CONSERVATION OF THE GROTTOES AND EARTHEN ARCHITECTURES ON THE SILK ROAD IN CHINA

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Foreword

There are a great deal of grottoes and earthen architectures along the Silk Road in China which are of historical, scientific and aesthetic significance. They are big-league of the world because of scale magnificence, amount excessive, excellent art and far-reaching affect. [1~4]. It is the urgent affairs to salvage the ancient sites because they are going to destroy. The Fig.1 is the distributing graph of the vital grottos and earthen sites on the Silk Road in China.

34 grottos have being announced as the Key Cultural Relic Unit under State Protections[5], 3 grottos in Shanxi Province, 10 grottos in Gansu Province,1 grottos in Ninxia, 5 grottos in Xinjiang. The most famous grottos is such as Mogao Grottoe(Fig.2), Yulin Grotto of Anxi(Fig.3), Maijishan Grotto of Tianshui(Fig.4), Binling Temple Grotto of Yongjing(Fig.5), Mati Temple Grottos of Zhangye, and Kezi'er Grotto(Fig.6), Kumutula Grotto(Fig.7) and Bozikelike Grotto(Fig.8) in Xinjiang, ect.

Announced the Key Cultural Relic Unit under State Protections 22 within Xinjiang Uigar municipality, 11 within Gansu Province, 5 within Ninxia, 5 within Qinghai Province[4]. The famous earthen sites is the Banpo site, the Terracotta Warriors site, Dadiwan site in Qin'an of Gansu, the Yumen Pass, Hecang site and the Greatwall of Han Dynasty in Dunhuang(Fig.9,10,11,), the Suoyang site in Anxi(Fig.12), the Camel City site on in Gaotai, the Heishui site in Inner Mongolia(Fig.13), the Western XiaEmperor No.3 mausoleum in Yinchuan(Fig.14), the Jiaohe Ruins(Fig.15), the Gaochang ancient city and the Loulan Ruins in Xinjiang.

The Existing Environment of the Grottoes and earthen sites on the Silk Road

Chinese silk road locates at the centre of the Eurasia, the natural disaster is high frequency, such as drought, sand blown by wind and storm, this area is one of the severest aridity areas in China, even in the world, so the economic development is limited by the natural condition and also the existing of ancient sites in here have been threatened. The characters of the climate in here as follows:

1) Drought and short of the rain, but the evaporation is great, the rainfall is inequality during one year. Generally, the yearly rainfall under 450mm, it seems that the trend is gradually reduced from the Helan Mountain towards its west. The rainfall is concentrated, mainly in the summer: July, August and September, the rainfall of the summer is 70% of the year; the rainfall in the winter is 2.2% of the year, many regions less than 10mm, and the storm is frequent. But the evaporation is more than 2000m, some regions more than 3000mm. This kind of special climate is the key reason of ancient sites can exist long time, but objectively, the dry and cold climate causes the earth architecture from dry to damp and produces the disease of freeze-melt, the surface of ancient sites is damaged by the weathering [1,4].

2) The gale and dust devil are strong and frequent, they are outburst suddenly. Affected by the high air pressure from the Siberian-Mongolia, the strong west wind prevails, it transports a lot of sand, causes the fierce wind and dust devil. The "carrying sand wind" always can be seen, the wind speed is more than 5m/s, the peak speed is grade 12[6]. The sites are eroded by the sand blown by wind and the safe of themselves and their existing environment is threatened.

3) The sunshine is abundance, the temperature is variational. The obvious character of continental climate in here is the difference in temperature (generally more than 10~20^{o}C): winter and summer, day and night[6].

Primary conservation issues of the grottoes and earthen architectures on the Silk Road

As a result of different geologic and climatic condition, and the difference of constructional material and

constructional techniques of the site, the primary disease is different.

1 The primary issues of the grottoes

(1) Damage that the atmospheric precipitation and groundwater cause leaks and infiltrates.

This is the most commonly, endangers and greatest disease in the grottos . Atmospheric precipitation enter along crack, cause rock soften, so the historical relic in the grotto is corroded seriously. Mogao Grottoes of Dunhuang and Yulin Grottoes of Anxi generally have this disease. Corroded seriously grottoes by groundwater is the Maijishan Grotto and Binglin temple Grotto in Gansu Province, the Great Temple Grotto in Shanxi Province.

(2) The unstable wall rock of caves

Generally, the grottoes are cut at banks of river valley. There are many relief crack in the side slope(Fig.16), whose obliquity is close to 90^{o} and which incline extroversion. The side slope is incised by the tensile crack, construct crack, weather crack , crack among the layers, fracture surface or shear band , weak intermediate layer ,etc, which make up slipping moving , collapse and straggly separation body potential. So the slope exist hidden dangers. This kind of damages generally exist in all grottoes. The most typical one is Mogao Grottoes of Dunhuang , Yulin Grottoes of Anxi, the Maijishan Grotto and Binglin temple Grotto in Gansu Province.

(3) Weathering of the rock body

Weathering is threatening the Cave Temple constantly and it has different forms of expression in different climate regions. The grottoes, along the Silk Road, mainly is the strong wind and water erosion (Fig.17). Such as Mogao Grottoes of Dunhuang , Yulin Grottoes of Anxi and Kezi'er Grottoes in Xinjing.

(4) The Deteriorations of the wall-painting and sculptures in Grottoes

The kinds of reasons result in the deteriorations of wall-painting and sculptures, the main are following：

A Detached wall-paintings are divided into two types: (1) Partly loss of the wall-painting; (2) Wall-paintings plaster detaches from the rock but remained. The cracked and detached wall-painting are the main damages of wall-painting. (Fig18).

B Moving of Salts and water causes the structural damage of plaster layer even lose(Fig19) and another kind of damage, the blister wall-painting.C because of the material and techniques of wall-painting and changing of environment, the flaking of painting layer wall-paintings almost distributes in every caves(Fig20).

D Sunlight and higher humidity and other factors cause the color change(Fig21)

E the particle of pigments gradually lose and make the painting layer to be faintness(Fig.22).

F The mildew developed under the higher humidity before and left the mildew spots in the surface of the wall-painting(Fig23). Another, some insects left their egesta to pollute the wall-painting.

G The changing of the structure of the painted sculptures causes its damage even collapse(Fig.24).

H The man-made destroys from visitation affact the conservation of wall painting now. before some people lived in the caves to produce the soot deposit(Fig25).

4.2.4 Reinforcement of Thin- Roof Caves

After making the simulated test, we cooperated with GCI to consolidate the thin- roof cave 460 by using seepage proof materials. The results show that it is not only very effective, but keeps the original shape of the cliff. However, that adds load to caves.

4.3. Restoration of Wall-paintings and Painted statues

4.3.1 Restoration

Polyvinyl Alcohol and Polyvinyl Acetate are used to restorate the faking wall-paintings. These two materials had been used for 30 years in this dry environment, and result shows that they are very effective. This method of work involved in following steps: A. clearing away the dust on the surface of the flaking wall-paintings; B. injecting binder of 20% to 30%; C. flattening the flaking wall-paintings by cotton ball which is bound of absorbent cotton; D. spaying binder on the surface of the consolidated wall-paintings; E. pressing the surface of wall-paintings .

4.3.2 Restoration and Consolidation of the Detached Wall-paintings

Edge reinforcement was applied to renovate the first type of detached wall-paintings, while anchor reinforcement and grouting were applied to the second type. However, anchor reinforcement could cause damage to paintings, and grouting has some defects on both material itself and grouting technology. Now we work together with GCI to do test for choosing suitable grouting materials and technologies, and that developed remarkably.

4.3.3 Restoration of the Disruptive Wall-paintings

We didn't get much development to the treatment of

disruption, which is compared to the “cancer ”of wall-paintings. Same problems were produced in 1980s on the wall-paintings that had been renovated in 1970s. Same problems were produced again in 1990s on the wall-paintings that had been renovated in 1980s. Therefore, we cooperated with GCI to choose the suitable materials of renovation and technologies, and had achieved some exciting results.

2 The Primary Issues of earthen site

(1) Weathering of the Surface of the architectures

It is a kind of issues that generally exists in earthen sites (Fig.26). The dominating destroying agency is wind, rain, abrupt change of humidity and temperature, transporting moving and capillarity of salts, the plant root system grows and destroys. The main type is as follows, ①exfoliate; ② Cracking; ③Massiveness peeling off; ④Salts action; ⑤ Biological weathering; ⑥ Rain erosion.

(2)Undercutting of the foot of wall in the sites

The disease has destructiveness strong., which can cause crack and crack expand , lead to the fact the site collapse. Destroy pay for wind-force , flowing water erode foundation of the wall, capillarity and salts dissolve-crystallization. The wind erosion is the most serious destroy(Fig.27).

(3) Crack

Crack is one of the dominating factors that cause the collapse of earthen architectures. Under the internal and external function for a long time, the crack type is mainly joint, relief crack, space of discission and the joint of structure. The crack inclination approximate to upright, and the strike is parallel with or perpendicular to wall(Fig.27).

(4) Collapse

Refer to the site suddenly break down caused by gravity or other forces (Fig.29). There is collapse of three kinds of forms mainly in the site: ①Careen collapse. ②strewn at random.③Pull apart collapse.

Jiaohe Ancient city

(5)Man-made destroy

Artificial damages refer to the intend and dinvoluntary action in the course of vita and production. The main type is as follows: ①Dig the site to made up fields; ②Dig the wall to pass; ③Tourism exploitation; ④Other artificial distruction.

Conservation methods and existing problems

1 Conservation method of grotto temple on the Silk Road

4.1.1 Bulkhead, breast wall and large-scale building body to keep off

In view of the fact that the Mogao Caves so excessively dense, the cavern does not have the lining work, the rock body’s intensity is low, the cracks cut the rock body. Using the rubble stone or the reinforced concrete girder to support the cliff body; constructing the rubble stone or the concrete gravity bulkhead to resist the rock body’s lateral pressure, to prevent the cliff body’s cracks slip to outside and falls(Fig.29). It has manifested the thought “An empty vessel makes the most sound ", which from Mr. Liang Sicheng proposed for the Mogao Caves reinforcement project. Eliminating the rock body which hangs excessively and fragmentary danger stone which unnecessary goes against.

4.1.2 Anchor technology

The rock body anchor project around caves is different to the general geological disaster prevents project, which permit changing original natural landform landscape, but in the heritage sites reinforcement project it is absolutely forbidden, it must achieve repairing old as before, maintain original nature and humanities landscape. Using the advanced anchor cable technology to reinforce the danger rock and broken body in the Yulin grottoes and Mogao grottoes (Fig.30). The top of the anchor and the bearing plate sealed in the rock body, the rock surface decorated with the same rock matter, which implement the principle repaired the old as before, solve the steady issue of the rock caves , maintain the original landscape of the Grottoes, all of this mentioned a new altitude to Chinese heritage sites reinforcement technology.

4.1.3 Crack grouting

The crack grouting may not only prevent the atmospheric precipitation destroy the wall painting, but also coordinates with the anchor cable project, strengthen effectively the rock body’s own anti- destructive capability. Regarding the low intensity and argillaceous cemented or half cemented condition conglomeration of the grotto on the Silk Road. The PS-F serosity has good fluidity, does not come into being eduction, the PS-F concretion has favourable contractibility and stability, cold resistance and slake durability and acid and alkali resistant. The PS-F serosity intensity can be controlled approaches with the rock body intensity. The construction technics is briefness and the cost of PS-F is vile(Fig.31).

4.1.4 Draining water and the method against infiltrate

The main method of draining water is make the drain on the top of the caves, changing and leading the direction of surface current of water. Pave the layer against infiltrate,

meanwhile grout the crack. Drain the water in front of the caves, drill or excavates the tunnel to low the ground water.

4.1.5 Reinforcement of weathering cliff surface

Under the serious weathering, the top of the grotto goes thinly, endangers the grottoes' preservation. Along with the PS material prevented the sandstone weathering develops successfully [3], the cliff surface reinforcement against weathering uses it. The room tests, the wind tunnel simulation test and the scene effect observation indicated that, after the PS material reinforcement, weathering quality of the sandstone is enhanced approximately 200~300%, and the erosion resistance has been increased. meanwhile the cliff surface has not changed its original condition (Fig.32).

4.1.6 Conservation and restoration of wall-painting and sculptures

(1) The digital preservation of wall-painting and sculptures

From 1990's, Dunhuang Academy begun this important works. With the development of digital and compute technology, the Digital Dunhuang grottoes works has obtained the important advances[7]-.

（2）the Conservation and restoration of the wall-painting and painted sculpture

A. Restoration of the flaking wall-painting

We used to adopt polyvinyl acetate and Polyvinyl alcohol to restore the flaking wall-paintings. After dozens of years of practice, we have explored a set of complete repairing techniques. At present, the gelatin is used to replace polyvinyl acetate and Polyvinyl and has a good effect. It possesses the main characteristics of having the identical properties with the material of the wall-paintings, the excellent compatibility as well as the multiple permeability of the other restorative materials. Surely it takes time to test the consolidating effect of this material[9].(Fig.34)

B. Restoration of the detachable wall-paintings

The wall-paintings consists of two types: the shedding of partial wall-paintings and the separation from the precipice. For the former, we employ the method of marginal reinforcement to restore , whereas for the latter, we used to adopt the means of the combination of slip casting and anchor to reinforcement and had restored plenty of wall-paintings. Nowadays with the cooperation of the protection project upon N. grove wall-painting between Dunhuang Academy and GCI ,USA ,under the guidance of minimal interference and maximal compatibility, we successfully sifted the suitable grouting materials and techniques and promoted its reinforcement and restoration. (Fig. 35)

C. The Restoration of salt –damaged wall-paintings

The disease of salt–damaged is so called cancer for the protection of the wall-paintings and for a long time we had no effectual treatment toward it. The wall-paintings which had been restored in the 1970s arose the same problems in the 1980s , moreover after the reinforcement in the 1980s they experienced the same in the 1990s. Therefore, Dunhuang Academy and GCI ,USA sifted the materials and techniques for this disease, particularly we have achieved inspiring accomplishments in the technique of desalination of the wall-paintings[10] (Fig.36).

D. The Restoration of the sculpture

We adopt the methods of "remould oneself" and consolidation plus strengthening to restore and reinforce those sculptures with decayed frames which tend topple with the effort not to alter their present protecting form[11]. They are not replenished and restored in case the requirements of maintaining stability. Employing these methods the sculptures in force have been restored. (Fig.37)

2 Conservation of earth heritage sites on the Silk Road

4.2.1 Reinforcement and conservation against weathering

For the destructive effect of the wind, rain and temperature difference to the earthen sites on the Silk Road are long-term, it's inevitable to reinforce the heritage sites surface against weathering. In allusion to the Silk Road special environment characteristic, many kinds of surfaces shielding material applies to the ruins reinforcement. At present applied to the Silk Road earthen sites reinforcement material mainly is PS material, the organic fluorine polymerization and methacrylate and so on. PS material applies to the scene reinforcement project of the Guo country tomb chariot pit in the Sanmen Xia city , the Gansu Dunhuang Yumen pass, the Hecang city and the Ningxia king mausoleum third(Fig.38). After reinforcment, the enduring weathering capability get the distinct improvement. Reinforcing the Banpo Site experimental study with the organic fluorine polymerization indicate that is suitable to the water environment earthen site conservation [7, 8, 9].

4.2.2 Anchoring

Anchoring can transfer and enhance the earth intensity and ability keep steady, greatly reduce the structure weight, save the construct material, and guarantee the construction security and the project stable; it is one kind of effective method to the heritage sites reinforcement. During the year 1999~2000 the anchoring experiment has been systemically

carried on natural earth body nearby the Dunhuang Hecang city, which use the flinty wooden rod as the anchor rod, take PS-F, PS-C as the serosity, has obtained the good effect [1,4.,10,11]; after the experiment, in the Yumen pass, the Hecang city and the Ningxia king mausoleum reinforcement project the wooden anchor rod has been used to reinforce the wall in danger(Fig.39).The project application effect is good. Recently, the Dunhuang Academy carry out the field test about "the Mao bamboo compound anchor rod" in Turfan Jiaohe ancient city. The preliminary result indicated that this kind of anchor rod had the very good effect to the earth body, prevented the collapse, and explored a road of the success on the heritage sites reinforcement (Fig. 40).

4.2.3 Crack grouting

The combination of crack growth can make the ruins construction in danger of collapse, seriously destroys the heritage sites. Therefore to the crack, especially to those possibly creates collapse, we should reinforce them by grouting. The crack after anchoring must be filled with grout, or once the rain infiltrates in the crack, it will soften the earth body and cause the anchor rod lose its function. At present the main grouting material is Epoxy resin, the acrylic acid fats and PS (+ F, +C) series inorganic material and so on, because of its good bonding properties, low viscosity, may fill the nature good, solidify under the room temperature, frozen endurance and water resistance.

4.2.4 Remedy

Remedy is a traditional reinforcement measure and is used in early conserveting work. This technique is propitious to conserveting earthen site shortcoming and caving zone by using the soil-made brick. The increased part shoud be close contact with the site. The soil-made brick is made up of silt that has the same quality to the soil of the site, and the silt salinity is less than 0.50%, the the water content is less than 3.0%, the density is more than 1.70g/cm^3. In order to enhance the wholeness, the wooden anchor is used to joint the site and the increased part(Fig.41).

3 The existing Issues

4.3.1 In a way, engineering geology theory and practice does not have the more thorough application on the earth heritage sites, which is insufficient on the research to geological environment of the heritage sites and the conservation influence. So the effect of the reinforcement material and technology in laboratory is very good, but when makes concrete to the scene, the effect is not really ideal.

4.3.2 On the heritage sites conservation, the material, craft and reinforcement effect of conservation and reinforcement are the base and difficulty. These are the key to evaluate our conservation work. We must give to solve these problems. Until now it's still not finding out the useful method to carry on the reinforcement effect examination in the scene, which increased the difficulty for the project approval and the evaluation. The suitable conservation material and the automatic construction craft is the difficulty to the heritage sites conservation

4.3.3 At present the talented person on the heritage sites conservation is very short. The existing conservation and reinforcement techniques are not able to meet all conservation damages.

Looking forward to the future

Since the development of economy and the improvement of the synthetic national power of China, the awareness on the conservation of cultural relics will be accepted by all communities, the fund invests in the conservation of relics will be increased. The conservation work needs scientific technology, and the demand becomes more and more urgent. Meanwhile, the scientific research on other fields will pay more attention to the relics conservation, a spring of tackling key problem on the conservation through multidisciplinary cooperation is coming.

According to the special character of earth sites, the engineering geological survey which fits on the conservation will be developed, and the theories of engineering geological research, such as: monitoring, reverse analysis, forecast and numerical value's simulation will be applied in the ancient architecture's conservation, they will guide the various conservation practice in different environment, it is a perfect orientation for combining the engineering geology and cultural relics conservation.

The applications of China Principles will greatly enhance the level of the conservation of the grottoes and earthen sites along the Silk Road in China. The conservation standards of guidelines of the grottoes and earthen sites should be finished as soon as possible. All these will insure the ancient sites to be got the scientific and standard conservation.

The persons with ability trained should be important tasks of the conservation of the grottoes and earthen sites along the Silk Road in the future.Now, the Dunhuang Academy together with Lanzhou University have founded the research center of cultural relics conservation, the key tasks of the center is to train the staff and to tackle key problem on scientific conservation, it will play an active role on the conservation at the northwest of China, especially on the

fields of grottoes and ancient earth architectures. Bases on the center, the stated center of ancient sites conservation should be actively applied, it will stand at Dunhuang and serve for the northwestern region, and drive the cause in here to develop rapidly.

Abstract

The grottoes and earthen architectures on the Silk Road in China are of great cultural significance. Most of the grottoes were excavated into conglomerate rock, which is soft, consisting of gravels and sands bound by clay or calcium salts. Earthen structures were built using sand and clay as raw materials. The climate of the Gobi desert—characterized by strong winds carrying wind-blown sand and occasional heavy rain—is responsible for severe damage to earthen structures. Many ancient sites are facing the threat from desertification. Moreover, site protection in the past was inadequate, and unable to combat such practices as exploitation of earthen sites for farming, inappropriate use, and unplanned excavations by foreign explorers. At present, many ancient sites on the Silk Road are in danger of disappearing.

Dunhuang Academy has over the years conducted conservation research, including the assessment of significance, condition recording, analytical research, and the development of conservation materials and technologies for many sites on the Silk Road. A number of major conservation projects have been undertaken, including the Yumen Pass and Hecang site in Dunhuang, Western XiaEmperor No.3 mausoleum in Yinchuan, and the Beacon tower of Jiaohe. The results of the consolidation have assessed and judged effective.

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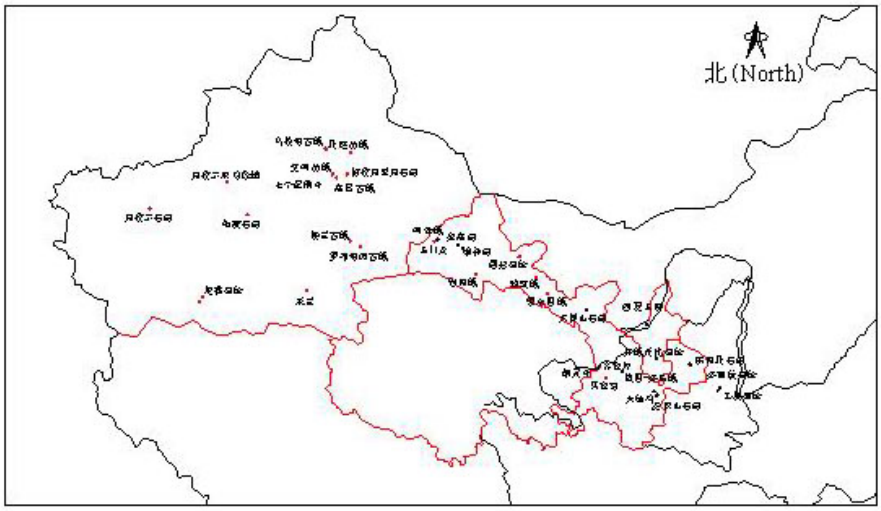

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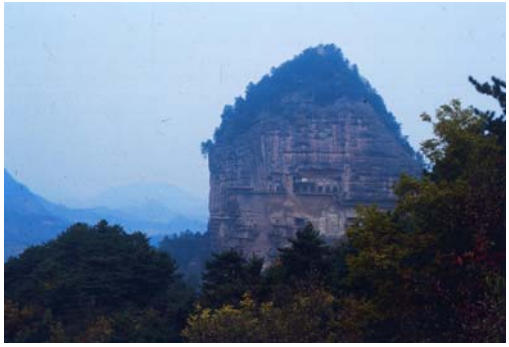

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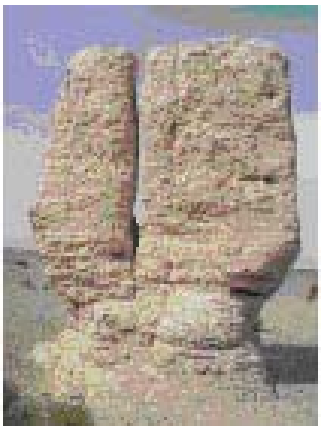

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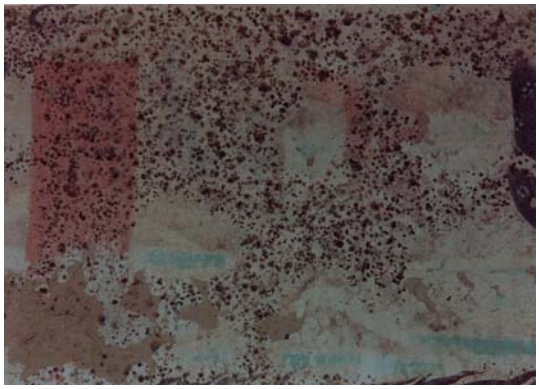

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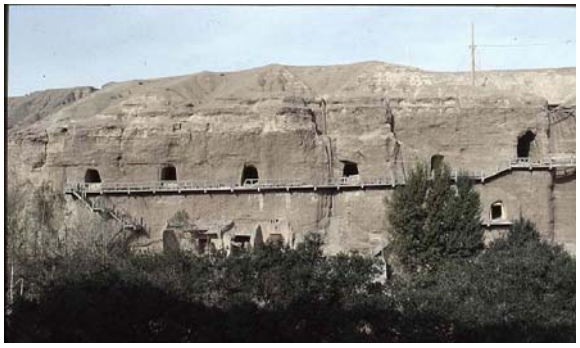

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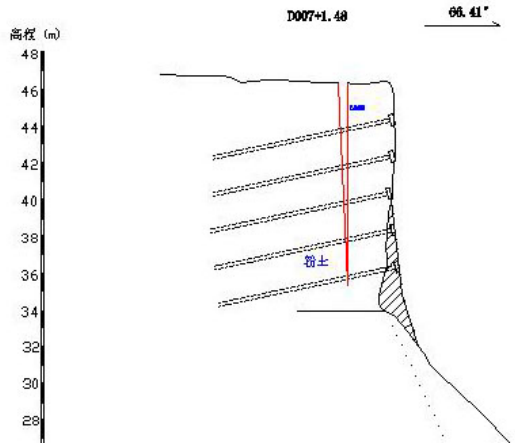

Fig.40

Fig.41