84 Feasible Study of the Siting of China's High-Level Radioactive Waste Repository in an Area of Northwest China

Yuan Gexin, Zhao Zhenhua, Chen Jianjie, Jia Mingyan, Han Jimin, and Gao Weichao

Abstract

With the fast development of national nuclear industry, it is extremely urgent to disposal the high-level radioactive waste (HLW) properly. Aqishan area lies to the south of Turpan in Xinjiang Province. As one of the important candidate sites for China's HLW repository, it has many potential advantages, such as arid climate, water poverty, sparse population, large-scale granite body, and high crustal stability. The preliminary work proves that: (1) Granite batholith is widely distributed over the Aqishan area, which had formed in Late Hercynian—Early Indosinian period, with a thickness of over one thousand meters; (2) The Aqishan area is in a state of peneplain, with the latest fault activity in Middle Pleistocene and the seismic intensity of VI degree; (3) The total dissolved solids (TDS) of groundwater is up to 100 g/L because of high evaporation intensity, and the isotope data indicate that the groundwater is mainly recharged from atmosphere precipitation. Through an overall evaluation of the Aqishan area, it is found to be the feasible site for China's HLW disposal.

Keywords

HLW geological disposal • Hydrological condition • Crustal stability • Granite pluton

84.1 Introduction

Disposal of high-level radioactive waste (HLW) is generally implemented by deep geological disposal (Min 1998). Geological disposal stores long-lived radioactive materials in a stable geological repository, a geological unit which is required to remain stable for tens of thousand years. In this way, the risk of accidental waste exposure caused by human or natural disturbance can be reduced to a significantly low level. The principles for siting of an HLW repository mainly include sparse population; stable geological condition with no mineral resources; and host rocks with sufficient thickness and area, simple hydrogeological environment, low porosity, high thermal conductivity, great mechanical strength, and high thermal and radiation stability. According to the *Guideline of Site Preselection for HLW Repository* issued by the Commission of Science, Technology and Industry for National Defense and in view of the favorable factors such as non-permanent residents, arid climate, and large granite pluton in a northwest region, the granite zone in Aqishan area of northwest China is presently thought to have potential advantages for building a geological HLW repository in terms of climatic condition, geographical environment, granite pluton distribution, water resource distribution, crustal stability, and HLW safety management.

In this study, comprehensive geological studies have been focused on the large intact Xianshuigou granite pluton in this region. Surface geological mapping, seismic method, and transient electromagnetic exploration, combined with rock fracture statistics and engineering property testing, are used to study the distribution of granite pluton and the characteristics of rock minerals, as well as the lithology of surrounding strata; structural characteristics and integrity of granite pluton; and the morphology and type of deep granite

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pluton. Associated hydrogeological characteristics are analyzed with relevant topographical and surface-water chemical data and groundwater isotope values; regional crustal stability is evaluated according to the characteristics of tectonic movement combined with those of seismic activity and geophysical field within and surrounding the northwestern region; the Quaternary geology and climate—environment change trend are evaluated by surveying the periods of regional tectonic activity and the characteristics of paleo-environmental evolution.

84.2 Traffic, Physical Geography, and Society

The northwest region is located in southeast Turpan, Xinjiang Uygur Autonomous Region. This region is approximately 160 km distant from Turpan City. The West-East Natural Gas Transmission Pipeline crosses the north part (Fig. 84.1) and connects to Dikaner County via a Class III highway. The terrain is relatively flat and most areas are reachable with vehicles.

Topographically, there are mainly denuded hills and plains in the northeastern region. The altitude of the flat terrain is 1050–1150 m above sea level. The climate is arid and water sources are lacking. The drainage system is poorly developed with no permanent runoff. Annual precipitation is 20–60 mm and the total precipitation time is less than 20 days. Annual average evaporation capacity is up to 2250–2900 mm. There are no permanent residents. To solve water shortage problems, domestic water is generally supplied from other regions.

84.3 Geological Characteristics of Xianshuigou Granite Pluton

There are mainly five granite zones surrounding the Aqishan area, which are generally composed of Middle—Late Variscan and Indosinian intrusive rocks with a total area of approximately 1200 km^2. The present survey focuses on Xianshuigou granite pluton, a regular oval-shaped pluton with an area of approximately 300 km^2. Few dykes are developed in the granite zone, which exert less impact on the integrity of pluton.

In the Late Carboniferous—Permian period, Tarim and Junggar plates collided; associated independent intrusions and regional dykes from different sources were widely distributed. In the Permian period, regional curst was uplifted due to NS extrusion; ductile crust below the uplift belt underwent selective melting due to the reduction of pressure (caused by the uplift of brittle crust) and the increase in heat energy (transformed from kinetic energy of tectonic movement); then, molten magma was uplifted and localized in the NE-SW-trending fracture zone after differentiation, leading to the formation of Xianshuigou granite pluton (Xinjiang Bureau of Geology and Mineral Resources 1997).

According to the results of remote sensing, aeromagnetic interpretation, and field geological survey, Xianshuigou granite zone mainly consists of four intrusions (Fig. 84.1). The outcropped sedimentary strata consist of hornfels and skarns of the Lower Carboniferous Gandun Formation and alluvial gravel and alluvial aeolian deposits of the Quaternary Holocene strata. Flesh red medium-grained syenogranite

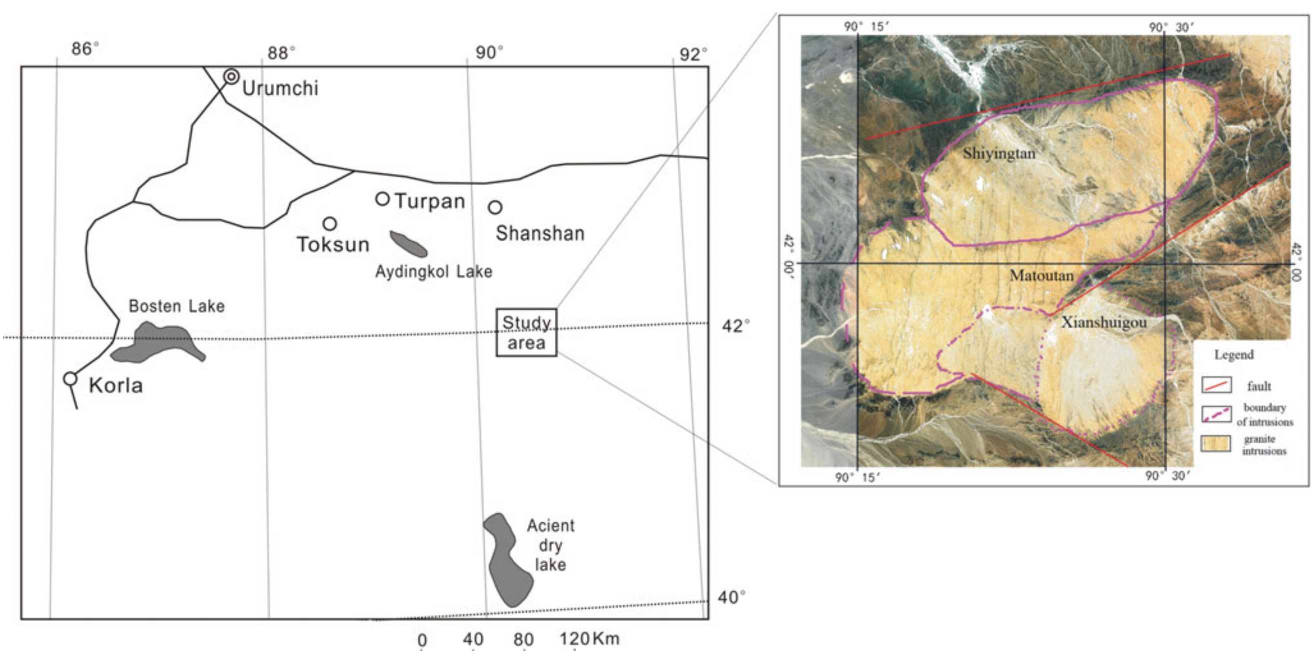

Fig. 84.1 Sketch map of the location of granite pluton in the area

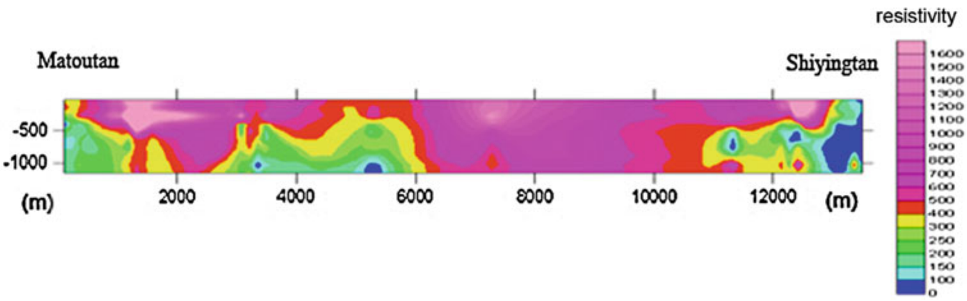

Fig. 84.2 Resistivity profile of Xianshuigou granite pluton determined by transient electromagnetic method

forms the pluton with strongest γ-ray spectrum field in the whole zone. In the granite rock outcrops near Xianshuigou, the latest strata intruded are Lower Permian strata with the zircon U-Pb isotopic age of 200.1 Ma (Xinjiang Bureau of Geology and Mineral Resources 1997). Together the characteristics of geophysical field reflected by the pluton, we preliminarily identify Xianshuigou granite pluton as Early Indosinian intrusive rocks (according to *prospecting report of Xianshuigou granite zone*, 2004).

The development of internal fault in Xianshuigou granite pluton is explored with an ATEM Transient Electromagnetic System. The exploration profile is 600 m long and nearly EW trending, with depth inversion at 200 m. The resistivity is high in the upper part of the profile, which decreases with increasing depth. Within the depth of 150 m, the resistivity is greater than 1000 Ωm and shows even electrical distribution. The electric property is evenly distributed with no substantial changes in the horizontal direction. There are no abnormal segments with abrupt vertical changes. No anomalies of fault structure are found in the profile.

The morphology of granite pluton on the plane is investigated by remote sensing-based geological interpretation and site exploration; the vertical morphology of deep pluton is explored mainly using transient electromagnetic technique and shallow high-resolution seismic reflection wave method.

Through the exploration with transient electromagnetic (Fig. 84.2) and seismic methods and comparative interpretation of geological profile, we propose that the pluton may belong to large-scale granite batholith; there may exist underlying strata at 400–900 m depth of the granite pluton at 4–5 km north of Matoutan; there are no large fractures within the granite pluton; and the thickness of the granite pluton is greater than 1000 m.

84.4 Hydrogeological Conditions of Xianshuigou Granite Zone

Xianshuigou granite pluton is located in an area with a typical continental climate, dry weather and less rain, windy spring and autumn, and large temperature difference between day and night. There is no perennial water; all valleys are seasonal ravines which only have temporal floods flowing after rainstorms; the evaporation is rapid.

The major type of groundwater within the pluton is bedrock fissure water. Due to insufficient supply, granite fissure water is lacking. According to the *1:500000 regional hydrogeological survey report of Shanshan—Aqishan region* (1978), groundwater has been drilled in the north at the depth less than ten and a few meters; the unit water inflow is 19 m^3/d, and groundwater salinity is 33.31–125.27 g/l, i.e., saline–brine water.

Topographically, the study area is high in south and low in north, with surface runoff flowing toward a northwest lowland, Aydingkol Lake (Fig. 84.3). There is no perennial surface runoff. Groundwater recharge completely depends on the infiltration of atmospheric precipitation, i.e., non-continuous supply. This area is arid with less rain; average annual rainfall is 20–60 mm only, mostly concentrated in summer; temporary surface floods are commonly formed after occasional storms.

In the arid and hot climate, annual evaporation is a hundred times more than precipitation. Thus, groundwater discharge is dominated by evaporation in this region.

Stable hydrogen (δD) and oxygen (δ^{18}O) isotope data of groundwater indicate that the source of groundwater recharge is infiltration of atmospheric precipitation. The δD-δ^{18}O relationships of groundwater samples from different areas are compared. As compared to those from the central area, water samples from the south and north margin of Kuruketage Mountains have small δD/δ^{18}O slope, indicating that groundwater migrates from the center area to two sides.

84.5 Crustal Stability

Regional crustal stability is evaluated by analyzing the data of regional geophysical field, deep fault zone, seismic activity, and neotectonic unit division, combined with the results of field geological survey.

An average Bouguer gravity anomaly map compiled by the Geophysical Exploration Team of Xinjiang Bureau of Geology (1983) shows that there is a nearly EW-trending gravity anomaly in the south of the study area whose

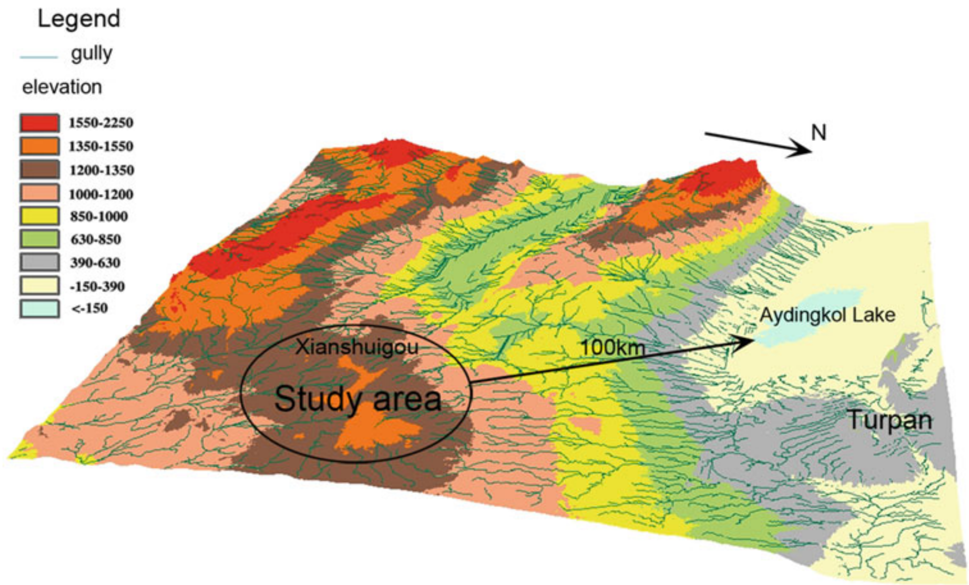

Fig. 84.3 3D terrain map of study area

amplitude is (−110 to −170) × 10^{-5} m/s^2. The study area is situated in a nearly EW-trending gravity gradient wide—gentle zone with the amplitude of (−120 to −130) × 10^{-5} m/s^2; this indicates that there is no large faults crossing this area. According to the 1:50,000 regional aeromagnetic ΔT plane anomaly map of Xinjiang (1989), the aeromagnetic anomaly is wide and flat, indicating that the geological body is homogeneous in the granite zone. According to the Moho depth contour map (1997) in *Xinjiang Geological and Mineral Chronicles*, the study area is located on the margin of an EW-trending gradient zone; the crust thickness is 46 km which changes smoothly.

As shown in the regional epicenter distribution map (Fig. 84.4), Xianshuigou granite pluton lies in the north of Aqikekuduke fault (Fig. 84.4, No.1) where seismic events are relatively rare and the earthquakes are generally less than magnitude 5.0. As shown in the seismic intensity map of Xinjiang, the seismic intensity of the study area is magnitude VI. Overall, the study area is associated with weak seismic activity.

There are mainly two regional deep faults developed around the study area (Fig. 84.4), mostly thrusting strike-slip or reverse faults. Ophiolite, mictite, and acidic granite are distributed along the faults.

Aqikekuduke fault (Fig. 84.4, No.1) is approximately 30 km south to the study area. This fault is NW-EW-NE trending and more than 1400 km in full length. It is overall south-dipping at 50°–80°, as classified as a dextral strike-slip and reverse fault. In the south of the study area, the profile of the fault shows that a gravel layer overlies the fault zone. Thermoluminescence dating samples collected from the find sand lens of sand—gravel layer are estimated to be (143.70 ± 12.21) ka BP (according to *regional crustal stability report of northeast of Korla*, 2010). According to the profile, Bolokenu—Aqikekuduke fault has never been active since the Late Pleistocene period, thus belonging to Early—Middle Pleistocene fault.

Yamansu fault (Fig. 84.4, No.2) is approximately 40 km north of the study area, part of which is associated with pluton emplacement. Regionally, this fault is nearly EW

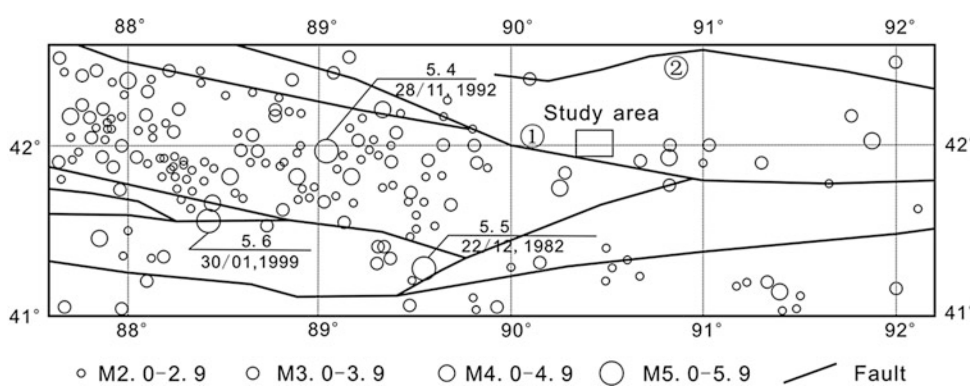

Fig. 84.4 Regional network distribution of earthquake epicenters (January 1970–2005, M ≥ 2.5)

trending and extends in a soothing wavy pattern. It is generally north-dipping at 60°–70° and belongs to high-angle thrust fault, i.e., brittle—ductile fault. This fault does not dislocate the Middle—Late Pleistocene strata. Therefore, Yamansu fault is identified as an Early Pleistocene fault.

Together the above results indicate that the study area is located in a granite zone with less aeromagnetic anomalies, no abnormal abrupt changes in the EW distribution, and wide—gentle gravity gradient. This area is located in a crustal structure on the margin of an EW-trending gradient belt, which has relatively simple structure with no large faults. The study area lies in a slight uplift zone with weak seismic activity and low seismic intensity (<VI). That is, the neotectonic activity is weak and regional crust is relative stable in the study area.

84.6 Preliminary Assessment

In the northeastern region, Xianshuigou granite pluton belongs to early Indosinian intrusive rock; this pluton is affected by post-tectonic movement to a relatively low degree; there are no large faults in the pluton, with few faults and dykes developed only; the geological repository has complete surrounding rock mass, high engineering strength, and uniform stable engineering performance. Xianshuigou granite pluton is of batholith type, whose thickness is generally greater than 1000 m. The granite pluton has an area of more than 300 km^2, providing enough space for engineering disposal. Regional structure has little impacts on the pluton. The geophysical field is relatively stable and the seismic activity is weak, with seismic intensity of magnitude VI. Therefore, the preselected site is a relatively stable area conducive to long-term storage of HLW. The northeastern region is a water-poor area where the arid climate and pluton characteristics prevent the infiltration of surface precipitation. Therefore, the water system has little impact on the repository. The groundwater flow path is quite long, approximately 100 km to Aydingkol Lake in the northwest direction.

Overall, the northeastern region has good prospects as a preselected area of geological repository for HLW disposal.

Future feasibility study of the northwestern region as a preselected area of geological repository for HLW disposal needs to investigate the lithological evolution and distribution patterns of deep granite pluton; combined with geophysical data, more deep drillings should be carried out.

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