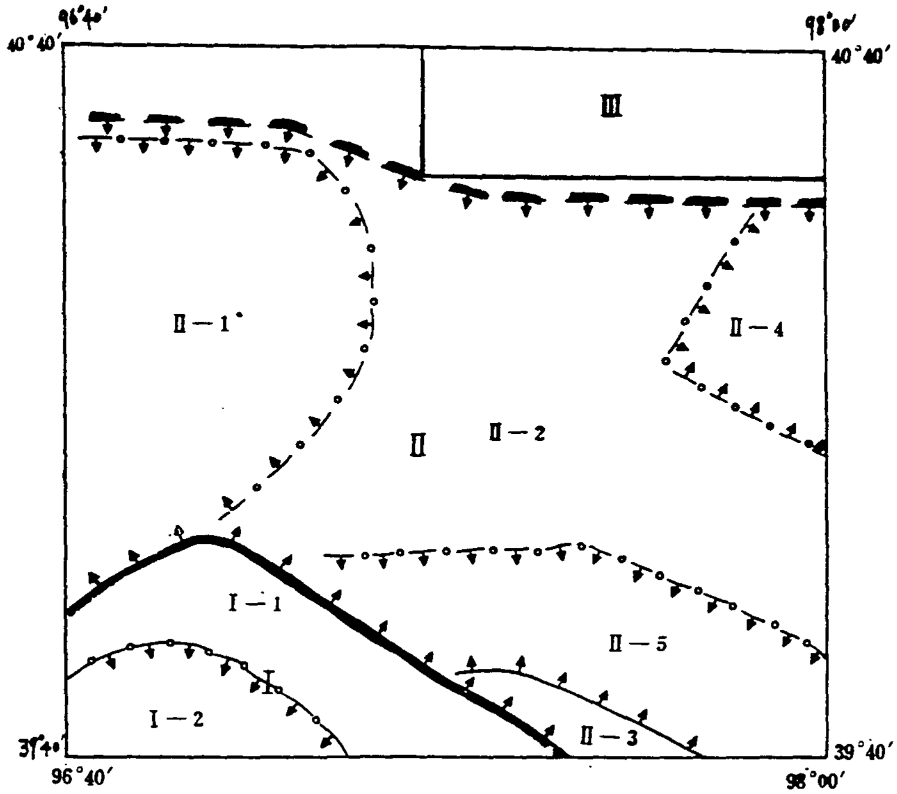


Fig. 3 Map showing the regions of neotectonics,
I- Qilian Mt. intensive uplifting region
II- Hexi Corridor Depression region,
III- Beishan slight uplifting region

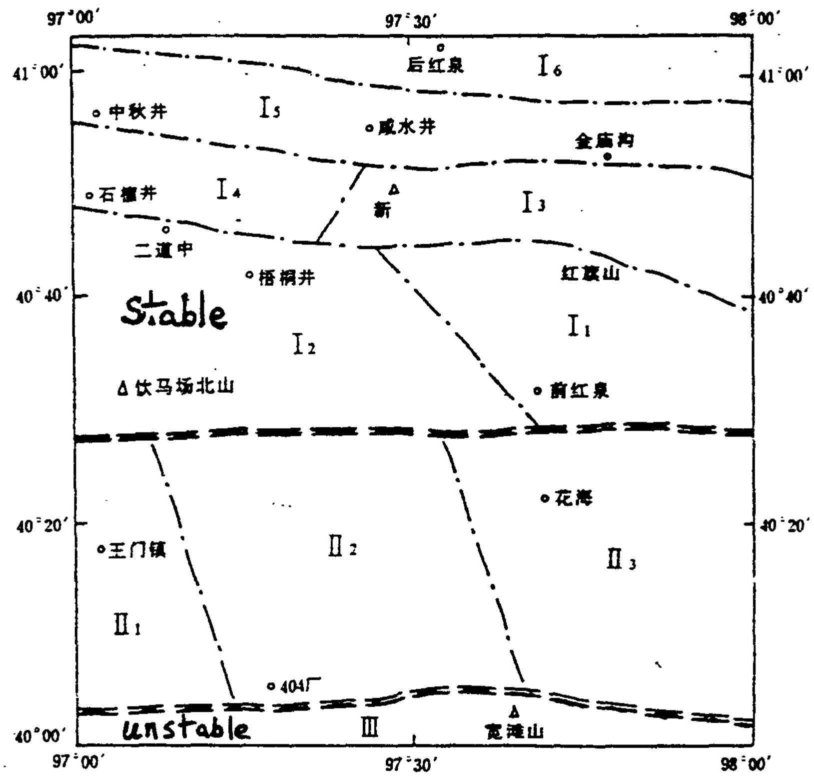


Fig.2 Map showing the classification of crustal stability of NW Gansu province.
I- Beishan stable region, II-Yumenzhen-Huahai sub-stable region, III-Hexi Corridor unstable region

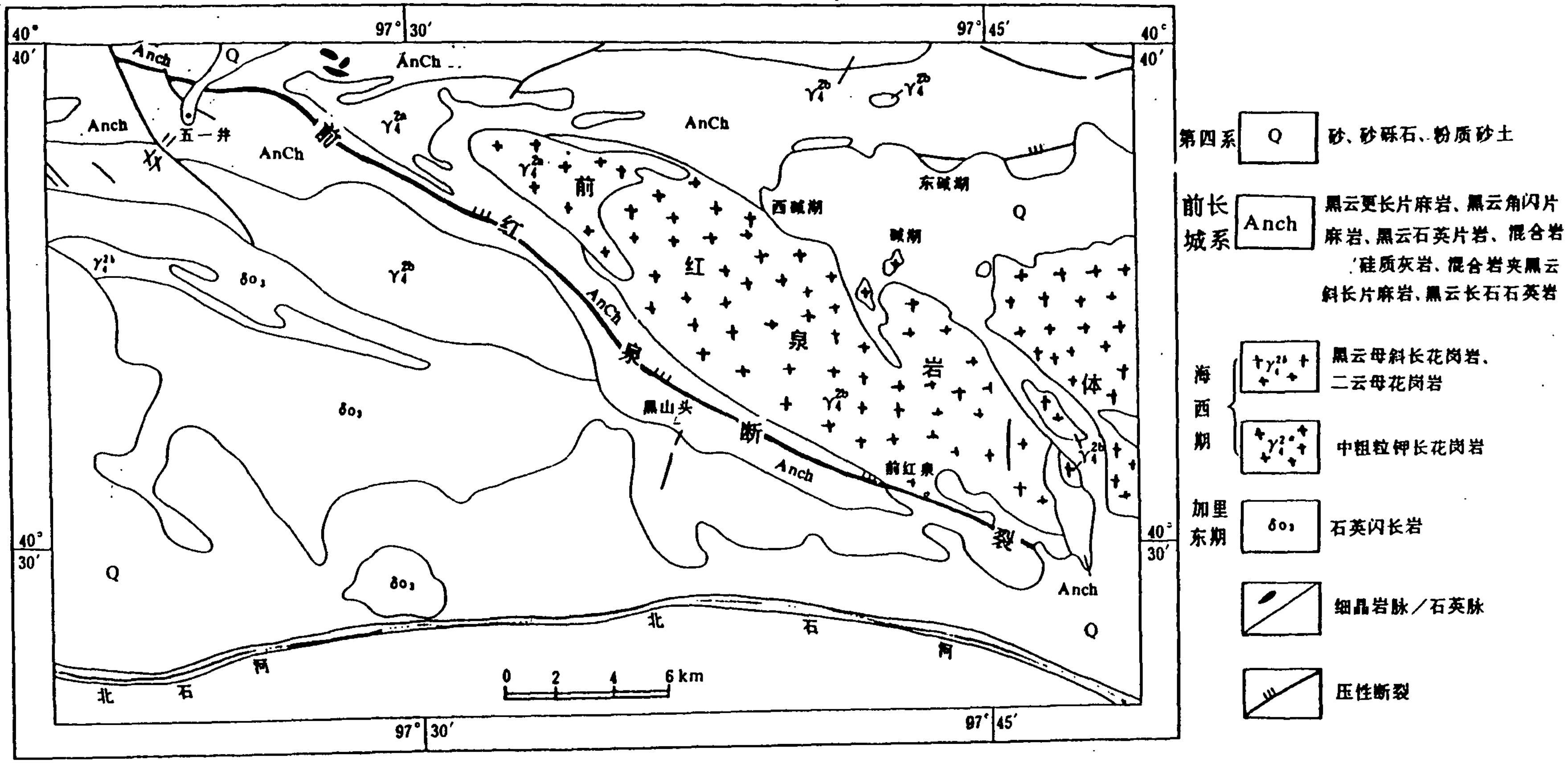


Fig. 1 Geological map of Qianhongquan Granite, Beishan area, Gansu province, NW China

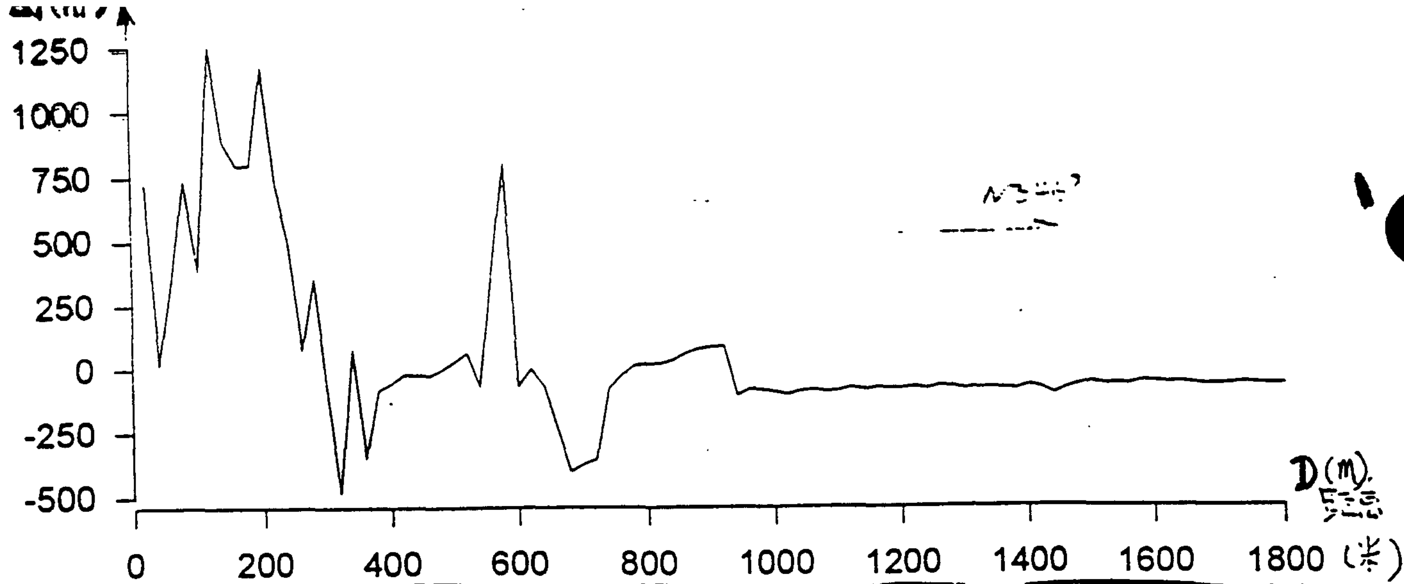


Fig. 4 Cross section of ΔT by high resolution magnetic survey

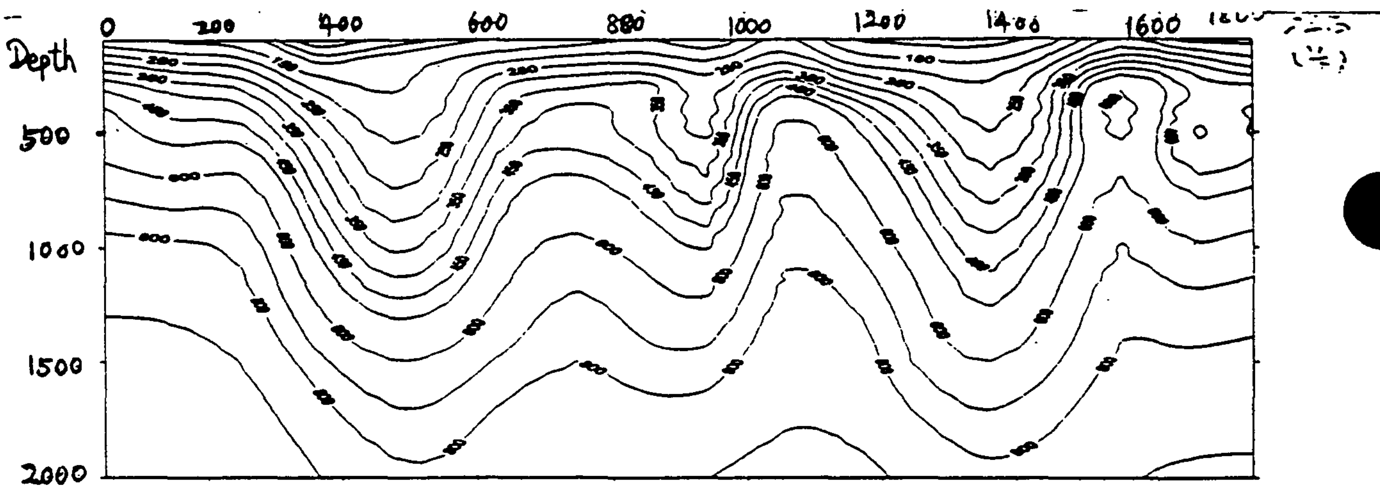


Fig. 5 Cross section of resistivity by EMAP survey

OTHER STUDIES CONDUCTED

–Site preselection for underground research laboratory;

–Experiment on radionuclide migration (in situ and in laboratories);

–Study on natural analogies;

–Study on buffer /backfill materials and their geotechnics;

–Study on speciation of transuranic elements in solutions;

–Study on heater test;

–Study on models for safety and environmental assessments.

A presentation to the winter meeting of US Nuclear Waste Technical Review Board, January 10-12, 1996, Las Vegas, Nevada.

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1. INTRODUCTION

China is now facing the challenge of how to safely dispose of nuclear waste.

China's nuclear industry was preliminary established in 1955, 5 years after the birth of the People's Republic of China. With the development of nuclear facilities, more and more radioactive waste has been generated. A lot of liquid high level waste has been accumulated to date(Luo et al, 1995), and they are stored in stainless casks, waiting for vitrification.

On the Chinese mainland, there are 2 nuclear power plants(NPPs) in operation: the Qinshan NPP in east China's Zhejiang province and the Daya Bay NPP in south China's Guangdong province(Fig. 1). In the next 5 years, 4 more NPPs(8 units)will be built(Fig. 1), their estimated capacity is listed in Table 1. China has a big plan for nuclear energy development. The total electricity capacity produced by NPPs is planned to reach up to 20,000 MW by 2010. So, in the near future, China is also facing the problem to dispose of the spent nuclear fuel from the NPPs. China's policy now is that the spent fuel should be reprocessed before final disposal.

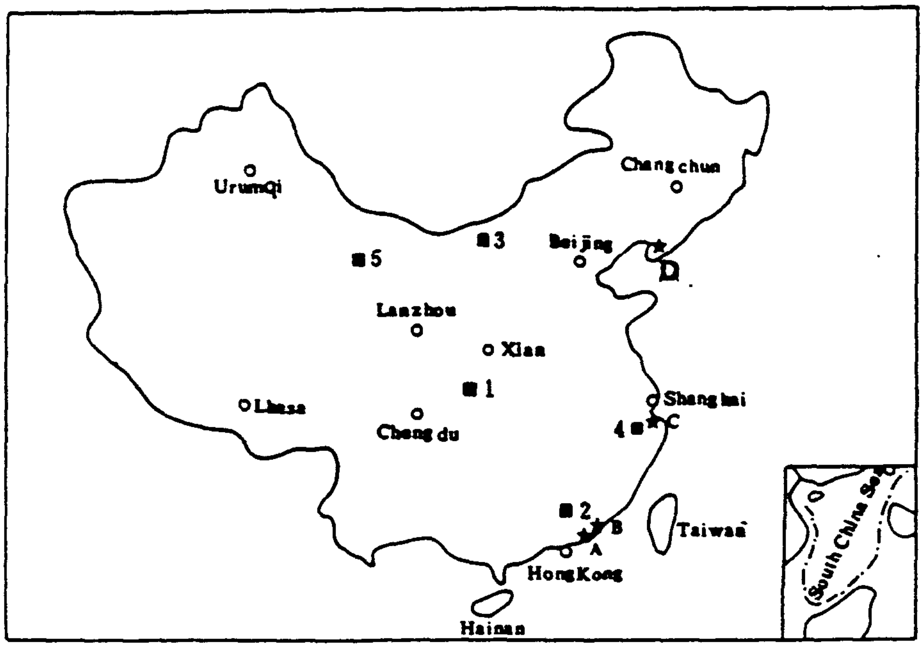

Fig. 1: Map showing the distribution of Nuclear Power Plants (NPPs) on the Chinese mailand and the pre-selected regions for China's HLW repository. 1. SW China (granite, shale); 2. Guandong area(granite); 3. Inner Mongolia (granite); 4. East China (granite, tuff); 5. NW China (mudstone, shale, granite); A. Daya Bay NPP; B. Lin'ao NPP; C. Qinshan NPPs (phase 1, 2 and 3); D. Liaoning NPP.

Table 1. China's NPPs and their capacity

	Name of NPP	Province	Capacity (MW)	remarks
1	Qinshan	Zhejiang	300 × 3	in operation
2	Qinshan(2nd phase)	Zhejiang	600 × 2	under construction
3	Qinshan(3rd phase)	Zhejiang	700 × 2	to be built
4	Daya Bay	Guangdong	900 × 2	in operation
5	Lin'ao	Guangdong	1,000 × 2	under construction
6	Liaoning	Liaoning	1,000 × 2	to be built

2. ORGANIZATION

In China, the work related to radioactive waste disposal is managed by the China National Nuclear Corporation(CNNC). The organizational structure for the disposal of high level radioactive waste is shown in Fig. 2.

The China Environmental Protection Bureau is responsible for the issue of related regulations, the final review of environmental impact statement, the licensing for the construction and operation of a repository. The China National Nuclear Safety Bureau is responsible for the safety issues related to the disposal of high level waste.

The China National Nuclear Corporation(CNNC) is responsible for the transportation of HLW and spent fuels, reprocessing of spent fuels, vitrification of liquid HLW, final geological disposal of HLW. Under CNNC, four bureaus are involved in the disposal: Bureau of Planning, Bureau of Nuclear Fuels, Bureau of Science and Technology and Bureau of Safety, Protection and Health.

The Everclean Environment Engineering Co., CNNC, is responsible for site selection and characterization, design, construction, operation, closure, and monitoring of repositories for LLW, ILW, and HLW

~~The Qingyuan Environmental Engineering Co. Ltd., attached to CNNC, is responsible for the operation, closure and monitoring of repositories.~~

A Coordination Expert Group was organized for the geological disposal of HLW in 1986. The group is composed of experts from Beijing Research Institute of Geology, Beijing Institute of Nuclear Engineering, China Institute of Atomic Energy and China Institute for Radiation Protection. The group is responsible for R & D program, site selection, research work related to site characterization, repository design, environmental assessment, safety analysis and performance assessment.

3. DGD PROGRAM

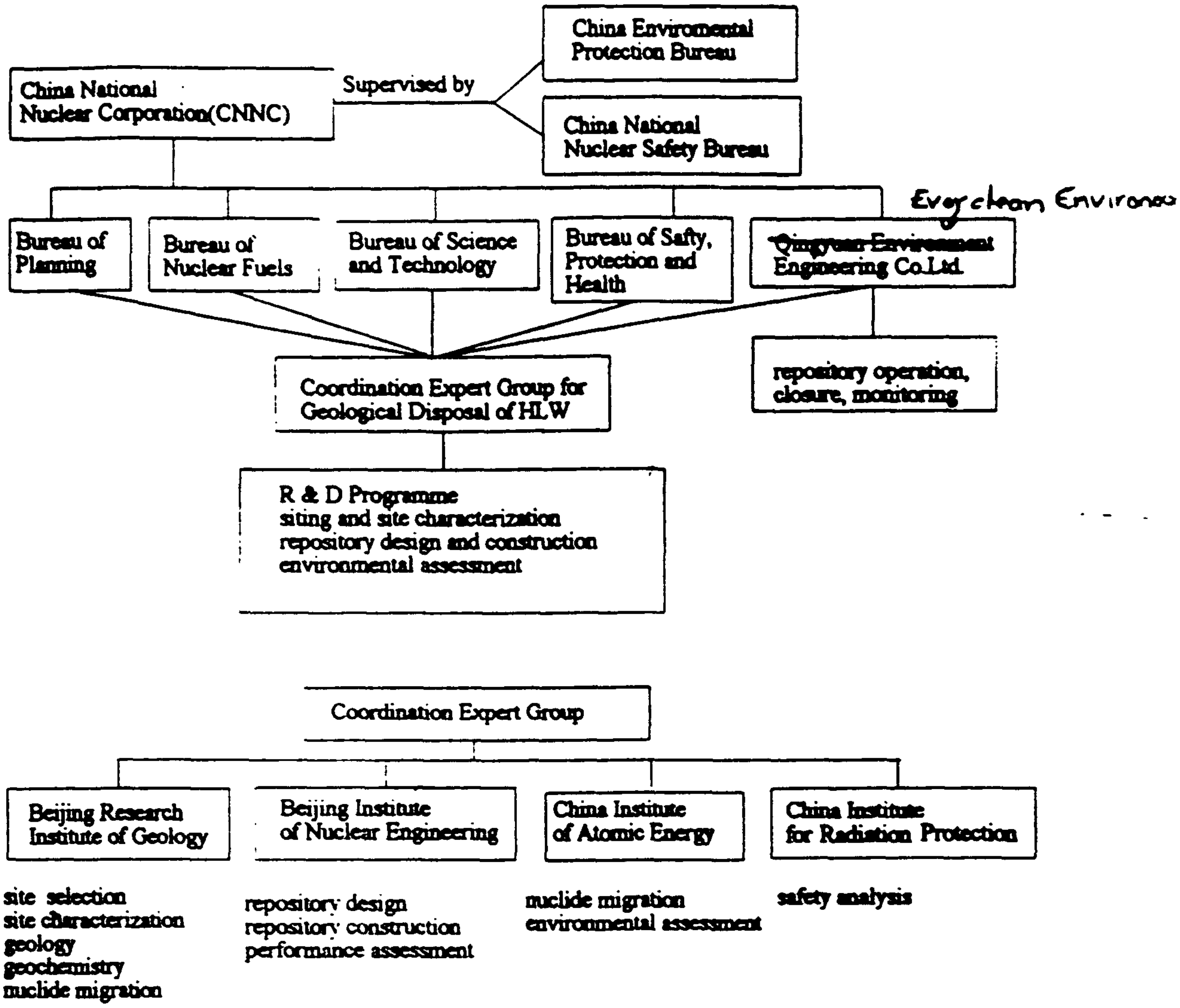

Fig. 2 China's organization structure for the disposal of high level radioactive waste

In 1985, CNNC worked out an R & D program called DGD Program for the Deep Geological Disposal of HLW(Yang,1992).

The program is divided into 4 phases:

Phase 1: 1985—2025 site Selection and Site Characterization

(1)1985—1986 nationwide screening

(2)1986—1988 regional screening

(3)1989—2010 district screening and preliminary site characterization

(4)2011—2015 pre-feasibility study of the pre-selected district

(5)2015—2017 licensing for site characterization

(6)2017—2023 site characterization and suitability study

(7)2023—2025 licensing for the site

Phase 2: 2025—2029 Repository Design

Phase 3: 2041—2050 Repository Construction

Phase 4: 2051— Repository Operation

Between Phase 2 and Phase 3, There is a 10-year interval, during which an underground research laboratory will be built near the selected site between 2028 and 2033. A full-scale in-situ test and disposal demonstration will be conducted in the laboratory between 2034 and 2040. The final repository design will be revised after the work in the underground research laboratory.

According to China's policy, the final disposed waste will be vitrified radiowastes after reprocessing, the conception design for China's HLW repository will be shaft-tunnel model, which will be located in saturated zone in granite.

4. PROGRESS IN SITE SELECTION

According to the DGD Program, the site selection for China's HLW repository is in progress and granite is considered as candidate host rock for the repository.

The site selection process, started in 1985, is composed of 4 stages: nationwide screening, regional screening, district screening and site screening. At present the third stage is reached and the screening efforts are focused on the Beishan area, Gansu province, NW China.

4.1 Siting Criteria

Because of the high radiotoxicity and long half-life of radionuclides in the high level waste, it is very strict to select sites for HLW repositories. Siting guidelines or siting criteria have been issued by many countries or international organizations, such as USA, Sweden, EC, IAEA etc. Taking into account of China's situation and other countries' experiences, we proposed our preliminary siting guidelines which have been followed during our work(Xu, 1992).

The general siting principle is that , under the effects of natural and human activities, the long term (100,000 year) safety of the repository can be obtained and the disposed radioactive wastes can be avoided from entering the biosphere and harming the human beings. Furthermore, the following factors are considered in the siting process. However, detailed and exact technical requirements and limits for the natural factors have not been worked out.

4.1.1 Social Factors

—the distribution of nuclear industry in China;

—the animal and plant resources, the potential mineral resources;

—the attitude of the public and the local government;

—the requirement of national environmental protection laws;

—the feasibility for construction and operation of the repository.

4.1.2 Natural Factors

—natural geography, including topography, climate, hydrology etc.;

—geology, including crustal stability(earthquakes, active faults, etc.);

— crustal stress, crustal thermal flow, host rock type, hydrogeology and engineering geology.

4.2 Progress in Site Selection

Since 1985, the site selection for China's HLW repository went through 3 stages: nationwide screening (1985-1986), regional screening (1986-1988), and district screening (1988-present).

4.2.1 Nationwide Screening (1985-1986)

During this stage the first work to do was the investigation of the site selection process conducted in other countries. Then, based on the experiences in other countries, and considering the distribution of China's nuclear industry, crustal stability and social economic conditions , we selected the following 5 regions for the repository (Fig. 1): SW China, Guangdong Area, Inner Mongolia, east China and NW China. In this stage, granite, tuff, mudstone and shale were considered as candidate host rocks.

4.2.2 Regional Screening (1986-1988)

Based on the work of stage 1, 21 districts were selected for further investigation within the 5 above mentioned areas.

1). SW China 3 districts were selected: Hanwangshan district, Zhongba district and Hannan district, whose host rocks are shale, biotite granite, plagioclase granite respectively.

2).Guangdong Area Since the Daya Bay NPP is located in the area and more NPPs are planned to be built, it was considered as a potential area for the HLW repository. The candidate geological formations are Fuogang Granite Body and Jiufeng Granite Body. However, because of the rapid development of Guangdong province, this area may not be considered for further investigation.

3). Inner Mongolia The selected districts, including Parjiang Haizhi and Dabaolitu districts, are located in central Inner Mongolia. The host rock is Hercynian granite.

4). East China In east China's Zhejiang and Anhui provinces, 6 districts have been selected: Lin'an, Gaoyu, Chenshi, Jiangshan, Guangde and Yixian. The host rocks include granite and tuff. The Chenshi district is located on a small island composed of granite.

5). NW China The selected area is located in NW China's Gansu province. It is the most potential area for the construction of China's HLW repository. It is a arid gobi area with very low population density and without economic potential. Total 5 districts have been selected:

—Toudaohe-Xiatianjinwei, the host rock is biotite monzonitic granite;

—Kuangqu, the host rock is mudstone;

—Baiyuantoushan, quartz diorite;

—Qianhongquan, K-feldspar granite and plagioclase granite;

—Jiujin, plagioclase granite.

4.2.3 District Screening (1989-present)

Since 1989, our work has been focused on NW China and granite is considered as the candidate host rock. The following aspects of the area were studied: earthquakes, structural frame, active faults, crustal stability, lithology, hydrogeology, engineering geology. According to the crustal stability, we considered the Qianhongquan and Jiujin districts, located at the southern part of the Beishan Folded Belt, as the most prospective districts, and further work will be conducted in those areas.

5. BEISHAN AREA, GANSU PROVINCE, NW CHINA

The Beishan area, Gansu province, is the preselected area for China's high level radioactive waste repository, and is located in the Erdaojin-Hongqishan compound anticline of the Tianshan-Beishan folded belt.(Fig. 3). The candidate host rock for the repository is granite. The regional brittle faults, including Erduanjinnan Fault, Zhongqiujin-Jinmiaogou Fault and Erdaojin-Hongqisham Fault, are nearly EW-striking, shallow and non-active faults. The crust in the area is block structure, with the crust thickness of 47 through 50 km. The depth contour of the crust is nearly EW striking, with very little variation. The gravity anomaly is -150 ×

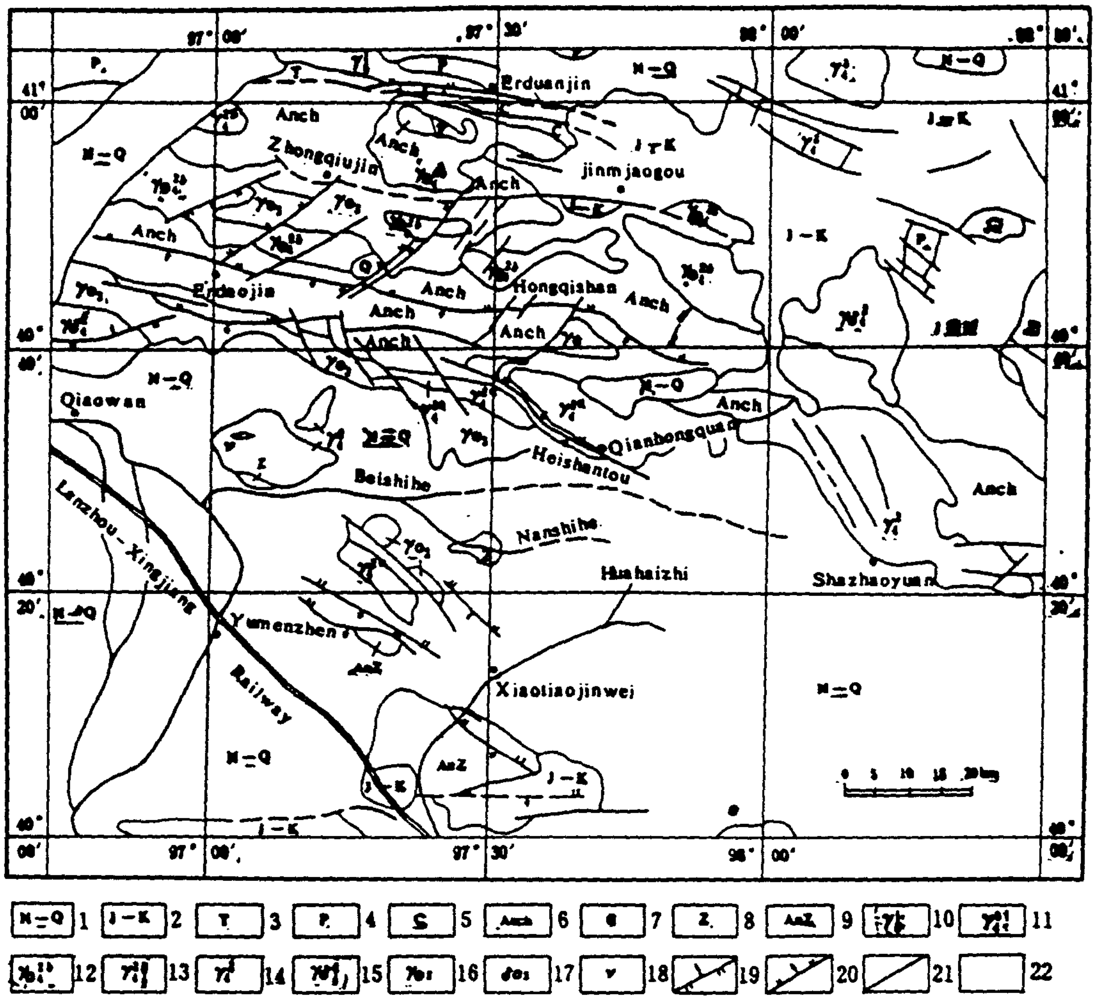

Fig. 3 Geological sketch map of the Beishan area, Gansu Province, NW China — the Pre-selected area for China's high level radioactive waste repository

1-Tertiary and Quaternary sediment; 2-Cretaceous and Jurassic sandstone, shale and mudstone; 3-Triassic conglomerate and pebbly sandstone; 4-Permian System; 5-Carboniferous System; 6-Pre-Changchengian schist, gneiss, marble and migmatite; 7-Cambrian System; 8-Sinian System; 9-Pre-Sinian System; 10-Yanshanian granite; 11-Heicynian granite; 12-Heicynian plagioclase granite; 13-Heicynian orthoclase granite; 14-Heicynian Plagioclase granite and two-mica granite; 15-Heicynian granite diorite; 16-Caledonian plagioclase granite; 17-Caledonian quartz diorite; 18-gabbro vein; 19-normal fault; 20-reverse fault; 21-fault

10^{-5} ~ $-225 \times 10^{-5} m/s^2$. The gravity gradient is less than 0.6 mGal/km. On the gravity anomaly map, the gravity anomaly contour is distributed very sparse without obvious step zones, indicating that there are no great faults extending to the depth of the crust. The seismic intensity of the area is less than 6, and no earthquakes with $Ms > 4\frac{3}{4}$ have been happened. The land form of the area is characterized by flatter gobi and small hills with elevations above sea level ranging between 1000m and 2000m. The height deviation is usually several ten meters. Since Tertiary it is a slowly uplifting area without obvious differential movement. The uplifting velocity of the crust in the area is about 0.6 ~ 0.8 mm/a, much lower than that of the Qilian region (1.5 ~ 1.8 mm/a). Comprehensive analysis of structural deformation of the Cenozoic faults and folds indicates that the area is undergone horizontal compression at present, and the direction of the principal compression stress is between 30° and 60°. The data provided by the mechanism at the source of earthquakes show that the direction of the principal compress stress is about 40°, and the superimposed fault angles range between 55° and 80° ,which are within the ranges of stable superimposed fault angles, suggesting that the main faults are stable and will not have strike-slip displacement. The geological characteristics of the Beishan area shows that the crust in the area is stable, and it has a great potential for the construction of a high level radioactive waste repository.

The geological work on the Beishan area is at a very beginning stage, and the above mentioned are only preliminary results. In the future, systematical site characterization work will be conducted year by year, to see the suitability of the Beishan area and to select the final site for the HLW repository.

6. OTHER STUDIES CONDUCTED

The geological disposal of HLW is a long-term comprehensive task. Besides site selection and site characterization, other studies are also being conducted:

—Site preselection for underground research laboratory;

—Experiment on radionuclide migration (in situ and in laboratories);

—Study on natural analogies;

—Study on buffer /backfill materials and their geotechnics;

—Study on speciation of transuranic elements in solutions;

—Study on heater test;

—Study on models for safety and environmental assessments.

The safe disposal of high level radioactive waste is a worldwide challenging task. Although China has made much progress in this field, there is still a long way to go. For example, a policy act related to nuclear waste disposal should be established, a more effective organization should be formed to promote the related work, a way should be explored to raise enough money for the safe disposal of nuclear waste.

Information exchange is very important for the disposal of radwaste. China is willing to learn the successful experiences from other countries and to strengthen international cooperation. China is also willing to share its own experiences and achievements with other countries, for the purpose of protecting the living environment of the human beings and protecting the Earth.

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