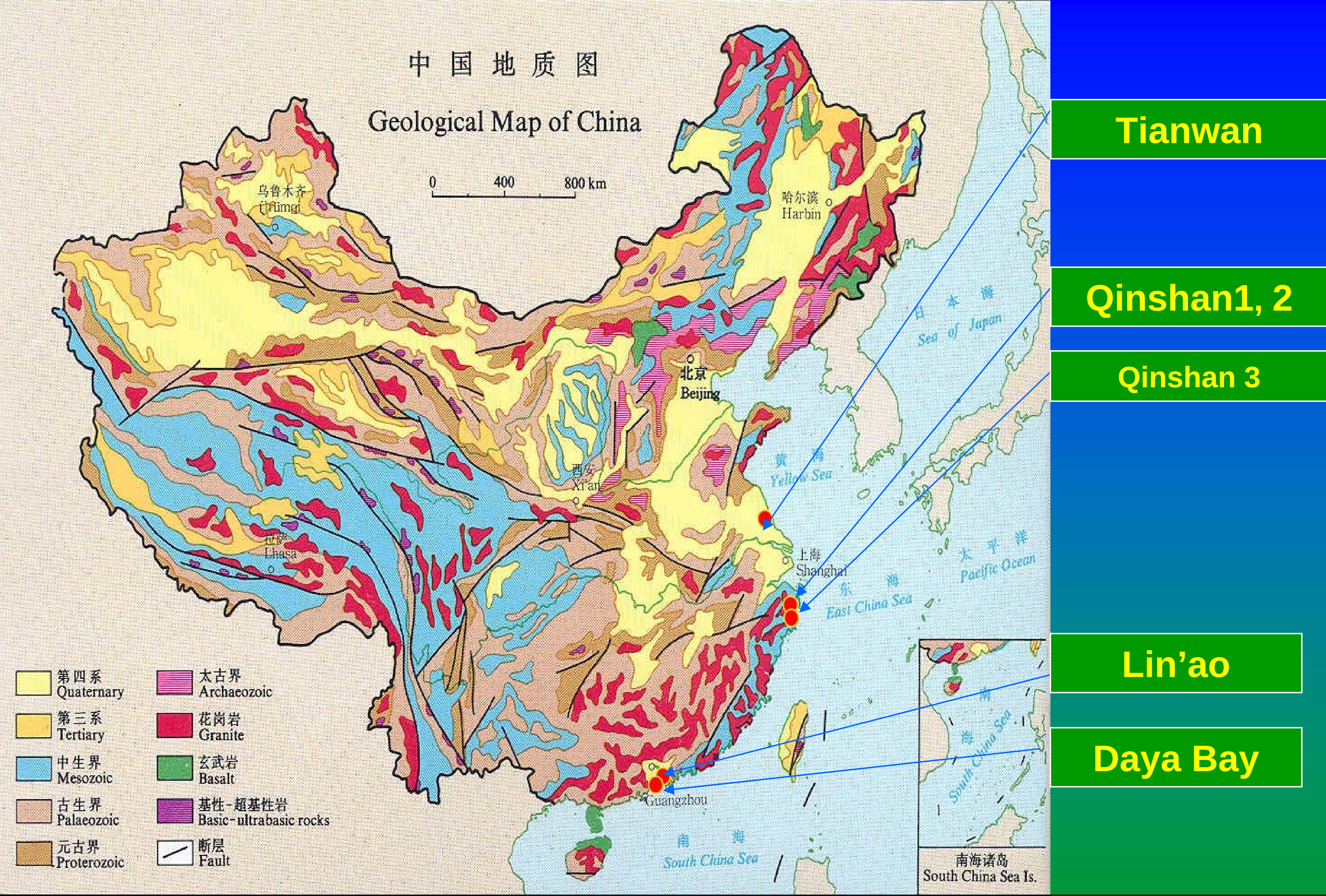
WM2010, 8-12 March, 2010, Phoenix，AZ，USA

The Current Status of Geological Disposal in China

WANG Ju

中国高放废物地质处置

王　驹



Nuclear power plants in Chinese Mainland in 2010:
11 reactors in operation, 28 under construction

2006-2020 NPP Plan 核电规划

- Installed capacity of NPP:

  40 GW in operation

  18 GW under construction

- 29 more 1000 MW NPPs will be built in Chinese Main Land, even more !!!
- Cost: 60 billion USD
- Total spent fuel: 83,000 MTU
- Even more!!!

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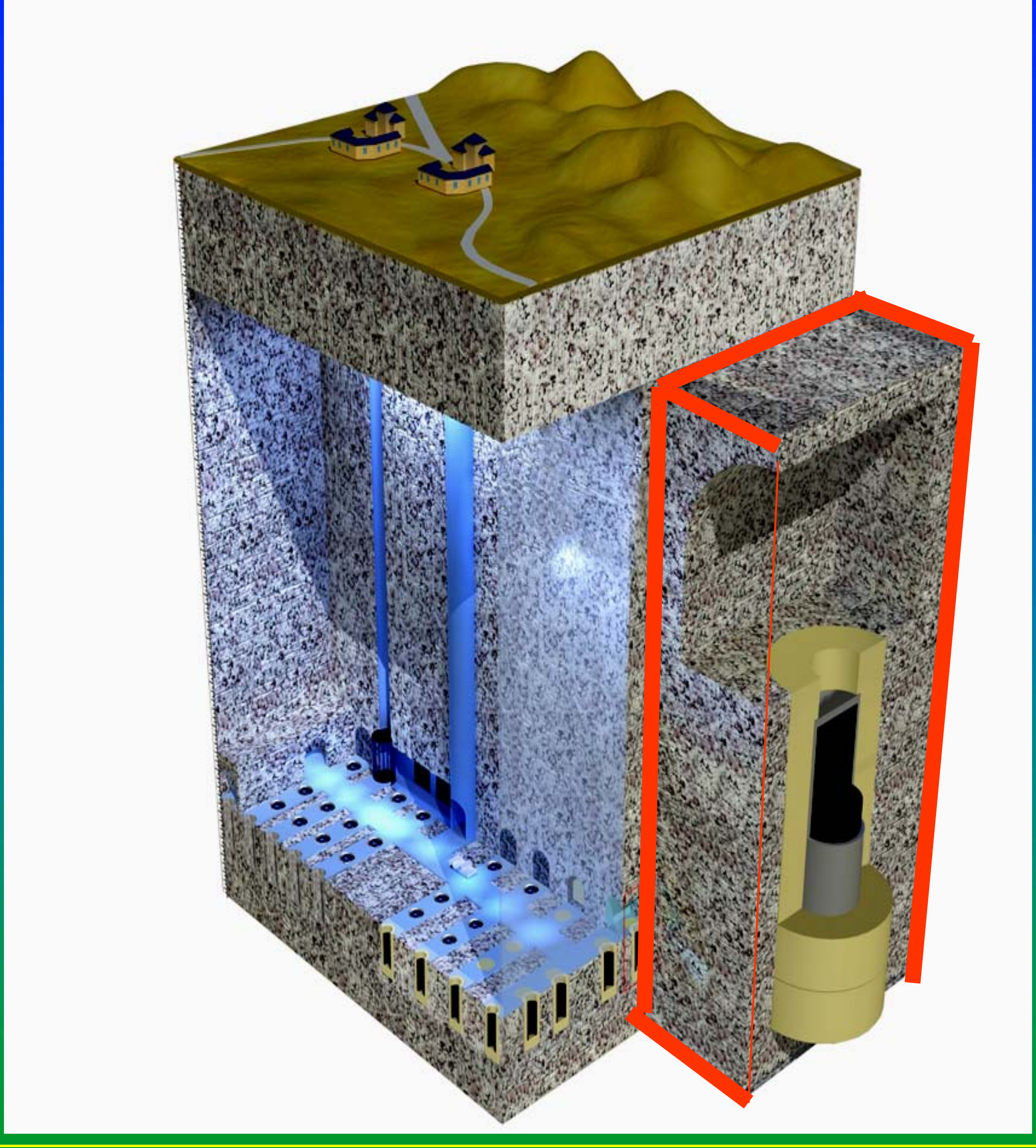
Basic Policy for HLW Disposal
中国高放废物处置基本政策

- spent fuel should be reprocessed
- waste form: vitrified waste, CANDU SF
- deep geological repository
- host rock: granite / clay ?
- repository concept:
  - multi-barrier concept,
  - shaft--tunnel-disposal hole,
  - located in saturated zone

Preliminary Concept for China's Repository

A multi-barrier concept



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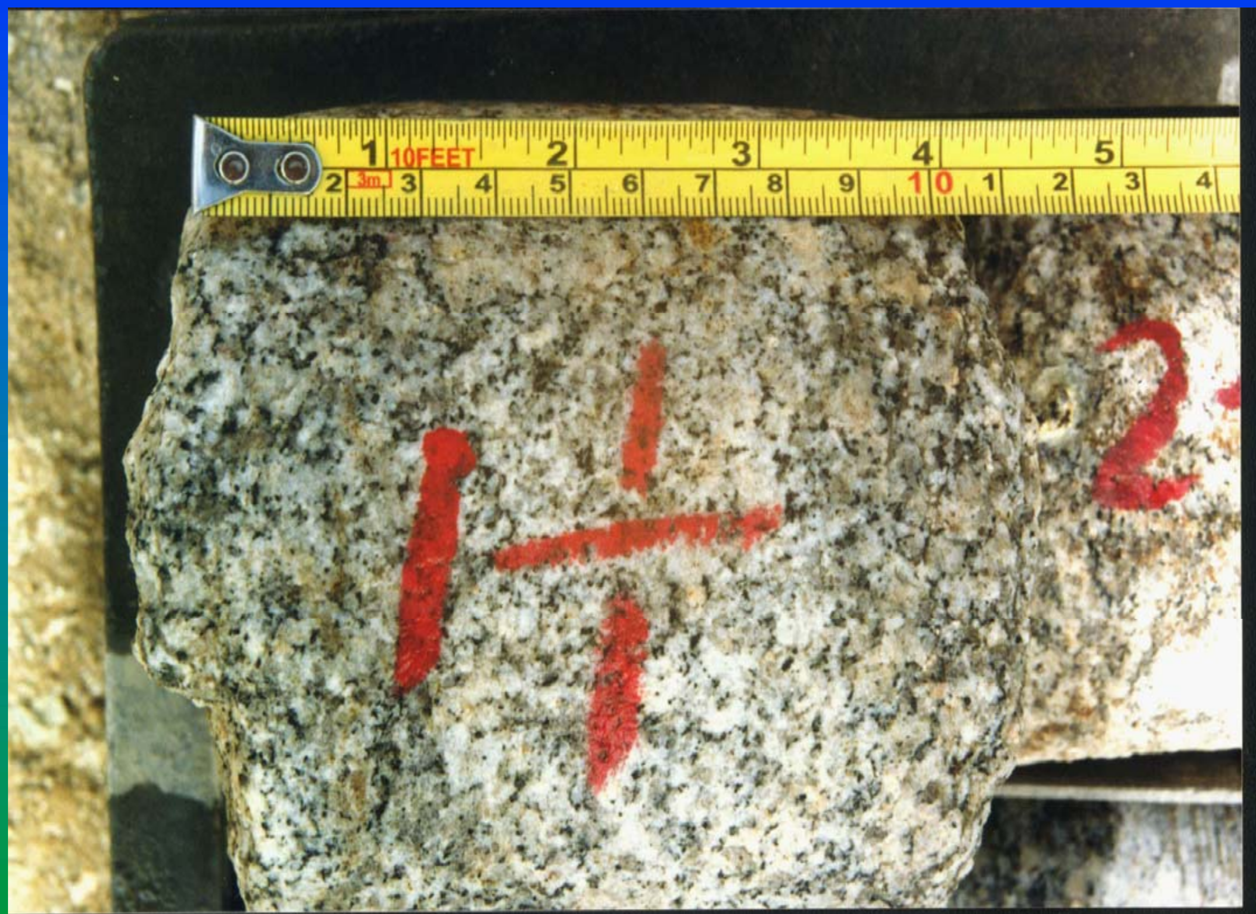
Host rock for China’s HLW repository

Granite： 中国高放废物处置库候选围岩：花岗岩



国家环境保护部
国家核安全局

Regulatory body

国家原子能机构

Project and fund control

Ministry of Environment Protection (MoEP)

National Nuclear Safety Admin. (NNSA)

China Atomic Energy Authority (CAEA)

China National Nuclear Corporation (CNNC)
-- possible implementation body

BRIUG

CNPE

CIAE

CIRP

Universities, CAS

Institutes Involved in HLW Disposal R&D

4 Leading Institutes

- Beijing Research Institute of Uranium Geology (BRIUG):
  - site investigation / PA/ EBS
- China Institute of Atomic Energy: Radionuclide Migration
- China Institute for Radiation Protection: Safety assessment
- China Nuclear Power Engineering Co. : Engineering Design

- other institutes and Universities
  - Tongji University, Beijing Univ., Nanjing Univ., Lanzhou Univ.,
  - East China Univ. of Technology,
  - Chinese Academy of Science

Undertake fundamental studies

Law 政府法律

- 2003: Law of People's Republic of China on Prevention of Radioactive Pollution:

  "high level radioactive waste should be disposed in centralized geological repository"

Government regulations 政府规划

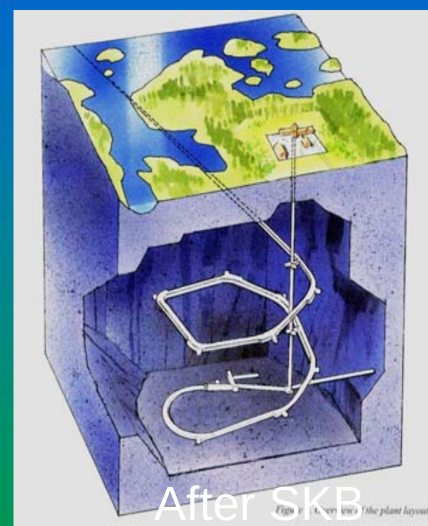
- **2006: R&D Guidelines for Geological Disposal jointly published by China Atomic Energy Authority, Ministry of Sci. &Tech., Ministry of Environ. Prot.**

- **2007: the Long Term Development Plan for the NPP in China (2006-2020). Approved by the State Council -- The construction of an URL for HLW in China should be completed by 2020**

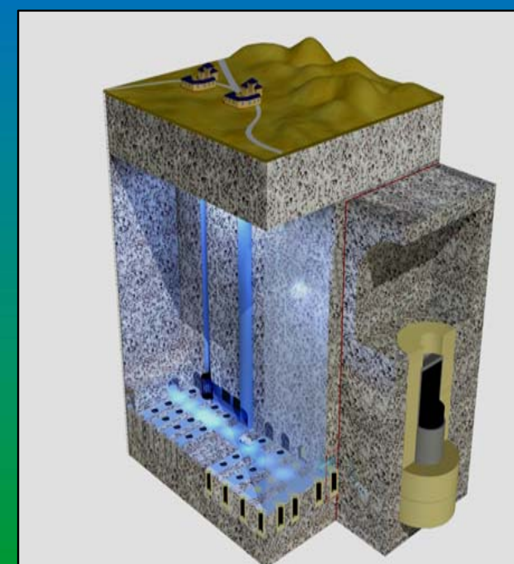
a 3-step strategy for HLW disposal
3部曲式的技术路线

Site

URL



Repository

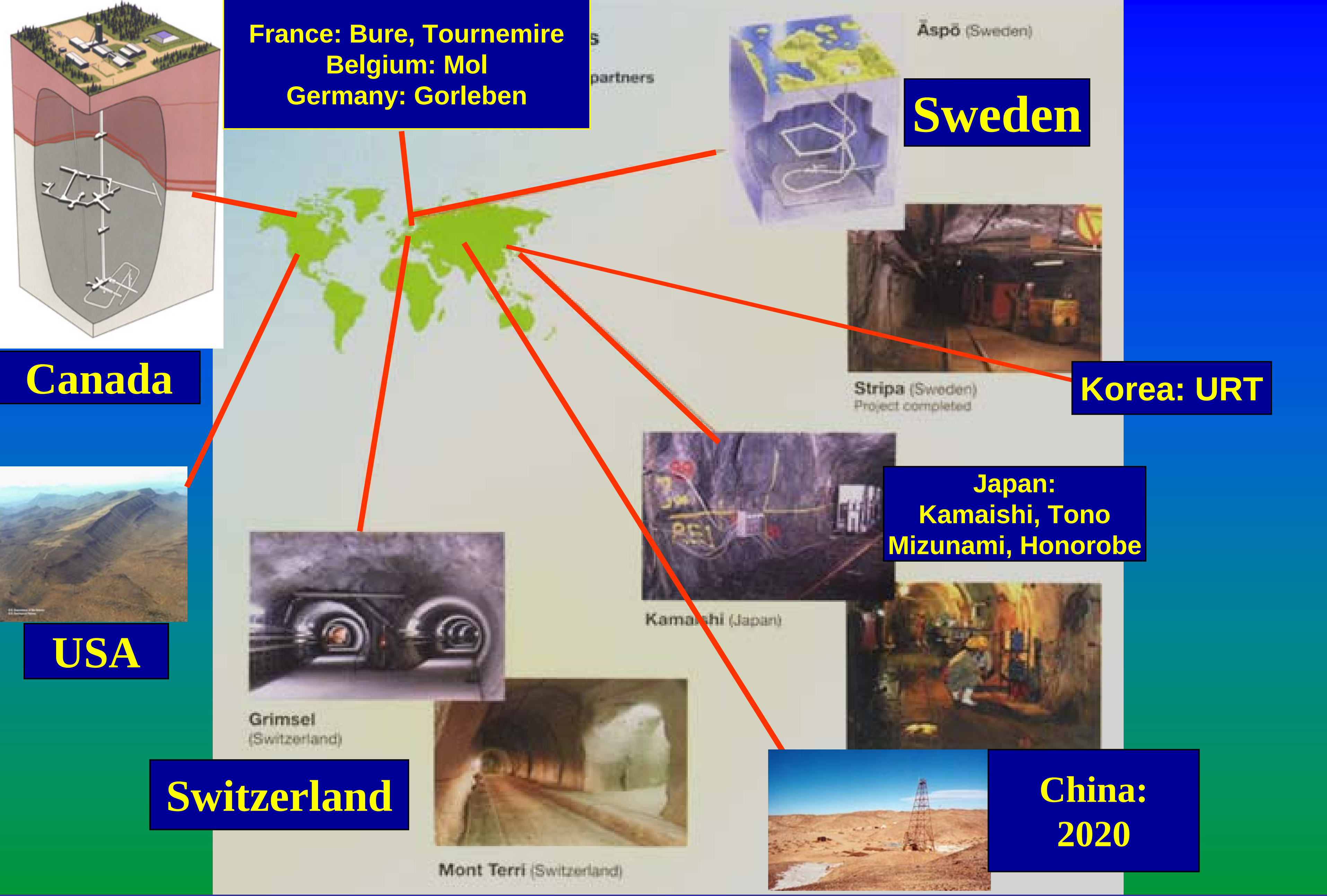


Long term plan for HLW disposal

- 2009--2020：
  Basic Study and Site Selection

- 2020--2040
  In Situ R&D in Underground Research Laboratory

- 2040--middle of 21st Century
  Repository construction



URLs for nuclear waste disposal: 国际地下实验室分布

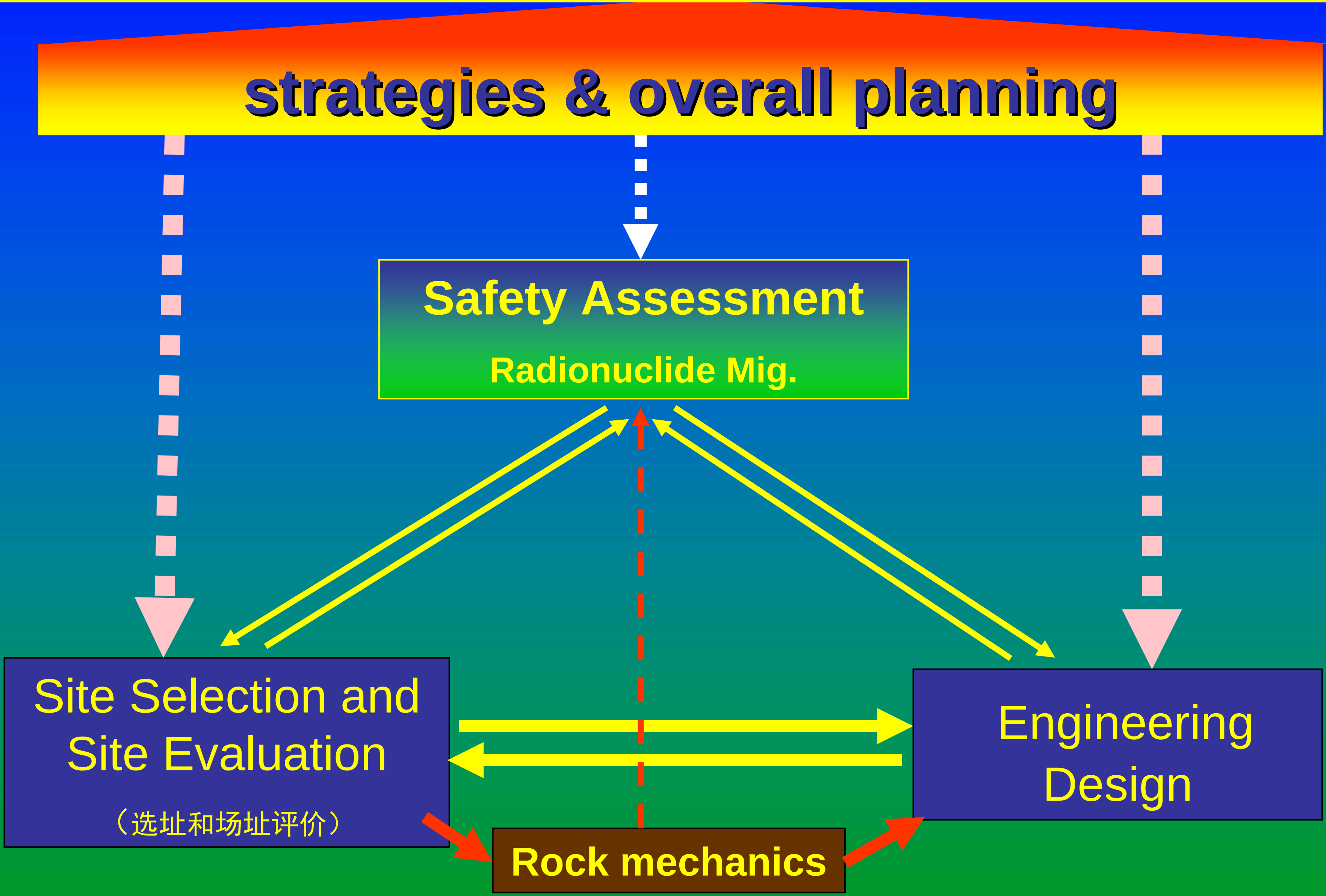
China plan to build an URL before 2020 中国拟于2020年前建成地下实验室

Major Research Activities between 2010-2020

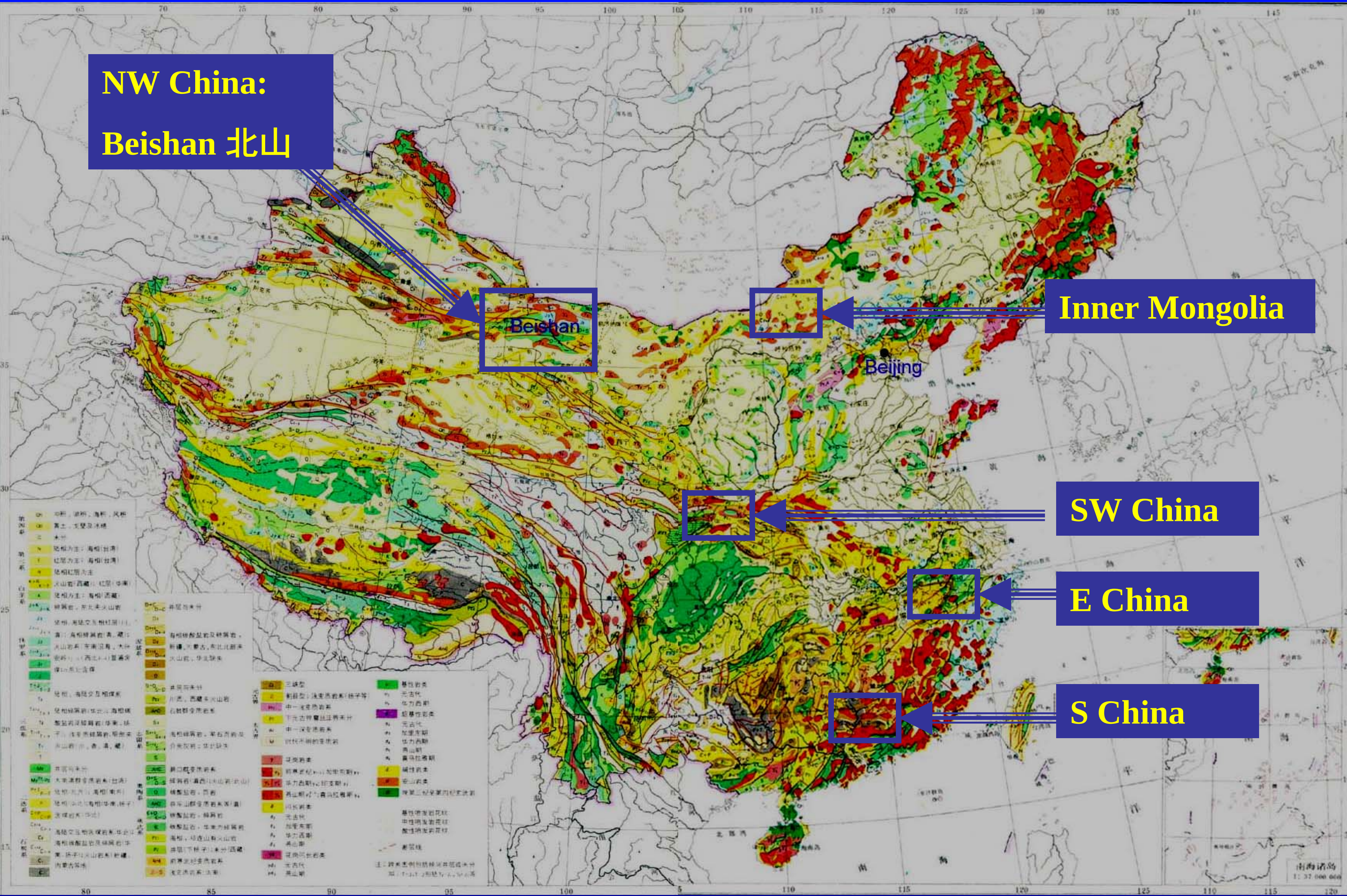
2010-2020 主要工作内容

- Strategies and overall planning
- Engineering design & EBS
- Site selection and site characterization
- Radiochemical studies for disposal
- Safety assessment

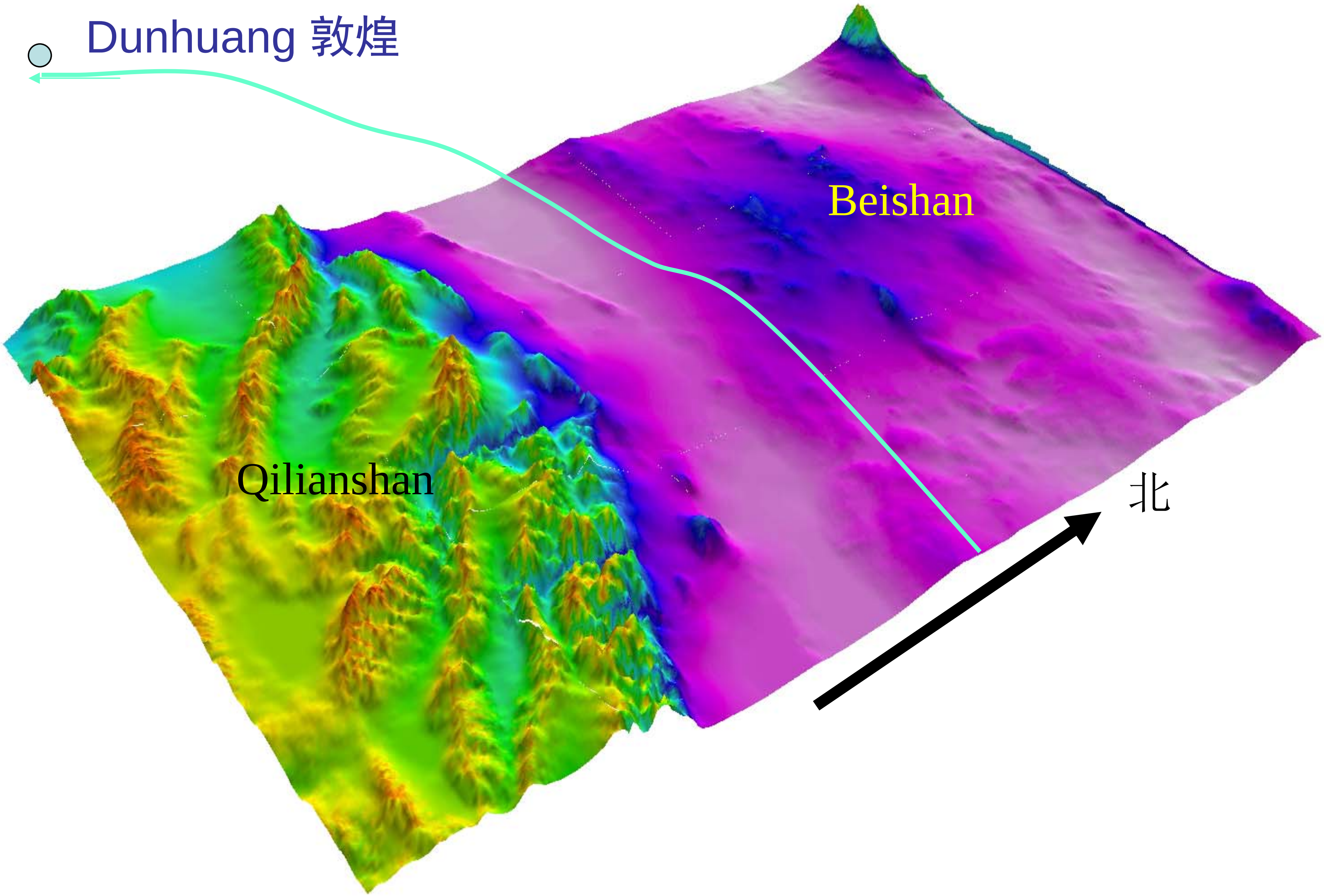
Major activities between 2010—2020: relations



Major activities: Site selection and site characterization



5 Pre-selected regions for China's HLW repository since 1986

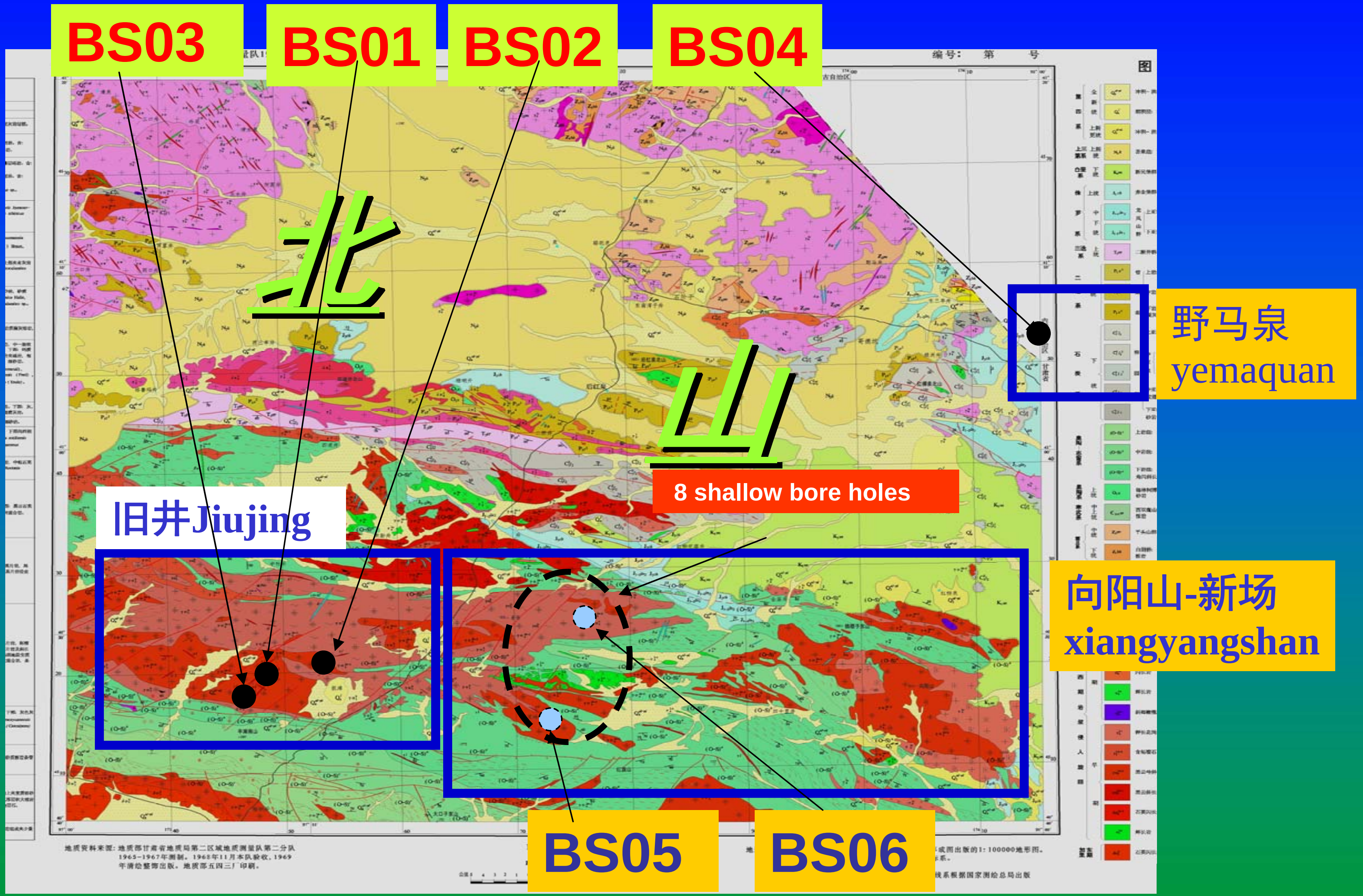


Beishan: the most potential site

Beishan site 甘肃北山场址晨曦

Major activities in Beishan 选址主要工作

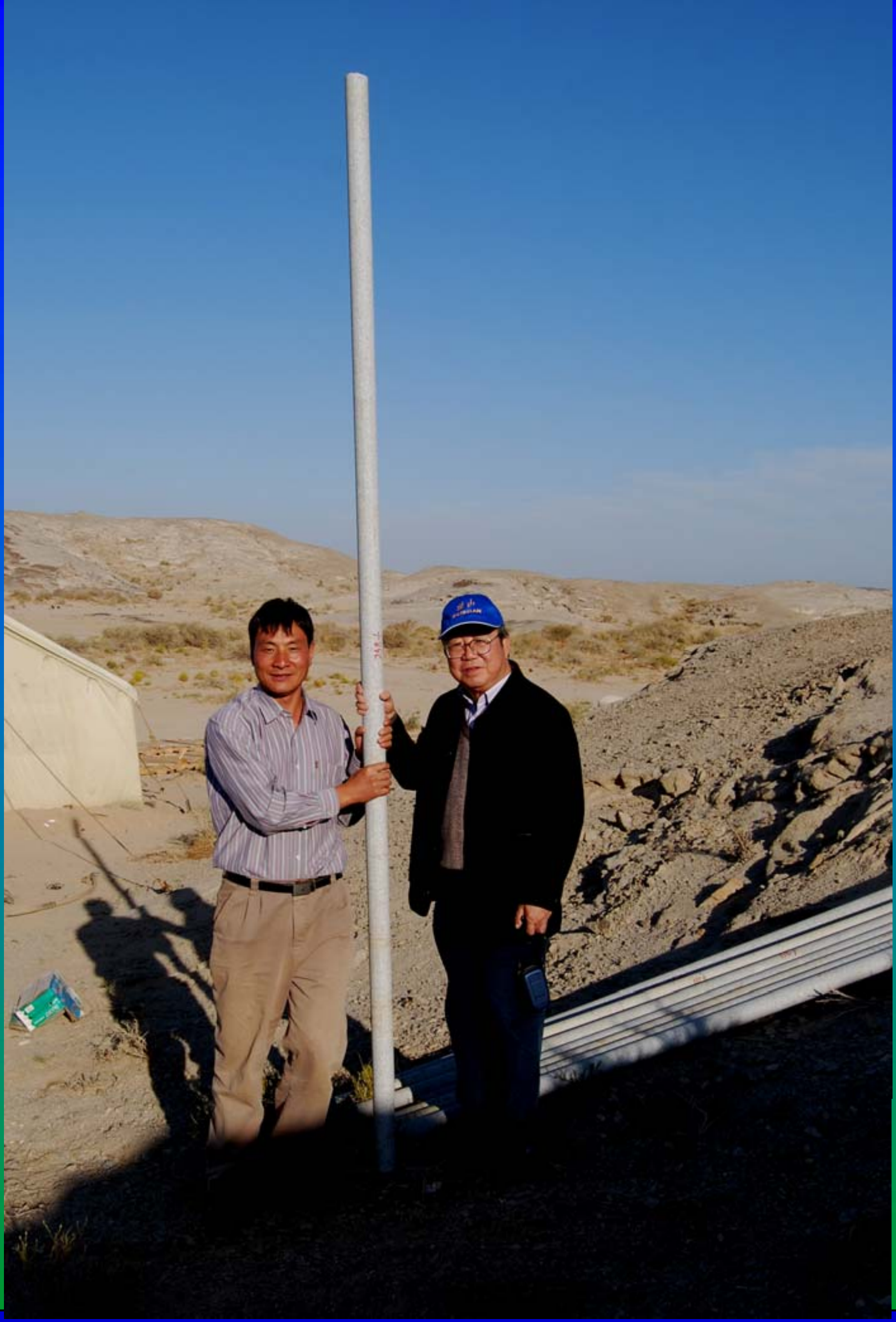
- Regional geological setting
- Geological mapping
- Hydrogeological investigation
- Shallow bore hole drilling at
  - Jijicao Section: 5 bore holes
  - Xinchang Section: 3 bore holes
- Bore hole tests
- Studies on site characterization methodologies



Bore holes in Beishan site 北山场址的钻孔分布

Drilling sites at BS01, BS02, BS03, BS04 boreholes

Opening Ceremony of BS06

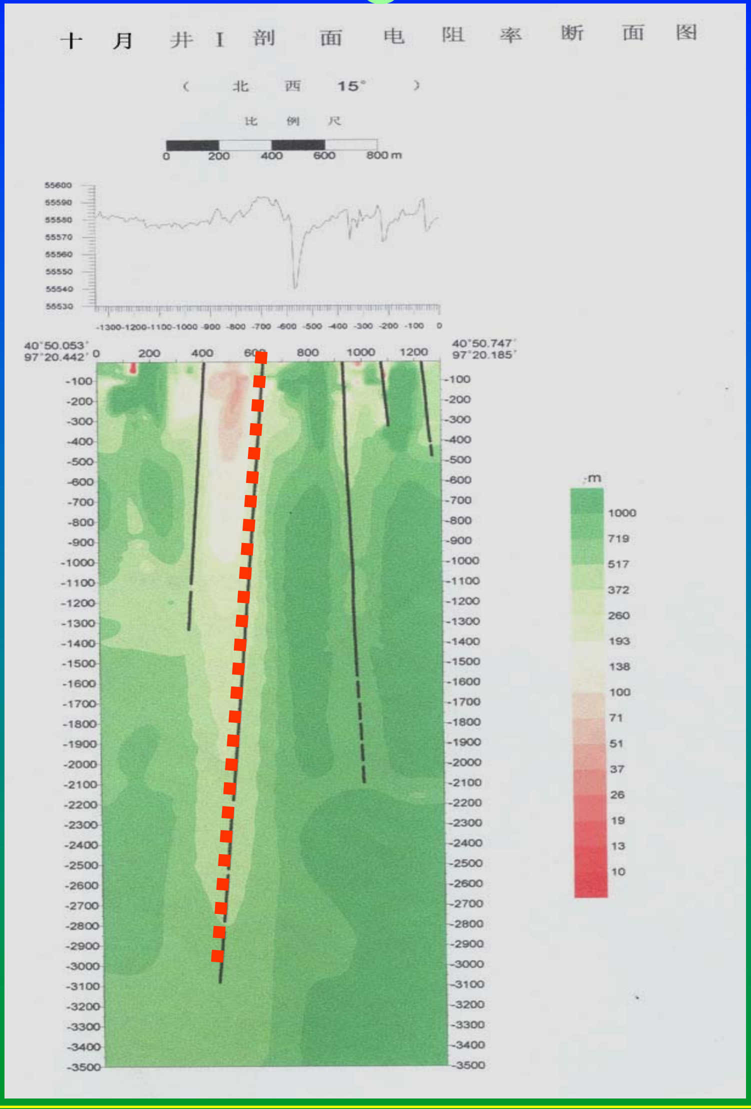


Core sample from BS05, 2008-09-27 北山场址完整岩心

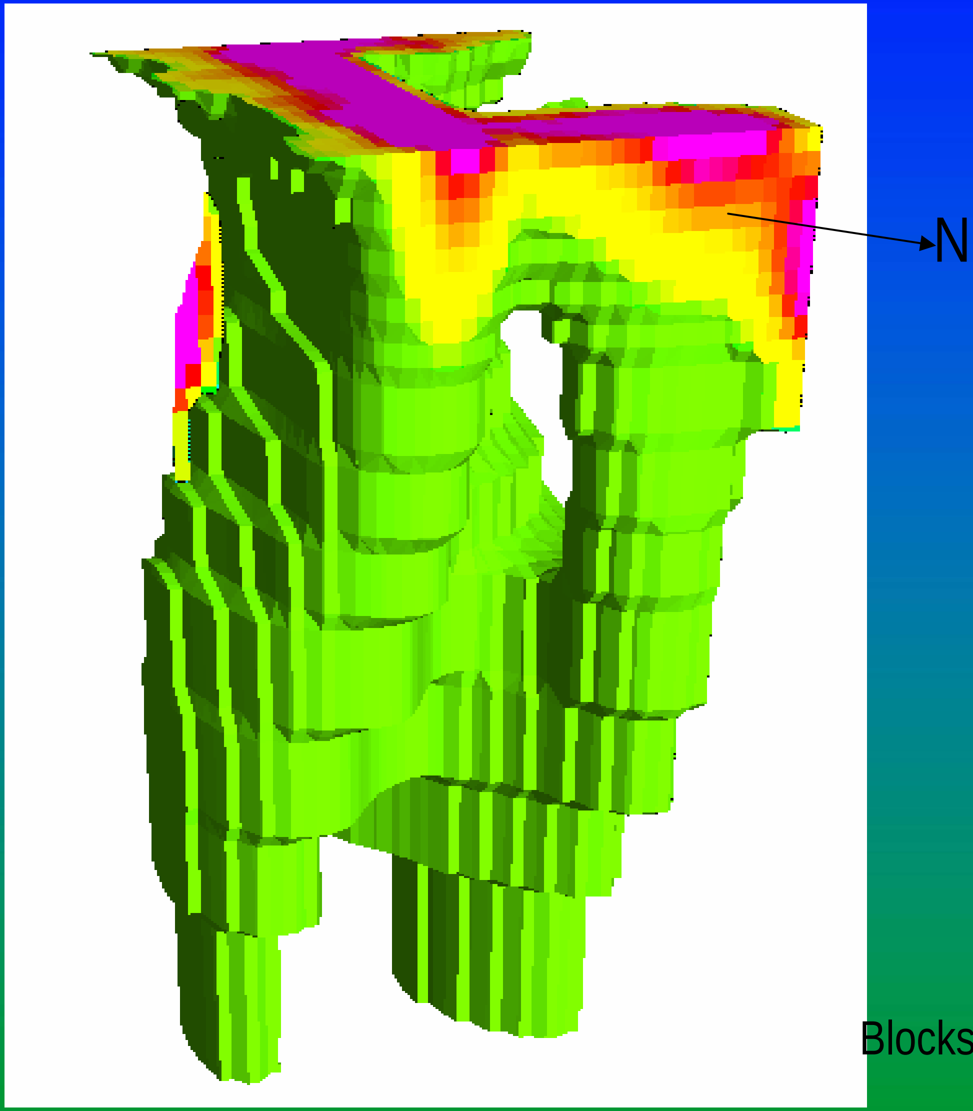
Beishan site 甘肃北山场址

- in NW China
- the most potential area for China's repository
- Gobi desert area
- low population density
- low precipitation : 60--80 mm/a
- high evaporation: 2900-3200 mm/a
- no economical prospect
- no important mineral resources
- convenient transportation
- stable crust
- favorable hydrogeological conditions
- host rock: granite and diorite

Surface geophysical survey: to investigation the faults

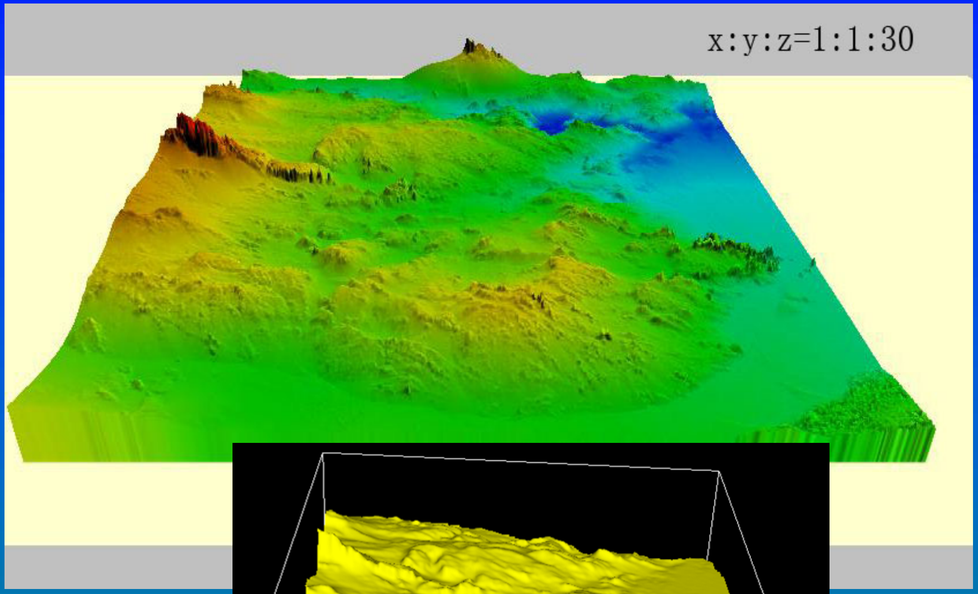


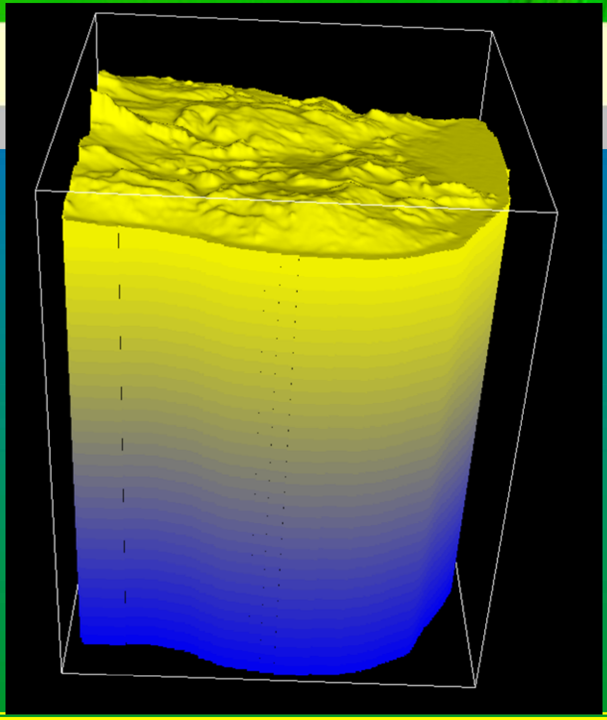
3-D image of faults in granite

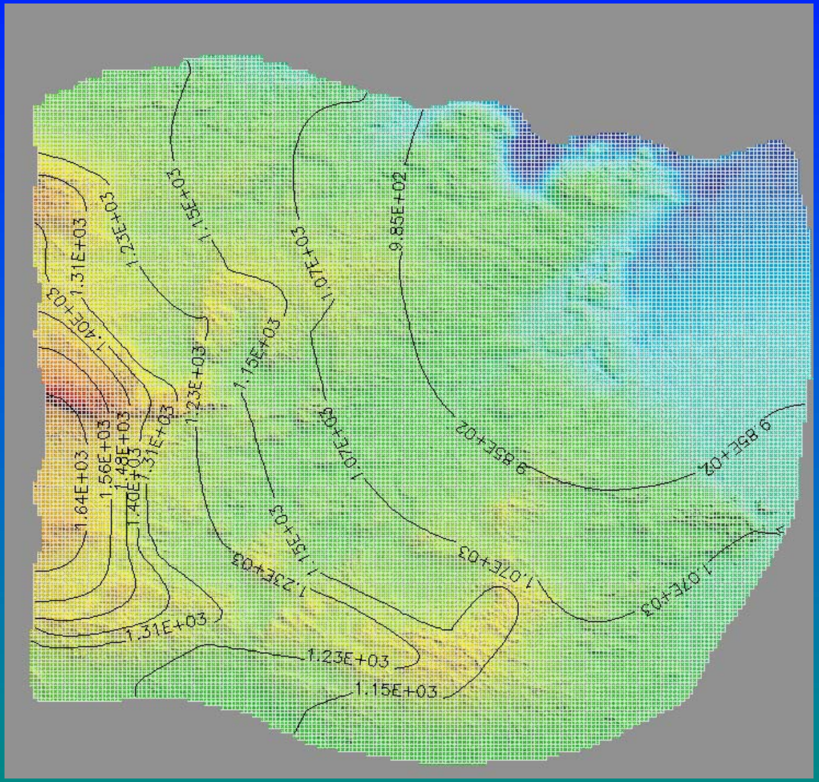


Blocks with less than 700 Ω・m

Groundwater modelling



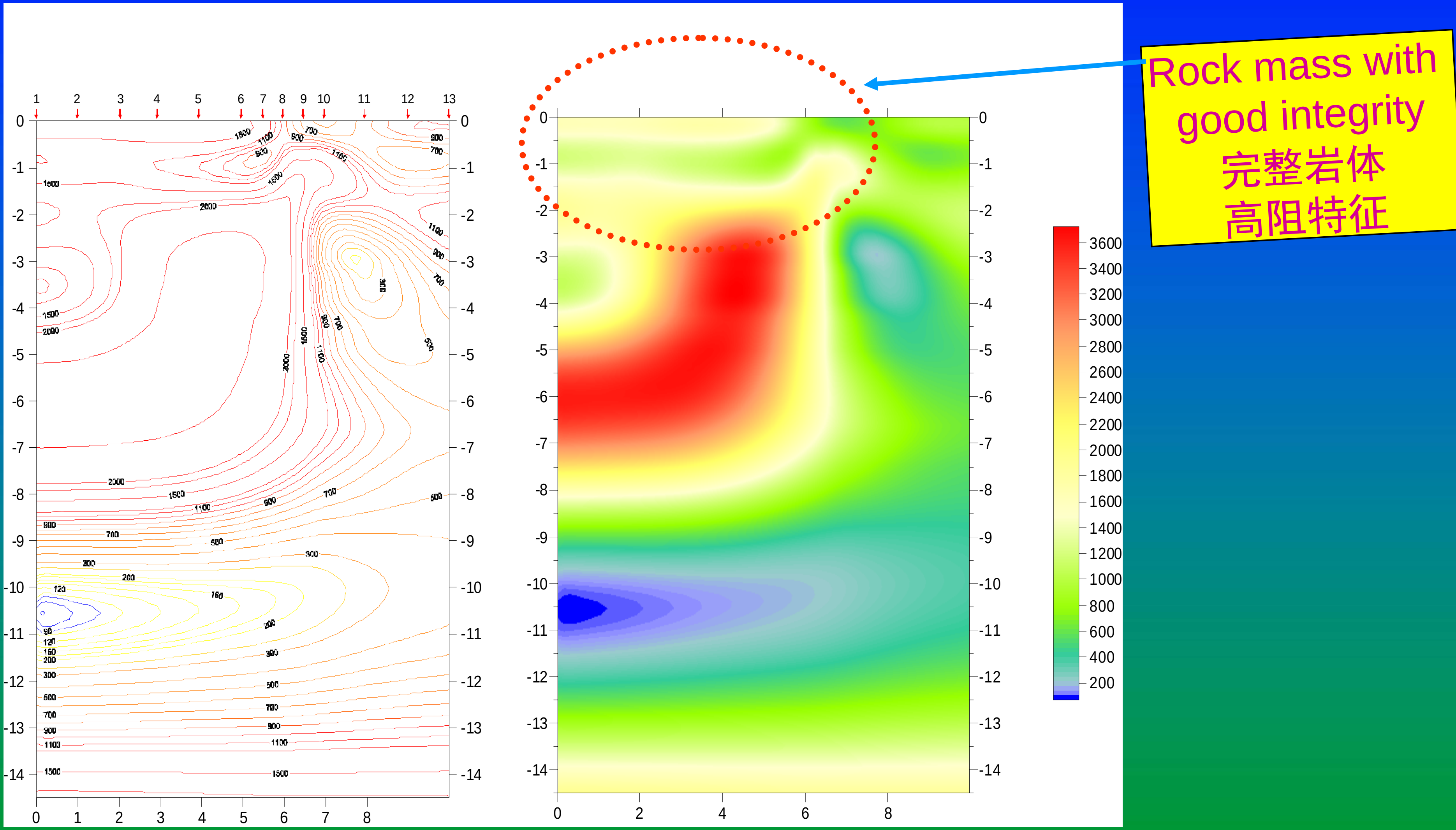




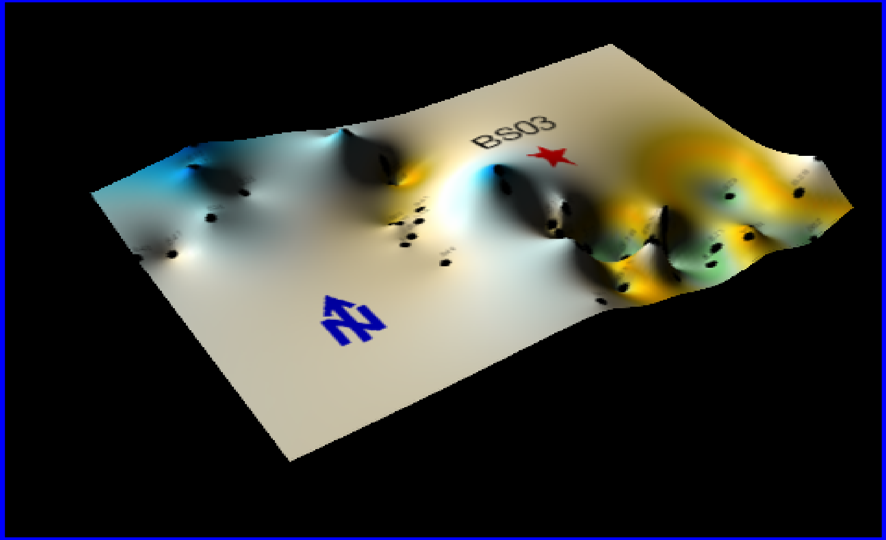
模拟水头等值线

Rock mass investigation by geophysical survey:

岩体质量评价：采石场岩体MT结果



Fracture Mapping



Area, BS03 1km×1km

43 windows,

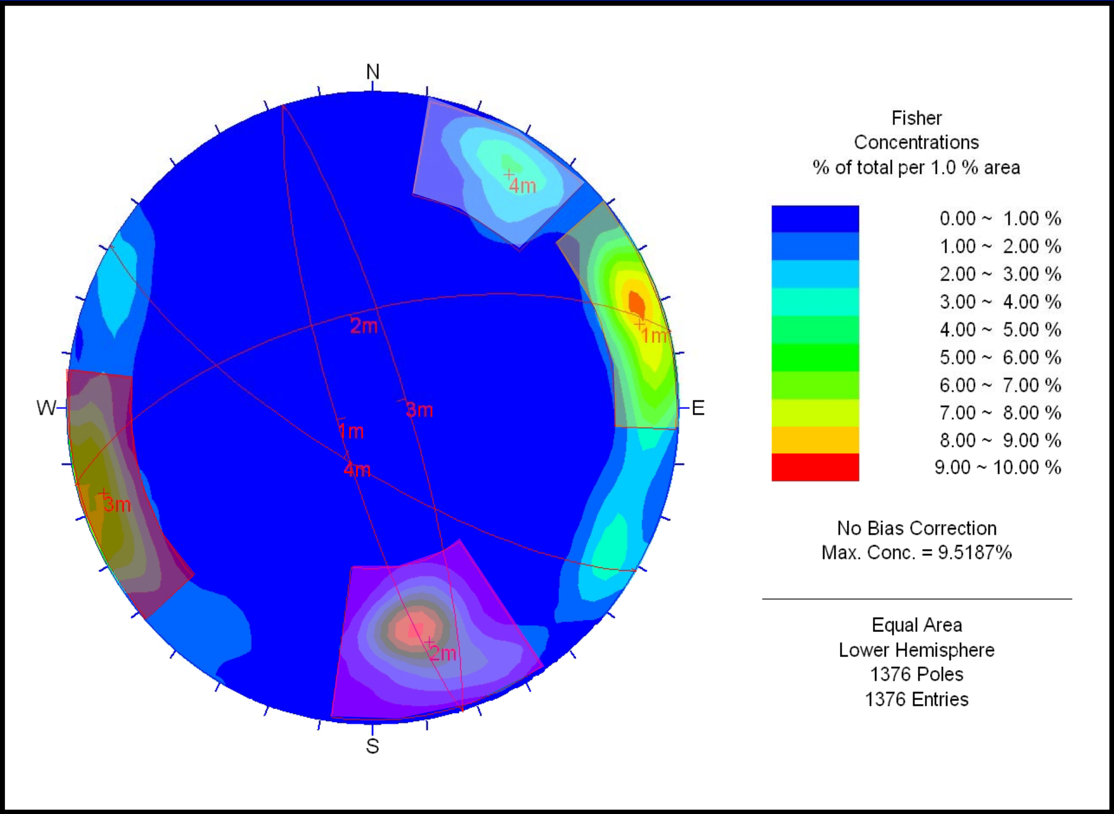
Min 10.84㎡,

Max 194.75㎡,

1796.06㎡ measured,

1376 fractures obtained.

Fracture Orientation 裂隙研究



ID	TREND /PLUNGE	DIP /DIPDIRECTION	K	LABEL
1m	73.2/9.9	80.1/253.2	55.2	set1
2m	166.3/25.2	64.8/346.3	41.5	set2
3m	252.8/9.0	81.0/72.8	41.0	set3
4m	31.1/15.4	74.6/211.1	62.2	set4

- Four sets of fractures are dominant in the studied area
- orientation of each set is well fitted by Fisher distribution
- Trace length is fitted by log-normal distribution

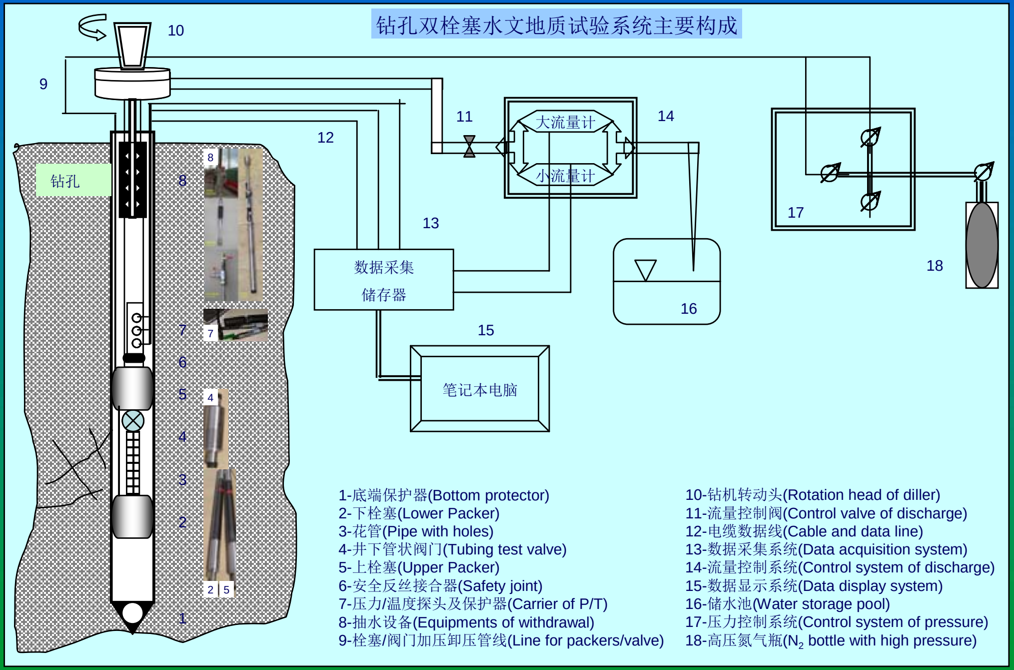
钻孔双栓塞水文地质试验系统

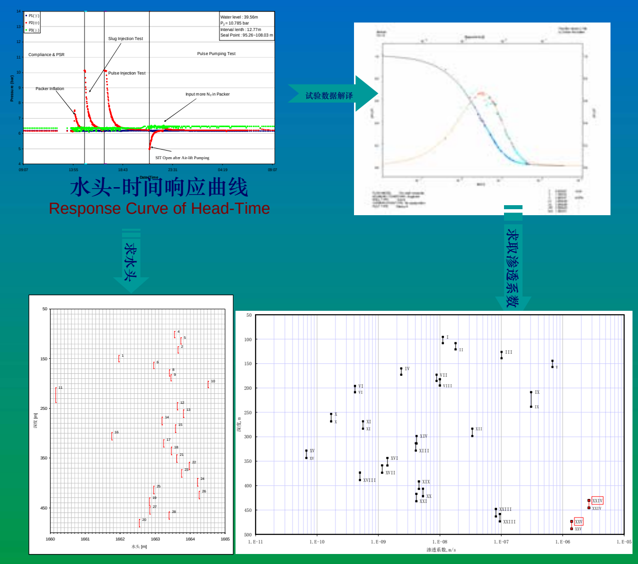
Permeability study:

BOREHOLE DOUBLE PACKER HYDRAULIC TEST SYSTEM

钻孔双栓塞水文地质试验系统是国内首套适合干旱地区低渗透介质渗透性评价的先进设备。具有性能优良、自动化数据采集、分段适时监测压力温度等特点。最大安装深度600米工作；最大降深190米；抽水流量范围4.8-50l/min。

Double Packer Hydraulic Test System is an advanced equipment suitable for hydraulic characterization of low-permeable medium in arid area. It is characterized by advanced performance and automatic data acquisition and timely monitoring of pressure/ temperature in different intervals.
Maximum Installed Depth: 600m; Maximum Drawdown: 190m; Discharge: 4.8-50l/min.





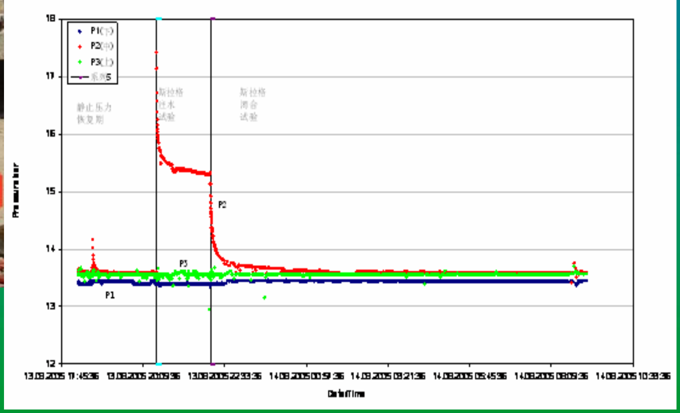
水头-时间响应曲线
Response Curve of Head-Time

BS03钻孔水头随深度变化特征
Profile of Head in BS03

BS03钻孔渗透系数随深度变化特征
Profile of Hydraulic conductivity in BS03

核工业北京地质研究院环境保护研究所
Institute of Environment Protection, BRIUG,CNNC

Double packer test in BS03



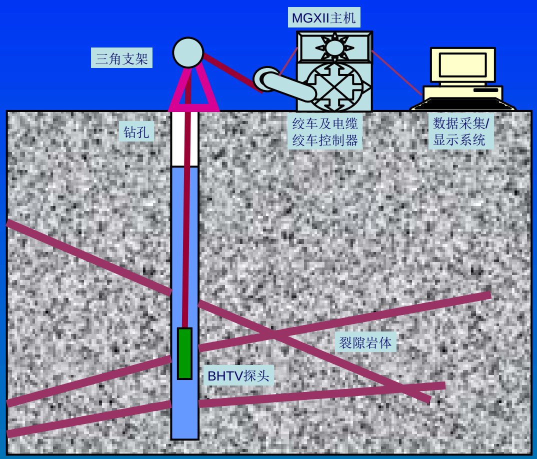
双栓塞水文地质试验系统现场实验

超声波钻孔电视

ACOUSTIC BOREHOLE TELEVIEWER

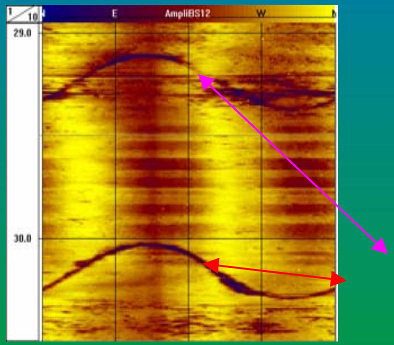
超声波钻孔电视测量是一种获得钻孔直观图像的地球物理测井方法。其主要特点是获得钻孔孔壁高分辨率图像，进而确定钻孔揭露的结构面的特征。

Acoustic Borehole Televiewer (BHTV) logging is used to obtain the image of borehole wall. The main advantages of the BHTV are of high resolution and 360-degree coverage of the borehole from which the characteristics of fractures can be defined.

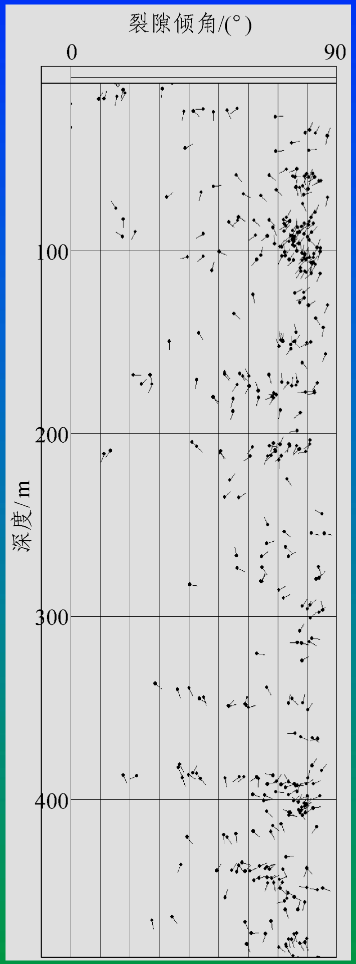


BHTV法裂隙测量原理及过程
Principle and Procedure of BHTV

钻孔超声波电视现场测量
Measurement of Borehole Acoustic Televiewer in-situ



BHTV法裂隙测量结果与岩心对比
Comparison of the results obtained by BHTV and Core



裂隙随深度分布特征
Fractures Distribution with depth

核工业北京地质研究院环境保护研究所
Institute of Environment Protection, BRIUG,CNNC

钻 孔 雷 达
Borehole radar measurement

IAEA 援助钻孔雷达仪器
Borehole radar instrument

●仪器性能 specifications

- 测量深度(Measuring depth): 1000m
- 天线频率(Antenna frequency): 250MHz
- 钻孔中侧向探测半径(Detecting radius): 15m
- 花岗岩中分辨率(Resolution in granite): 0.26m
- 最大时窗(Maximum time window): 6000ns
- 道采样数(Number of trace): 128～2048
- 叠加次数(Number of stacks): 1～32768
- 采样频率(Sampling frequency): 0.4～100GHz

仪器功能（Function)

1、单孔测量：能够获取钻孔孔壁外围一定距离（探测半径）内的岩石结构（裂隙或空洞）信息；

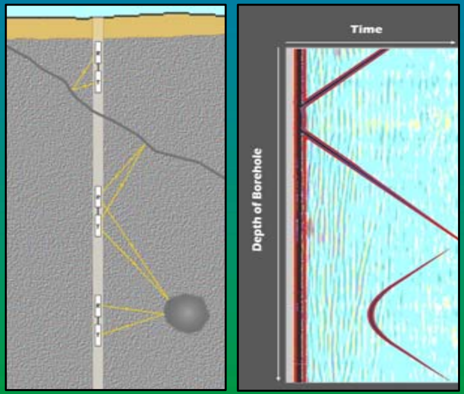
2、跨孔测量：能够获取一定距离内两个钻孔之间岩石结构（裂隙或空洞）信息。

总之，钻孔雷达是高放废物处置库场址评价中是一种有效和必不可少的手段。

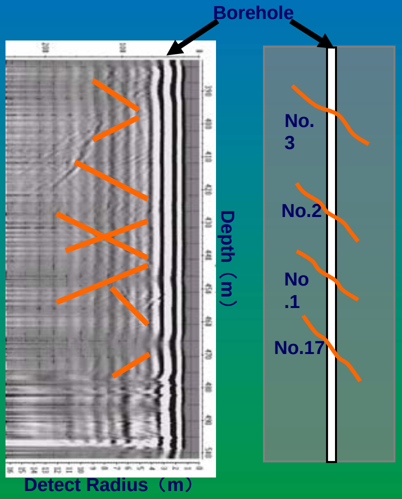
1、Reflection: to get the information of rock structure (such as fractures and holes) within limited lateral distance outside of borehole surface;

2、Tomography: to get the rock structure information (such as fractures and holes) between two boreholes of limited distance .

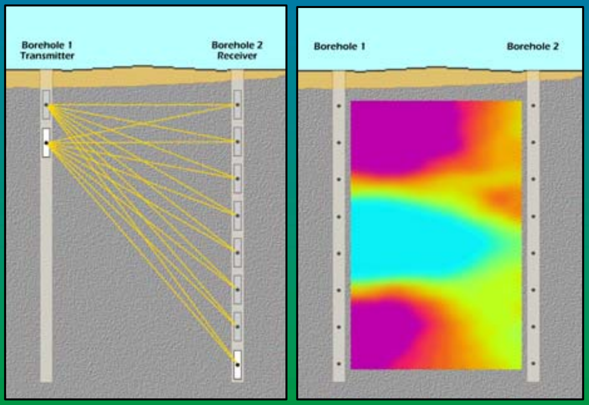
Borehole radar is an effective and necessary tool of site characterization for the disposal of high radioactive waste.



单孔反射原理
Basic principle — reflection



单孔测量结果
Result from a single borehole



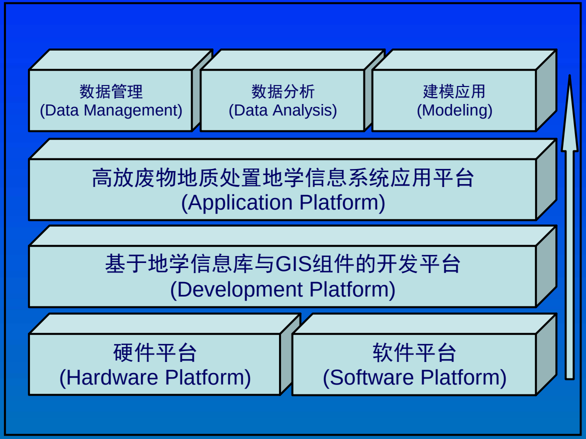
跨孔测量原理
Basic principle — tomography

核工业北京地质研究院环境保护研究所
Institute of Environment Protection, BRIUG,CNNC

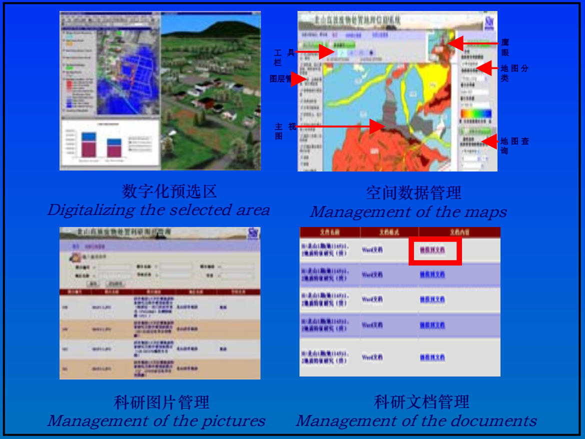
中国高放废物地质处置地学信息系统

Geosciences information system

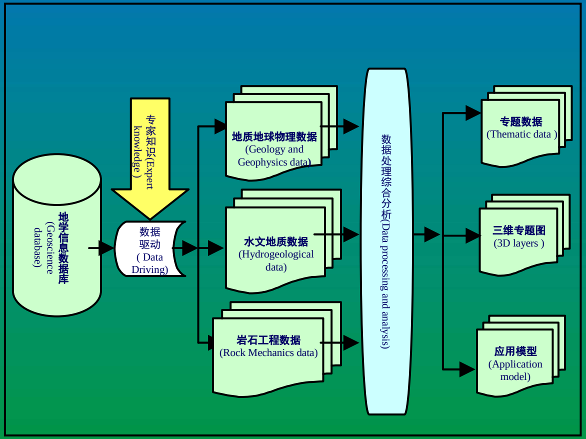
The GIS provides various data management and analysis services to site selection, repository design and construction.



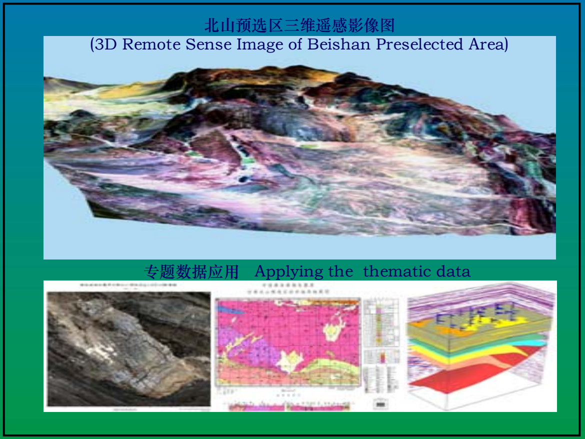
高放废物地质处置地学信息系统总体架构
Architecture of GIS for HLW disposal



基于GIS数据采集与管理
Collection and management of the maps and other data based on GIS



基于GIS技术数据分析模型
Data analysis model based on GIS technology



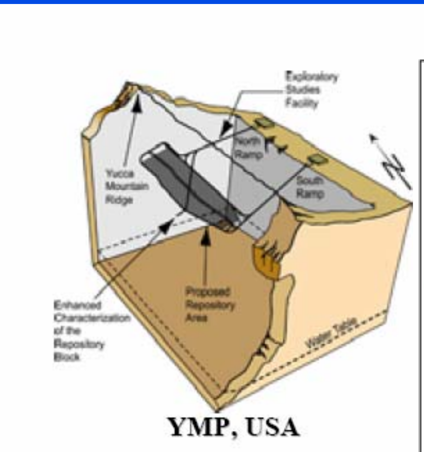
数据与模型的表达应用
Application of thematic data and model

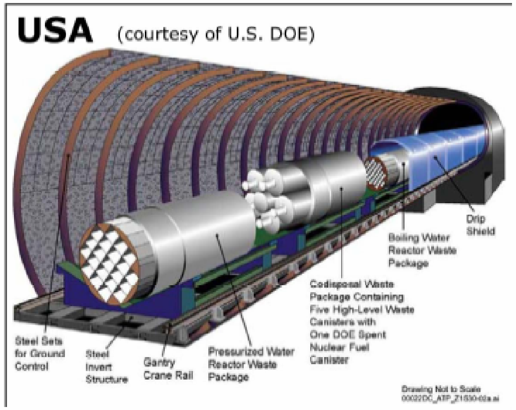
Engineering Design

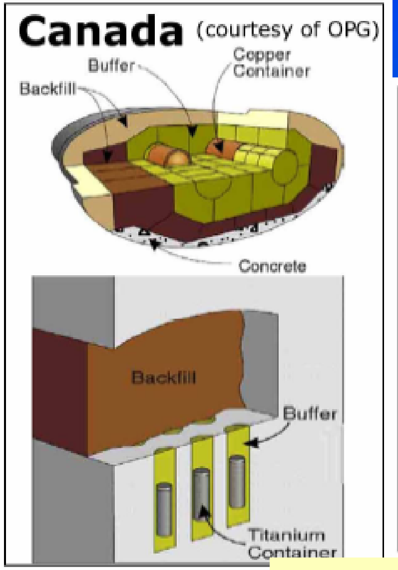
- Investigation of repository design in other countries
- Capability building for concept design
- EBS studies

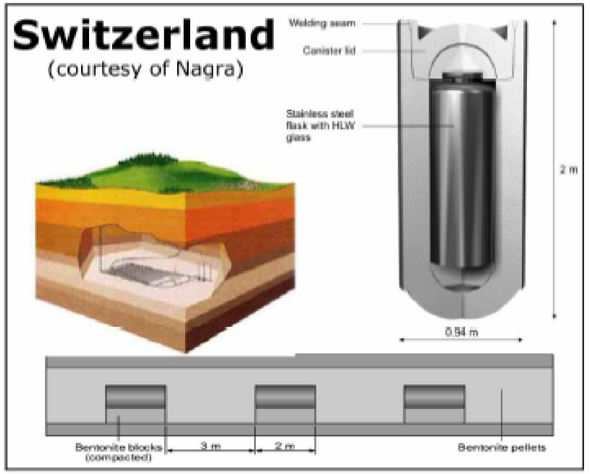
Investigation of repository design in other countries

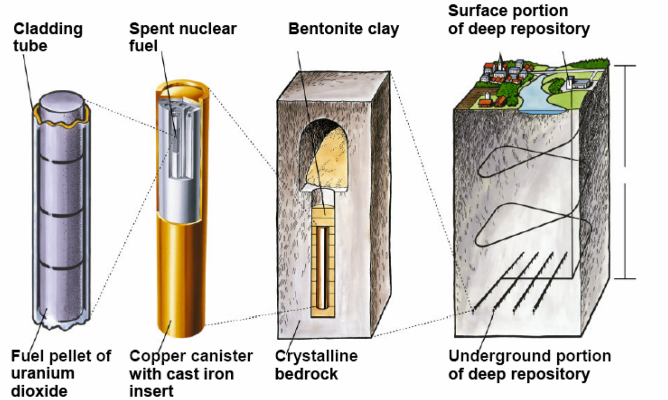
世界地质处置概况











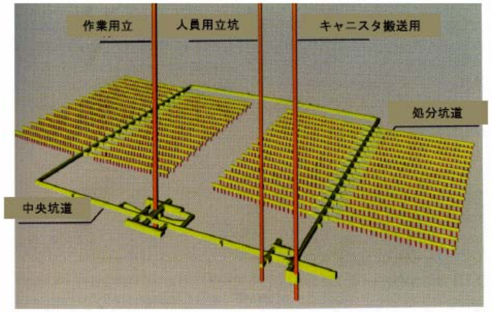
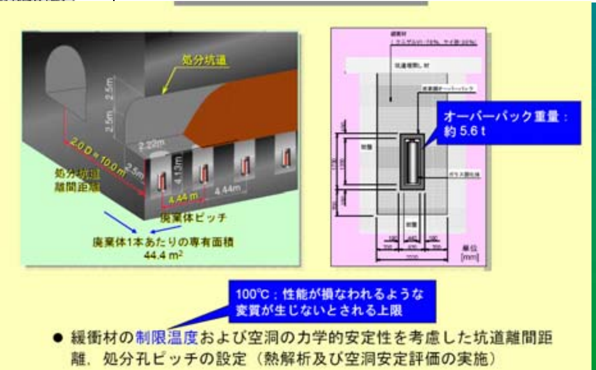
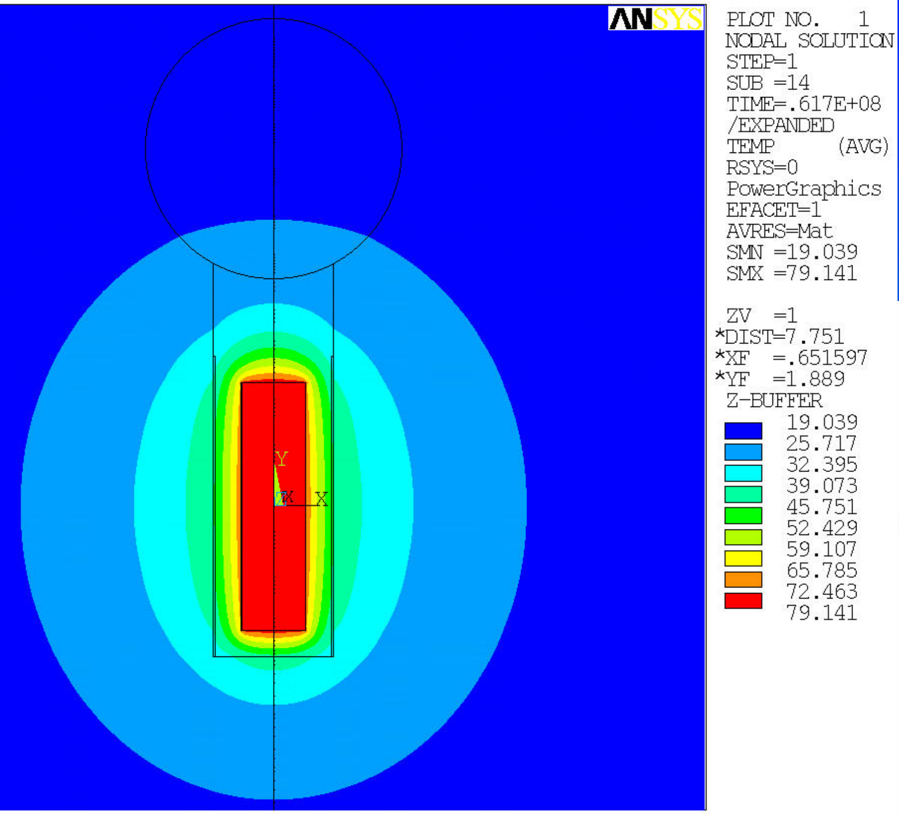


図-2 処分場のレイアウト及びキャニスタの定置イメージ

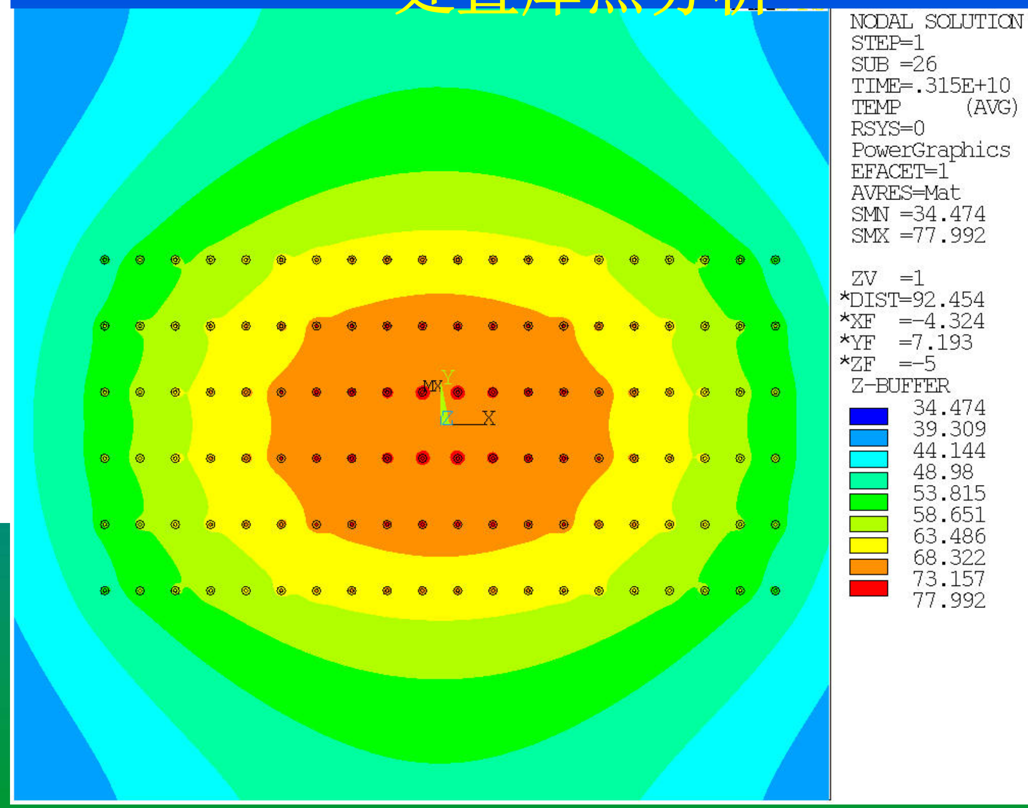


Engineering Design--thermal analysis



单个废物罐热分析

处置库热分析

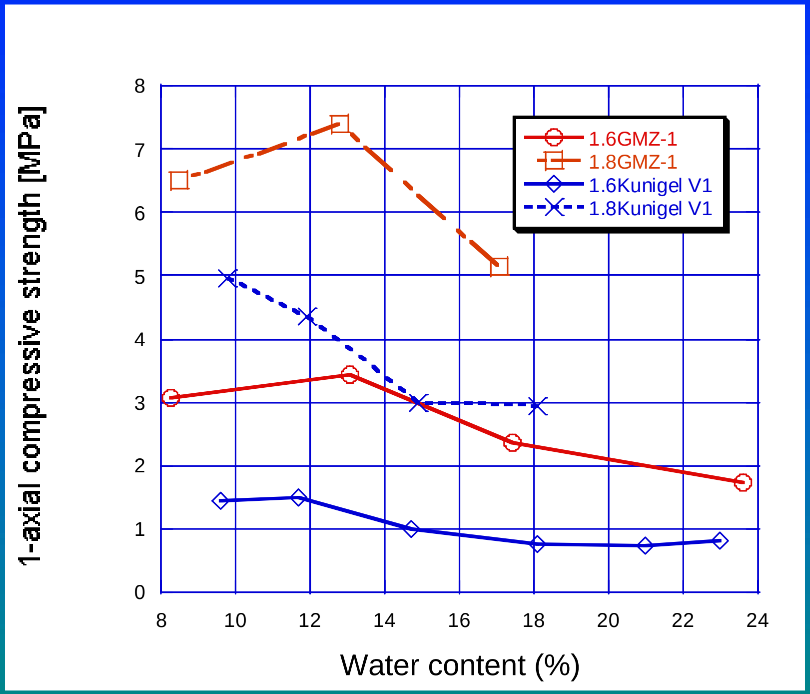


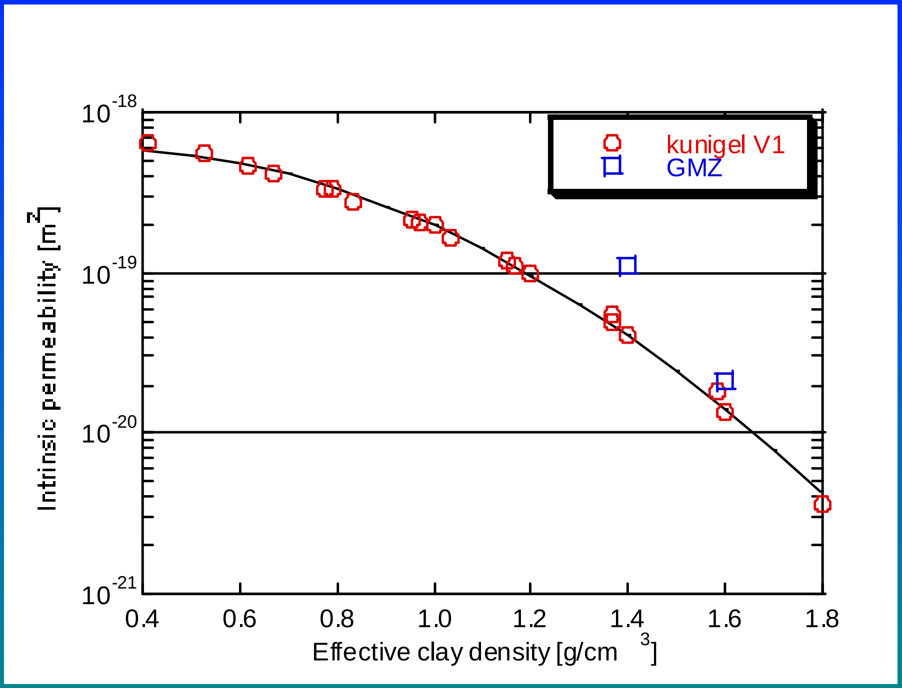
Screening for bentonite deposits

GMZ bentonite deposit was selected as the most potential supplier for buffer material

Super large: 160 M T

Mechanical /hydraulic characteristics of bentonite





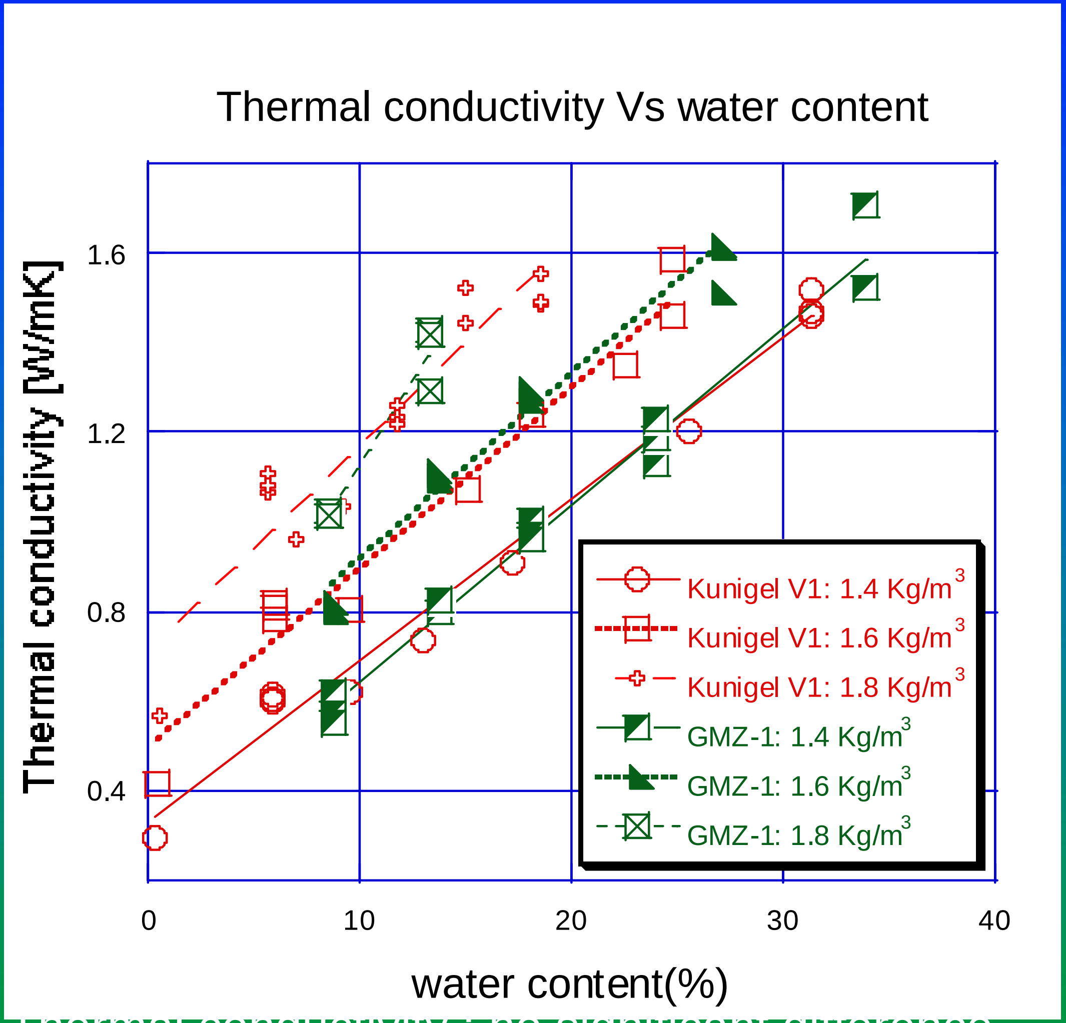
GMZ-1: 2 times of Kunigel V1(1.6g/cm3);

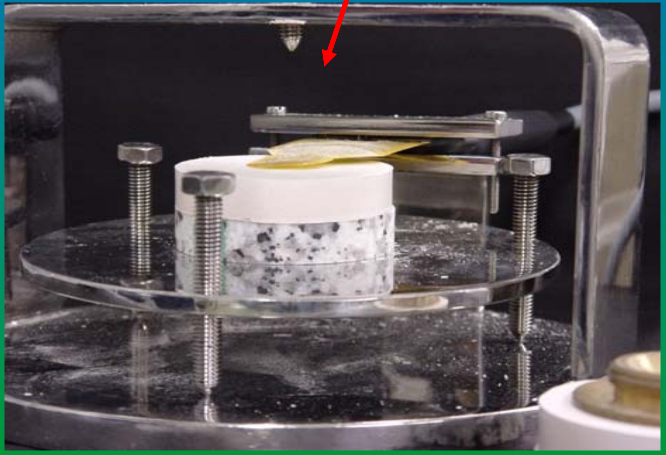
50% higher than Kunigel V1 (1.8g/cm3);

The intrinsic permeability: GMZ-1 > Kunigel V1. higher content of Na-montmorrillonite in Kunigel V1.

Due to a little difference of experimental condition (i.e. pressure of compressed air), it is possible that data obtained to some extent didn't reveal the fact of difference.

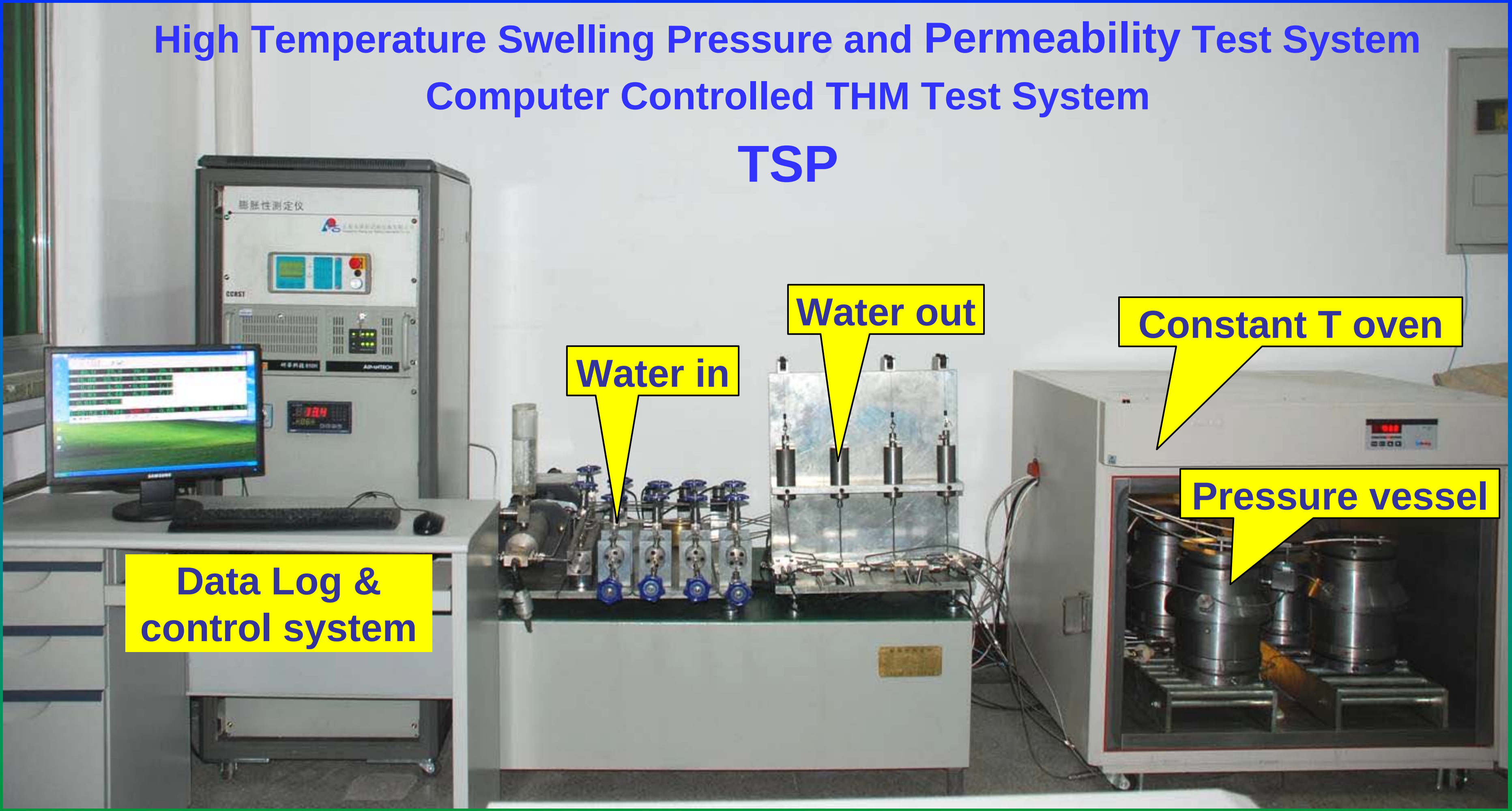
Thermal property of bentonite



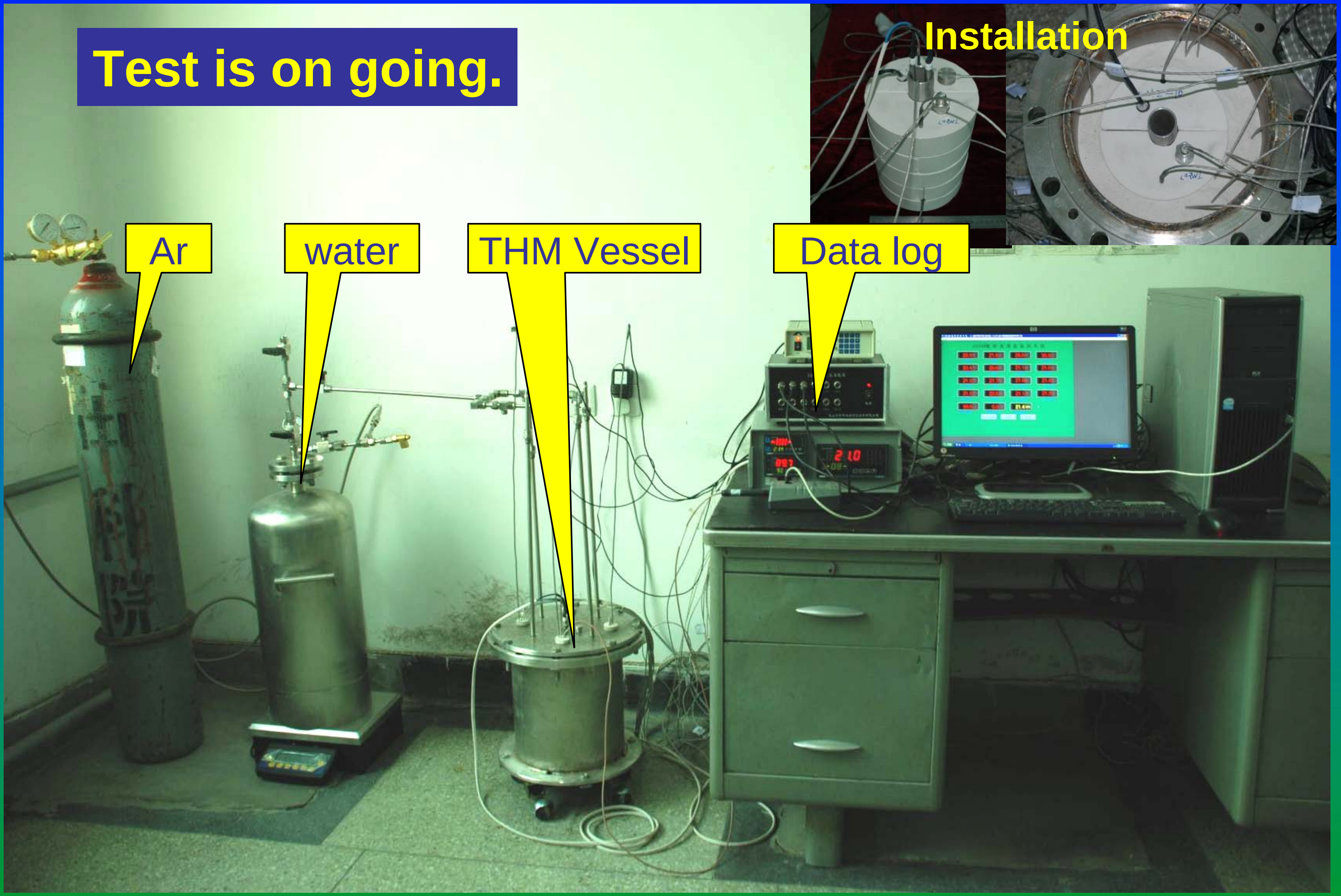


Thermal conductivity : no significant difference

Swelling Pressure and permeability Test

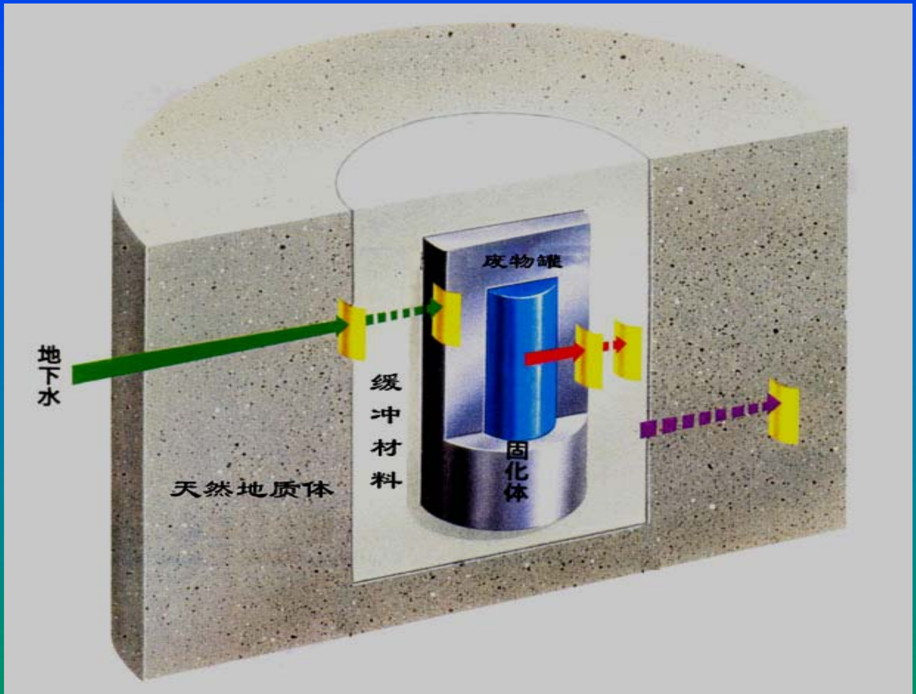


THM Bentonite MINI-Mock-Up test



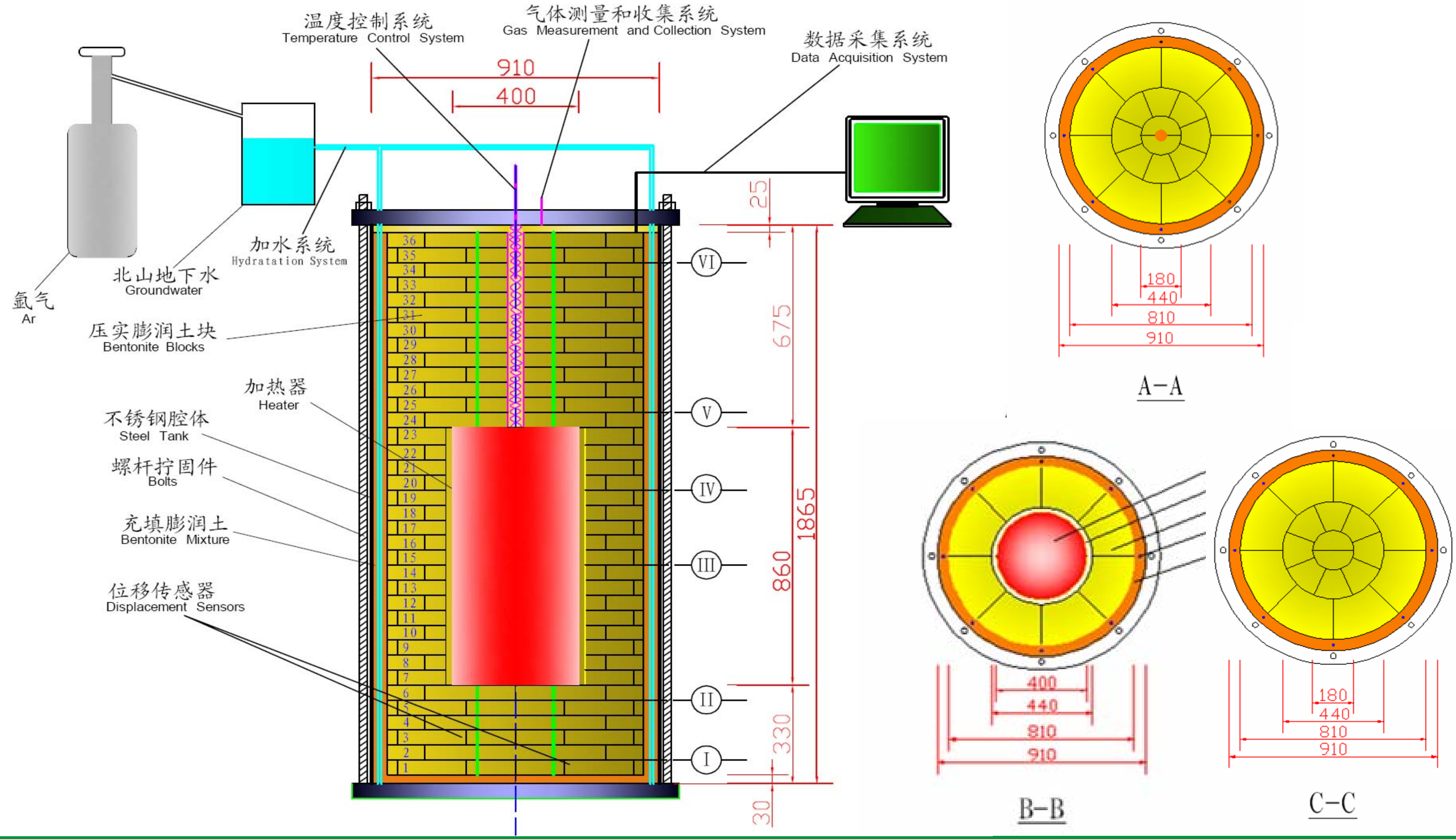
Preliminary Plan for EBS

- Buffer materials: bentonite
- Canister
- Vitrified glasses



- Interaction:
  host rock-bentonite-canister-glass

T-H-M-C China-Mock-up of Bentonite
中国膨润土THMC耦合实验台架



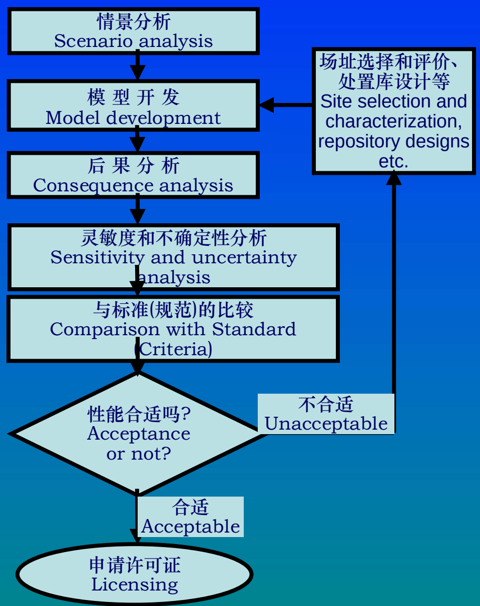
Low Oxygen glove box in CIAE

性能评价

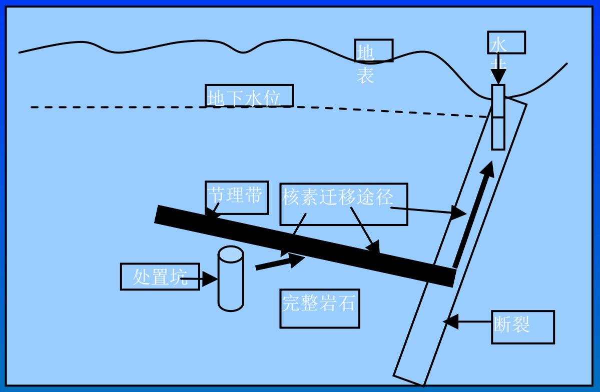
PERFORMANCE ASSESSMENT

高放废物处置库系统性能评价可以正确预测放射性废物处置系统的长期放射性影响，在场址选择和评价、处置库设计与建造、场址许可证申请、获得公众认可、保证处置库长期安全运行等方面均有重要意义。

Performance assessment of high level radioactive waste disposal system is able to evaluate the potential long term radiological impacts of a radioactive waste disposal system, plays a critical role in site selection, site characterization, repository designs and construction, site licensing and gaining public acceptance, assuring long term safe operation of disposal system.

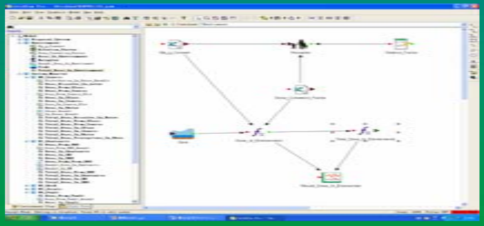


性能评价过程
Procedure of performance assessment

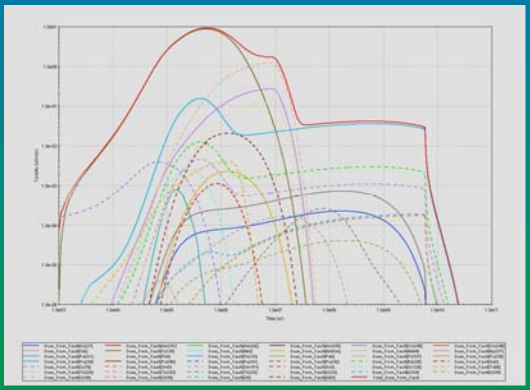


北山预选区地质屏障概念模型
Conceptual model of geological barrier for Beishan site

工程屏障概念模型
Conceptual model of engineered barrier



IAEA 援助性能评价软件—GOLDSIM
GOLDSIM，a PA software

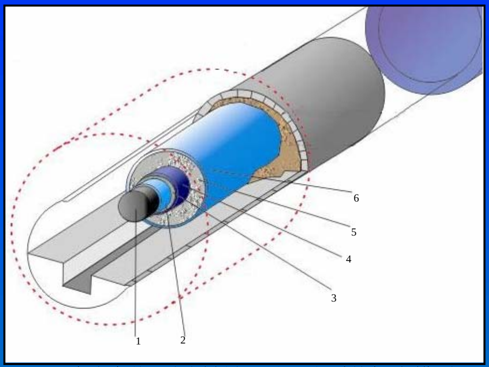


处置库系统毒性释放率
Toxicity release rate from repository system

核工业北京地质研究院环境保护研究所
Institute of Environment Protection, BRIUG,CNNC

玻璃固化体-缓冲材料-黏土岩系统中的核素迁移

Radionuclide Transport Modeling in Vitrified Waste-Buffer-Clay System

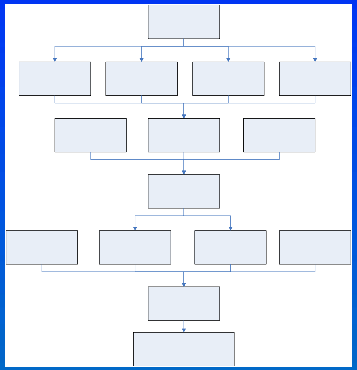


玻璃废物-缓冲材料－黏土岩系统概念模型

1-废物体,2-废物罐,3-填充料,4-外包装,5-缓冲材料,6-外壳

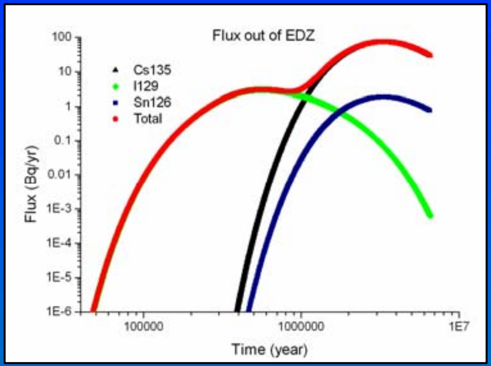
Conceptual Model of Vitrified waste-Buffer-Clay System

1-Waste form,2-Canister,3-Filler,4-Overpackage,5-Buffer,6-Envelope



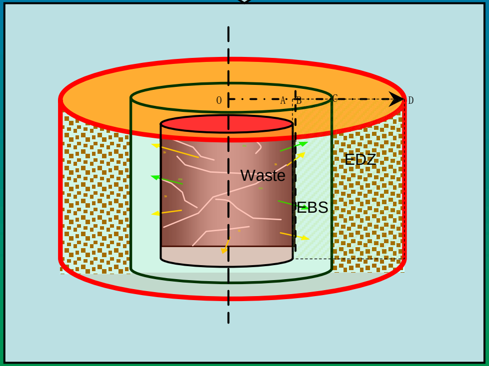
基于 **Porflow**的性能评价流程图

Flowchart of Performance Assessment Based on Porflow Software



核素在系统外边界的通量随时间的变化(情景1)

Flux of Radionuclide at outer boundary in Scenario1

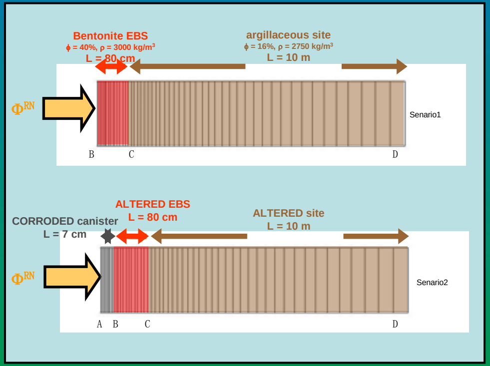


玻璃废物-缓冲材料－黏土岩系统简化模型

OA-玻璃固化体半径,AB-废物罐厚度,BC-缓冲材料,CD-黏土岩(开挖扰动区)

Simplified Model of Vitrified waste-Buffer-Clay System

OA-Inner Radius of Canister ,AB-Thickness of Canister ,BC-Buffer ,CD-Clay (EDZ)



系统研究单元网格化及其边界条件

Senario 1-情景1，BC-膨润土，CD-扰动区(黏土岩)；Senario 2-情景2，AB-废物罐的厚度。图中L为长度，Φ为有效孔隙度，ρ为密度。上下界面为不透水层。

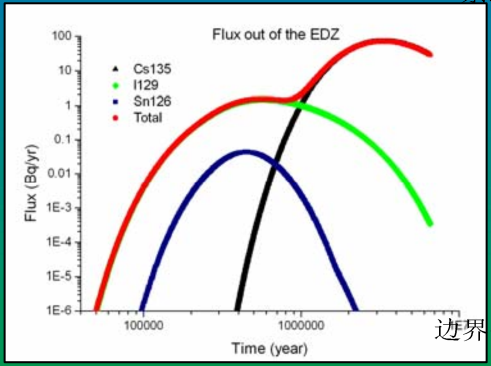
Meshing of System and Boundary Conditions of Different Scenarios

AB-Corroded Canister, BC-Bentonite EBS,CD-EDZ, L-Length, Φ-Porosity ρ-Density

系统尺寸

系统演

初步计



边界条件

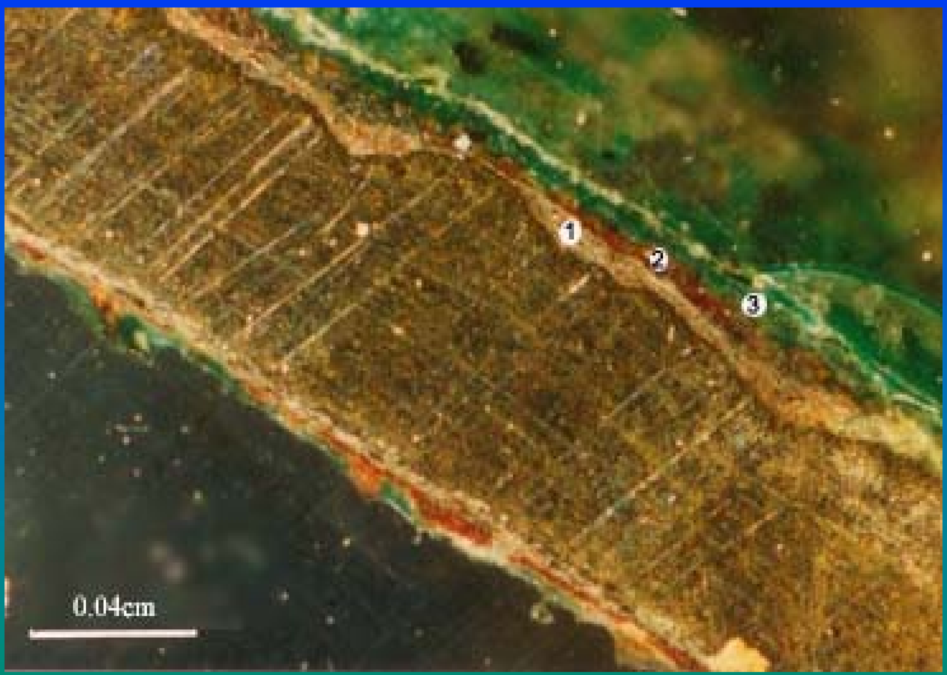
核素在系统外边界的通量随时间的变化图(情景2)

Flux of Radionuclide at outer boundary in Scenario2

核工业北京地质研究院环境保护研究所

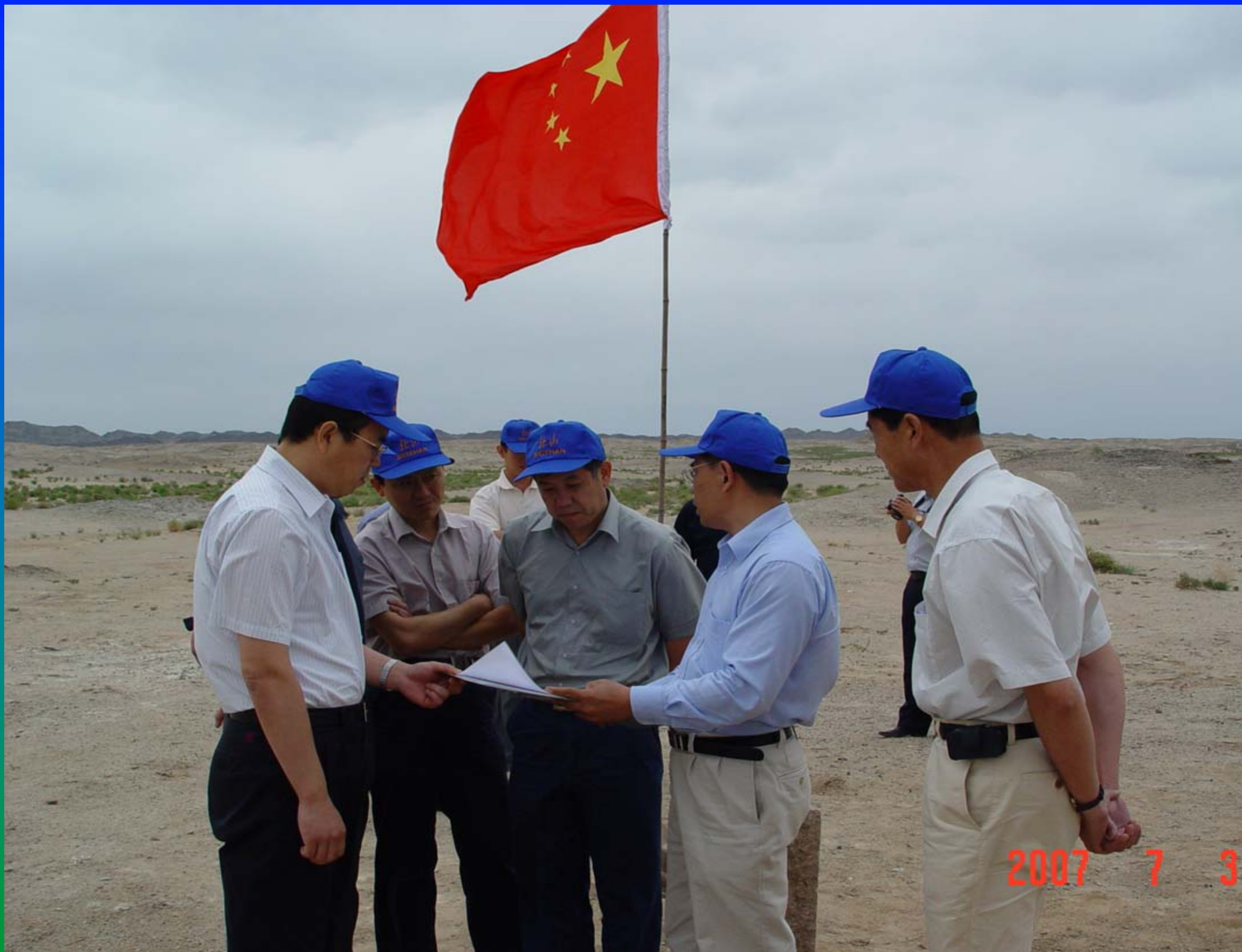
Institute of Environment Protection, BRIUG,CNNC

Corrosion of bronze ware: analogue study



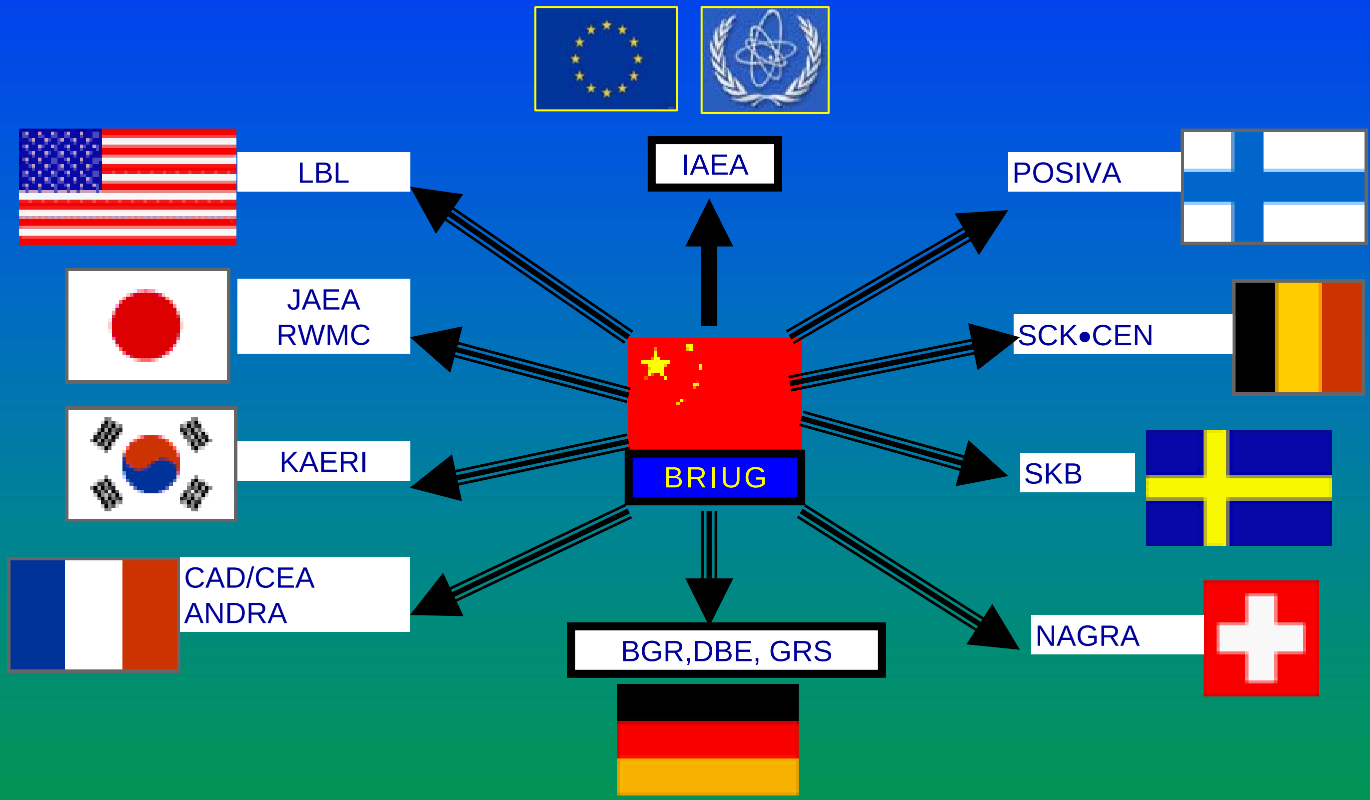
Wine cup 3000 years ago

Chairman of CAEA, Mr. SUN Qin (孙勤）visits Beishan site 2007-07-03



National Conference on Waste Disposal, 2008-09-23, Dunhuang, China

国际交流与合作
International Exchange and Cooperation



核工业北京地质研究院环境保护研究所
Institute of Environment Protection, BRIUG

Chinese-Germany Workshop on Radioactive Waste Disposal, May 28-31, 2007, Beijing

IAEA training course on geological disposal

Director General of the International Atomic Energy Agency,

Dr. ElBaradei

visiting CNNC, in front of core sample from Beishan site

2009-04-21

Challenges

- Social
- Economic
- Public acceptance
- Scientific & technological
- Engineering


Thank you