Chapter 6

Engineering Construction and Geo-environmental Assessment

Construction of Mining-Metallurgical and Chemical Projects

Mining-Metallurgical and Chemical Projects

Regional conditions are favourable for the development of mining-metallurgical and chemical industries. The research region is rich in mineral deposits with a variety of accompanying elements and supplementary metals. Water resources are extremely abundant.

The regional plan has emphasised the steel industry's production plan. In steel production, the index for production of vanadium and titanium is determined, and, on this basis, the extraction rate of iron mines, production, and the supplementary inputs are planned. At the same time, construction plans for non-ferrous metallurgical and chemical industries and for the exploitation of non-ferrous metallic mines are drawn up according to the location of raw materials. Figure 13 shows the structural plan for mining and metallurgical projects in this region.

The deposits of vanado-titano-magnetite in this region can meet the raw material requirements needed to produce 10 million tonnes of steel. Increasing the regional steel yield to six million tonnes annually by the end of this century and to 10 million tonnes in the first half of the 21st century is feasible. Therefore, the Panzhihua Steel Company can expand to increase its annual production capacity to an iron yield of three million tonnes and 2.5 million tonnes of steel by 1995. Limited by the landform conditions, other sites must be chosen for expansion. It will be more beneficial to select sites inside this region rather than outside because of the local mineral resources and inexpensive electricity.

After the extension of Panzhihua, it will be able to supply up to six million tonnes of iron ore. About four million tonnes of good quality coal can be provided by the Baoding, Huaping, and Hongni coal mines, and any shortfall can be overcome by importing coal from the Liupanshui district of Guizhou Province. Until the establishment of Ertan Hydropower Station, the demand for electricity can be met by Panzhihua Power Station by increasing the current installed capacity of 0.15 million kW.

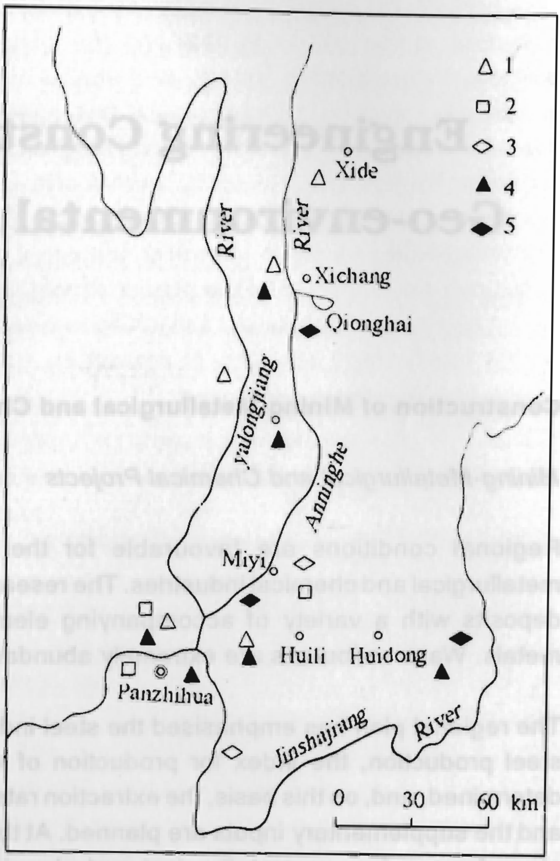

Fig. 13: Planning of Mining -Metallurgical Industry

1. Iron mine 2. Coal mine 3. Copper-lead-zinc mine
4. Steel plant 5. Non-ferrous metal smeltery

The construction of a second steel plant, which will be as large as the extended Panzhihua Steel Plant, is planned (i.e., with an annual capacity of three million tonnes of steel and three million tonnes of iron). The corresponding annual demand of 25 million tonnes of iron ore can be provided by the Taihe and

Baima mines. Brown coal may be supplied by the Yanyuan Coal Mine and anthracite can be supplied by the Hongni Coal Mine in Yanbian. The shortage of fuel can be supplemented by fuel from the Chuxiong District in Yunnan Province. The energy resource for the second steel base will be provided by Ertan Hydropower Station. The building materials can be provided by local factories (Plate 17). Along with the construction of the steel plant, vanadium, titanium, and other metals can be extracted and used for the production of alloys and a vanadium and titanium pilot plant can be built during the construction of the second steel base.

Besides the vanado-titano-magnetite resource, this region is very rich in other kinds of metallic resource, many of which are of good quality and have a variety of accompanying components. Minerals suitable for producing alloys that are easy to separate and can be efficiently exploited are present in concentrated deposits. Twelve kinds of metallic resource have been surveyed in this region which is abundant in zinc, aluminum, copper, silver, and rare earths. Since there is already a steel industry, non-ferrous metal bases can be established here. The construction of a Sichuan Non-ferrous Metal Smeltery, which will obtain raw materials from the mines in the region, is planned. The Tianbaoshan Lead-Zinc Mine in Huili and the Lalachang Copper Mine and Daliangzi Lead-Zinc Mine in Huidong will be constructed and extended to use the resources available.

According to the plans for developing the local economy, the medium and small mines will be worked step by step; of these 12 lead-zinc mines, three tin mines, and 14 copper mines will supply the Sichuan Non-ferrous Metal Smeltery.

This region is also very rich in chemical resources. Besides sulphuric acid, which can be extracted in large amounts during the exploitation of non-ferrous metals, the halite deposits in the Yanyuan Basin can be used to build up systematic production based on chloric soda (Figure 14). There is a large amount of low grade phosphate ore inside the Huidong Mine which can be used to produce sulpho-phosphate compound fertilisers.

Geo-environmental Problems in the Construction of Mining-Metallurgical and Chemical Projects

For the systematic development of mining, smelting, and chemical industries, an adequate number of smelteries, iron mines, coal mines, non-ferrous metallic mines, salt mines, and building sites must be established and/or extended. Many geo-engineering and environmental problems will have to be studied before their construction.

A. <u>Site Selection for a Smelting Base and Its Geo-environmental Problems</u>. According to the plan, the primary projects are the extension of the Panzhihua Steel Plant, the construction of a second steel base and Sichuan non-ferrous metal smeltery, and some processing plants for steel and raw materials.

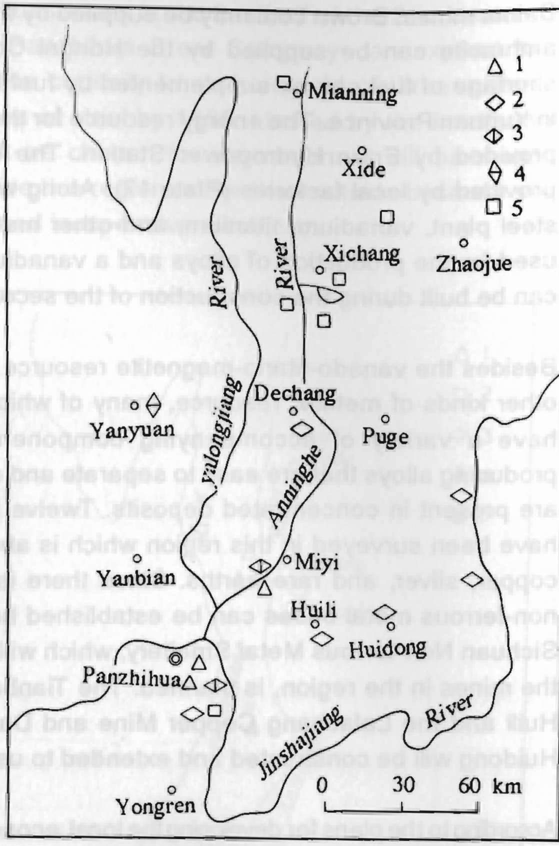

Fig. 14: Regional Planning of Chemical and Processing Industries

1. Chemical factory 2. Sugar plant 3. Timber processing 4. Salt plant 5 Light industry

Sites should be selected taking geological conditions and engineering possibilities into account. They should be selected near mines to facilitate the transportation of ore. At the same time, they should be close to the main highways to facilitate the export of metal and other products and shorten the construction period. Therefore, the big smelteries, in principle, should be located near the Cheng-Kun Railway, in the section approximately south of Panzhihua and north of Xichang. Considering the support provided by the Panzhihua Mine and Baoding Coal Mine for the extension of the Panzhihua Steel Plant, the plant should be established in Panzhihua. The production of the extended plant is dependent upon the Taihe Iron Mine near Xichang and the Baima Iron Mine in the north of Miyi. The plant should be located in Dechang to avoid the Xichang high intensity seismic zone. The zone between Dechang and Miyi is a comparatively stable massive and is more stable than Xichang. The conditions in the zone are even more favourable than those in Panzhihua. The plants can use the water from the Anninghe River and are close to Ertan Hydropower Station. The Sichuan Non-ferrous Metal Smeltery was to be built in Xichang, but the seismic intensity of Xichang is high, and, even though it is located near Cheng-Kun Railway, the distance from Xichang to the non-ferrous metal mines is comparatively long. Therefore, it is more convenient for the smeltery to be located in Miyi, because the distance between the smeltery and the Xichang seismic zone, as well as that between the smeltery and the Yuzha seismic zone, are both more than 100 km. The smeltery is close to the relevant mines as well. Therefore, the new plants should be located in the wide valley of the Anninghe River where there is a rich agricultural base.

In light of the experiences gained during the construction and operation of Panzhihua Steel Plant, a series of environmental and geo-engineering problems must be considered. The smelteries are located at sites with open landforms where often semi-cemented Xigeda strata exist. Such strata are widely distributed throughout the valley and basins of the Anninghe River. The Xigeda strata are a kind of intermountainous lake facies, the sandstones of which often contain soft silty layers which render the strata liable to sliding and swelling. During the excavation of the strata and their use as a foundation, landslides and foundation swelling often occur and, therefore, cause significant hazards in the construction of key projects. Landslides in the Xigeda strata cause a number of slope failures at locations inside Panzhihua Steel Plant (Figures 15 and 16), resulting in heavy economic losses and delays in construction. For example, during the excavation of the foundation of a blast furnace which had to be extended, there was a landslide in the Xigeda strata and the cost of reparation was as high as 30 million *yuan*.

The amount of slag dumped annually from large-scale steel enterprises totals up to 10 million tonnes, and, therefore, the site must be carefully selected. Inappropriate site selection will cause secondary landslides, debris flows, or the contamination of rivers. Similar problems have often arisen in Panzhihua Steel Plant. Along the Jinshajiang River, the debris flow is extensive, causing severe hazards during industrial construction (Figure 17).

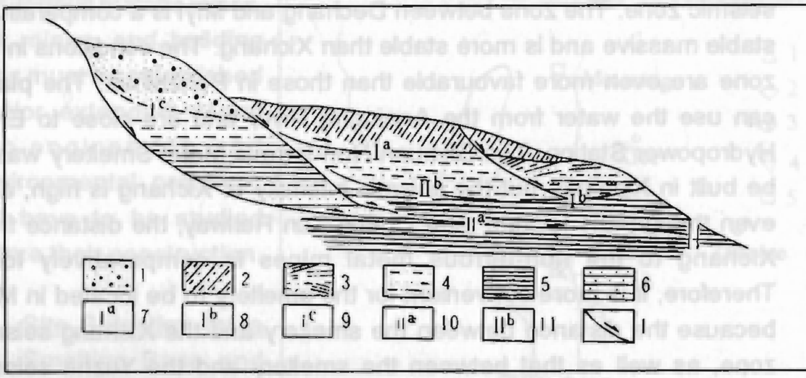

Fig. 15: Landsliding in Xigeda Strata

1. Gravel 2. Silt 3 .Xigeda siltstone 4 .Xigeda silt-sandstone
5. Xigeda clay stone 6. Xigeda sandstone
7,8,9. Sliding on upper layer 10,11. Sliding in middle layer

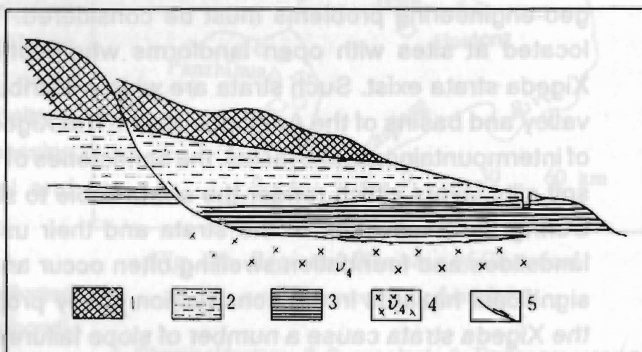

Fig. 16: Landsliding on Bottom of Xigeda Strata

1. Artificial filling material
2. Xigeda siltstone
3. Xigeda claystone
4. Intrusive bedrock
5. Sliding surface

When deciding on the site of a plant, the landform factor should be taken into account. The gorge of Jinshajiang River was selected as the site for Panzhihua Steel Plant. The elevation is low, the climate is moist, and the dispersal of smoke is difficult and aerial pollution is a problem.

B. Geo-environmental Problems in Mining. Many of the vanado-titano-magnetite deposits and non-ferrous metallic deposits are exposed and so the method of open cast mining can be adopted. Underground mining methods should be adopted for coal mines having thin coal seams and unfavourable mining conditions.

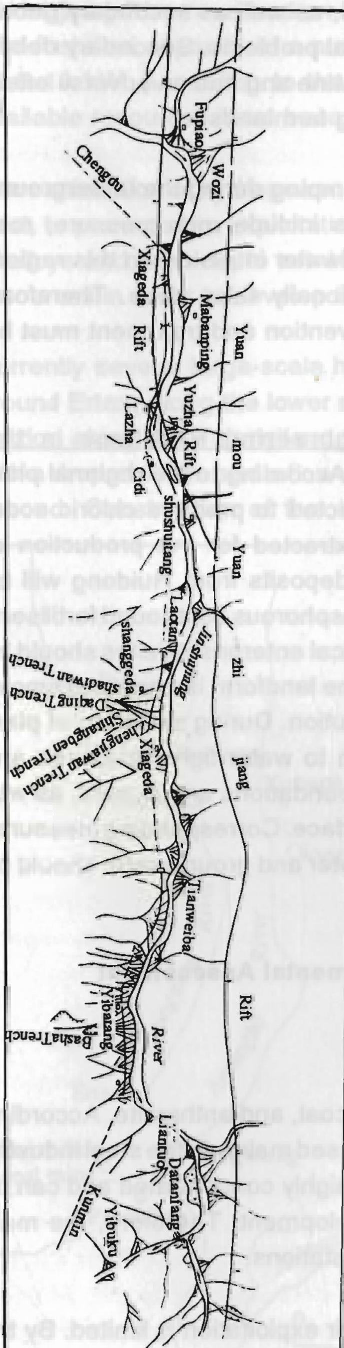

Fig. 17: Debris Flows along the Jingshajiang River Valley

Panzhihua vanado-titano-magnetite deposits occur at the contact point with gabbro and marble. The rock mass around the ore is faulted and contains weak interlayers with mud and weathered hornblende schist. The slopes in the lower wall of the deposits are often excavated along the bedding plane, and, therefore, the fractured layer composed of hornblende schist can form a sliding plane, influencing slope stability. Vanado-titano-magnetite mines located in Taihe, Baima, and other places will be extracted by open cast mining also. Therefore, when the depth of excavation is more than 100m, slope stability must be carefully assessed.

The most serious landslide in a mining area was the H2 landslide that occurred in 1981 in Panzhihua Limestone Mine. The volume of the landslide was about $5x10^6$ cubic metres and it held up production. The slope in the open pit of the limestone mine is composed of Yangxing limestone of the Permian period and is overlying Denying dolomite of the upper Sinian period. The stratum dipped towards the pit at between 30 to 40.5 hours, after the foot of the slope was cut by blasting, and a large landslide occurred.

In mining projects, a great amount of waste is produced annually and the sliding of dumps and tailing dams, as well as secondary debris flows, are also important environmental problems. Secondary debris flows also occurred in the Panzhihua Mine and had an adverse effect on project facilities and on surrounding farmlands.

In addition to the problem of waste dumping during the underground mining of coal mines, other problems include rock pressure, rock burst, coal burst, and gas and groundwater intrusion. In this region, rock pressure and coal burst occasionally take place. Therefore, during coal-mining, measures for prevention and treatment must be taken.

C. Geo-environmental and Geo-engineering Problems in the Construction of Chemical Industries. According to the regional plan, rock salt from Yanyuan is to be extracted to produce chloric soda, limestone from Panzhihua will be extracted for the production of polyvinyl chloride, and phosphorate deposits from Huidong will be mined for use in producing sulphur-phosphorous compound fertilisers. Before the construction of these chemical enterprises, sites should be carefully selected at locations where the landform is open and smoke can disperse easily to prevent air pollution. During selection of plant sites, more attention should be given to water-tight structures and hydrogeology in the strata on which foundations are located, as well as to the distribution of runoff on the surface. Corresponding measures to prevent contamination of surface water and groundwater should be taken.

Hydropower Planning and Geo-environmental Assessment

Projects for Hydropower Development

This region is primarily rich in coal, coking coal, and anthracite. According to the prevailing conditions, coal should be used mainly in the steel industry. The hydropower resource in this region is highly concentrated and can be exploited for large-scale hydropower development. Therefore, the main energy policy is to build large hydropower stations.

Hydropower resources are plentiful but their exploitation is limited. By the end of 1984, only one medium-scale hydropower station (Mofanggou II

Power Station) had been built. This station used a branch of the Yalongjiang River and had an installed capacity of only 37.5x10 kW. The total installed capacity of a number of small hydropower stations is only 92.5x10 kW. According to the electricity yield, only 0.3 per cent of the available resources have been exploited.

The exploitation of hydropower resources in this region has two objectives. First, to promote the exploitation of mineral resources and the production of alloys and, second, to establish an energy base, mainly of hydropower resources in order to develop Sichuan and southwestern China.

Currently several large-scale hydropower stations are being constructed around Ertan, along the lower reaches of the Yalongjiang River. The river section along the Yalongjiang from Jinping to Panzhihua is 360km long, with a drop of 678m and a flow capacity of 1,235 to 1,935 cubic metres per second. Construction of five hydropower stations--Jinping I, Jinping II, Guandi, Ertan, and Tongziling -- on the mainstream of the Yalongjiang River (Figure 18) has been planned. Ertan and Tongziling, particularly, have favourable conditions for communication and construction. After the establishment of the five hydropower stations, the total installed capacity will amount to 10.8 million kW. The annual electricity yield will amount to $6.884x10^{10}$. At present, the construction of Ertan II and Tongziling,

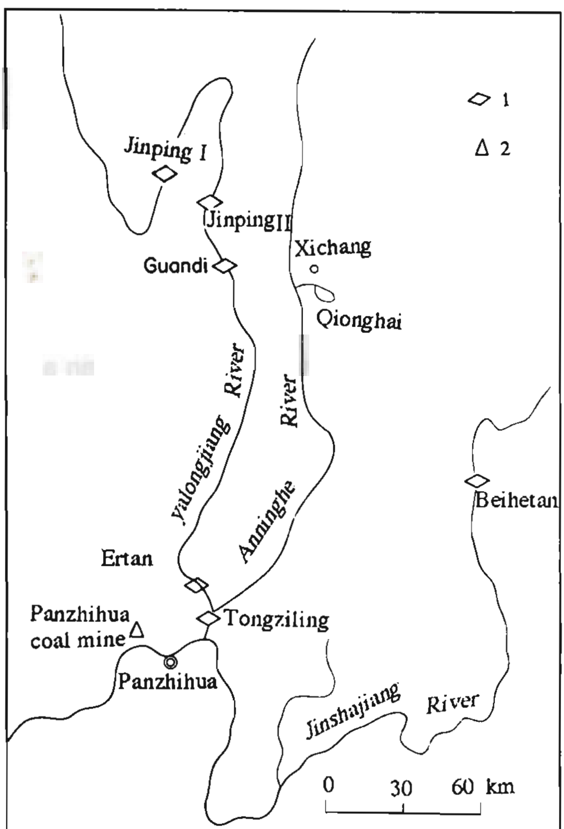

Fig. 18:Planning of Energy Development

1. Hydropower station
2. Thermal plant

located along the lower reaches of the Yalongjiang River, will be stressed and it is expected that construction will be completed by the year 2000 A.D. It will not only meet the needs of steel industries in Panzhihua and Dechang but will also supply electricity outside the region. Along with the exploitation of the hydropower resources of the Yalongjiang River, preliminary preparations should be made for the exploitation of the Jinshajiang River. Along the Jinshajiang River, from Banbianjie to Yibin, five cascade, large-scale hydropower stations can be constructed with a total installed capacity of 25 million kW.

Medium and small hydropower stations (Plates 18 and 19) are being constructed on the tributaries of the Anninghe River concurrently with the construction of the large-scale hydropower station on the Yalongjiang River. They are located in the centre of the region and have the advantages of favourable conditions for power generation and relatively small investment needs and, thus, are suitable in both the economic context and in the context of local development. More than 30 small hydropower stations have been established. Before the year 2000, a number of small and medium-scale hydropower stations will be constructed, such as Mofanggou I and Heshuihe, with an installed capacity of 0.3 million kW, in order to meet the needs of the local consumers and to mitigate the shortage of electricity in this region.

Geo-environmental Assessment for Hydropower Development

The regional plan focusses on the key hydropower stations of Ertan and Tongziling. A lot of preliminary survey work has been carried out to assess their feasibility and construction conditions. At present, Ertan Hydropower Station has entered the construction stage.

Ertan Hydropower Station lies along the lower reaches of the Yalongjiang River, 40km from Panzhihua City, and 18km from Tongziling Station on the Cheng-Kun Railway. The function of the hydropower station is mainly to yield electricity, but it also facilitates the transportation of timber, navigation, and the water supply for industries and cities. Because of its climate and fishing facilities it is suitable for tourism. Ertan Hydropower Station is the supplier of electricity in this region and has an installed capacity of three million kW, an annual electrical yield of 1.62x10 kW/h, and is running at a profit.

Ertan Hydropower Station contains a 245m high arch dam, lying in the Ertan Gorge section. The river valley is in the form of a "V", with steep slopes reaching 35$ to 40$. The strata at the dam site belong to the basalt of the Upper Permian period ($P_2\beta$) and syenite intruded in the Indo-sinian Period. The syenite massive is in the EW direction and is six kilometres long and one kilometre wide. The dam site is located at the southwestern end. The slope of the right bank is composed mainly of syenite and the left is mainly of basalt (Figure 19).

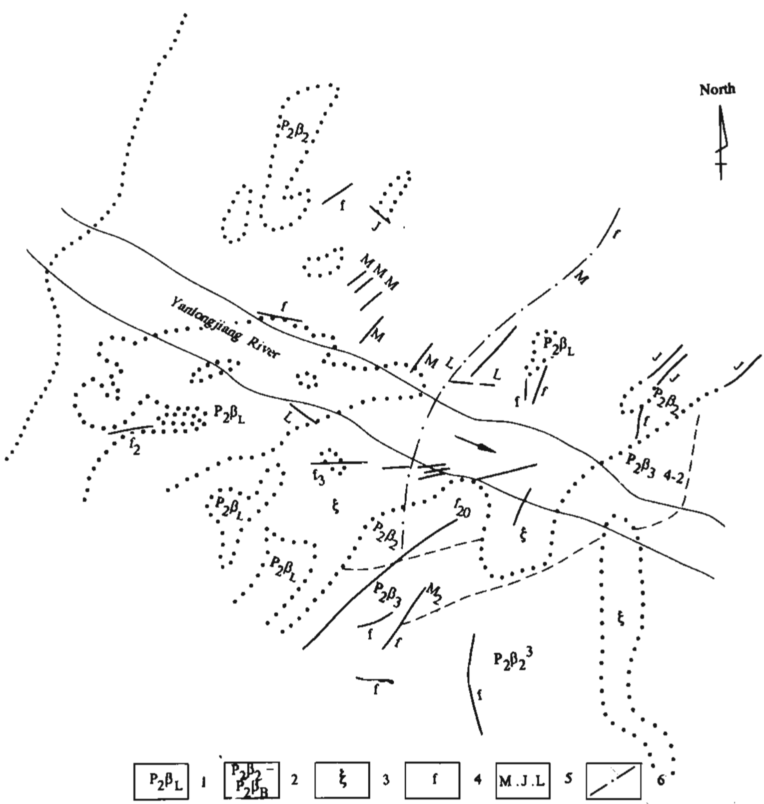

Fig. 19: Geological Sketch of Ertan Dam Site

1. Altered basalt 2. Basalt 3. Syenite 4. Fault 5. Fractured weathering zone (L), zone of dense joints (M), fissures (J) 6. Dam axis

The syenite at the dam site is grayish white, dense, and strong, with a cryptomerous structure. The basalt at the dam site mainly contains P_2B_2, $P_2B_3H_2$, and P_2B_2 layers. Layer P_2B_2 is a kind of micrograin-cryptocrystalline basalt with a dense rock property that is homogeneous, strong, and brittle and which is comparatively fractured due to local alteration. The filling material in the P_2B_2 layer is mainly chlorite, with unfavourable geo-engineering properties. The chlorite is sensitive to weathering and hence subject to reduction in rock strength. P_2B_2 is a kind of grayish basalt with a fine grain structure, or a kind of concentric, massive volcanic clastic rock with open pores in which pellet weathering easily occurs. P_2B_2 is a kind of altered basalt, with a non-homogeneous structure and low resistance to weathering.

The rock mass at the dam site is comparatively intact, and the weak structure planes are not well developed. A few faults, most of them occurring in the form of small faults or shearing zones and joints, can be observed.

The geo-engineering condition of the dam site is suitable for the construction of a high arch dam and underground plant with a large span. From the point of view of environmental and geo-engineering the assessment of Ertan Hydropower Station is as follows.

(1) The dam site is located on the Gonghe faulted block which is comparatively stable. Its eastern and western boundary faults are prone to minor earthquakes, with a historic record of earthquakes of M=5 in the past. Considering the influence of strong earthquakes from Xichang and Yuzha outside the region, the basic seismic intensity of this dam site is VII. The main buildings of the Ertan project are designed to avoid damage from earthquakes up to a seismic intensity of VIII. It is difficult to select a zone with a seismic intensity of VII for a dam site near the lithospheric active fault in the basin of the Anninghe River with its strong seismicity.

(2) According to the aero-remote sensing results and ground test investigations for the dam site, the loss of mineral resources caused by water impounding is small. Only a number of small coal mines are located on the margin of the reservoir. Rare and valuable plants will not become extinct through submergence. The ecology and climate will improve as a result of the reservoir, and it will be possible to

cultivate southern subtropical plants suitable for hot and damp climates.

(3) The ground of the reservoir is well-contained and the problem of seepage will not occur; there are more than 100 landslides in the reservoir zone, which can slide again after storage, but they will not have a negative impact because many of them are located far from the dam site (Figure 10). Protection measures will have to be taken only for the Jinglongshan Landslide located in front of the reservoir. There are 89 active debris flow gullies in the reservoir zone (Figure 20), but only seven lie in front of the reservoir. Since the locations of most gullies are higher than the water table of the reservoir, the flow zone of the debris flows obviously will not change.

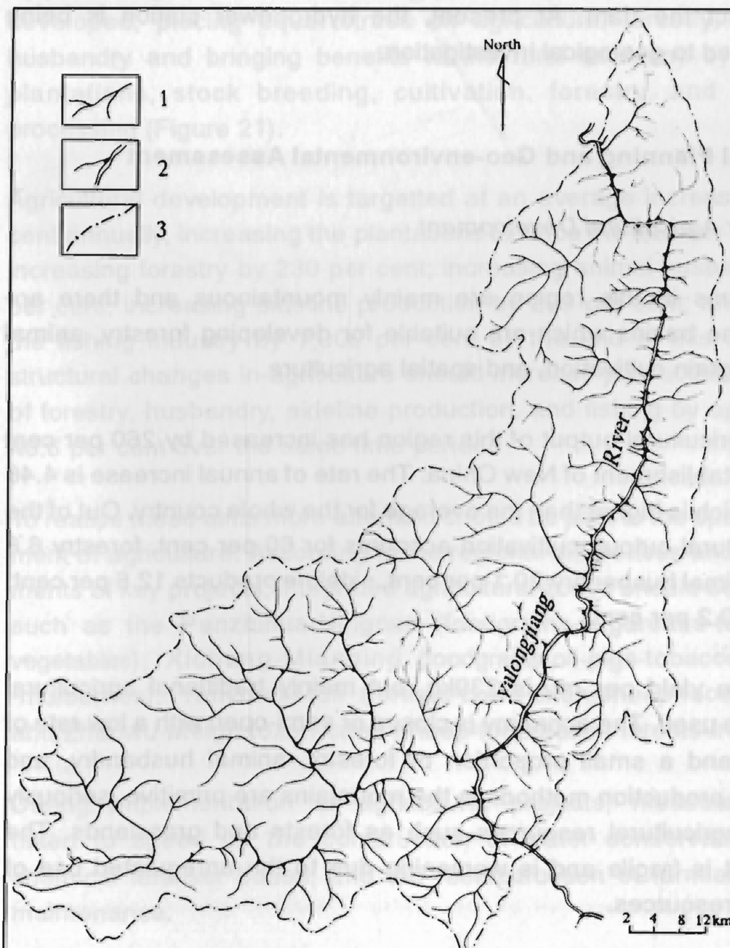

Fig. 20: Debris Flow in the Ertan Reservoir Area along the Yalongjiang River

1. Surface water system
2. Gully of debris flow
3. Boundary of drainage area in reservoir

(4) The geo-engineering condition is good with the rock mass intact and undeveloped faults. Nevertheless, there are still some problems such as the deep weathering zone caused by unloading in the deep canyon; the breaking of the rockfall around the underground plant due to high geostress; and the scouring downstream by overflow from the dam. However, these problems have been solved by detailed geo-engineering research.

The geo-engineering condition of the Tongziling dam site is less favourable than that of the Ertan dam site. It is located at the southern end of the Liminjiu Fault near the Yuzha seismic zone where the rock mass is strongly weathered and faults are well developed. The Tongziling dam has a low water head, and, after comparative strengthening measures have been taken, it may be possible to construct the dam. At present, the hydropower station is being subjected to geological investigation.

Agricultural Planning and Geo-environmental Assessment

Planning for Agricultural Development

The landforms in this region are mainly mountainous and there are inter-montane basins which are suitable for developing forestry, animal husbandry, grain cultivation, and spatial agriculture.

The total agricultural output of this region has increased by 260 per cent since the establishment of New China. The rate of annual increase is 4.46 per cent, which is higher than the average for the whole country. Out of the total agricultural output, cultivation accounts for 60 per cent, forestry 6.8 per cent, animal husbandry 20.1 per cent, sideline products 12.6 per cent, and fishing 0.2 per cent.

The average yield per *mu* is 239kg, but mainly traditional agricultural methods are used. The economy is closed or semi-open with a low rate of production and a small proportion of forestry, animal husbandry, and fishing. The production methods in the mountains are primitive, seriously damaging agricultural resources such as forests and grasslands. The environment is fragile and is worsening due to the unregulated use of agricultural resources.

The principle of agricultural development is to increase grain production, adjusting the agricultural structure within an ecosystem having many levels and functions, in order to create an open and optimum environment for agricultural production, thereby changing the traditional mode of agriculture to an ecologically favourable one. The following agricultural types can be developed in this region, such as the "integrated" type (processing-cultivation-plantation); the ricefield, ecological type (rice-duckweed-fish); the sugarcane field, ecological type (sugarcane-vegetables-mushrooms); the dryland, ecological type (grain-grass-animals); the orchard, ecological type (fruit-grass-animals); the forest/field, ecological type (forest-grass-animals); and the suburban breeding, ecological type (chickens-pigs-fish).

By promoting the above-mentioned types of agriculture, a structure can be developed, placing equal stress on agriculture, forestry, and animal husbandry and bringing benefits to the rural economy by developing plantations, stock breeding, cultivation, forestry, and agricultural processing (Figure 21).

Agricultural development is targetted at an average increase of 5.4 per cent annually, increasing the plantations to twice the number in 1984; and increasing forestry by 230 per cent; increasing animal husbandry by 130 per cent; increasing sideline production by 279 per cent; and increasing the fishing industry by 1,000 per cent by the end of this century. The structural changes in agriculture should increase production in the fields of forestry, husbandry, sideline production, and fishing by approximately 46.6 per cent over the same time period.

To realise these aims more attention should be paid to the spatial arrangement of agriculture. According to the regional differences and the requirements of key projects, integrated agricultural zones should be established such as the Panzhihua-Ningnan (foodgrains-sugarcane-tobacco-pigs-vegetables), Xichang-Mianning (foodgrains-oil-pigs-tobacco-vegetables -mulberries), Yanyuan-Muli (forests-cows-oxen-sheep-foodgrains-fruit), and Zhaowu-Meigu (oxen-cows-sheep-foodgrains- forests-fruit).

During implementation of agricultural projects, measures should be taken to speed up the construction of water conservation facilities, chemical fertiliser bases, and the reconstruction of farmlands and soil maintenance.

Geo-environmental Considerations for Water Conservation Projects

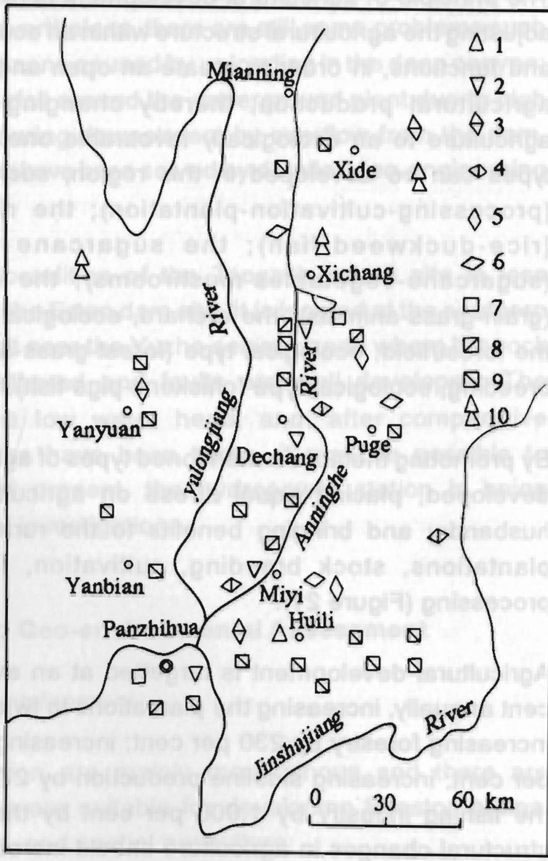

Fig. 21: Agricultural Planning

1. Grains 2. Vegetables 3. Fault 4. Sugarcane 5. Tobacco 6. Silkworms 7. Fishing 8. Poultry 9. Husbandry 10. Forestry.

Water conservation is one of the major measures for the development of plantations and for increasing the unit yields of crops in this region. The dry season in this region is as long as seven months and the climate in the river valleys, which are the principal plantation zones, is characterised by high temperatures,. scant rainfall, and strong evaporation. There is a shortage of water in early spring and summer which seriously affects crop yields per unit. In the wide valleys and open basins, the land resources also have not been used fully because of the shortage of water in winter, making replantation very difficult.

The available water conservation facilities in this area are mainly diversion works (82%) and storage projects (15%). To meet the target of the agricultural development plan, it is necessary to construct large-scale key reservoirs in a planned manner and to complete construction of the water conservation facilities to increase the area under irrigation. It is planned that, in this century, two large-scale reservoirs will be built in Yanyuan and Mianning and 12 middle-scale and 27 small-scale ones will be built in Shengli (Panzhihua), Xianfeng, Donghexiang (Xichang), Beihe, Xinhua (Huidong), Xiaoshuijing (Huili), and other places, and corresponding irrigation canals will also be constructed. Thus, the area under irrigation will be increased by 1.05 million *mu* which will raise the effective irrigation rate to 39.4 per cent.

The major water conservation projects mentioned above are distributed throughout the wide valleys and their branches as well as throughout the inter-montane basins of the Anninghe River. Therefore, different environmental engineering problems frequently occur. Dam sites are generally located at the exit of a gorge in order to make use of gravity irrigation in the alluvial fan at the base of the mountains until irrigation reaches the central rivers and basins. Generally, the foundations of dams are constructed on bedrock with suitable geo-engineering conditions. For example, the dam site of the reservoir near Mianning Bridge belongs to the metamorphic rock system of the early Sinian period; the dam site of the Penhe reservoir in Huili is composed of granite; and the dam site of the Tianweichun reservoir in Huidong belongs to the basalt of the Permian period. The dam site of the Shengli Reservoir in Panzhihua is composed of quartz-diorite. However, this region is located in an active seismic zone with three epicentres in Yanyuan, Xichang, and Yuzha, and there are active seismicity-prone faults in the region. The geological preconditions for earthquakes, therefore, must be taken into account in selecting dam sites in order to avoid active faults. Appropriate anti-seismic measures should be taken if necessary.

The rapid uplifting of crust and the cutting of rivers caused by neotectonic movements result in steep slopes, and, therefore, slope mass movements, such as landslides, collapses, and debris flows, are violent and frequently threaten the safety of dams and reservoirs. More attention should be paid to the selection of dam sites and to their construction. In particular, investigations should be made regarding the axis position and the contact points of dams with banks to determine whether or not landslides might occur. A small reservoir in mountainous areas does not have a large capacity, therefore, landslides and debris flows can result in silting, leading to the loss of effective reservoir capacity.

Many solid runoffs with a lot of mud and sand, together with the instability of reservoir banks, cause collapses and landslides during the rainy season every year. Thus, many of the reservoirs in this area have a short effective operation time of less than 100 years. Siltation reduces the storage and irrigation capacity of some reservoirs. The maintenance of soil in the upstream area and on the banks of reservoirs, therefore, should receive more attention. Unregulated exploitation of forests must be forbidden and afforestation should be carried out.

The seepage from reservoirs and irrigation canals sometimes causes major damage to the water conservation facilities in this region. One kind of seepage is focussed leakage, such as piping and pouring, into reservoir banks or under dam foundations as a result of karst or faults. For example, the Langtang Reservoir in the Yanyuan Basin, the dam site of which is located in the Triassic limestone zone, has a seepage of nine to 13 million cubic metres annually (taking up 7.2 to 10.5% of its total capacity) as a result of developed karst. Therefore, measures must be taken to prevent leakage during reservoir construction.

Another kind of seepage occurs in some small reservoirs built on alluvial strata. The alluvial strata in mountainous areas often include thick layers of gravel and pebble, and thin or discontinuous layers of clay. Thus, the leakage in dam foundations is often a serious problem for small reservoirs.

The problem of leakage from canals is encountered while carrying out diversion works. When a canal leads out from the front of the reservoir, it often passes an alluvial fan located near the mountains or near the margin of a basin which is composed of coarse pebbles. In such circumstances, construction costs increase because the canals must be lined for prevention of leakage.

Layers of silty soil and the Xigeda strata are liable to softening and swelling on contact with water, and these are present in the basins and river terraces in this region. When canals pass through these soil layers, instability of banks and collapse deformations can often be found, and these require reinforcement measures.

There is no doubt that reservoirs and diversion works play an active role in the agricultural development of this region. But, as a result of the high rate of evaporation in the dry season, more attention has to be given to irrigation as a means of preventing salinisation. During the construction of water conservation projects and the excavation of tunnels, efforts should be made to recover the original landforms, conserve vegetation, and carry out tree plantation to prevent desertification of the silty soil.

To sum up, during the construction of agricultural projects, more attention should be paid to geological hazards and to soil maintenance as well as to the prevention of soil salinisation and desertification so that agricultural production increases.

Urbanisation and Communications' Development

Planning in Urbanisation and Communications' Development

After construction of mining and chemical industries and development of energy resources and agriculture, the population in the area and the pace of socioeconomic development will increase. Consequently, urban construction and the corresponding development of the building materials' industry and transportation and communications will take place.

The reason for the concentration of the urban population in this region is the existence of large-scale mining and smelting bases. By the end of this century, the cities and towns along the Anninghe River and along the Cheng-Kun Railway will develop rapidly.

During the past 20 years, the Panzhihua Steel base has been constructed and farmers have now settled in cities and towns. At present, two cities in this area have populations of more than 0.3 million, i.e., Panzhihua City and Xichang City. In addition, the total population in the other small cities in this area has increased to 0.95 million. The rate of concentration is 23.1 per cent. At the same time, urban communications, postal services, and commerce, as well as tourism and hotel services, have been developed.

While planning the construction of mining, metallurgical, and chemical as well as energy industries, the availability of urban facilities has been taken into account, therefore, some key enterprises are based near existing cities and towns. Urban construction planning aims at developing the existing cities and county towns, such as Panzhihua, Xichang, Dechang, Miyi, Huidong, Huili, and Yanyuan and, at the same time, at rationally adjusting the urban arrangement to ensure the development of key projects. The important cities and towns and the communication and transportation facilities in this area are shown in Figure 22.

With urban development, the building material, light, and agricultural processing industries will also develop. Cement resources are plentiful in this region, and there are gypsum, talcum, marble, granite, kaolin, diatomite, and asbestos as well as glass materials such as dolomite and quartz sandstone. Timber resources are also abundant in this region which is one of the main forest zones in the country.

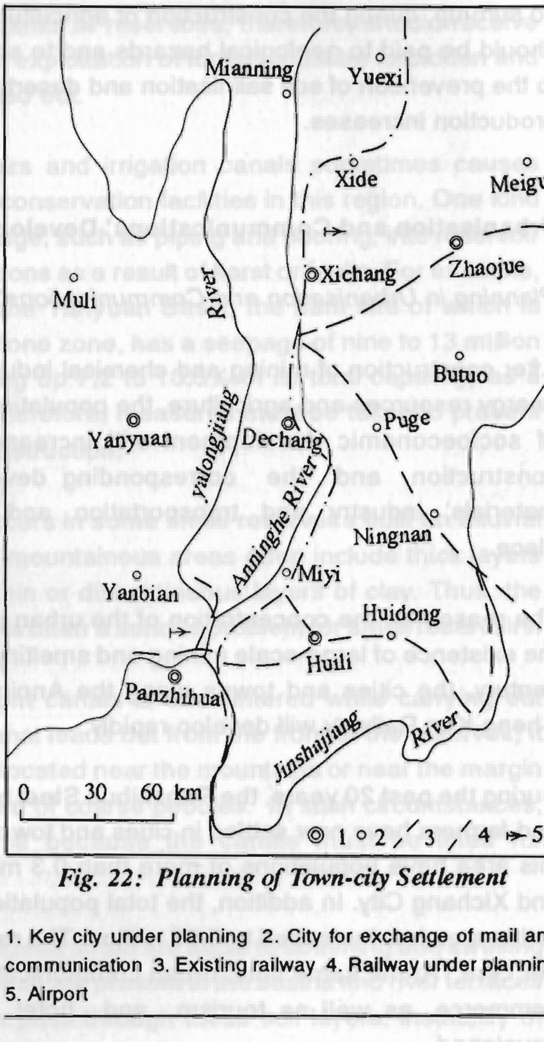

Fig. 22: Planning of Town-city Settlement

1. Key city under planning 2. City for exchange of mail and communication 3. Existing railway 4. Railway under planning 5. Airport

The construction of Ertan hydropower station needs about 2.2 million tonnes of cement and more cement is needed for urban, industrial, and mining construction. In 1983, the total cement yield was 0.5 million tonnes, and this was inadequate.

For this reason, construction of limestone mines has been planned in Longdong and Panzhihua. The Panzhihua cement factory will be enlarged. Cement factories will be built in Miyi, Dechang, and other places to meet the regional requirements for cement.

Development plans should focus on industries such as sugar-processing, paper-making, cigarettes, perfume, catering, hide-processing, plastic, hardware, furniture, domestic electrical products, and handicrafts. Light and processing industries should also be established in important urban areas.

Geo-environmental Considerations for Urbanisation

The cities and towns that are to be developed, apart from Panzhihua City which is located in the gorge of the Jinshajiang River, are all geomorphologically located in wide valleys or basins, thus there is enough space for extension.

Constructued only 20 years ago, Panzhihua City, which has mining and metallurgical industries and a population of 0.64 million, is the biggest city in this region (Wang Sijing and Yu Suolong 1987a). Its urban district lies along the Jinshajiang River (Figure 23). The main buildings and streets are situated on the narrow terraces of the river banks. A series of bridges has been built on the Jinshajiang River to facilitate traffic circulation. The administrative section of Panzhihua City is located in Bingchaoguang, which is founded on a terrace composed of a Xigeda stratum. The city has five districts. The centre of the urban district is located in Longlongping and the others are located on several wide terraces along the Jinshajiang River.

The geo-environmental conditions of the Panzhihua urban area are complex and there are many problems (Wang Sijing et al. 1988).

(1) The direct distance between Panzhihua City and the active Yuzha seismic zone is only 30km. The basic seismic intensity of Panzhihua is between VII-VIII (Figure 24) and, because of the steep landforms and developed rock fractures, anti-seismic measures must be taken into account in planning urban construction.

(2) The rock mass in Panzhihua City is fractured and weathered and most urban districts are located on semi-cemented Xigeda strata (Q1x). In road, industrial, and civic construction, the levelling of land and the excavation of slopes often induce landslides and collapses. Many gullies form channels for debris flows. For example, the normal operations of Power Plant No.401 were interrupted because of destruction of its residential quarters by debris flow. The maintenance of slope stability must be taken into account in urban planning. Safety measures, such as tree plantation and improvement of surface runoff, must be taken.

(3) The foundation of Panzhihua City--the Xigeda stratum (Figure 25) and alluvial deposits are often characterised by swellings which cause cracks in the houses as well as collapse. Hence, measures to prevent the swelling of foundations must be undertaken during construction.

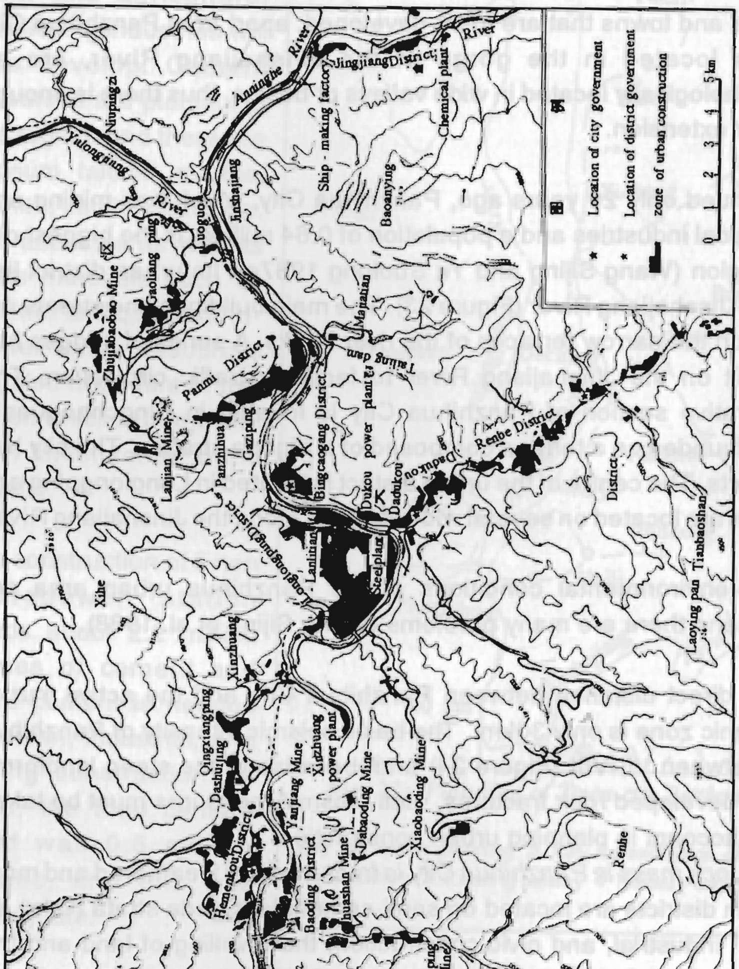

Fig. 23: Urban Area of Panzhihua City

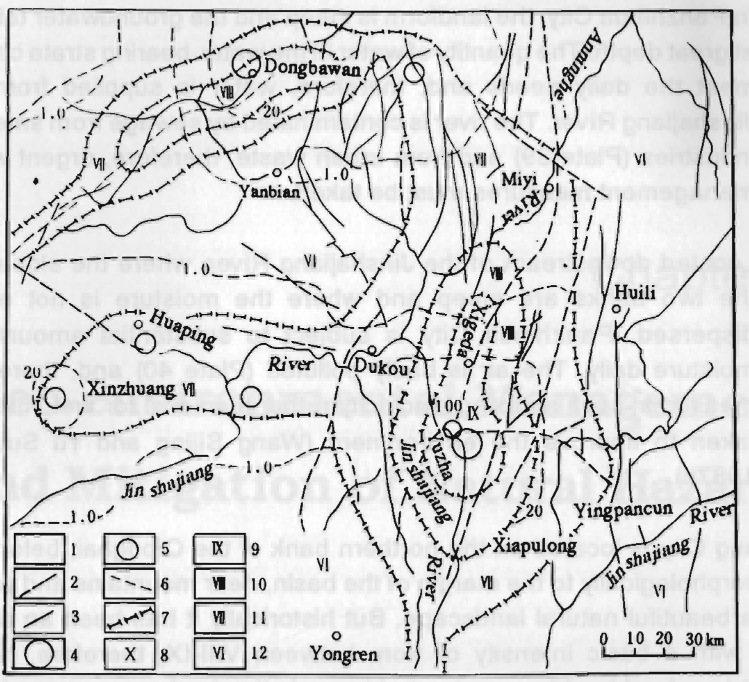

Fig. 24: Seismicity in Panzhihua Area

1. Lithospheric Fault 2. Crustal fault 3. Basement Fault 4. 7.0M=6.0; 5. 6.0M=5.0
6. Cover Fault; 7. Boundary of zone with different intensity 8-10. Intensity value

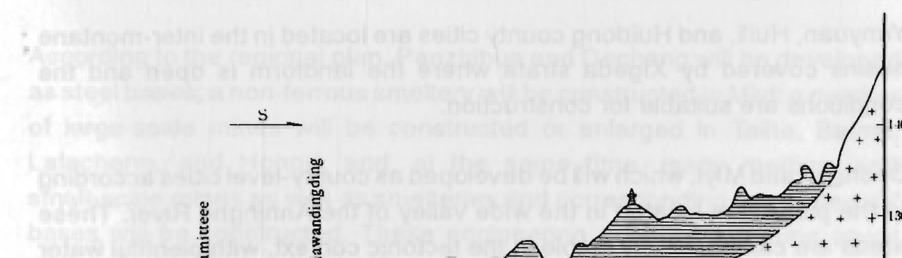

Fig. 25:Geological Cross Section at Panzhihua

1. Terrace 2. Gravel 3. Xigeda stratum 4. Conglomerate 5. Granite

(4) In Panzhihua City, the landform is steep and the groundwater table is at great depth. The quantity of water in the water-bearing strata cannot meet the daily needs and, therefore, water is supplied from the Jinshajiang River. The river is contaminated by sewage from smelting industries (Plate 39) and from urban waste, therefore, urgent water management measures must be taken.

(5) Located downstream of the Jinshajiang River, where the slopes on the two banks are steep and where the moisture is not easily dispersed, Panzhihua City is subject to substantial amounts of moisture daily. The air is badly polluted (Plate 40) and, therefore, measures, such as using electricity rather than coal for fuel, must be taken to improve the environment (Wang Sijing and Yu Suolong 1987b).

Xichang City is located on the northern bank of the Qionghai, belonging geomorphologically to the margin of the basin, near mountains and water, with a beautiful natural landscape. But historically it has been an active zone with a basic intensity of from between VIII-IX, therefore, heavy industries should not be constructed here. Anti-seismic measures should be taken while constructing buildings and the problem of groundwater contamination in the Qionghai River area should be tackled.

Yanyuan, Huili, and Huidong county cities are located in the inter-montane basins covered by Xigeda strata where the landform is open and the conditions are suitable for construction.

Dechang and Miyi, which will be developed as county-level cities according to the plans, are located in the wide valley of the Anninghe River. These areas are comparatively stable in the tectonic context, with plentiful water resources (including surface water and groundwater), an open landform with transport facilities, and supported by nearby agricultural areas. Therefore, this area is suitable for construction and development.