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REPORT ON THE AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA 1979

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REPORT OF THE AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA, 1979

by

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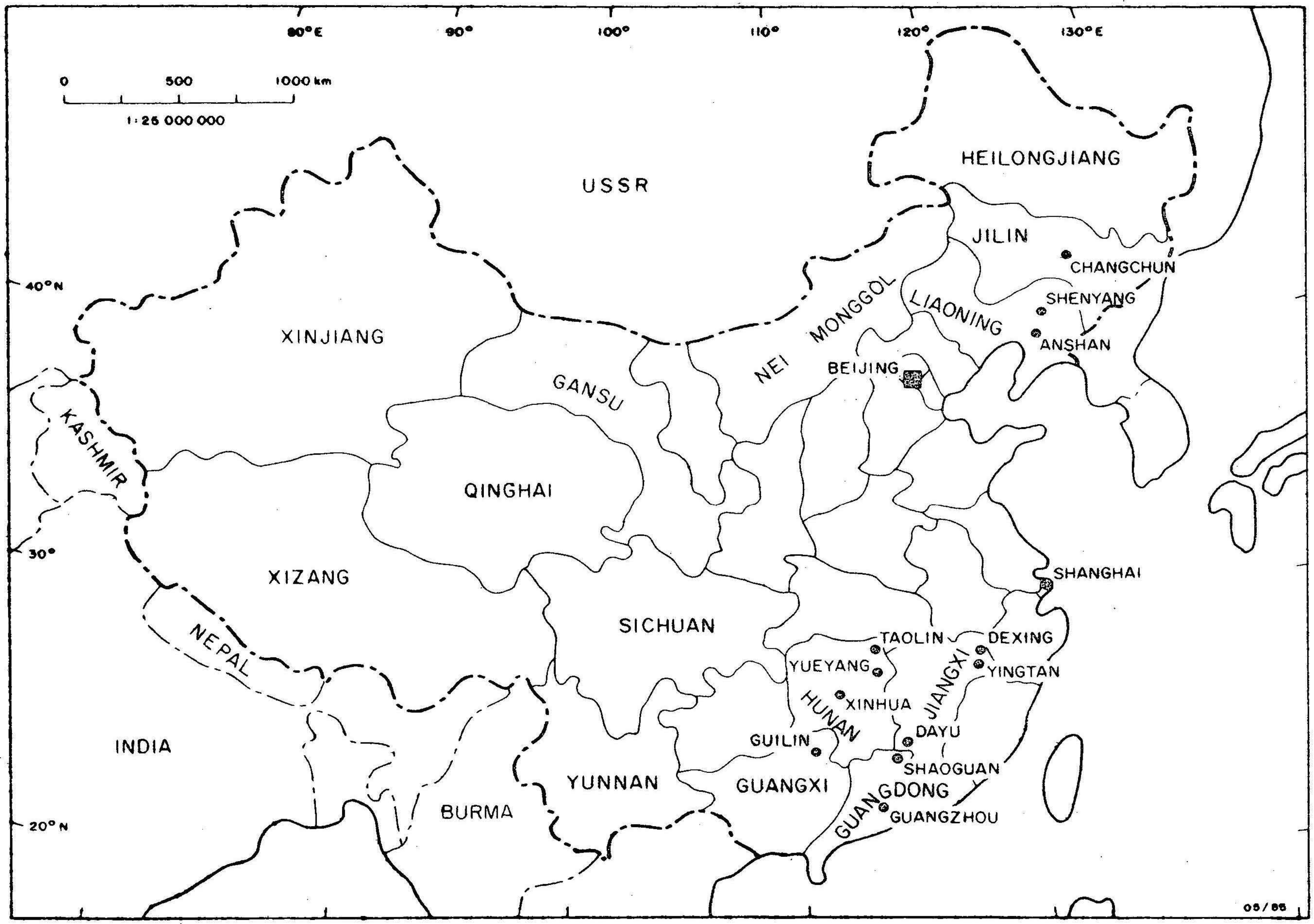

FRONTISPIECE

PEOPLE'S REPUBLIC OF CHINA

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Technical Director, Australian Mineral Development Laboratories

HISTORICAL BACKGROUND

Following discussions which took place during and immediately after the 25th Session of the International Geological Congress in Sydney in 1976, proposals were formulated to exchange delegations of Chinese and Australian geoscientists. These delegations were to comprise experts in applied geoscience - notably mineral exploration geoscience - to complement the exchanges of pure scientists which are sponsored by the Australian Academy of Science and Academia Sinica.

From Australia's point of view the objectives of the applied geoscience exchange were to:

- identify common problems in exploration geoscience in both countries and to discern any innovative measures which the Chinese were applying to them.
- identify problems which could be solved by the application of expertise which is available in Australia - either in industry or Government agencies.
- identify problems of common interest or concern, the solution of which could be accelerated by joint projects dealing with different aspects of the problem in the most advantageous environment.
- establish points of contact with geoscience organisations in China which would lead to an ongoing exchange of information and proposals for further cooperation.

The Chinese Government agreed to sponsor the first leg of this exchange in 1978, in spite of the earlier expectation that the Australian delegation would initiate the exchange. BMR was the Australian Government body charged with responsibility for organising the Chinese visit. In discharging this responsibility it received the active support of the Department of Trade and Resources, and the co-operation of State Geological Surveys and important segments of the mining industry.

The visit of the 15-man Chinese delegation was very successful in that it demonstrated the Chinese preparedness for technological development, and their enthusiasm for using commercially available expertise in this field as well as that of governmental institutions.

In June 1979, BMR received an official invitation from the Bureau of Geology to send a 15-man delegation to China in October of the same year, and after negotiations within Government, with State Government bodies, and with the mining industry, it was resolved to accept the invitation, but to send a delegation of eleven; four from BMR, one from NSW Geological Survey, and six from the mining industry.

ITINERARY

DATE DAY	MORNING	AFTERNOON	EVENING
8 OCT MONDAY	In Hongkong	Arrived in Guangzhou (15.55)	Presentation of itinerary Briefing on geology of China
9 OCT TUESDAY	Sightseeing in Guangzhou	Left Guangzhou by train (13.15) Arrived Shaoguan (17.00)	
10 OCT WEDNESDAY	Left Shaoguan (08.00) by road Arrived Dayu (11.00)	Briefing at Xihuashan	
11 OCT THURSDAY	Visited Xihuashan Mine	Visited Xihuashan Mine	Dinner as guests of the Mine
12 OCT FRIDAY	Visited mill at Xihuashan Mine	Left Dayu by road (14.00) Arrived Shaoguan (17.30)	
13 OCT SATURDAY	Left Shaoguan by train (02.30)	Arrived Yueyang (14.50) Left Yueyang by road (15.00) Arrived Taolin (16.30)	Briefing on Mine Dinner as guests of the Mine
14 OCT SUNDAY	Visited Taolin Mine	Visited mill at Taolin Mine	Left Taolin by road (20.00) Arrived Yueyang (21.40) Left Yueyang by train (22.10)
15 OCT MONDAY	Arrived Xinhua (06.10) Left Xinhua by road (06.30) Arrived Xikuangshan Mine (07.15) Briefing on Xikuangshan Mine	Visited Xikuangshan smelter, surface outcrops, and Mine museum	Dinner as guests of the Mine Visited the cinema
16 OCT TUESDAY	Visited Xikuangshan Mine	Visited mill at Xikuangshan Mine	Discussion on Mine
17 OCT WEDNESDAY	Left Xikuangshan by road (08.45) Arrived Xinhua (09.45) Left Xinhua by train (10.00)	Continued train journey	Arrived Yingtan (23.57)
18 OCT THURSDAY	Left Yingtan by road (08.15) Arrived at Jienzhu (09.30) Briefing on Deposit 60 exploration	Visited field outcrops and inspected drill cores Left Jienzhu by road (16.15)	Arrived at Yingtan (17.40)
19 OCT FRIDAY	Left Yingtan by road (08.10) Arrived Dexing (12.00)	Briefing on Dexing Mine	Visited the opera
20 OCT SATURDAY	Visited field outcrops	Visited Dexing Mine and ore dressing plant	
21 OCT SUNDAY	Left Dexing (07.00) Arrived Yingtan (11.30)		Dinner as guests of Dy Director Jiangxi Provincial Bureau Left Yingtan (20.00)
22 OCT MONDAY	Arrived Shanghai (09.30) sightseeing in Shanghai	Sightseeing and shopping in Shanghai	
23 OCT TUESDAY	Sightseeing in Shanghai	Visited Trade Exhibition Left Shanghai by air (15.00) Arrived Shenyang (17.25)	Left Shenyang by road (18.00) Arrived Anshan (20.30)

Times, given in brackets on the 24-hour clock system are standard (Beijing) Chinese times.

ITINERARY

DATE / DAY	MORNING	AFTERNOON	EVENING
24 OCT WEDNESDAY	Briefing on Anshan and Dashiqiao Mines	Visited field outcrops	Dinner as guests of the Mine
25 OCT THURSDAY	Visited Anshan (Dagushan) Mine	Visited Dashiqiao Mine	Left Anshan by train (20.05)
26 OCT FRIDAY	Arrived Changchun (01.45) Visited Changchun College	Visited either Geological or Geophysical Department	Dinner as guests of College
27 OCT SATURDAY	Discussion at College with senior staff	Sightseeing at Changchun Left Changchun by air (16.10)	Arrived Beijing (20.00)
28 OCT SUNDAY	Visited the Summer Palace, Beijing	Visited the Forbidden City, Beijing	
29 OCT MONDAY	Visited the Great Wall	Visited the Ming Tombs	
30 OCT TUESDAY	Visited the Aero-geophysical Team and Computer Centre	Visited the Geological Museum (Ministry of Geology) Briefing on responsibilities of Ministries	
31 OCT WEDNESDAY	Visited the Mining and Metallurgical Institute and Ministry of Metallurgy	Presented lectures on aspects of geoscience in Australia	
1 NOV THURSDAY	Visited the Academy of Geological Sciences (Ministry of Geology)	Visited the Beijing Uranium Geology Research Institute (Second Ministry of Machine Building)	Dinner as guests of Mr Li Jianping th Vice-Minister for Geology
2 NOV FRIDAY	Sightseeing and shopping in Beijing	Left Beijing by air (14.40) Arrived Guangzhou (17.15)	
3 NOV SATURDAY	Left Guangzhou by air (10.30) Arrived Guilin (11.15)	Viewed extensive karst topography from Li Jiang River	Dinner as guests of Director, Institute of Karst Geology
4 NOV SUNDAY	Visited caves and other karst features near Guilin	Left Guilin by air (13.45) Arrived Guangzhou (14.30)	Dinner as guests of Dy Director of Guangdong Provincial Bureau
5 NOV MONDAY	Left Guangzhou by train (08.30) Arrived Hongkong (11.30)		

GEOSCIENCE INSTITUTIONS IN BEIJING

The Delegation visited six geoscience institutions in Beijing, and was given a briefing by Professor Zhang Bingxi on the organisation of the Ministry of Geology and on the other Ministries which employ appreciable numbers of geoscientists.

Members of the Delegation were assigned responsibility for principal authorship of the various sections of this chapter, but each such author received considerable help in his task from other members in the form of contributed notes, or of critical comment on the first draft. The names of principal authors are shown in parentheses below the heading of each section.

Four members of the Delegation gave lectures on aspects of geoscientific work in Australia. They were:

K.R. Walker - Geological Structure of Australia
I.R. McLeod - Mineral Resources of Australia
D.W. Suppell - Metallogenic Mapping in Australia
R.E. Wilmshurst - Metallurgical Research and Development in Australia.

GEOSCIENCE IN CHINESE MINISTRIES

(A. Renwick)

Professor Zhang Bingxi gave an account of the Ministry of Geology and other organisations which employ geologists during a briefing of the Delegation on the subject in the Peking Hotel on 30 October 1979.

THE MINISTRY OF GEOLOGY

Soon after 'liberation' a committee was set up under Li Shiguang (J.S. Li) to develop geological work in China. The old Central Geological Survey and the Chinese Academy of Geological Sciences were revived, as were the schools of geology in the older universities.

A Ministry of Geology, headed by J.S. Li, was set up in 1952. In 1970 its status was relegated to that of a Bureau, and it became the Geological Bureau under the State Planning Commission. In 1975 the State Planning Commission was reorganised and the State Bureau of Geology was formed. In August 1979, that organisation was elevated to the status of a Ministry. Geological work is still a weak link in the development of State economy, and an increase in capacity has a high priority.

The main task of the Ministry is to lead and manage the exploration of mineral resources; and also energy, environmental, water, and engineering geology resources. It is also responsible for research programs and the training of professionals; the training of technicians; and the design and construction of relevant equipment.

Total staff under the Ministry is nearly 400 000, of whom about 60 000 are professional/technical staff; including 30 000 geologists, 800 exploration geophysicists and geochemists, and 3000 engineering staff for drilling and exploration. The Ministry operates 9 factories for the manufacture of drilling rigs and deploys some 2800 drilling rigs throughout the country. It also operates 3 factories which manufacture geophysical equipment. Provincial Bureaux, which were established in 1958, come under the joint direction of the Ministry and the Provincial or Regional Governments. Their task is to integrate planning and carry out geological work in the Provinces.

The Ministry of Geology is divided into Departments (which perform scientific and administrative tasks); Bureaux (which have executive powers); and Research organisations.

<u>Departments</u>

Head Office
Planning
Education
Geology and Mineral Resources
Labour and Wages
Exploration and Engineering
Marine Geology

Bureaux

Geophysical and Geochemical Exploration
Foreign Affairs
Hydrogeology and Engineering
Regional Geology
Geological Equipment
Petroleum Exploration
Special Mineral Resources
Logistics

Training

There are six geological colleges, eight schools for training technicians, and twenty geological departments in universities and polytechnic institutes. Some 70 000 geologists have been trained in the past 27 years - a remarkable achievement from a base of only some 250 in 1952.

Research organisations

There are three research organisations within the Ministry which, between them, employ about 6000:

The Research Institute of Geological Planning
The Research Institute of Exploration Techniques
The Chinese Academy of Geological Sciences

of which the last is the largest and by far the most important.

The Academy was established in 1956 and now has a staff of more than 4000, some 2000 of whom are professional or technical. Its most important human resource is its access to 60 000 geologists in the Ministry and Provincial Bureaux.

The Academy consists of five institutes in Beijing and five provincial research institutes elsewhere, three other topic-oriented research institutes, and the National Geological Library and National Geological Museum in Beijing. (Details are given elsewhere in this chapter).

OTHER MINISTRIES EMPLOYING GEOLOGISTS

A number of Ministries also have their own geology departments. As distinct from the Ministry of Geology their main concern is the exploitation of the mineral which comes within the functional responsibility of the particular ministry involved. They are:

Ministry of Metallurgical Industry
Ministry of Coal Industry
Ministry of Petroleum Industry
Second Ministry of Machine Building (uranium)
Ministry of Building Materials
Ministry of Chemical Industry

These Ministries employ a total of about 60 000 professional and technical staff engaged in geological work.

The distinction between when exploration by the Ministry of Geology finishes and exploitation of a reserve by one of the above Ministries commences, is not always clear. However in general, once a deposit has been proved as being economically viable and defined in broad outline, one of the ministries will take over detailed work and exploitation.

The Second Ministry of Machine Building however carries out its own work from exploration through to exploitation.

AIRBORNE GEOPHYSICAL TEAM - MINISTRY OF GEOLOGY

(L.W. Williams)

The Delegation visited the team on 30 October

History

Airborne work started in China in 1954 using aeromagnetic methods only. The equipment was Russian made and had an accuracy of 100 γ; the accuracy was improved to 25 γ in 1956. The present team was set up in 1956, and in 1960 started using equipment made in China (accuracy 5-10 γ). In 1960 research was also commenced into airborne radiometric and airborne EM methods; this research was later extended to navigation and location equipment. A remote sensing section was set up in 1973 and initially used aerial photos only, but added infrared scanning methods in 1975. Recently an integrated airborne system has been imported from North America but has not as yet been put into operation.

Operation

The airborne team is responsible for the airborne geophysical surveying of the whole country, and sometimes does land geophysical work to follow up anomalies located by the airborne surveys.

Over 60% of the country has been covered by aeromagnetic surveys at scales from 1:25 000 to 1:1 000 000 (line spacing of 250 m to 10 km). Surveys are carried out in the search for oil and for metalliferous deposits. The surveys have covered 1.3×10^6 km^2 over the Yellow, East China and South China Seas.

A smaller area has been covered by EM methods, and radiometric surveys are only being undertaken in conjunction with other techniques.

The airborne surveys are stated to have four purposes:

- to provide basic geophysical maps to other Departments
- to study tectonics and to help map soil covered areas
- to look for ore deposits - iron, copper, lead, zinc and uranium
- to help find oil.

Since 1956 the airborne surveys have located more than 200 ore deposits and have supplied data to assist oil search.

Equipment

Very recently an integrated airborne system has been imported but not yet put into operation. It consists of four units:

- 3 frequency EM equipment
- magnetometer
- four-channel radiometric equipment
- low-frequency EM equipment.

The integrated system is Scintrex. This was selected because of its association with discoveries in the Canadian Shield.

They have three types of magnetometer and are currently using them all - proton precession magnetometer (made in Beijing) with an accuracy of 0.5 γ which is used to 1 γ in the aircraft, fluxgate magnetometer, and an optically pumped Helium magnetometer with an accuracy of 0.5 γ. The optically pumped magnetometer has been available for three years but has only been used on surveys for about 12 months.

The team has four Twin Otters and a radio-phase navigation system using 3 base stations and 3 frequencies.

For magnetic interpretation, computers are used to apply upward and downward continuation theories and second derivative methods.

Computer Centre (T. Quinlan)

Two computers were shown to the delegation, these were made in China, and were operated by the 'Institute of Applied Computer Technology' (part of Academy of Geological Sciences). These machines are designated as -

a) DJS-6 with a core size of 32K x 24 bit words, with, as peripherals:

 4 x 32K discs,
 1 x 5 level paper tape reader and punch,
 2 x 600 lpm line printers,
 2 x 9 Track magnetic tape drives,
 1 Flat bed plotter, which plots an area 100 mm x 200 mm in 10 minutes.

b) DJS-11 with a core size of 132K x 48 bit words, with, as peripherals:

 4 x 5 level paper tape readers and punches,
 4 x 600 lpm line printers,
 4 x 16 track magnetic tape drives,
 2 Flat bed plotters,
 2 seismic magnetic belt recorders,
 1 Optical plotter for the preparation of seismic sections,

The principal applications for these machines are -

(1) Contouring of geophysical and geochemical data
(2) Preparation of corrected wriggly trace and variable density seismic sections
(3) A geophysical data interpretation system with the ability to transform potential fields, their analysis in the frequency domain, the computation of horizontal and vertical derivatives, the reduction of magnetic data to the pole, and the computation of pseudo gravitational fields.

FORTRAN and ALGOL are used as programming languages.

The computing facilities of the Institute are being increased with the installation of an HITACHI model M 160 from Japan. This machine has a central memory of 768 x 64 bit words, and will be used for the storage and retrieval of geological data banks.

THE NATIONAL GEOLOGICAL MUSEUM

(K. Kappelle)

The Delegation visited the Museum on 30 October, and was shown round by its Head, Pan Jiang.

The Museum was established 20 years ago under Pan Jiang, who has remained in charge ever since. He is now assisted by a staff of 110, of whom 40 are geoscientists engaged on various research topics. He himself is an authority on the Devonian.

The Museum is divided into two main sections: the general, and the specialised.

The specialised section

This section occupies the upper levels of the Museum and contains three units:

Palaeontology
Mineralogy
Ore deposits

The standard of specimens in these displays is high, although many of the display cases are old fashioned and tend to detract from the appearance of the exhibits. However, the whole museum is being refurbished, and when this work is completed the excellence of the collections will be more easily appreciated.

The general section

Refurbishing of this section is well advanced, and the standard of presentation is very high. There are two main themes:

Mineral resources of China
Earth history of China

There are several moving exhibits, and others which have variable or progressive illuminations to emphasise important aspects or to illustrate stages of development. Additionally, there are static exhibits also of a high quality.

Displays which were particularly noted by members of the Delegation included:

- the Precambrian phosphate model
- the placer and lode tin model, Yunnan Province
- diamond occurrence at Sandung, Hunan Province
- the Hopeh oil field model - oil in Precambrian dolomitic limestone Karst cavities
- fluorite occurrences in Mesozoic volcanics

BEIJING RESEARCH INSTITUTE OF MINING AND METALLURGY

(R.E. Wilmshurst)

Beijing Research Institute of Mining and Metallurgy, which forms part of the Ministry of Metallurgical Industry, was visited by the delegation on the 31 October, 1979. The Institute was founded in 1957 and is devoted to the mining and beneficiation of non-ferrous metals. In practice this is taken to include beneficiation of iron ores, but does not include work on uranium ores which is undertaken by another Ministry.

The Staff of the Institute is stated to be about 800 total, including 400 technical personnel of whom 220 are qualified engineers. In this context, new graduates are not regarded as qualified, but require 5 years of experience prior to recognition.

Typical research projects were stated to be:-

(a) comprehensive utilisation of magnetite containing both titanium and vanadium

(b) comprehensive utilisation of complex sulphide ores such as those containing nickel copper and cobalt of copper lead and zinc.

The Institute includes seven separate laboratories, as follows:-

(1) Mining Laboratory which is said to be incomplete.
(2) Beneficiation Laboratory which includes extensive pilot plant facilities.
(3) Extraction of non-ferrous metals.
(4) Design of beneficiation machinery.
(5) A laboratory devoted to metallurgical reagents.
(6) A Mineralogical Laboratory.
(7) An Analytical Laboratory.

In addition there is a small service workshop. Reference was also made to metallurgical test work on tin and tungsten being carried out in laboratories outside Beijing.

BENEFICIATION LABORATORY

The Beneficiation Laboratory has facilities at both bench and pilot scale. The bench facilities which were inspected consist mainly of flotation equipment using cells ranging in size from 250 ml to approximately 2 L.

The most popular size of cell appears to be 500 ml. All cells are constructed of clear plastic, and equipped with mechanical froth paddles. Flotation charges were ground in small conical ball mills mounted on tilting frames.

The pilot plant which has a nominal capacity of 1 tonne per hour is well equipped and housed in a spacious two storey building.

Three stages of crushing are available and the range of mineral dressing equipment includes:

Banks of flotation cells containing a total of about 50 8" cells and some 12" cells. These are of Chinese manufacture with mechanical froth paddles, but generally similar to Denver machines.

Flotation columns are used also, ranging in diameter from 25 to 75 mm and about 3 m long. There are 8 or 10 of these columns.

Heavy media drum separator approximately 12" x 36".

Jigs of various sizes.

A half size shaking table.

A Warman cyclone and pump, one of the few pieces of Australian equipment seen in China.

A high intensity wet magnetic separator similar in design to the GILL separator.

A drum magnetic separator approximately 12" x 12".

Belt magnets of various kinds.

Davis tube magnetic separator.

Fibreglass spirals of conventional design.

Spiral sluices rather similar to the normal spiral, but with flat bottom cross section.

Institue staff indicated that a 20 tonne per hour pilot plant is available on a separate site, but whether this is under the control of the Institute is not clear.

MINERALOGICAL LABORATORY

The Mineralogical Laboratory of the Institute is the best equipped of its kind seen in China.

The laboratory is well equipped with microscopic equipment, most of which is of West German origin. The differential thermal analyser, also of West German origin, is some 20 years old, as is the Stanton thermobalance. Equipment for surface area determination by a B.E.T. technique was made in Beijing.

The laboratory is also equipped with an electron probe micro analyser made by JEOL, Japan.

Dielectric separation, a common laboratory technique in China, is used to separate mineral/mineral and mineral/fossil mixtures. Equipment in use, capable of operation at a number of electrical frequencies, is designed by Institute staff.

Somewhat surprisingly, the laboratory is well equipped for mineral synthesis under hydrothermal conditions. Equipment is largely of Chinese manufacture, although reactors for the highest temperature and pressure conditions are imported from the United States.

ANALYTICAL LABORATORY

The Analytical laboratory is equipped with X-ray diffraction and X-ray fluorescence spectrometers, both of East German origin. Other equipment includes atomic absorption spectrometers of Chinese, American and British manufacture. There are three emission spectrometers of East German origin each equipped with arc sources and one equipped with a laser-excited source, which was designed and built within the Institute. In common with many other analytical laboratories in China, extensive use is made of polarography. In this instance, the instruments were of British design and manufacture.

Although no concrete examples of specific project work were discussed, the Institute appeared to be busy, and at least superficially the work would be expected to be of high standard.

MINISTRY OF METALLURGICAL INDUSTRY

(K. Kappelle; G.C. Hall)

During a visit to the Ministry of Metallurgy on 31 October 1979, 2 lectures were presented on China's most significant mercury and tin deposits which, for lack of time, could not be visited.

Wanshan Mercury Mine

The Wanshan Mine ($27^{\circ}32'$N, $109^{\circ}12'$E) is located in Guizhou province at the boundary of Hunan and Guizhou provinces. Here, in a 500 km NNE striking belt are a large number of mercury occurrences. The Wanshan Mine is located centrally in this zone; the Shanmudong (Yanwuping) mercury mine is located further to the north. The mercury orebodies are all stratified and lenticular and of simple mineral composition, mainly cinnabar. Alteration of the country rocks is low grade and consists mainly of silicification, dolomitisation and calcitisation. The range of temperature of formation is 62°C - 162°C, and the average temperature is 120°C. The analysis of the S_{34} isotope from Cinnabar gives a range of 1.31 to 1.74%. The stratigraphy is mainly flat lying undulating Cambrian sediments, with the middle Cambrian consisting of four subdivisions and the lower Cambrian of 5. The lower Cambrian is mainly limestone. The middle Cambrian is banded dolomite. The mercury deposits are multi-layered: there are four in the middle Cambrian, in layers 2, 3, 5 and 7, while in the Lower Cambrian three layers are mineralised. The orebodies occur mainly in the upper part of the Middle Cambrian. Structurally the mineralised zone is controlled by NE striking anticlines and fractures. The deposits occur on the intersections of these structures with E striking structures. The orebody is controlled by a NW trending anticline.

The Wanshan Mine is China's largest mercury mine. Total reserves are nearly 10 000 t Hg metal. The average geological grade of the deposit is 0.3% Hg.

The thickest part of the orebody is over 40 m thick; minimum mining width is 10 cm.

The time span from exploration to production was three years. Regional mapping delineated a number of areas for follow-up. These were then drilled, and further assessed by underground exploration. Drilling was a grid of 60 m x 40 m.

Exploration was based on three parameters :

1. Structure: favourable areas are any NW striking structures intersected by a crossing fracture.
2. Geochemistry: primary geochemical exploration where anomalous values of $>$.4 ppm Hg were encountered.
3. Old mine workings and orebody outcrop.

The genesis of the mercury deposits was in the past considered to be of low temperature hydrothermal origin. Recent research has changed this idea, and preliminary thinking is that the deposits may be of reconstituted sedimentary origin i.e. the mercury deposits are layered. The sulphur is presumed to have been derived from seawater, and the original brines presumed to have a NaCl content of 25 to 26.1%.

Deposition of mineralisation is considered to have been in two stages:

1. deposition of dolomite containing disseminated mercury
2. remobilisation of the mercury solution and enrichment.

In the past, exploration was carried out only on the hydrothermal origin theory, and while some areas of interest were located, no viable mineralisation was found. The Chinese now first look at areas of suitable sedimentary environment before applying this model, i.e. a combination of factors is required. Mercury vapour surveys are still in the experimental stage. Electrical methods have been abandoned as unsatisfactory.

(Note that, according to a 'model' at the uranium institute museum, U is associated with this Hg mineralisation. No mention was made of this at the lecture).

Gejiu (Kochiu) Tin Mine

The Gejiu mining district is located some 300 km south of Kunming in Yunnan province 22°45'N, 102°35'E. The area of the mining district is 1500 Km^2. The district was worked by locals as long as 400 years ago but is now run as a State enterprise by the Yunnan Province Tin Company.

The mine district is located at the junction of 3 tectonic systems

1. Winshan epsilon
2. Yunnan metamorphic zone
3. Ailoshan structure

All three systems are old and have been uplifting continuously whereas the central area sank. As a result this area is now covered by a 20 000 m thick section of marine and littoral marine deposits extending in age from the Proterozoic to the Triassic. During the Yenshan period this area became folded and uplifted and is now a mountainous area ranging from 1700 to 2400 m above sea level. The Chinese equate this with the Laramide in the U.S.A.

There are three tectonic systems associated with the mineralisation:

1. NNE system - 6 zones of anticlines and thrusts spaced about 5 km apart.
2. E system
3. NW system

The mine district consists predominantly of Triassic deposits, composed mainly of limestone. Sandstones and shales occur but are rare. The limestone is the most important for tin mineralisation. To the west of the mine area is extensive outcrop of granite of the Yenshan stage. Three types are recognised. The earliest is a gabbro monzonite, the second is a porphyritic granite, and the third is a nepheline syenite. The whole intrusive covers about 320 Km^2 and plunges east. The age of the intrusive activity is 130 to 60 m.y.

The deposits are characterised by their size, complex mineral assemblage and large variety of ore types. The four main types are -

1. zoned tin veins in the tourmaline zone
2. skarn type tin-copper ore
3. tin sulphide orebody
4. tin bearing dolomite.

There is little sulphide tin. In addition to the tin ores, there are occurrences of skarn type scheelite, coarse grained wolframite and a series of rare element minerals related to alkaline rocks. 70% of ore forming granite has a high potassium content. The orebodies are distributed in a definite pattern. A group of mines located to the SE of the granite is distributed in two zones. The first zone deposits are controlled by an anticline, and carbonate stratigraphy in which the deposits are named in order from north to south Malagua, Sunsujio, Laochang, and ?

The second zone is controlled by thrusts and contains many small orebodies. The third is controlled by the granite margin and has small-scale orebodies.

The distribution of the orebodies shows certain characteristics:

1. all occur around the granite, especially to the SE where the best mineralisation exists. e.g. the Malagua deposit occurs 1 km to the SE of a granite stock.

2. the deposits themselves are zoned, with overlapping mineral zones. A typical section is that of the Laochang deposit and shows in descending order placer (secondary) (yellow in colour), tin sulphide (pink or red), skarn tin-copper (dark yellow). The interval for zoning here is 400m but elsewhere this may reach 2000 m. The host rocks are Triassic limestone.

3. the deposits are themselves zonally distributed. This zoning, progressively away from the granite is beryllium, tungsten, copper, tin and then lead-zinc.

Prospecting indicators are:

1. presence of minor granite stocks
2. zoning characteristics
3. interfaces between different rock types- here between limestone and dolomite.

Average grades of the various ore types are typically:

1. veinlet zone : 4% Sn
2. skarn tin-copper : 1% Sn 1% Cu
3. tin sulphide : 1% Sn (thin zone is deeply oxidised)
4. tin bearing dolomite : .4% Sn

The largest tonnages occur in categories 2 and 3. Total proved reserves of all ore types in the district exceed 1 million tonnes of metallic tin. There are in addition copper, lead and zinc reserves. The Chinese have one exploration team engaged in prospecting for additional reserves. Annual production was quoted as a vague range of several 1000 to several 10's of 1000 tonnes tin.

CHINESE ACADEMY OF GEOLOGICAL SCIENCES

(W.J.S. Howell)

INTRODUCTION

The Delegation visited the Academy of Geological Sciences in Beijing on the morning of 1st November, 1979 at 9.30 am.

Mr Zou Jiayou, President of the Academy, in welcoming the Delegation expressed friendship between the geologists of China and Australia. He noted that exchanges and contacts in the past year had resulted in closer relationships and he hoped that further co-operation and correspondence between the Chinese and the Australian Government and Australian mining companies and research institutes would lead to even closer ties. Mr Zou briefly detailed the structure and locations of various Institutes making up the Academy. Personnel of the Institute of Mineral Deposits then presented aspects of their work, and an inspection was made of the activities of the Institute of Laboratories and Determinations. The Delegation ended its visit to the Academy at about 12.30 pm.

THE ACADEMY AND ITS STRUCTURE

The Ministry of Geology contains a number of research organisations, having a total staff of about 6,000 people, which include:-

- Chinese Academy of Geological Sciences, Beijing
- Institute of Exploration Techniques, at Zhoukoudianzhen, south-west of Beijing
- Institute of Geophysics and Geochemistry, Lantian County, Jiangxi Province
- Institute of Hydrogeology and Engineering Geology, Zhending County, Hebei Province
- Institute of Karst Geology, Guilin
- Research Institute of Geological Planning, Beijing
- Institute of Computer Technology, Beijing

The Chinese Academy of Geological Sciences was established in 1956 and is by far the largest and most important of the research organisations, employing some 4700 people of whom about 2000 are professional or technical.

The role of the Academy is to carry out research work in the development of geological sciences and mineral resources in China, by using and correlating the work and results obtained by more than 60,000 geoscientists employed in the Ministry of Geology and the Provincial Geological Bureaux field teams by scientists from universities, and by those from other institutes. One of the Academy's main assets is its high proportion of geologists having many years of experience and knowledge. Organisation of the Academy is made up of a number of research institutes structured on speciality disciplines and regional location.

In Beijing itself, the Academy is divided into the following five institutes:-

- Research Institute of Geology
- Research Institute of Mineral Deposits
- Research Institute of Laboratories and Determinations, also referred to as the Research Institute of Mineral Analysis
- Research Institute of Geological Information
- Research Institute of Geomechanics

The Academy also controls the National Geological Library and the National Geological Museum in Beijing.

Outside Beijing, the Academy is responsible for the following regional research institutes:-

- North China: Tianjian Institute of Geology
  Northeast China: Shenyang Institute of Geology
- Northwest China: Xian Institute of Geology
- Central-south China: Yichang Institute of Geology
- Southwest China: Chengdu Institute of Geology
- Eastern China: Nanjing Institute of Geology

Finally, the Academy also runs the following organisations:

- Comprehensive Research Brigade of Geomechanics near Beijing
- Institute of Comprehensive (or Multi-purpose) Usage of Minerals which is mainly involved in ore-dressing research and is located in Remai County, Sichuan Province
- Institute of Plateau Geology located in Chengdu, engaged mainly in research in Qinghai and Xizang (Tibet).

EXAMPLES OF THE WORK OF THE ACADEMY

Institute of Mineral Deposits

Introduction

One of the five Beijing based institutes, the Institute of Mineral Deposits, is itself sub-divided into nine sections:-

- Regional metallogeny
- Metallic deposits
- Rare metals and minor elements
- Geophysics and geomechanics
- Sedimentary-type ore deposits
- Mineralogy
- Stable isotopic geology
- Experimental petrology and mineralogy
- Geological information

Several aspects of the Institute's research work were presented to the Delegation, and some papers in Chinese with English abstracts were distributed.

Porphyrite Iron-Ore Deposits

These are iron-ore deposits occurring in fault-controlled basins in a 2000 km^2 area between Nanjing and Wuhu in the middle to lower reaches of the Yangtze Valley. The deposits are believed to be genetically related to Mesozoic, relatively alkaline, continental, sub-volcanic, porphyritic rocks of dominantly andesitic composition. Because of this relationship, the deposits have been termed porphyrite iron-ore deposits. They have a basic assemblage of diopside - (actinolite) - apatite - magnetite with average grade 30-40% Fe.

100 geologists have been engaged in research work on this type of iron-ore deposit, to the extent that the Chinese geologists state that they have now established a genetic model and indicators for further discoveries.

Some of the research work being carried out includes:

- detailed geochemistry of zoning in wall rock alteration associated with the deposits

- multi-discipline interpretation using gravity, airborne magnetics, geology and geochemistry, development of three-dimensional geo-mathematical models, correlation coefficients.

- experimental laboratory studies which indicate a relationship between albitization of the porphyritic sub-volcanics and the iron-ore deposits. NaCl bearing solutions in the albitization process are considered to play an important role in extracting iron from the sub-volcanics as source rocks and concentrating it to ore grade.

Porphyry Copper Deposits

The Institute is undertaking research into trying to distinguish between the characteristics of ore-bearing porphyry bodies and barren porphyry rocks. The research is based mainly on fluid inclusion and mineral geochemistry studies of more than twenty porphyry bodies.

Institute of Laboratories and Determinations

An inspection was made of a number of laboratories operated by the Institute. These were engaged in:-

- pressure-temperature work on hydrothermal systems using a U.S. made, West HR-IB12 vessel. The Chinese have ordered an internally-heated Barnes hydrothermal-volumetrical dry system for sulphide studies which will enable them to conduct experiments up to 10 kilobars pressure and 1400°C.

- The identification of trace and rare-earth elements using a Japanese Shimad Zu CW170 optical emission spectrograph with laser beam attachment and RE7 recording control. The spectrograph is equipped with photo-multiplier tubes set at particular wavelengths of the sensitive element lines to measure light intensities directly. (Fig. 1)

- atomic absorption spectrometry using a Chinese-built GGX-1 Mark 3 AA unit for less sensitive work (Fig. 2) and a Perkin-Elmer 403 unit for low-level determinations. (Fig. 3)

- high frequency dielectrical separation of minerals and micro-fossils. (Fig. 4) The main use of this technique is to separate finer minerals of similar specific gravity and magnetic properties but having different dielectric constants. It has also been used by the Chinese to separate micro-fossils such as ostracoda, charophyta and foraminifera.

BEIJING URANIUM GEOLOGY RESEARCH INSTITUTE

(T. Quinlan)

TheInstitute, which is part of the Bureau of Uranium Geology is in the Second Ministry of Machine Building, was visited by the Delegation on 1 November, and was welcomed by Professor Gao Zhidi, Deputy Chief of the Bureau.

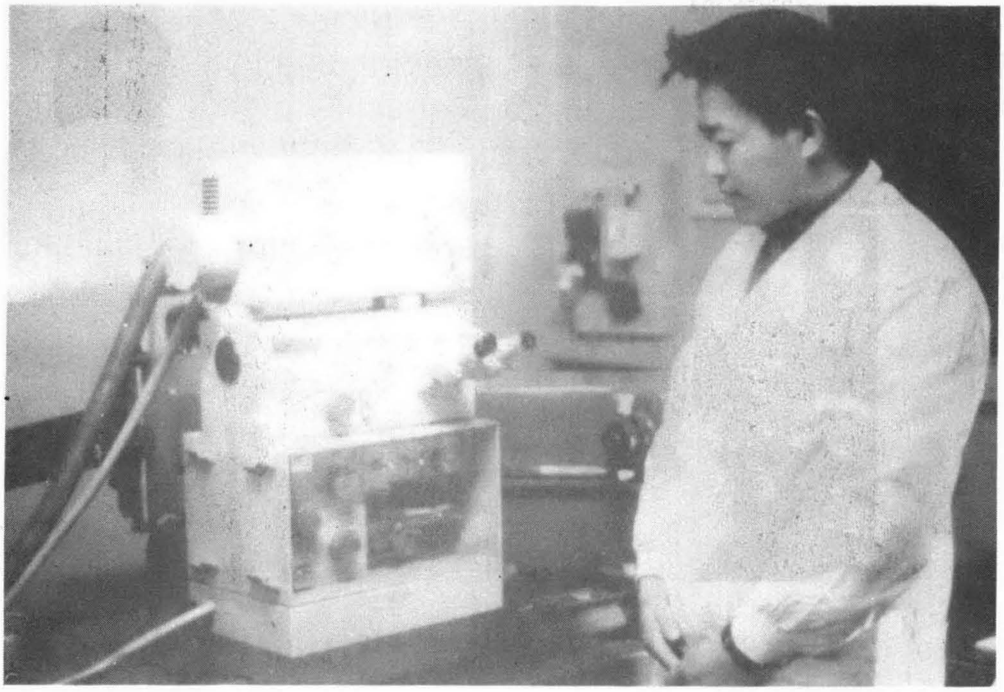

Fig. 1. Laser beam attachment for Japanese Shimad Zu CW 170 optical emission spectrograph equipped with photo-multiplier tubes, Chinese Academy of Geological Sciences, Beijing.

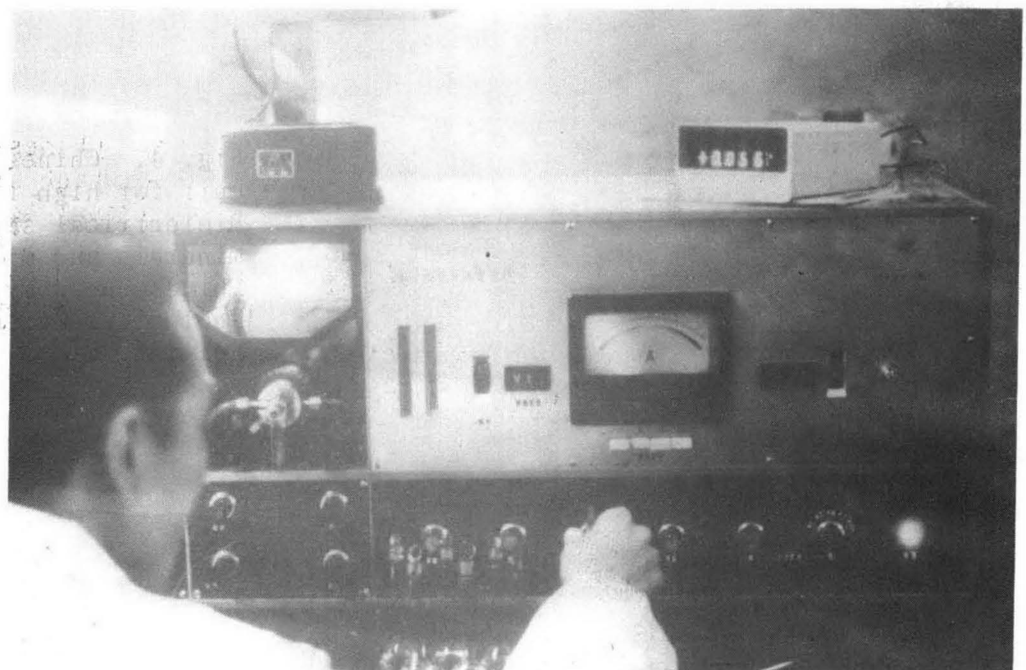

Fig. 2. Chinese-built GGX-1 Mark 3 atomic absorption spectrometer with digital read-out, Chinese Academy of Geological Sciences, Beijing.

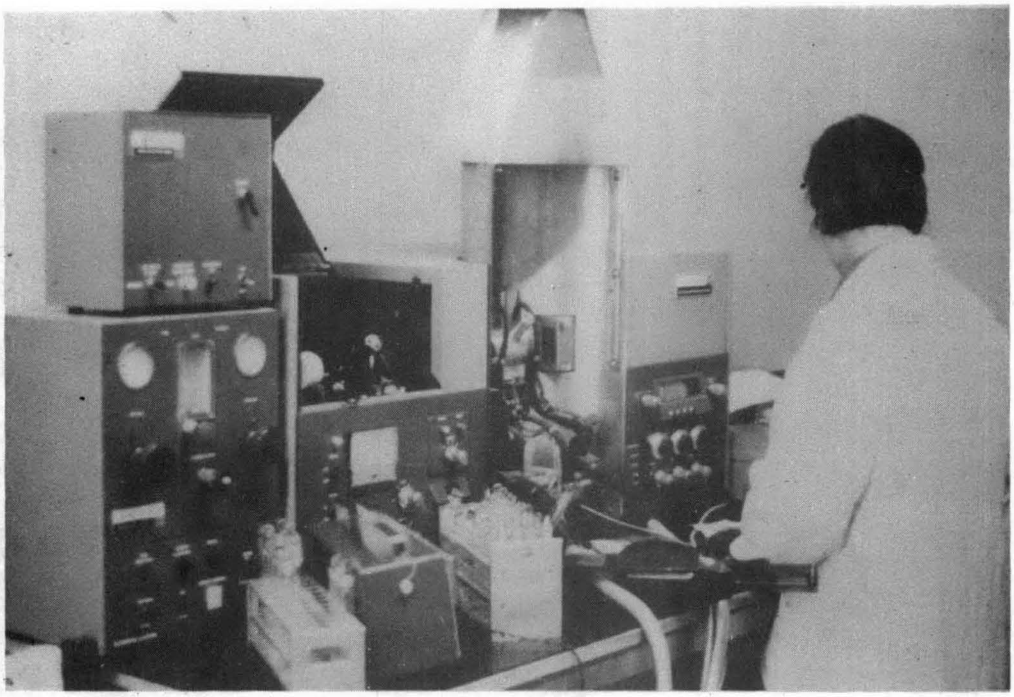

Fig. 3. Perkin-Elmer 403 atomic absorption spectrometer, Chinese Academy of Geological Sciences, Beijing.

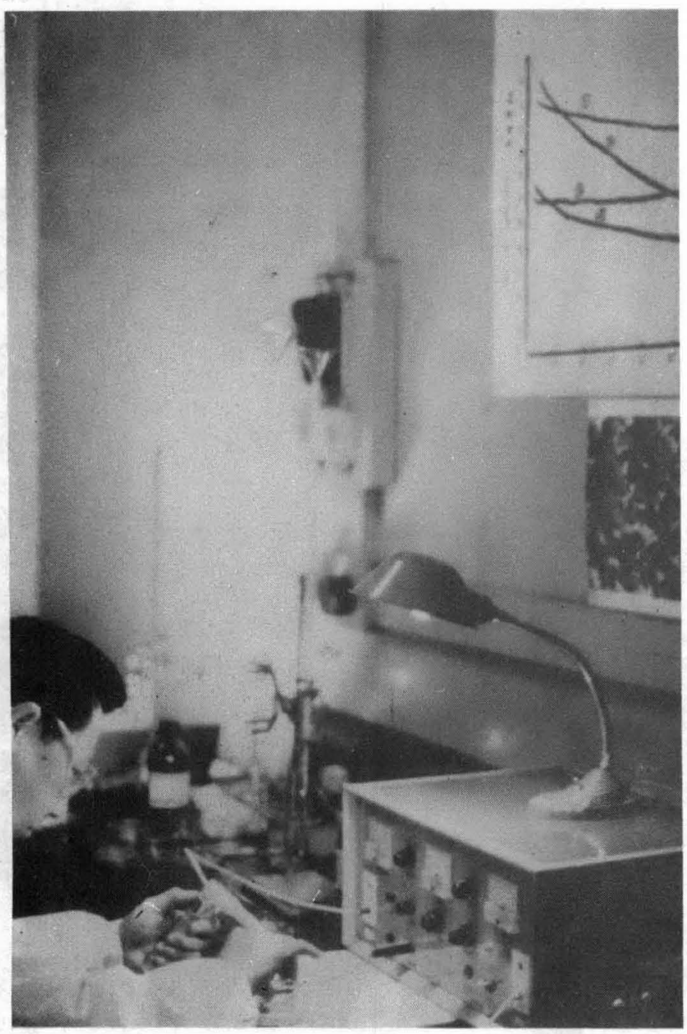

Fig. 4. Chinese-designed unit for high frequency dielectrical separation of minerals and microfossils. Chinese Academy of Geological Sciences, Beijing.

History

The Institute was established in 1959 to provide central laboratory facilities. Its present functions are:

a) the mapping of uranium deposits and their metallogenic study.
b) the choice of target areas for exploration
c) the evaluation of exploration techniques through orientation surveys
d) the identification and analysis of rocks and minerals
e) the development of instruments for field and laboratory use
f) the calibration of instruments
g) a publications and information service

Exploration techniques

Geochemical and geophysical methods are used, the latter include radiometric and non-radiometric parameters.

Specific reference was made to the following:

(a) experimental Helium surveys
(b) Track Etch surveys, which gave a noisy response and were difficult to interpret
(c) the determination of Polonium 210 isotope in soil samples, to assist in the interpretation of the Track Etch results
(d) the use of the thermo luminesence property of quartz grains.

Down hole logging methods are used in core holes to determine ore and waste boundaries, and to estimate the grade of intersections. Four channel logging equipment is used, but the Institute is having difficulty in calibrating the equipment, in particular the determination of a stripping coefficient for Thorium.

Equipment

The laboratories were well equiped for analytical determinations by the following methods, X-ray fluoresence, Neutron activation, and the counting of α, β and γ particles. Much of the equipment was locally made.

The petrological laboratories contained Opton, Leitz and Zeiss equipment for the examination of polished and thin sections, and the determination of optical constants.

Use was made of a Chinese computer, Model FD 2, with a 32 K X 48 bit core memory. Peripherial equipment included 3 drums with a storage capacity of 14 K bytes, 2 X 80 character printers, 2 x 16 channel magnetic tape drives, and 8 level paper tape readers and punches.

This equipment was installed in 1974 and was used for the statistical analysis of exploration data (including Trend Surface, Factor, Correspondence and Discriminant analysis). Some work was being done on the use of an Eigen Vector technique for the selection of areas with the highest potential for exploration.

Museum (K. Kappelle)

The museum houses a well organised and comprehensive worldwide collection of radioactive minerals and ore types. A number of wall displays showed the ore types currently known in China. Some of these are:-

1. Tamafou type: hydrothermal mineralisation in muscovite - biotite granite. The mineralisation consists of pitchblende, base metal sulphide, and fluorite and is accompanied by silicification. Rich ore pockets occur where lamprophyne dykes cut the mineralisation. Age of the mineralisation is 140 million years.

2. Rockhou type: Sedimentary uraniferous phosphate in Cambrian limestone overlying Sinian rocks. The uranium mineralisation is uraniferous collophane, and is accompanied by chalcedony and chlorite. The locality is 'Whitehorse Cape', SW China.

3. Uranium associated with mercury, in Guizho Province, where the mineralisation occurs in limestone, adjacent to fissures underlain by dolomites and overlain by shales. Note that this deposit may well be in the Wanshan area, described separately in the section on the Ministry of Metallurgical Industry.

4. Uraniferous collaphane as in deposit 60, similar to 65, and described separately elsewhere.

5. Lenticular deposits, grade .1%U, mainly of pitchblende in Jurassic sandstones at Taladee? near Shenyang.

XIHUASHAN WOLFRAM MINE

by I.R. McLeod

ABSTRACT

The Xihuashan wolfram mine, one of the largest in China, produces about 2500 tonnes/year of 65% WO_3 equivalent concentrate from a daily treatment of 3300-3400 tonnes of ore. Head grade is 0.21% WO_3 and reserves are sufficient for 14.9 years production. Molybdenite, cassiterite and bismuth are produced as by-products.

The deposit is a quartz vein type, the host rock being a multiphase granite stock of early Yenshanian (Jurassic) age. The veins were emplaced in fractures formed by repeated activity of two major structural zones, trending easterly and NNE.

The granite adjoining the veins is hydrothermally altered, and better mineralisation is associated with stronger alteration; mineralisation however, is largely confined to the quartz veins. Different combinations of ore minerals are associated with the several kinds of alteration.

The ore minerals are thought to have been derived from the second phase of the granite under the influence of stress, and subsequently deposited along with quartz as veins in fractures in the granite stock.

INTRODUCTION

The Xihuashan wolfram mine is 9 km northwest of the county town of Dayu, in southwest Jiangxi province.

The deposits were mined by simple hand methods from at least 1908. Construction of an integrated mine began in 1953 and was completed in 1959, when production was about 2250 tonnes/day of ore. After an increase in capacity in 1970 to 3000 tonnes/day of ore, annual production is now about 2500 tonnes of 65% WO_3 concentrate equivalent, making the mine one of the largest, if not the largest, in China.

REGIONAL GEOLOGY

The country rocks are slightly metamorphosed sandstone, phyllite and slate of Sinian and Cambrian age. They have been altered to biotite hornfels at the contact with the granite bodies. The regional strike is northerly, but in the vicinity of the mine it is easterly, and the dip is steeply to the south.

A Hercynian gneissic granite (K-Ar age 242 m.y.) which crops out south of Dayu has no genetic relation to the tungsten mineralisation.

Several granite stocks related to the Yenshanian orogeny (Jurassic) crop out in the region. The tungsten mineralisation is associated with these, and the Xihuashan stock, which is typical, is described in more detail below.

The Xihuashan deposit is at the junction of two structural zones, one trending east-west, the other north-northeast - south-southwest. The east-trending zone is represented by faults and a foliation parallel to these. It has been active on at least five occasions since the late Palaeozoic, the strongest activity being in the Jurassic and Cretaceous.

The NNE trending belt is slightly later, of Neo-cathaysian age with several phases of activity. It consists mainly of compression faults and folds.

DETAILED GEOLOGY

The stock containing the Xihuashan deposit forms a steep hill rising to 880 m above sea level, i.e. about 600 m above the floor of the nearby river valley. The stock has a length (north-south) of 6 km, and a width of about 4 km, and consists of five separate intrusive phases, each accompanied by pegmatites and aplites. Mineralised quartz veins are associated with each phase also, the veins having a spatial relationship with their parent granite, but the veins of each phase have different metallogenic characteristics.

Granite of the earliest phase (denoted by γ_5^{2-1}) occurs in the south and east of the stock. It is composed of medium grained biotite granite and its quartz veins are characterised by W and Mo. K-Ar ages on biotite range from 180 to 184 m.y.

The second phase (γ_5^{2-2b}, age 165 m.y.) is mainly in the southwest of the stock. It is a medium grained biotite granite with a margin marked by pegmatitic granite; associated quartz veins are marked by W, Sn, Bi and Mo. Measurements on muscovite suggest a mineralisation age of 155 to 160 m.y.

The third phase (γ_5^{2-2c}), a fine grained biotite granite 160 m.y. old, occurs mainly in the north of the stock, with quartz veins characterised by W, Be and Mo and an indicated mineralisation age of 148 m.y.

The fourth phase (γ_5^{2-2d}), is a fine grained biotite granite containing garnet, occurring in the marginal parts of the stock; related quartz veins are characterised by W, Sn and sulphides.

The fifth phase (γ_5^{3-1c}) occurs mainly in the central part of the stock. It is a granite porphyry with quartz veins characterised by W and sulphides.

No age measurements are available for rocks of the last two phases.

Yenshanian granites are very acid The SiO_2 content is 74.59% to 76.43%, and Na_2O+K_2O is 7.86 to 8.13%, and the volatile content is high (see also Department of Geology, Nanking University, 1974).

The content of some elements in the several phases is given in Table I. These data are derived from over 100 samples by XRF analysis.

More than 40 accessory minerals have been identified. The content of some of these is shown in Table 2.

THE MINERAL DEPOSIT

Quartz veins

The Xihuashan deposit is a quartz vein type of deposit. Most of the veins are in the granite, but some extend into the country rock. They occur within an area of 6½ km^2, but mineralisation is confined to 3 km^2.

Over 500 veins containing economic mineralisation have been identified. (The comment that all the quartz veins are economic was made later). Their average length is 250 metres, the maximum being 1075 metres; their width averages 31 cm, with a maximum of 3.6 metres; their extent down dip ranges from 250 to 400 metres. It was also stated that they occur over a total vertical distance of 3000 metres. Each vein thins out downwards and, less rapidly, upwards, and those penetrating the country rock pinch out rapidly.

The veins are concentrated in three groups, referred to as the north, centre and south groups. Five vein systems have been identified on the basis of strike directions: easterly, 80°, 100°, 70° and 65°. Most of the veins dip north at 75° to 80°. The first three systems occur mainly in the north group of veins, the fourth at the boundary between the north and central groups, and the fifth in the central and southern group. Most veins reach the surface or the upper margin of the granite where it is covered by the country rocks.

Hydrothermal alteration

The country rocks have been affected by four kinds of alteration; in order of intensity these are: greisenisation, silicification, microclinisation and albitisation; greisenisation is of four kinds: mica rich, qufrtz rich, normal (i.e. equal amounts of quartz and muscovite) and greisenised granite. Alteration is zonally distributed; outwards from the quartz vein the sequence, which occupies a width of 10-50 cm, is mica rich and quartz rich greisen, normal greisen, silicification, and microclinisation and albitisation.

There is a close relation between the intensity of the alteration and degree of mineralisation, with better mineralisation being associated with stronger alteration. Greisenisation is confined to parts of the mine, whereas albitisation and microclinisation are widespread, but are more common in the deeper levels of the mine.

Table 1

Contents of certain elements in Xihuashan granite (ppm)

Phase (all γ_5)

	2-1	2-2b	2-2c	2-2d	3-1c
W	153	48	87	43	70
Sn	48	50	42	34	39
Bi	27	9	17	29	9
Mo	31	10	30	10	19
Li	143	170	188	200	480
Y	17	25	43	64	60

Table 2

Content of selected minerals in Xihuashan granite (gm/tonne)

Phase (all γ_5)

	2-1	2-2b	2-2c	2-2d	3-1c
Bertrandite	132	122	44	10±	5±
Cassiterite	1.1	5.4	20	37	0.3
Wolframite	24	0.2	3.2	12	39
Molybdenite	0.2	$<$0.2	3.7	1.6	n.d.

Mineralisation

A total of 33 minerals has been identified in the quartz veins; these include quartz, potash feldspar, fluorite, beryl, calcite, lithium muscovite, biotite, topaz, helvite (a beryllium garnet) and adularia; metallic minerals include wolfram, cassiterite, molybdenite, native bismuth, bismuthinite, scheelite, chalcopyrite, bornite, pyrite, pyrrhotite, arsenopyrite, galena, sphalerite, xenotime, tantalo-columbite, datolite and bertrandite; secondary minerals include wolframine (tungsten molybdate), molybdenum ochre, limonite, covellite, and marcasite. The wolfram : scheelite ratio is 10:1.

Mineralisation is largely confined to the quartz veins, but occurs in the altered wall rocks in parts.

There is a relation between the mineral association and the type of alteration. W, Bi, Be, Mo and Sn are associated with greisenisation; W, Mo, Sn, Pb, Zn and Cu with silicification; and Ta, Nb, and rare earth minerals (xenotime and fergusonite) with microclinisation and albitisation.

Wolframite is the main ore mineral, tending to occur as clusters up to 10 cm and more across. Its composition was stated to be -

WO_3	74.37%
MnO	9.55%
FeO	13.52%

Trace elements include Nb, Ta, Sc, Sn, Pb, Zn, Ti, Y, Yb, Zr, the content of Nb, Ta and Sc being sufficiently high that they "can be extracted".

There were three stages of metallogenesis. The first, hypothermal, stage was characterised by Sn, W and Be; the second, high to mid temperature hydrothermal, is characterised by sulphides; and the third, low temperature hydrothermal, stage is characterised by calcite.

Wolframite mineralisation occurred at a temperature of 267-320° and a pressure of 450 to 800 atmospheres.

Ore Controls

Three ore controls have been recognised: (1) structural features, (2) magmatism, and (3) country rocks.

(1) The primary control is structural, the quartz veins filling fractures in the granite. The veins do not cut the fractures, and they do not cut each other.

Strain analysis methods have been used to determine the directions of stress and the pattern of its relief during ore formation (Research Group, 1976). Three important faults (or fault systems) have been identified. All were active before mineralisation, and activity continued after ore formation. All controlled quartz vein formation. F1, which formed under the influence of the Neo-cathaysian movement, is a sinistral shear trending about NE and forms part of the southern margin of the granite. F3 is a fault between the central and southern parts of the mineralised area, trending generally somewhat south of east; it was first a compression fault and subsequently a dextral shear, and resulted from activity in the major east trending structural belt. F4, resulting from activity of the ENE trending belt, is a dextral compression shear trending about ENE, and is the northernmost of the major faults in the mineralised area.

The northern part of the deposit was affected by all three systems, so mineralisation is strongest there. The southern part was affected by F3 and F1 so mineralisation there, while not as strong as in the northern parts, is better than in the central part.

(2) The second controlling factor is magmatism. Tungsten deposits in southern Jiangxi province, including the Xihuashan deposit, are related to Yenshanian granites. The content of trace elements in these granites is higher than in normal acid rocks by factors of 3 to 100; the granites are also very acid (see above, Detailed Geology).

The second phase of the Xihuashan granite body (i.e. γ_5^{2-2b}) contains less trace elements and accessories than the other phases (Tables 1, 2), but is the main host for tungsten mineralisation. Microscopic examination suggests that it has undergone strong stress and has recrystallised after being crushed - quartz is biaxial, with wavy extinction, and potash feldspar is zoned. The mine geologists suggest that under this stress, the ore forming elements migrated into solution from the granite and were subsequently deposited in the quartz veins, so that the trace element and accessory mineral content of this phase is low compared with that of the other phases.

(3) The country rocks away from the zones of alteration have a relatively high content of Si, K, Na, Al, Fe, Mn and F; their content of some metals (in ppm) is: W, 28; Sn, 26; Bi, 3; Mo, 7; Be, 10.

The mine geologists believe that available data suggests that material for the deposits comes from post-magmatic hydrothermal solutions and metasomatism of the country rocks.

All tungsten deposits in southern Jiangxi province are characterised by wall rock alteration, and this alteration is thought to be important in metallogenesis - intensity of mineralisation and degree of alteration go together. Alteration is thought to have helped migration and concentration of elements, and the valuable elements are thought to have been derived from the country rock by the metasomatism referred to above. Deposition of the tungsten was aided by the solution changing from weakly acid to weakly alkaline.

The physical properties of the country rocks also are believed to be an important factor in ore control. Unlike the granite, they did not fracture under stress, and so served as a barrier to the ore solutions, confining them largely to the granite.

PROSPECTING

The mine was originally designed on the basis of 7 years reserves, but 20 years later, at the time of the visit, current reserves were stated to be sufficient for 14.9 years. It seems that, in view of the regular vein pattern, new mineralisation has been found by more or less systematic drilling on a 200 m grid. It was stated that no exploration has been done recently, but a program is now beginning. In the mine area, attention is being concentrated on discovering blind veins under the partial roof of country rock in the northwest of the deposit, and under the first phase of the granite body, which also forms a partial roof to later phases.

Away from the mine area, heavy mineral stream-sediment sampling is being used to search for new deposits.

MINING

The mine has been operating since 1959. The total operation (including mill, administration, medical, etc) employs over 3000 people, of whom between 1500 and 2000 work underground. Most employees live near the mine. The mine operates 3 shifts a day for a 6-day week. The mill works continuously.

Although the hand picking lines were predominantly women, no women work underground, the given reason being that it is too hot, although the delegation did not encounter any particularly hot conditions.

The parts of the mine seen gave the impression of a tidy, well maintained operation.

PRODUCTION, GRADES AND RESOURCES

It is always difficult to estimate grades and reserves for this type of deposit, especially as some country rock has to be mined along with the quartz veins, and various grade figures were quoted. The average grade of veins was stated to be 1.0% WO_3, but because of country rock dilution, the average head grade is 0.212% WO_3. Cut off grade for the thicker veins was said to be 0.12%, and for multiple veins mined in the one stope, 0.1%. The minimum cut off grade was said to be 0.05%. Stope plans showed some blocks as averaging 3 to 4%, and more, but values were commonly around 1.5%. Designed mill capacity is 3000 tonnes/day but current treatment rates are 3300 - 3400 tonnes/day. Current annual production is equivalent to 2500 tonnes/year of wolfram concentrates of 65% WO_3 equivalent. Molybdenite, cassiterite and bismuth minerals are produced as byproducts.

Reserves were said to be sufficient for another 14.9 years. Ore is known to occur below the lowest (215 metre) level but has not yet been worked. The statement that the total height of the veins is 300 metres would suggest that the lower limit of the vein zone has been delineated in part at least.

MINING METHODS

As the deposit is in a granite hill rising 680 metres above the floor of the valley (which is about 200 metres above sea level), entry is by adit, and all ore is brought to the surface by adit. Two internal shafts are used for man and materials access.

There are 12 levels, the highest 745 metres and the lowest 215 metres a.s.l. There are two main haulage levels, at 215 and 431 metres. The usual level interval is 38 metres.

Most of the economic veins trend east to ENE and dip nearly vertically. The main drives run about westerly; north-south cross cuts are driven from these at intervals across the quartz veins, and minable veins then driven on. Veins (or groups of closely spaced veins) are driven on initially for 5 to 10 metres to test the grade.

The granite host rock is very competent - virtually no ground support was seen in the mine, and mining is by fairly conventional shrinkage stoping. Drilling in the roof is by airleg drills, taking 1½ metre lifts. Ammonium nitrate explosive is used. Normally a 2 metre floor pillar is left, but in rich veins, this is taken out and a concrete and timber floor constructed. In the mining area visited (mining area 29) stopes were 80 metres long. Ore is withdrawn through chutes about 20 metres apart to maintain a working height of 2 metres between the floor and the roof. Eventually crown and rib pillars are taken out and the stope left open.

Ore on the 431 level is trucked to one of two tipples; ore passes take the ore to the 215 level, which is the main haulage level to the surface. At one tipple trucks (which each have a capacity of about 1½ tonnes) are automatically side tipped. At the other, trucks (with a capacity of 3½ to 4 tonnes) are emptied in pairs on a rotary dumper, without uncoupling; dumper cycle time is about 25 seconds, and each train consists of about 12 trucks.

On the 215 level, ore is taken to the surface to the primary crusher in a 16 truck train, each truck taking 3 tonnes (it should be noted that ore trucks generally were not filled to capacity). The trucks, which are round bottomed, are tipped in pairs, without uncoupling, in an oscillating rotary dumper over the crusher bin. While the trucks are upside down, their bottoms are hammered by pneumatic hammers in an attempt to overcome hanging up. Despite this, the bottom of most trucks was caked with several centimetres of fines. Although the mine was dry, the ore in the trucks was very wet, because of the lavish use of water for dust prevention.

All haulage is by electric locomotive powered by 115 volt overhead cable.

Equipment seen in the mine included

(1) A Chinese made light air driven diamond drill, with a capacity of 100 metres. Core diameter was about 19½ mm, and hole diameter about 36 mm. The drill was drilling a horizontal hole at right angles to the vein trend to locate further veins.

(2) a rail mounted hydraulic feed 2 boom jumbo in a development heading. The machine uses removable tungsten carbide bits.

(3) A locally designed and made loader for mucking out headings. A truck located between the mucker and the rake of trucks carries a box of about 3/4 m^3 capacity on a pair of scissor arms. When the arms are lowered, the top of the box is in line with the top of the trucks, and in this position it is filled by the mucker. The scissors are then raised, and the box moves on its own wheels along the top of the rake of trucks until it can bottom-dump its contents into a truck. All movements are air powered. The top edges of the ore trucks have horizontal flanges about 10 cm wide, and the wheels of the box run along these. The gaps between the trucks were no impediment to the movement.

ORE TREATMENT

The head grade of the ore entering the treatment plant is 0.3% WO_3, 0.02% SnO_2 and 0.01% Mo. Ore from the bin under the tipple is fed via a grate conveyor to a 5 foot (approximately) gyratory crusher, where it is crushed to about -6 inches . Throughput is about 170 tonnes/hour. After screening, +3 inch material goes to two hand picking belts (about 20 people, mainly women, per belt), where the quartz is hand picked off. The waste ratio is 29 percent, and the grade of the waste is 0.018% WO_3. The waste is discharged to buckets on a ropeway and stacked near the crusher. The -3 inch material, representing 70% of the feed, is deslimed then recombined with the picked quartz, and carried by aerial ropeway to the concentrator 4½ km away. The ropeway has 1.3 tonne buckets, one of which is filled every 37 seconds.

At the concentrator the buckets are automatically discharged, the ore further crushed in gyratory crushers, and again hand picked (about 30 women to the belt). +2 mm material is sized to -10 mm and -4 mm fractions, which are ground to - 2mm in ball mills. Table feed is -2 mm. Coarse sulphides are separated by table, but fines, after regrinding in two small ball mills, go to flotation cells where molybdenite, bismuth, chalcopyrite and scheelite are floated separately. Altogether there were 6 floors each with about 20 tables. Wolframite is separated from other heavy minerals by one stage dry magnetic separation to produce a final concentrate at 68 - 69% WO_3. Overall recovery of tungsten was said to be 85%. The product is packed in 50 kg jute bags. Xenotime is recovered electrostaticallyby intermittent campaigns. The stage at which tin is recovered was not ascertained; possibly it is in the residue from magnetic recovery of the wolframite.

It was stated that this particular operation is paid 7 000 yuan/tonne ($A1 = 1.65 yuan approximately) for the concentrates; other mines are not necessarily paid this amount. Although the subject was not discussed in any detail, it seems likely that this amount covers operating costs and capital replacement costs.

GENERAL COMMENT

Those parts of the mine visited gave the impression of a tidy, well run, though labour intensive, operation.

Reserves have increased greatly since the mine was first opened. Despite the amount of work done on the genesis of the deposit, the delegation obtained no evidence that the theories have been applied to the search for further mineralisation in or away from the mine area.

The mine geologists' ideas on the origin of the deposits leaves several questions unanswered, in particular the idea that the country rocks were the source of the ore metals. No comparative metal contents for altered and unaltered country rock was given, nor quantitative data on tonnage of metal in the quartz veins as compared to tonnage - or depletion tonnage - in altered or unaltered country rock. The mine geologist, in his talk, did not discuss the origin of the granite itself. Some workers (e.g. Department of Geology, 1974) have suggested that the Yenshanian granites are the product of repeated granitisation and sedimentation cycles, with elements such as W, Sn, Be, Nb etc., being further concentrated by each cycle and eventually appearing in the small, younger granite bodies as workable ore deposits. The reference by the mine geologist to 'metasomatism of the country rock' (see Ore Controls) may relate to this granitisation process. Apart from the local alteration adjacent to the quartz veins (which was always called 'alteration') no mention was made of widespread alteration of the country rocks, which were described merely as 'slightly metamorphosed'.

The treatment plant is operated largely to pre-determined conditions with little or no account of variations in head grade or mineralogy. Facilities for chemical and mineralogical analysis of the feed or any products are minimal. In the absence of control data of this kind, it is surprising that the plant operates as efficiently as it is said to do.

The group was shown through a large workshop equipped with forges and a range of laths, drills, milling machines, etc. The mine makes its own electric and combustion engines and pumps.

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TAOLIN LEAD ZINC FLUORITE DEPOSIT

By K. Kappelle

ABSTRACT

The Taolin lead zinc fluorite deposit is a weakly mineralised breccia zone at the contact of Mesozoic granite and pre-Sinian metamorphosed sediments. Geological reserves are estimated to be 13 million tonnes of 1.06% Pb, 1.69% Zn .8% Cu and 15.7% fluorite. China's deficiency in lead and zinc makes this an important resource. Annual production is around 500 tonnes copper, 10,000 tonnes zinc, 6,000 tonnes of lead and 60,000 tonnes of fluorite.

GEOLOGY OF THE TAOLIN DEPOSIT

INTRODUCTION

Location

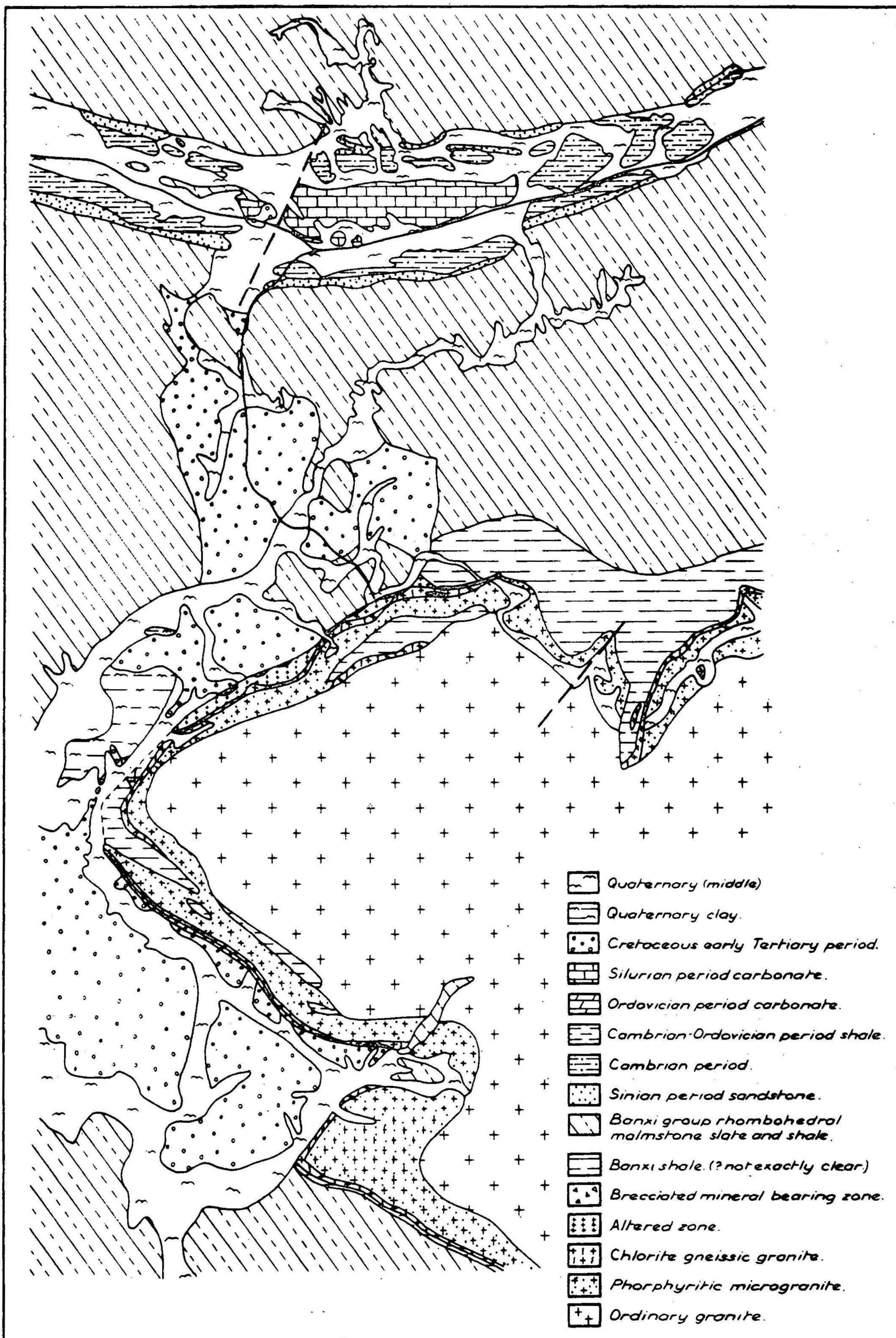
Taolin (29°22'N, 113°27'E) is located in the northern part of Hunan Province, some 50 km east from the city of Yueyang, a drive of one and a half hours by bus. The mine has a 20 km rail link to the main Guangzhou-Beijing railway line.

History

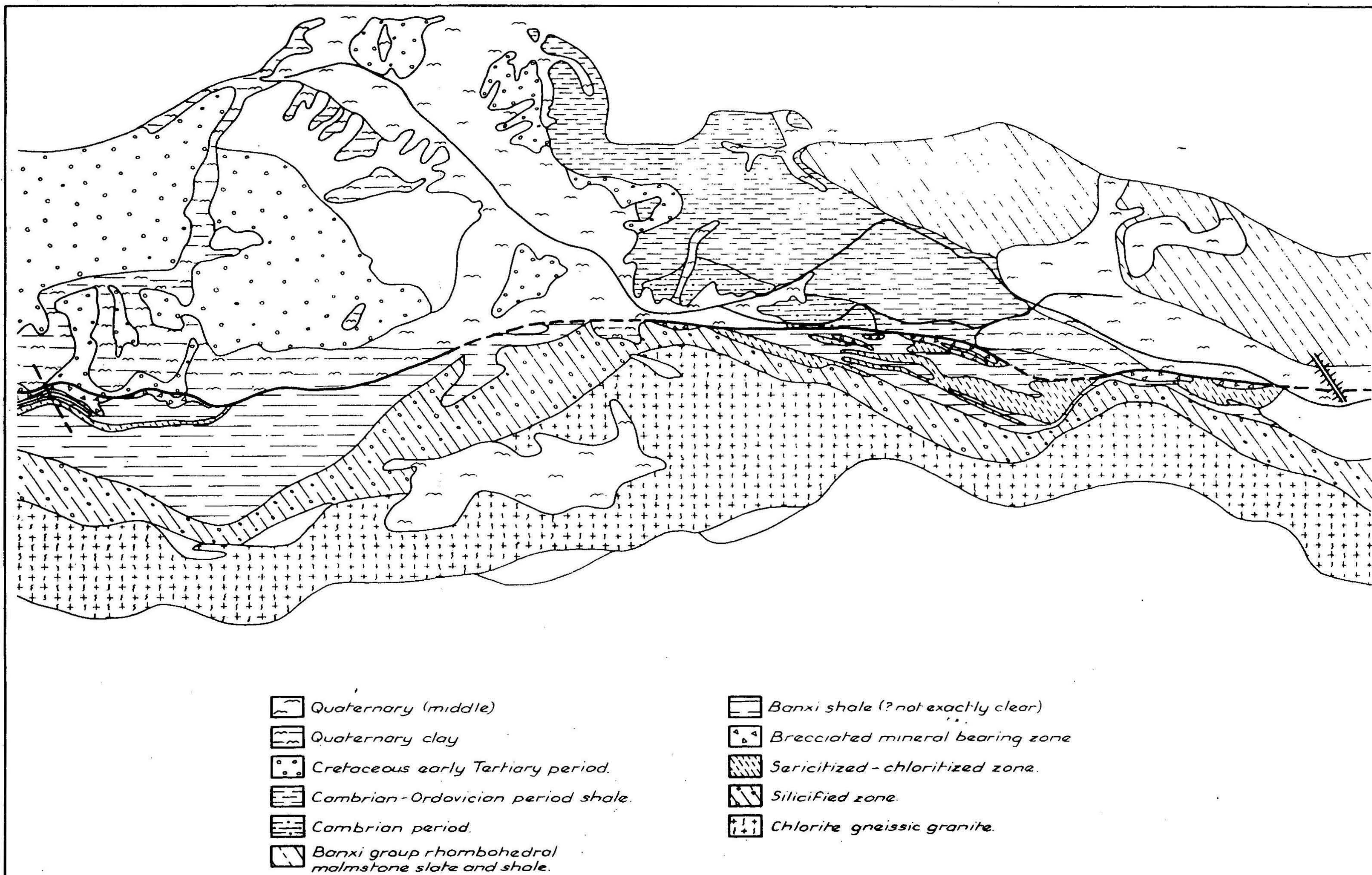
Scattered mineralised outcrop discovered by villagers led to an evaluation program. In pursuit of a policy of self-reliance on mineral commodities in which the PRC was deficient, development of this low grade deposit commenced in 1958. Production commenced in 1959.

REGIONAL GEOLOGY

Taolin is located on the northern flank of Jian-Nan 'old land', south of the Yangzi geosyncline. The stratigraphy is simple. The oldest rocks, the Banxi Group, are pre-Sinian i.e. late Upper Proterozoic. The thickness of this group is 8500 m. In the mine area this is unconformably overlain by late Cretaceous red beds and conglomerates. Elsewhere there occurs an 1800 m thick succession of Cambrian, Ordovician and Silurian rocks which in the mine area is either thin or absent.



REGIONAL GEOLOGY — TAOLIN DISTRICT Figure 5



REGIONAL GEOLOGY — TAOLIN MINE

Figure 6

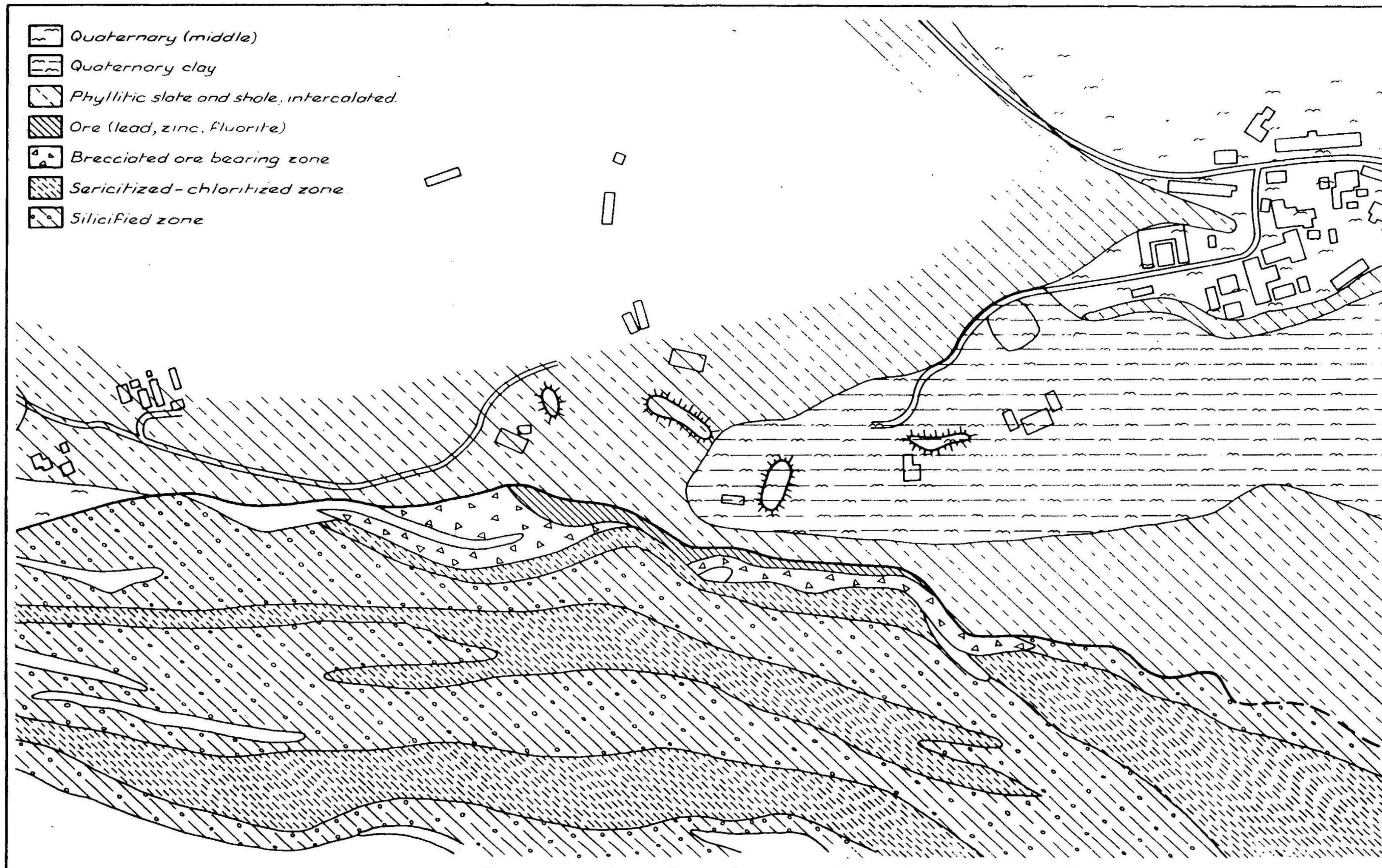
In the regional geological plan (Fig. 5) the Banxi Group can be seen to outcrop extensively to the north of the mine area. Outcrop at the plant is a buff weathered blocky fractured siltstone. An extensive area of granite occurs to the south. The granite appears to be a batholith, some 100 km long and from 32-40 km wide. The granite is of late Mesozoic age (Yenshan period). A major fracture zone separates the Banxi Group and the granite, and it is this zone which contains the lead zinc fluorite mineralisation. The fracture zone and its attendant hydrothermal alteration has been traced over a length of 13 km. In the vicinity of the contact the granite is gneissic. The mineralised zone itself is 3.3 km long. (Fig. 6)

MINE GEOLOGY

Mineralisation

In the centre of the mineralised zone is a 300 - 400 m barren zone of barite mineralisation. The eastern and western parts on either side of this barren zone are referred to locally as the Kungshan (Yinchunshan?) and Shangtangchung deposits respectively (Figs. 6, 7). In the eastern deposit, the orebody achieves its complete outline 10 m below the surface. Below this it branches and then rejoins again. In the western deposit the orebody achieves its complete outline at 20 m depth. Below this it branches into two parts (Fig. 8).

The general strike of the mineralisation is 75^{o}, dip NW $32\text{-}35^{o}$. The eastern deposit is from 600 m - 1000 m long, the western is from 800 - 1200 m long. Mineralisation extends down dip for around 300 m. Average ore width is 10 m, and the maximum width is 50 m. The average geological grade of the deposit is 1.06% Pb, 1.69% Zn, 15.7% fluorite, 0.8% Cu, 0.003% Ga, 0.004% In, Ag 7 gpt. Lead zinc grades deteriorate with depth. Gold grade is approximately 1 g/t in concentrates, and it is reported that "it will be recovered soon". The recovery of gallium is being studied. No cut off grades are used and the deposit is being mined to its geological limits except that barite rich zones are avoided because of metallurgical problems associated with fluorite recovery.



MINE GEOLOGY — TAOLIN MINE

Figure 7

Outcrop of the mineralised zone was apparently sparse and rubbly. Depth of weathering averages 1.5 m up to a maximum of 4.5 m and the deposit is therefore essentially primary in nature. The sulphides are galena, sphalerite, chalcopyrite and pyrite. The gangue consists of fluorite, quartz and barite and occurs as cement between breccia clasts of ore minerals. The mineralised zone is strongly brecciated. The mode of occurrence of the sulphide is as veinlets, massive, disseminated, or laminated. The ore minerals occur mainly as xenomorphic crystals. However many ore minerals seen underground were open space cavity fillings with laminated crystals. (Fig. 9)

The Banxi Group overlying the deposit is strongly folded. It consists of phyllite, phyllitic sandstone, slate and shale. There is no graphite. No geochemically anomalous lead-zinc values occur in the Banxi Group. They occur only in the granite and then only for a distance of 10 m from the mineralised zone. Mineralisation appears to be non-stratigraphic and follows the brecciated margin of the regional granite batholith (Fig. 5).

Structure

There were two major periods of faulting. The earlier one effectively controlled the mineralisation. The final period is reflected as a major fault which separates the hanging wall from the mineralised zone. This fault is a gouge zone several centimetres thick. Lack of alteration in the hanging wall above this suggests a significant displacement, with the added possibility of fault repetition elsewhere of the portion of the mineralised zone which may have been faulted off.

Alteration

An envelope of chloritisation and silicification surrounds the mineralised zone. Altered Banxi Group consisting of garnet bearing mica schist outcrops across the fault. The altered granitic material in the vicinity of the mine has a gneissic texture in places as observed during the underground visit. The Chinese were happy to call this material either granitised Banxi Group, or dynamically altered granite.

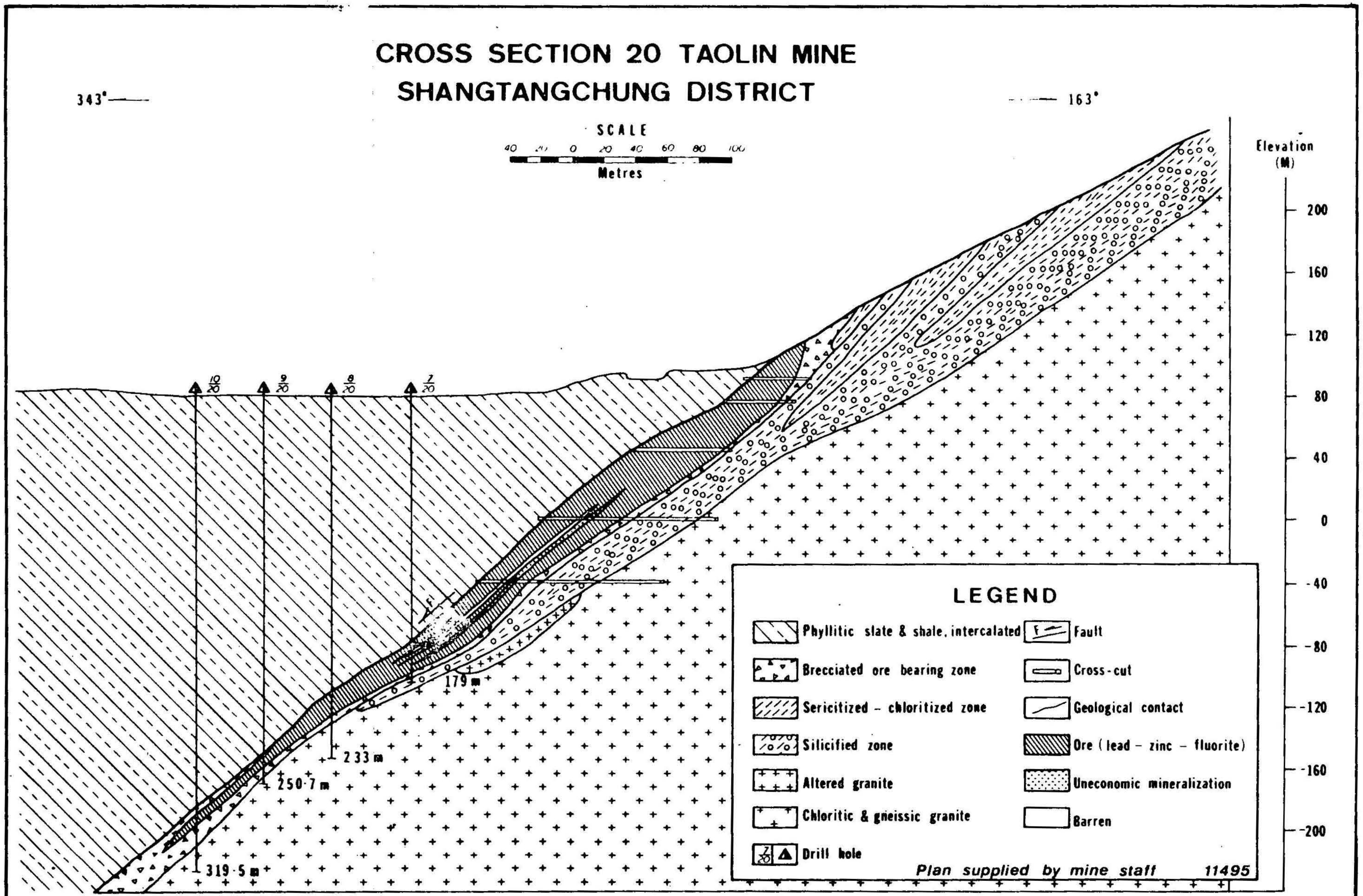

CROSS SECTION 20 TAOLIN MINE
SHANGTANGCHUNG DISTRICT
343°
163°
SCALE
40 20 0 20 40 60 80 100
Metres
Elevation (M)
200
160
120
80
40
0
-40
-80
-120
-160
-200
10/20
9/20
8/20
7/20
179 m
233 m
250·7 m
319·5 m
LEGEND
Phyllitic slate & shale, intercalated
Brecciated ore bearing zone
Sericitized - chloritized zone
Silicified zone
Altered granite
Chloritic & gneissic granite
Drill hole
Fault
Cross-cut
Geological contact
Ore (lead - zinc - fluorite)
Uneconomic mineralization
Barren
Plan supplied by mine staff
11495

Figure 8

The temperature of formation of the deposit is considered to be in the middle to low temperature range (Table 1).

TABLE 1

Temperature of Formation

Mineral Phase	Low Temperature Range (^{o}C)	High Temperature Range (^{o}C)
Galena	100 - 227	203 - 330
Sphalerite	152 - 216	282 - 333
Fluorite	109 - 164	169 - 256

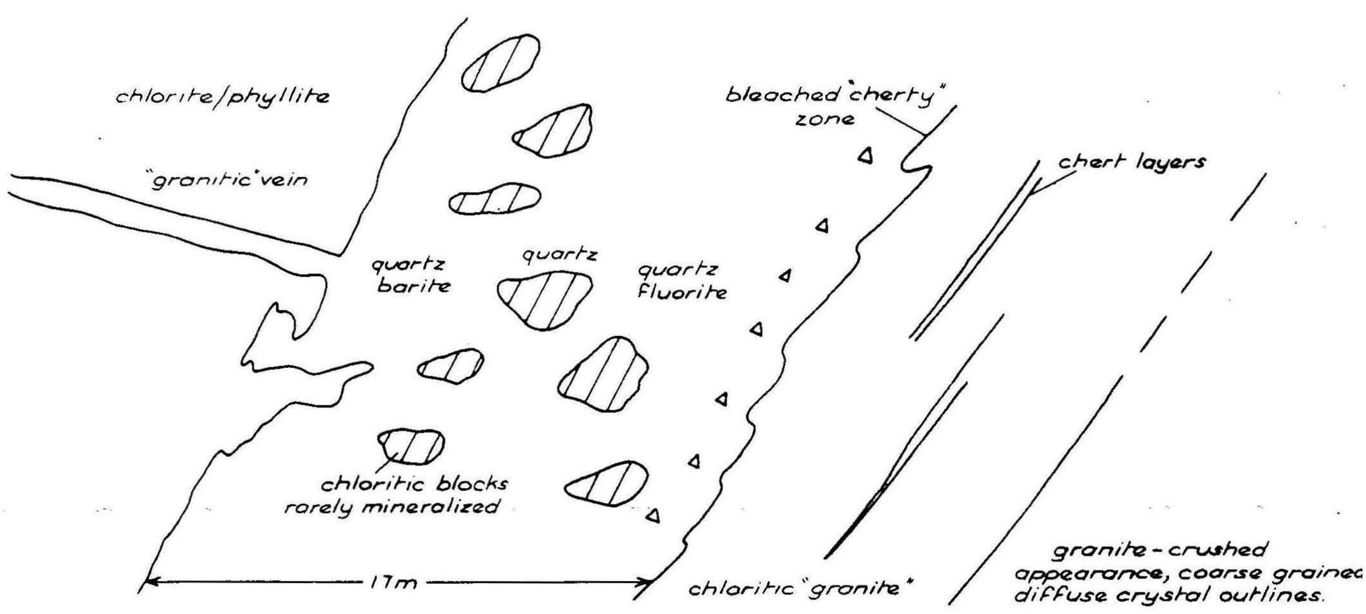
Mineralisation is structurally controlled. Metasomatism is not clearly shown. Mineralisation is considered to have been due to repeated hydrothermal activity occurring over a number of periods. The first period, and the main one, is associated with brown sphalerite, blue, green, and purple fluorite, and this phase of mineralisation filled all the available open spaces. Mineralised fractures re-opened during subsequent periods of mineralisation. The second period brought in brown to light yellow sphalerite and the bulk of the sulphides. The third period introduced mainly barite. Much silica was introduced during these later periods, the mineralised zone containing up to 68% SiO_2. (Table 2). Age of mineralisation, based on only one galena sample, is 142 m.y. S isotope measurements of Pb, Zn & Cu sulphides yield ΔS_{34} -4 to -5% but barite yields ΔS_{34} + 13% (so there could be mixing at a later stage).

The granite has no direct genetic relationship to the mineralisation, although it may have been the source of the late stage hydrothermal solutions. Some pegmatites containing berylium, lithium, niobium, tantalum and fluorine occur in the granite and these are considered to have been emplaced at the same time as the mineralisation. The mineralisation is considered to be of post-magmatic hydrothermal origin.

SCHEMATIC CROSS SECTION

SHANGTANG CHUNG DEPOSIT

TAOLIN MINE



80m LEVEL — WEST ORE ZONE

Figure 9

MINING

The main shaft used for hoisting services and personnel is vertical and located centrally, in the barren part of the deposit. Ventilation shafts are located on either side of the deposit. The level interval is 40 m. Each level is developed by two parallel drives along the orebody. Every 50 m there is a cross-cut. All drives and crosscuts carry rail track for an electric train ore haulage system. Bare overhead electric cables carry 250V and are 1.8 m above the track. Rail cars are of 2 m^3 capacity.

Ore transportation and dumping at the shaft ore pass follows a circular route, an ever expanding clockwise path, progressively travelling on crosscuts located further and further away from the shaft. The electric loading shovels are rated at 30 kw. The mining technique involves the blasting out of an entire block between levels and then drawing out the broken ore from ore shutes located in each of the crosscuts on the level below. By mining systematically from top to bottom no ore is lost in level pillars. Policy requires total extraction of mineralisation. The hanging wall of the mineralised zone is puggy and fractured and because of the flat dips, dilution is extensive. Attempts to minimise dilution have had to be balanced against total extraction policy with the result that dilution is 30%. The shaft hoisting speed is 4.7 m/sec.

Taolin has a temperate moist climate. Annual precipitation is 1300 mm the bulk of which falls during the wet season from April to June. The surface subsidence resulting from caving in the hanging wall acts as a water catchment and gives rise to temporary water influx problems in the mine. Each level has its own pumping station. At other times the mine is relatively dry. Prior to mine development two rivers crossing the surface of the deposit were diverted. This has not given rise to any subsequent water problem during mining.

The mining section is required to record any loss of reserves during mining in order to effect monthly and quarterly planning. The mine operates on a 3 shift basis 6 days per week.

Production

The mill produces copper, lead and zinc concentrates. Annual production is around 500 to 600 tonnes copper as 24% Cu concentrates and 10,000 tonnes zinc as 55% Zn concentrates. The mill also produces 60,000 tonnes of fluorite per year. The domestic requirement is for 95% fluorite grade; for export this is 97%. Some 40% of plant production was for export. Last year no fluorite for export was produced. There is no barite production but there are plans to produce barite from tailings. Mill feed contains 3% ore obtained from other commune member mines. The copper lead and zinc concentrates are railed to the custom smelter at Chuchow, 20 km E of Huangtan, Hunan province.

Unfortunately the reliability and authenticity of the production figures quoted at several stages of the visit were lost in the translation processes. Given the above metal production figures, ignoring the 3% outside ore source and assuming a 90% mill recovery for lead and zinc, an annual ore throughput of around 650,000 tonnes is indicated at the geological grades quoted earlier. At 30% dilution, this adds a further 180,000 tonnes. The mine, therefore produces 830,000 tonnes of diluted ore p.a.

In the opening technical session mine production was quoted at 1 to 1.2 million tonnes per annum, and some time later a figure of 4000 tonnes per day was used. The latter is quite consistent with this if one assumes 300 operating days per year. It does seem, however, that these statistics are not true production figures and merely reflect the theoretical capacity of the mining operation. The correct annual production is more likely to be in the range 800 to 850,000 tonnes per annum (diluted ore).

Costs

Delegation members tried to obtain payment figures for metals produced by the various mines. Given the nature of communal ownership and the Chinese social structure, the figures obtained were regarded by Delegation members as reflecting more the reimbursment of the operation's working and capital replacement costs rather than prevailing commodity prices.

Payments received by Taolin were as follows:

Copper	4200 - 4500	Y/tonne	contained	metal
Lead	1400	"	"	"
Zinc	800	"	"	"
Fluorite	160	"	concentrates	

(The export price c.f. domestic price for Fluorite is 100 Y/t:)

Given the annual production figures quoted above, total mine receipts were, therefore:

Copper	(550 x 4350)	=	2 392 500	Y
Lead	6000 x 1400	=	8 400 000	Y
Zinc	10,000 x 800	=	8 000 000	Y
Fluorite	60,000 x 160	=	9 600 000	Y
	Total, say		28.4 million	Y

As the mine produces around 830,000 tonnes of diluted ore, and ignoring custom milling, receipts amount to 34.2 Y/ton mined and milled.

METALLURGY

(contributed by R.E. Wilmshurst)

Ore from the mine, diluted with waste to grades approximately 30% below the geological values given above, is railed 5.6 km to the treatment plant.

Gyratory crushers are used throughout, reducing the ore in three stages, with 2 crushers each 2.5m diameter in parallel in the tertiary stage to give a product essentially minus 30mm. Three ball mills are used, each 3.2m diameter and 3.1m long, driven by a 600 kw motor and operating in closed circuit with a twin screw spiral classifier. The classifier overflows feed to direct to flotation, the sizing at this point being 50% minus 150 µm. Power and steel consumption are 30 kwhr/t and 1.5 kg/t respectively.

In the first flotation stage, sphalerite and pyrite are depressed using zinc sulphate and thiosulphate, while chalcopyrite and galena are floated, using xanthate in the normal way. Subsequently the galena is depressed with dichromate and the chalcopyrite floated. The copper concentrate grade is 24% Cu; the lead concentrate grade is 70% Pb.

Tailing from the copper-lead float is retreated, using copper sulphate and further xanthate to float the zinc into a concentrate of 55% Zn grade. Finally fluorite is floated using fatty acid. All fluorite produced is of acid grade, containing more than 95% CaF_2. About 40% of the fluorite is of premium quality, better than 97% CaF_2, and is exported to Japan and elsewhere.

Recoveries of base metals are around 80%, although copper recovery is somewhat lower. Silver recovery is poor, and the silver is spread through the sulphide products. Fluorite recovery is much lower, probably below 50%.

Flotation concentrates are thickened and filtered, using rotary disc filters. Sulphide concentrates are shipped as filter cake, only the fluorite being dried.

Three metallurgical problems are noteworthy. Firstly, in common with many similar operations, silver metallurgy is poor, the overall recovery being low and the recovered silver being distributed. Secondly, as mentioned earlier, barite in the ore reports with the fluorite, thereby producing off-grade product. For this reason parts of the orebody which are high in barite are not being worked. Finally, the lead and zinc minerals in some parts of the orebody exhibit surface oxidation which has an adverse effect on flotation performance.

As with other plants visited by the delegation, the electrical systems in the plant were of very poor standard. The absence of guards around belts and rotating machinery and the lack of hand rails in many sections suggest that the accident rate in the plant would be very high by comparison with similar operations in Western countries.

ORE RESERVES

The Chinese have adopted the Russian standard for ore reserve classification, and although no specific tonnages and grades were supplied, it is worth noting the general basis of this classification. Category A is proved reserves, category B covers indicated reserves and category C is for inferred reserves except that it is a category somewhat more definite than the usual sense of inferred reserves.

The original drilling grid for Taolin was 100 m x 50 m and the grades and tonnages based on this grid were classified as C1 reserves. This grid was expanded from 50 m to 25 m to a depth of 200 m and this had the effect of transferring the reserves in this block to the B category. Mine planning and development proceeded on this basis.

Actual reserve figures were not supplied. The Chinese stated that they had sufficient reserves for a 20 year operation. As discussed in the section on Production, annual undiluted ore production is around 650,000 tonnes suggesting that the geological reserves are around 13 million tonnes. It is assumed that the geological grade for this is the same as that quoted for the mine average, i.e. 1.06% Pb, 1.69% Zn and Fluorite 15.7%. As mentioned earlier, no cut off grade is applied, and there is a general deterioration of grades with depth.

The Chinese stated that on the basis of reserves (but not by annual production) Taolin was China's largest lead zinc deposit. This does not reconcile with published data and probably reflects the technical isolation of the mine operators. The Fankou mine north of Shaoguan in Guangdong province has reserves of 30 m tonnes of 11% Zn and 5% Pb. The largest lead zinc mine in China is the Shuikoushan mine in Southeastern Hunan Province (World Mining October 1979).

TABLE 2

TAOLIN ROCK ANALYSIS

One sample of each		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	**Loss on Ignition**
Gneissic Granite	120m level	78.40	0.01	11.85	0.49	1.00	0.02	0.12	0.49	4.00	2.40	0.023	0.80
Sericite-chlorite schist	120m "	74.30	0.48	10.58	4.59	1.50	0.06	1.16	0.82	0.36	3.26	0.11	2.22
Altered granite breccia	120m "	72.12	0.21	14.41	0.25	1.78	0.02	0.37	1.73	3.18	4.84	0.087	0.27
Pegmatite " "	120m "	72.28	0.14	14.45	0.21	1.87	0.01	0.54	1.86	3.10	4.54	0.078	0.41
Sericite-chlorite quarts	120m "	86.82	0.11	2.67	0.18	1.52	0.01	0.18	3.87	0.10	1.48	0.048	1.65
Sericite-chlorite schist	120m "	63.56	0.77	16.33	1.18	6.05	0.10	2.12	0.43	1.38	4.30	0.160	2.87
Silicified phyllite	200m "	71.66	0.65	12.92	1.06	3.70	0.01	1.04	0.72	1.32	2.96	0.165	2.05
"Breccia like"granite	80m "	83.92	0.10	5.90	0.44	1.33	0.02	0.33	1.92	0.98	2.90	0.037	1.40
"Phyllite-like" slate (i.e. phyllitic)		64.28	0.78	16.44	1.53	4.55	0.08	1.87	0.69	1.78	3.78	0.192	3.14
"Phyllite like" sandstone		71.22	0.64	12.47	1.06	3.67	0.08	1.58	1.44	1.80	2.64	0.137	12.78
Metamorphosed sandstone		64.06	0.67	14.11	1.89	3.83	0.05	1.56	0.30	1.96	2.66	0.156	2.90
Phyllite		68.16	0.58	12.27	0.78	4.57	0.15	1.54	2.56	1.02	2.72	0.147	4.32

THE XIKUANGSHAN ANTIMONY MINES

By D.W. Suppel

ABSTRACT

The antimony ore deposits of the Xikuangshan area are stratabound and occur in a sequence of limestone and shale of Devonian age. The deposits have both stratigraphic and structural controls;

- they occur in limestone below a relatively thick shale sequence
- they extend eastwards from a major fault
- they occur in small anticlines arranged *en echelon* in a larger anticline

The main ore minerals are stibnite and antimony oxides (antimony ochres). The main alteration is silicification of the limestone host rocks. The deposits are believed to have formed at low temperatures mainly by the filling of fissures and, less importantly, by replacement.

Current annual production is about 10 000 to 12 000 t of metal from two mines. Current reserve estimates indicate a mining life of about 20 years.

The ores, with grades in the range 2.5 to 3.3% Sb, are treated by hand picking, gravity concentration and flotation. Concentrates are smelted to produce ingot of grade 99.85% or better. About 20% of this ingot is converted to high grade oxide prior to sale. Overall recoveries from ore into finished products range from 86% for sulphide ores down to 76% for ores rich in oxide mineral.

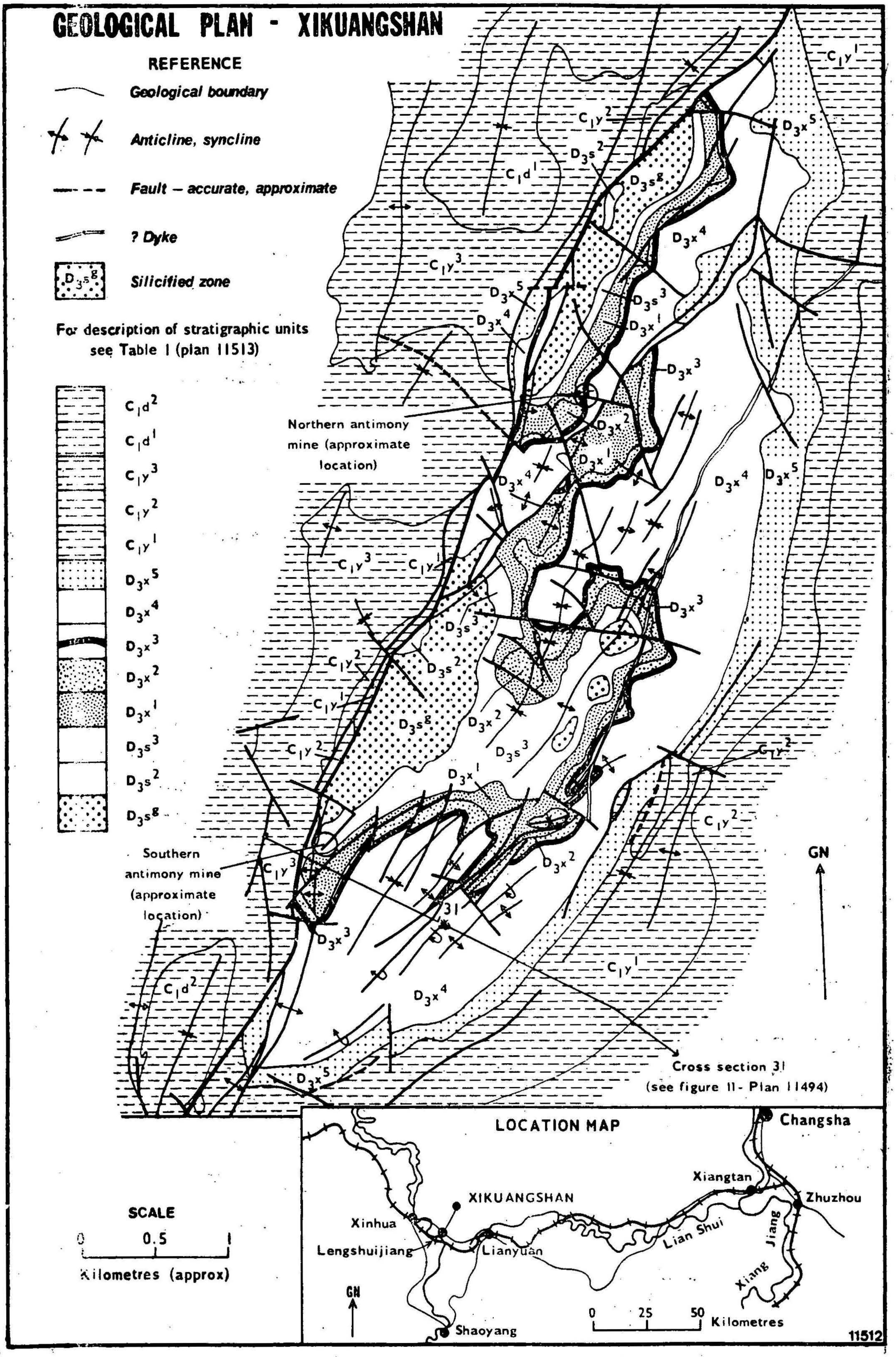


Figure 10. Geological Plan of Xikuangshan

GEOLOGY OF THE MINES

REGIONAL GEOLOGY

The rocks of the Xikuangshan area occur in a synclinorium extending from Lianyuan to Shaoyang in central Hunan Province. They were deposited in a depression during the Devonian. To the northwest, Early Palaeozoic and Late Proterozoic (Banxi Group) rocks have been exposed as a result of uplift in the Mesozoic.

This uplift is part of the Neocathaysian tectonic system. Many antimony deposits occur along the margin of the uplift.

There are two types of deposit:

- stratabound deposits mainly occurring in Devonian strata (the Xikuangshan type deposit)

- discordant deposits occurring in pre-Devonian metamorphic rocks.

Two intrusive bodies crop out in the Xikuangshan area. A northeasterly striking steep southeasterly dipping lamprophyre dyke, about 15 km in length, is situated about 22 km to the southeast of the mines. A granite body crops out about 25 km to the southeast of the mines. The granite is believed to be a high temperature type. Tin and tungsten mineralisation is associated with the granite.

DETAILED GEOLOGY

Stratigraphy

Interbedded limestone and shale of Upper Devonian and Carboniferous age crop out in the area of the mines. Middle Devonian limestone has been exposed at depth in the mines. No major unconformity has been mapped in the Xikuangshan area. Table 1 shows the stratigraphy and Figure 10 the surface geology of the Xikuangshan area.

TABLE I

STRATIGRAPHY – XIKUANGSHAN AREA

Age	Unit		Description	Thickness (metres)
Middle to Upper Carboniferous	C_{2+3}	Hutian Group		78
Lower Carboniferous (C_1)	C_1d^3	Tatang Group		90
	C_1d^2			110
	C_1d^1			380
	C_1y^3	Yenguan Group		178
	C_1y^2		Limestone, carbonaceous	35–60
	C_1y^1		Thick sandstone, shale at top	145–176
Upper Devonian (D_3)	D_3x^5	Xikuangshan Group	Interbedded sandstone and shale	116
	D_3x^4		Limestone	218
	D_3x^3		Shale with 1½ to 2 m thick haematite band	17–25
	D_3x^2		Limestone	25–40
	*D_3x^1	(* Xikuangshan Member)	Shale	45–60
	D_3s^3	Shetiangiao Group	Calcareous shale, intercalated bioclastic limestone	25–40
	D_3s^2		Limestone & silicified limestone	220
	D_3s^1		Sandstone	45
Middle Devonian	D_2q		Limestone	

The limestones probably are mainly bioclastic, with few or no reefs. Higher in the sequence, the Xikuangshan Group changes character to that of a shallower water facies. The topmost member, D_3x^5, contains fossil fish, mainly in sandstone. The limestone beds contain minor dolomite, but there are no dolomite beds. In the mine sequence, described in more detail below, the lower part of the unit D_3s^2 has the highest dolomite content. A mine geologist estimated that the highest dolomite content is still less than 10%.

Antimony mineralisation occurs within unit D_3s^2 of the Shetiangiao Group. This unit is overlain by two shale units (D_3s^3 and D_3x^1 , Table 1). The mineralised unit has been subdivided into three "beds", containing 28 "layers", as follows (from top to bottom):

"bed"	"layer"	description	approx. thickness (metres)
I	1	limestone	1 - 1.5
(average thick-	2	limestone & shale	2.5
ness 12 m)	3	limestone	5 - 6
	4	shale	0.3
	5	limestone	0.8
	6	shale	0.3
II	7	limestone	30
(average thick-	8	laminated limestone	16
ness 55 m)	9	limestone	6 - 9
	10	shale	2
III	11 to 28	alternating limestone	
(average thick-		and shale	
ness 150 m)			

Antimony mineralisation is confined mainly to the limestone layers and is more extensive in the top "bed" (bed I) and is least extensive in the bottom "bed" (see section on "Mineralisation" below). In bed I layers 1, 3 and, locally, 5 are mineralised. In bed II layer 7 is mineralised and layer 9 mineralised adjacent to the main fault (see below). Minor mineralisation occurs in the limestone layers of bed III; the shale layers are barren.

Tectonics

The Devonian strata in the Xikuangshan area occur in a major north plunging anticline. There are four smaller anticlines arranged *en echelon* within this larger structure. A major north-northeasterly trending fault and numerous subsidiary faults truncate the Devonian strata on the west (Fig. 10). The faults bring strata of Late Carboniferous age into contact with the Upper Devonian rocks. The stratigraphic displacement of the main fault is about 800 to 1 000 m. There has been repeated movement along the main fault, forming a zone of crushing 30 to 60 m wide.

Ore bodies extend to the east from the eastern (foot) wall of the main fault Fig. 11, which is a cross section of the southern main). The smaller *en echelon* anticlines are also considered to be favourable sites for ore.

Mineralisation

Antimony mineralisation in the Xikuangshan area has three main controls, briefly referred to above -

- the mineralisation is stratabound and occurs mainly in limestone in alternating limestone and shale occurring below a relatively thick shale sequence.

- the mineralisation extends to the east from the footwall of a major fault.

- the mineralisation occurs in anticlines.

The topmost mineralised layer, occurring in bed I immediately below the shale is the most extensive. In the south of Xikuangshan area it extends from the fault to the eastern limb of an anticline, a distance of over 400 m. The mineralised layer at the top of bed II extends to the axis of the anticline (200 m) and mineralisation in bed III extends only 100 m from the fault towards the axis.

As a general rule, the more extensive the mineralised layer is, the higher is the antimony grade. Antimony also is richest in the plunging sections of the anticline.

The main ore minerals are stibnite and antimony ochre (Sb_2O_3, stibiconite & (?) valentinite; Sb_2O_4, cervantite). Minor pyrite (about 1%) occurs in the shale. The main gangue minerals are quartz, calcite, barite, and fluorite. Stibnite occurs as idiomorphic and subidiomorphic crystals. These are the following structural ore types; laminated, brecciated, massive, disseminated, and drusy.

The dominant alteration is silicification of the host rocks, which is widespread. There are two major stages of alteration. The first stage is characterized by replacement by fine grained quartz, yielding mostly silicified limestone. Stibnite occurring with this first stage is fine grained and disseminated. Silicification accompanies and underlies the ore bodies, extending outwards from the footwall of the fault zone (Fig. 11). The second stage is characterized by coarse grained quartz which fills fissures, lines drusy cavities, and surrounds breccia fragments. Stibnite fills fissures and pores. This is the main stage of antimony mineralisation. Carbonate (mainly calcite), barite, pyrite and chlorite are also formed. Stibnite occurs with barite and calcite - this is considered to be a third stage of mineralisation. Associated stibnite and calcite mostly occur at the margins and at the base of the ore bodies.

Discussion

According to an analysis of monominerals the temperature of formation of minerals is believed to be as follows:

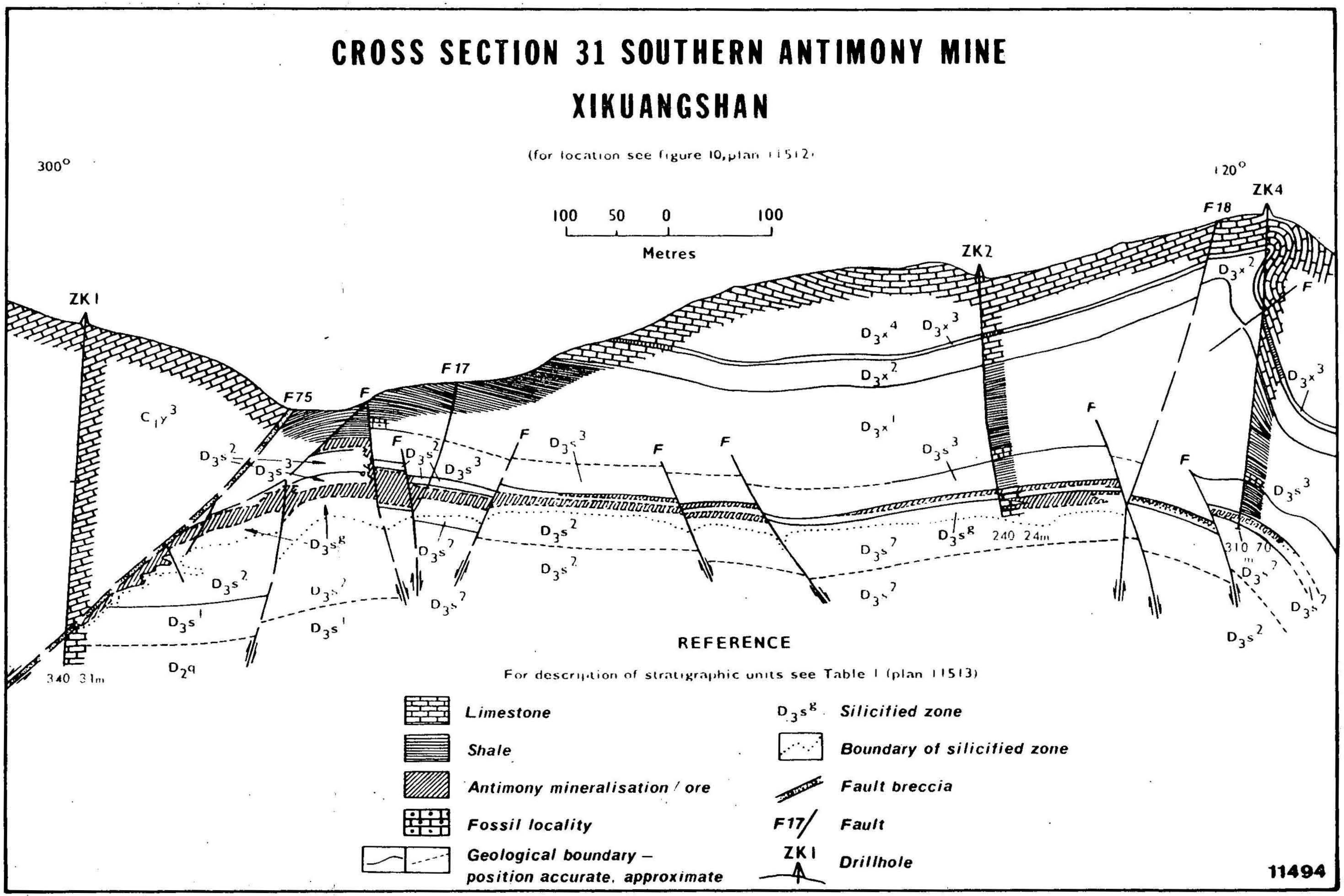


Figure 11. Cross Section 31 Southern Antimony Mine, Xikuangshan

stibnite	145 to 210 ^{o}C
calcite	140 to 220 ^{o}C
barite	145 to 190 ^{o}C
quartz	340 to 350 ^{o}C

The deposits are interpreted by the mine geologists to have formed at low temperatures, mainly by filling of fissures and to a lesser extent, by replacement.

Isotopic analysis of sulphur yielded a δS^{34} value of + 9.6‰. This result is interpreted as indicating that the sulphur of the deposits comes from depth within the earth's crust.

The sequence of limestone and shale below the Xikuangshan Group i.e. from the mineralised zone down, is about 700-800 m thick. It is (?)unconformably underlain by phyllite and slate. The shale at the top of the Shetiangiao Group and the base of the Xikuangshan Group (combined thickness about 100 m) is the lowest thick shale interval within the Devonian sequence. The mine geologists consider that this shale has acted as a barrier for mineralising solutions ascending the major fault. Upon reaching this barrier, the solutions have selectively mineralised strata on the footwall side of the fault, showing preference for limestone. The pattern of mineralisation is shown on figure 11. Limestone immediately beneath the shale is the most extensively mineralised, and mineralisation in this limestone extends farthest laterally from the fault. Below this, mineralisation in limestone extends progressively less far from the fault. A zone of silicification envelopes the ore beneath the shale. The overlying shale is not silicified or only very slightly silicified. There is very minor antimony higher in the Devonian sequence and no mineralisation in the Lower Carboniferous rocks which consist of carbonaceous shale and limestone and which presumably have acted as a barrier to mineralisation west of the fault.

There are some questions arising from this interpretation. The ore beds commonly contain brecciated limestone. The fault zone, which presumably was also a zone of brecciation and tension at the time of mineralisation, appears to contain no mineralisation. It is possible that later, non-mineralised, hot solutions have flushed out mineralisation from the fault zone. However, it is possible that the fault zone postdates mineralisation.

The SiO_2 content of the silicified limestone usually ranges from 70 to 90%, but locally reaches 98%. The evidence that these rocks were originally limestone is that a few silicified fossil fragments (brachiopods) have been found and that silicified units can be traced laterally to limestone. Nevertheless, it is possible that the silicified limestone is a cherty facies from time of deposition and not just the product of alteration.

The interpretation that mineralisation postdated faulting is favoured. The occurrence of antimony mineralisation in anticlinal positions suggests that structural control is important. The fact that mineralisation is stratabound is explained by a stratigraphic position which provided;

1. a limestone unit which brecciated during folding because of parting and significant movement along a contact with overlying thick shale

2. impermeable shale above the limestone

PRODUCTION

Total ore mined

The mines of the Xikuangshan area are among the oldest in China. Recorded production in the period 1892 to 1949 is 420 000 t of antimony metal. Between 1949 and 1978 260 000 t of metal were produced. Present annual production of metal is about 10 000 to 12 000 t.

Current production from the Xikuangshan area comes from two underground mines, a northern mine and a southern mine. The mines are roughly 4 km apart. The southern mine produces sulphide ore and accounts for 70% of total production. The northern mine produces mixed sulphide and oxide ore. Daily production of ore is about 1300 t from the southern mine and 500 t from the northern mine. Ore is mined from shafts using room and pillar methods, total extraction being achieved by the use of cemented fill. The entire production is smelted locally.

Grades

The geological grades of the southern and northern mines are 3.3% Sb and 4.8% Sb respectively. The respective mill (head) grades are 2.5% Sb and 3.0 - 3.3% Sb. Cut off grade for both mines is approximately 1.5% Sb. There is very little lead in the ore, and no gold is produced.

Reserves

To date reserves of 420 000 t of metal have been outlined, consisting of 130 000 t in the northern mine in ore averaging 4.8% Sb and 290 000 t in the southern mine in ore averaging 3.3% Sb. These reserves are stated to be proved, but no information is available about how they were established. One plan of the Xikuangshan area indicates that surface diamond drilling has been carried out on lines 150 m apart. Spacing of holes along these lines is variable, commonly 100 m to 150 m. The mine life is reported to be 20 years. Exploration is continuing.

Cost of Mining

The whole staff of the Xikuangshan Mining Bureau, which runs the two mines, is 6000 people. There are 2300 employed in underground mining operations, and 1300 in the ore dressing plants and smelters of both mines. The remainder are employed in machinery repair shops, electricity and water supply, transportation, schools, hospitals etc. The mines cover an area of 18 sq. km. The mines are worked by 3 shifts per day, 6 days per week. The smelters work continuously, the ore dressing plants and mining operations are shut down once a week. Currently the Mining Bureau receives 2450 Y per ton of metal from the State. This is reported to be profitable for this year (any profits are returned to the State). Thus, current production costs of antimony at Xikuangshan would be something less than 2450 Y per tonne.

It was reported that the previous year's production was 7000 t of metal, but an increase to 12 000 t was achieved when "profit sharing" was introduced as part of the new economic package of Chairman Hua. Under this scheme each mine "unit" (not specified) receives 5% of the profit up to the production quota, but 20% of the profit on production above the quota. The increase was achieved without any other changes.

YINGTAN NO. 60 URANIUM DEPOSIT

by K.R. Walker

ABSTRACT

The Yingtan No. 60 Uranium Deposit visited by the Delegation in N.E. Jiangxi Province of S.E. China is only in the exploration stage of development; but there are other deposits in the same province, such as No. 65 about 30 km WSW of No. 60, which are being mined for pitchblende and brannerite fissure fillings in ignimbritic tuff.

The No. 60 deposit occurs within the most mineralised horizon of the Jurassic/Cretaceous Ehuling Group rocks. The mineralisation is mainly associated with collophane in tuffaceous sandstone and siltstone, but some is associated with jarosite. The collophane type of mineralisation is either massive, colloform or disseminated, and uranium is probably adsorbed onto grain surfaces. The mineralisation is patchy and forms layers and lenses, and characteristically is stratiform and stratabound throughout. Grades range from 0.1 to 0.3% U_3O_8. Reserves have not been evaluated.

GEOLOGY

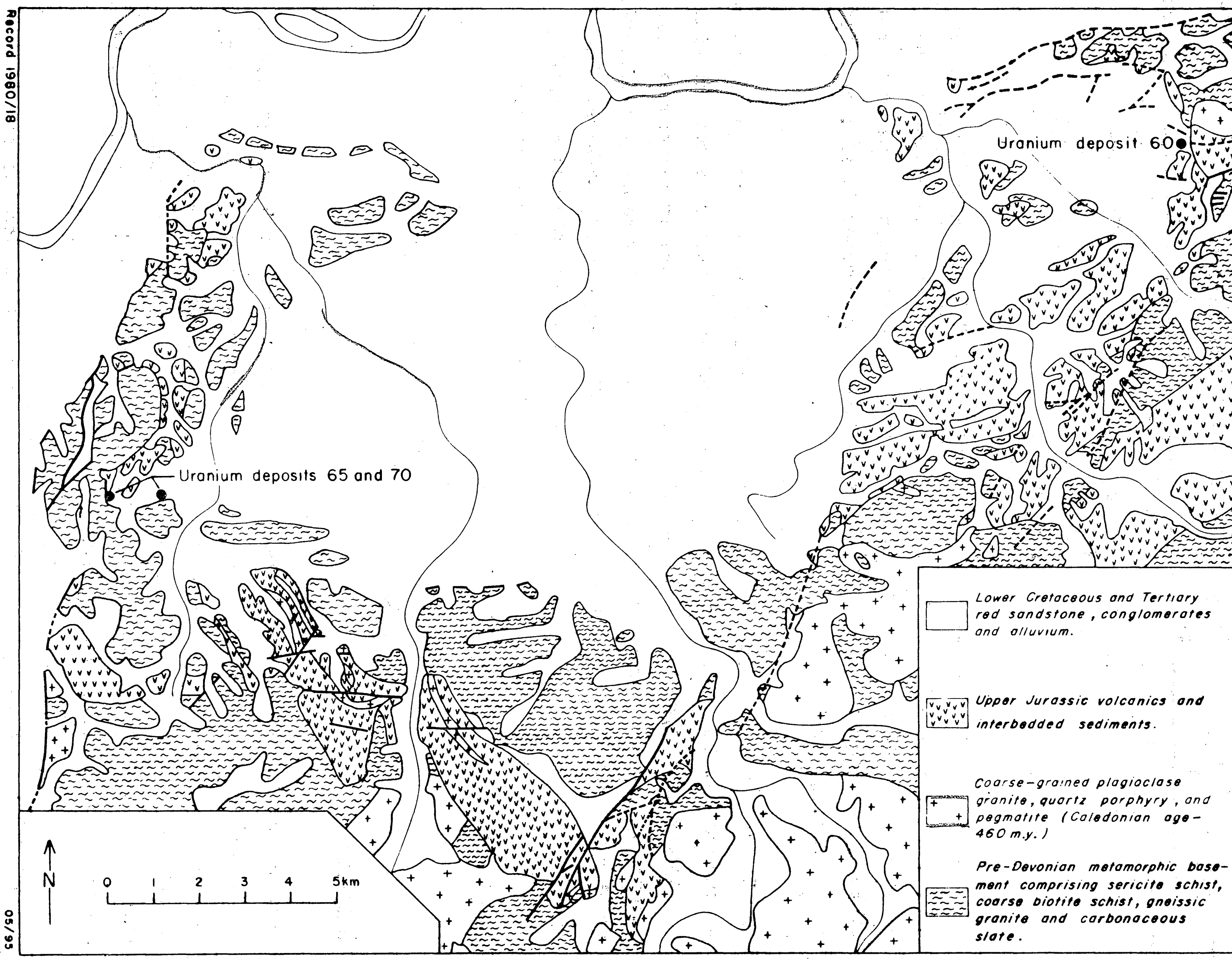
Location

Various uranium deposits are located in basin structures in NE Jiangxi Province, the deposit visited (No. 60) being about 50 km by road south of Yingtan city (Lat. 28°13' Long. 117°). Locally it is called the Jianzhu Deposit. It is situated in a subsidiary embayment at the NE corner of a diamond-shaped basin structure, about 25 km ENE of the main deposits (Nos 65 and 70) on the western margin of the structure (Fig. 12.).

The whole basin is referred to as Exploration Area 65, and is the responsibility of Exploration Team 265 from the Second Ministry of Machine Building. It measures 27 km from E to W and 20 km from N to S, and covers 318 km^2. Deposit 65 is being open-cut mined for pitchblende whereas Deposit 60 is only in the exploration stage of development, and there are no plans to proceed further than this for the time being.

Record 1980/18

Fig.12 Generalised regional geological map of Area 65 containing the Yingtan Uranium deposits, Northeast Jiangxi Province, China.



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Geological Setting

The ore deposits are associated with volcanics in the northern part of the NE-trending volcanic belt of SE China, where this intersects the junction zone of the Jiangnan and Cathaysian masses (cratons?). There is downwarping and faulting in this zone, and on either side of the downwarped zone volcano/sedimentary sequences developed in the Mesozoic and Cainozoic.

It is not known whether the downwarped zone is under compression or tension, but from the description given it would appear to have been a tensional zone at the time of volcanism as the structure forming the prospective mineralised basin is roughly circular and crudely reminiscent of a ring dyke structure.

The volcanics exposed along the margins are upper Jurassic in age, and contain some sediments. Cretaceous and Tertiary sandstones, conglomerates, red beds and alluvium occur within the basin, but intrusions or feeders to the volcanics have not been found. The maximum thickness of these sediments is 1500 m.

Area 65 has been mapped geologically at a scale of 1:25 000, and a more detailed geological map at 1:5 000 scale, covering the NE corner of the main basin structure, shows the embayment area containing deposit 60 and a small area to the west of this. This part of the basin is also composed of upper Jurassic volcaniclastic rocks and, as seen to the north, of a basement of pre-Devonian metamorphic rocks; and, thus, it is geologically consistent with the rest of the basin. The sub division of the volcano-sedimentary sequence applies equally to all of the basin, and is as follows.

Stratigraphy

The table shows the typical sequence of volcanics and sediments which is divided into 3 groups and 9 formations. Some of these formations are sub divided into members, but details were not provided for $J3d^{2}$, the formation that contains the main mineralised member $J3d^{2-2}$ found in deposit number 65. The stratigraphic table is compiled from the original Chinese version . The Lower Cretaceous to Tertiary red sandstones and conglomerates lie unconformably above the rock units shown in the table.

The stratigraphy of deposit 60 is essentially as shown under J3e in the Stratigraphic Table. The members are divided into lower (1) and upper (2) ore-bearing beds according to characteristics of the ore-bearing zones.

(1) $J3e^{3-1a}$ and $J3e^{3-1b}$ are regarded as the lower ore-bearing beds, and are characterised by bedded conglomerate and bedded tuff, shale, siltstone and some limestone.

(2) $J3e^{3-2a}$, $J3e^{3-2b}$, and $J3e^{3-2c}$ constitute the upper ore-bearing beds, and are characterised by bedded tuff with limestone and siltstone intercalations.

The lower ore-bearing bed has a higher volcanic content. Phosphatic and carbonate rocks are intercalated from top to bottom and carbonate apparently follows phosphate in time and space.

Limited isotopic dating undertaken so far provides dates consistent with observed geological events. A K-Ar age on sanidine in volcanics from $J3e^{4}$ gives a 127 m.y. age (minimum age), whereas U-Pb determinations in collophane-type ore from $J3e^{3}$ gives a 136 m.y. age, and the jarosite-type ore 106 m.y. age. This suggests that the collophane-type ore in $J3e^{3}$ formed before the volcanics in $J3e^{4}$.

Stratigraphic Table for Area 65

Groups	Formation	Members		Mineralisation
Shouchang	J3S	Liver coloured and grey-green sandstone intercalated with tuff lenses - contains ostracods - (parallel and angular unconformity) 0-873 m		
	J3e⁴ → $J3e^4$	Grey-purple and grey-green weakly welded tuffs 10-55 m		
			$J3e^{3-2c}$ Grey-black shale and siltstone with mineralisation at the base 40 m	
			$J3e^{3-2b}$ Grey, medium to fine grained sandstone and siltstone, argillaceous and sandy limestone; one of the main ore-bearing horizons 25-45 m	
Ehuling	$J3e^3$	20-300 m grey-white & grey-green bedded tuff and sandstone intercalated with shale and limestone	$J3e^{3-2a}$ Tuffaceous sandstone, medium and coarse-grained containing some pebbles; major ore-bearing zone 25-42 m	
			$J3e^{3-1b}$ Grey-black sandstone, shale and conglomerate with weak mineralisation 0-15 m	
			$J3e^{3-1a}$ Variable, but composed mainly of sandstone and conglomerate at the base; some siltstone and grey-white fine bedded tuff breccia with mineralisation 0-80 m	
J3e	$J3e^2$	Grey-purple welded tuff including volcanic bombs and glassy tuff. 0-187 m		
	$J3e^1$	Variety of purple tuffaceous sandstone and bedded tuff on basal conglomerate containing pebble clasts including andesite pebbles 0-10 m (angular unconformity)		
	$J3d^4$	Greyish purple andesite/basalt 0-140 m		
	$J3d^3$	Purple-red siltstone including biotite and glassy tuffs and calcareous concretions 100-380m		
Daguling		Grey-white volcanis welded tuff; glassy tuff 10-200 m	$J3d^{2-3}$	
J3d mainly red clastics and volcano clastics with a few lavas	$J3d^2$		$J3d^{2-2}$ No details supplied	
			$J3d^{2-1}$	
	$J3d^1$	purple-red mica-bearing clastics with tuff lenses 0-273m (unconformity)		

Pre-Devonian Rocks

Structure

Two fault systems are observed: (1) E-W striking thrust zone in which the younger rocks are overthrust to the south and the fault plane dips north, and (2) a NNE striking fracture zone.

Throughout the eastern part of the basin structure dips are west, and in the northern part they are south, but less steep being about 10-15^{o} south.

Mineralisation

The deposit 60 is an exploration prospect in which ore grades are too low and mineralisation too deep to warrant mining. Moreover, the ore is patchy and problems of ore treatment have not been solved yet.

This contrasts with mineralisation elsewhere in the area; so far mineable ore has been found only in two deposits, numbers 65 and 70. At deposit 65 mineralisation is in a zone of thrusting in fissure fillings in ignimbritic tuff, and there is silicification, chloritisation and kaolinisation associated; it formed after the main structure about 85 m.y. ago. Mineralisation as pitchblende is in $J3d^{2-2}$, and is sufficiently rich to warrant open-cut mining. Some brannerite is present. Although the ore is stratabound, structures in the enclosing rocks are complex as a result of deformation. This deformation also provided the access fissures for mineralising solutions to penetrate from the associated volcanics.

Apparently uranium is widespread throughout the stratigraphic succession, and the most uraniferous members are shown in the stratigraphic table, the richest members being $J3d^{2-2}$ and $J3e^{3-2a}$. $J3d^{2-2}$ does not occur in deposit 60. The mineralised zones form layers and lenses, and characteristically throughout the mineralised area are stratiform and stratabound. Much of the uranium is associated with collophane (collophanite $Ca_3P_2O_8H_2O$) and jarosite ($KF_3(OH)_6(SO_4)_2$). The Th/U ratio is about 0.3 for the whole area.

The mineralised zone in deposit 60 is $J3e^{3-2a}$ where mineralisation is associated with collophane in tuffaceous sandstone and siltstone. The zone is 25-225 m long in a N-S direction, and is from 55 to 240 m down dip. It ranges from 5-30 m in thickness. Mineralisation improves at depths below 150 m. Grades range from 0.1 to 0.3% U_3O_8, but no class A ore tonnages have been calculated. Because of the patchiness of the ore, reserves are hard to estimate.

There are two types of mineralisation present. The main type is uranium associated with collophane, and the other, which only occurs locally, is uranium associated with jarosite. The collophane type of mineralisation is generally massive and colloform with disseminated uranium.

On the basis of lithology the uranium mineralisation is further divided according to :

(1) tuffaceous type
(2) tuffaceous-sandstone type
(3) siltstone type

The uranium mineralisation in these rock types is similar. The main constituents in (1) are collophane, quartz, dickite, hydromica, and chalcedony. The minor constituents are calcite, pyrite, siderite and organic material (1-2%). In addition, there is some fluorite, sphalerite, chalcopyrite and molybdenite, but these metal sulphides and fluorite are much more common and characteristic of the jarosite type.

Type (2) is greyish black uranium associated with jarosite mineralisation containing ilsemannite, a bluish molybdenum-bearing mineral. This variety of mineralisation is colloform and in stockworks.

Type (1) has lower Si, K, and Na and higher P_2O_5 and CaO than type (2), and the U content is inversely proportional to Si content, and directly proportional to P; phosphorus has a correlation coefficient of 0.8 to 0.9 with U.

Fig. 13. Mineralised outcrop, Yingtan Uranium deposit.

In type (2) uranium decreases proportionately with Na, Ca, and Si, but increases with Mo. The correlation of U with P_2O_5 is complex, but there is a weak correlation between Mo and P_2O_5.

The jarosite-type U mineralisation is superimposed on the collophane type, and thus, is the later of the two types. The U-Pb age determinations are also consistent with this sequence of mineralisation events.

Gold was analysed for but none was detected.

Ore concentration processes and genesis

Two alternative explanations were advanced to explain the uranium-mineralising process.

(i) Uranium is adsorbed on colloidal collophane, and
(ii) Uranium is an isomorphic material, but some occurs in clay minerals, organic and colloform pyrite.

Hydrothermal alteration resulting in clay minerals is widespread, including the mineralised zone where formation of mica, quartz, dickite and carbonates can be attributed to this process.

There are two views on ore genesis:

(i) As the collophane type is associated with continental type volcanics and clastics, the advocates for a hydrothermal origin suggest that the collophane type U mineralisation and associated alteration resulted from hydrothermal solutions of volcanic origin being stratigraphically and structurally controlled during emplacement.

(ii) Advocates for a sedimentary origin look to both stratigraphic and lithological controls, and of a type similar to those forming marine and continental phosphorites. They claim that the sedimentary origin for the ore is supported by the fact that the bulk of the mineralisation is the collophane type, and that the jarosite-type mineralisation that follows is much less significant.

EXPLORATION AND FIELD PROCEDURES

Geophysical

The deposit was discovered by aerial radiometric (gamma) survey, and maps of 1:10 000 scale were compiled. The anomaly which was 10 times background was marked by flour bomb. The aeroradiometry was flown by the Provincial Airborne Division who classified the anomalies. This survey was followed in 1971 by ground scintillometer survey. Geiger counter anomaly is 14 times background.

Geochemical

Ground investigation also involved trenching, sampling, assaying and finally drilling. Trench assays indicated U_3O_8 in the range 0.1 to 0.3%. The presence of phosphorous in the field is monitored using the ammonium molybdate test.

Where the mineralised zone $J3e^{3-1a}$ crops out in the deposit 60 area, the gamma radiation is more than 10 times background and U_3O_8 is 0.1%. The ore zone is only 0.6 m thick.

A geochemical map showing U distribution based on a 1 metre grid spacing highlights this outcrop area as the major geochemical anomaly.

Drilling

The area containing deposit 60 has been drilled on a 50 x 50 m grid. However, initial drilling was on a 400 m square grid, and 18 holes were drilled before significant mineralisation was intersected. Two typical diamond drill cores were exhibited.

a. Core 2K 910-1 is 38 mm core 450 m long (90% core recovery). It illustrated a complete stratigraphic section through all members of 3 formations. Both core and hole were logged at 10 cm intervals with a gamma meter discriminating between Th and U content. The core was split and check assays were made. The mineralised zone (collophane type) was about 100 m down hole. Locality of the hole was not available.

b. Core 2K 1110 was located 50 m from hole 2K 910-1. It is 300 m long (85-90% recovery), and intersected jarosite-type mineralisation and zones of sulphides. Fluorite is seen in veins. Zones intersected were (1) 35 m of Mo averaging 0.05% MoS_2 (maximum 2.2%) and showing typical blue colouration of ilsemannite; (2) 19 m of U mineralisation containing 0.155 U_3O_8; (3) 27 m averaging 0.18% U_3O_8; and (4) 12 m of Th containing 0.2% Th.

THE DEXING COPPER DEPOSIT

by P.J. Legge

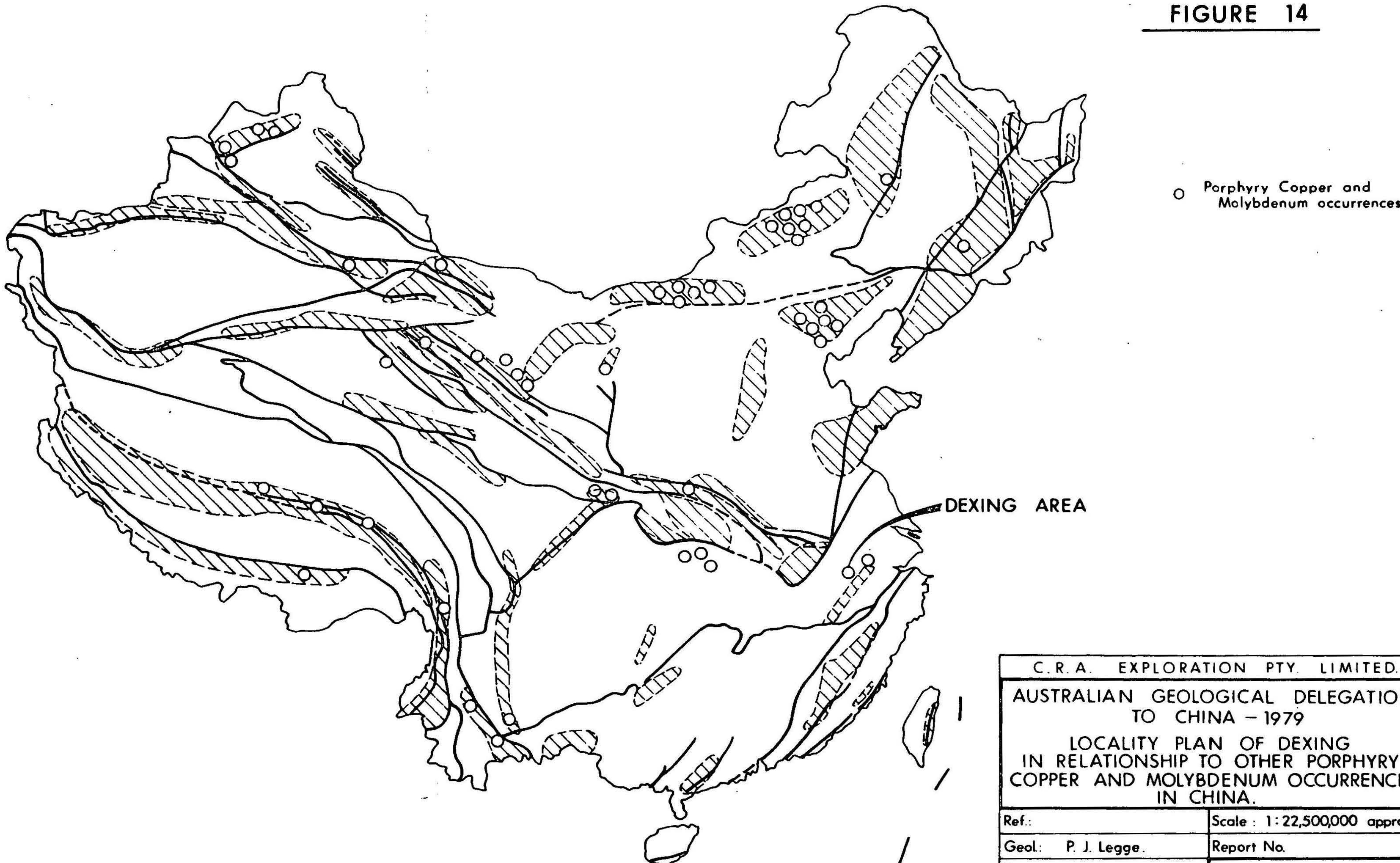
ABSTRACT

The copper porphyry deposit at Dexing, in northeast Jiangxi province of SE China ranks with the world's largest deposits of copper. The Tongchand (No. 2) open cut mine contains copper metal reserves in excess of 5 million tonnes at an in situ grade of 0.46% Cu, 0.01% Mo and 0.2g Au/t. Two other deposits located respectively 2 km northwest and southwest of Tongchand have potential to contain reserves 30 - 100% those of Tongchand.

At the Tongchand mine a NW elongated elliptical granodiorite stock of Jurassic age sharply transgresses weakly metamorphosed, poorly bedded Proterozoic tuff and phyllite. Sulphide mineralisation and secondary alteration are concentrated in a zone 200 m either side of the contact. The best copper mineralisation (greater than 0.4% Cu) is coextensive with the most intense secondary alteration which includes siliceous, carbonatic and chloritic phases. Supergene enrichment is absent in the deeply incised hilly sub-tropical region and oxidation depth is typically less than 20m. Copper mineralisation grading greater than 0.3% Cu is distributed in an elliptical area 2.5 km long and 1.2 km wide and to a depth of at least 800 m below surface.

Total sulphide content is about 5% and pyrite is the most abundant sulphide mineral. Chalcopyrite, the principal copper mineral, occurs mainly in fine veinlets. Dexing copper was known in the first century A.D. but systematic mining commenced only in 1967. Current production from the Tongchand open cut is 7 000 tonnes of ore and 20 000 tonnes of waste each day; a major increase in production to 130 000 tonnes per day is being considered. Fluor Corporation are understood to have conducted engineering studies to construct a new processing plant.

FIGURE 14



C.R.A. EXPLORATION PTY. LIMITED.

AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA – 1979

LOCALITY PLAN OF DEXING IN RELATIONSHIP TO OTHER PORPHYRY COPPER AND MOLYBDENUM OCCURRENCES IN CHINA.

Ref.:	Scale: 1:22,500,000 approx.
Geol: P. J. Legge.	Report No.
Drawn: January 1979	Plan No. M 1130

INTRODUCTION

The Dexing prophyry copper deposit is located in Jiangxi Province, SE China about 160 km ENE of Nanchang at 28°55'N, 117°33'E. The Australian Geological Delegation 1979, as guests of the Ministry of Geology, visited the mine on the 19th and 20th October 1979. The mine is reached from the railway town of Yingtan by driving for two hours along low gradient tarred and gravel roads along the river plains of the Xin Jiang and Le'an Jiang Rivers.

The mine is set in deeply incised hills which rise to 240 m above local river level. The highest point, close to mineralisation, lies at 420 m above sea level. Pollution controls are negligible and the river cutting the main deposit is loaded with ferric iron.

The Delegation was received warmly by Chinese hosts which included the Head of the NE Jiangxi Geological Brigade - Xiu Ji Shend, geologist engineer - Hu Kui, geologist field technician - Fan Mei Sheng, mining engineer - Xie Tong Ke and metallurgist - Zhen Xie Peng. The data made available was restricted almost entirely to the main deposit - Tongchand No. 2.

This paper documents translated data and observations of the Dexing copper deposit.

REGIONAL GEOLOGY

Dexing lies north of the South China Fold System within the tectonic unit known as the Yangtze Platform where the Mesozoic rests directly on Proterozoic basement. Caledonian tectonic patterns were strongly modified by Mesozoic tectonics particularly along a NNE trend when shearing caused differential uplift and downwarp associated with the Neocathysian System of Professor J.S. Li. Dexing is regarded as being located in Li's second uplift zone. Subjective considerations have led to the inference of an ancient subduction zone underlying this region, reactivation of which produced the Yenshen granites in the Mesozoic at deep crustal levels. The location of the Dexing porphyry copper deposit in relation to other prophyry copper and molybdenum deposits in China is shown on Fig. 14.

The regional rock distribution at Dexing is shown as Fig. 15. Basement rocks, containing microfossils which correlate with the Upper Proterozoic of Northern China, appear to be predominantly of volcanic and volcaniclastic origin. Principal lithology is of finely cleaved phyllite and tuff (symbol on figure: Zsh). Both glass and crystal dacitic tuff are present. Other phases include rhyolite, basalt, andesite tuff sandstone and phyllite (Zz_1z_1); sericit slate with tuff and andesite (Zz_1z_2) and carbonaceous cherty siltstone, sandstone limestone and clastic dolomite (Zzx).

A radiometric Rb-Sr age of 1401 m.y. B.P. was obtained on phyllite. The basement is broadly folded but lack of distinctive bedding especially in the tuff and phyllite (Zsh) has required structural inference based on cleavage orientation. The principal "synclinorial" structure is the Sizhoumiao NE trend synform lying 1.5 km to the north of the mine area (Fig. 15).

Younger basins of Jurassic age formed adjacent to major NE trend faults and are preserved south east of the mine.

Regional magmatism is varied in age and composition as shown on Table 1 and Fig. 15. Oceanic style magmatic activity is recorded in the Proterozoic followed by Cambrian gabbro and diorite stocks located to the north west of Dexing copper. The Dexing porphyry copper mineralisation is associated with Jurassic (160-170 m.y. B.P.) granodiorite stocks and an associated alteration which envelopes an area several times that of the granodiorite intrusions (Fig. 16).

LOCAL GEOLOGY

The Dexing copper deposits are associated with the margin zones of a series of granodiorite stocks and veins of middle Jurassic age which transect a sequence of Proterozoic tuffs and phyllites on the southern limb of a regional NE trend synform. A major NE trend fracture line lies to the southeast of the granodiorite stocks (Fig. 15). Mineralisation extends for 200 to 300 m on both sides of the contact between the granodiorite and the tuff. Field observation by the delegation established that the finely cleaved and altered tuff is cut by uncleaved altered granodiorite along irregular but sharp contacts.

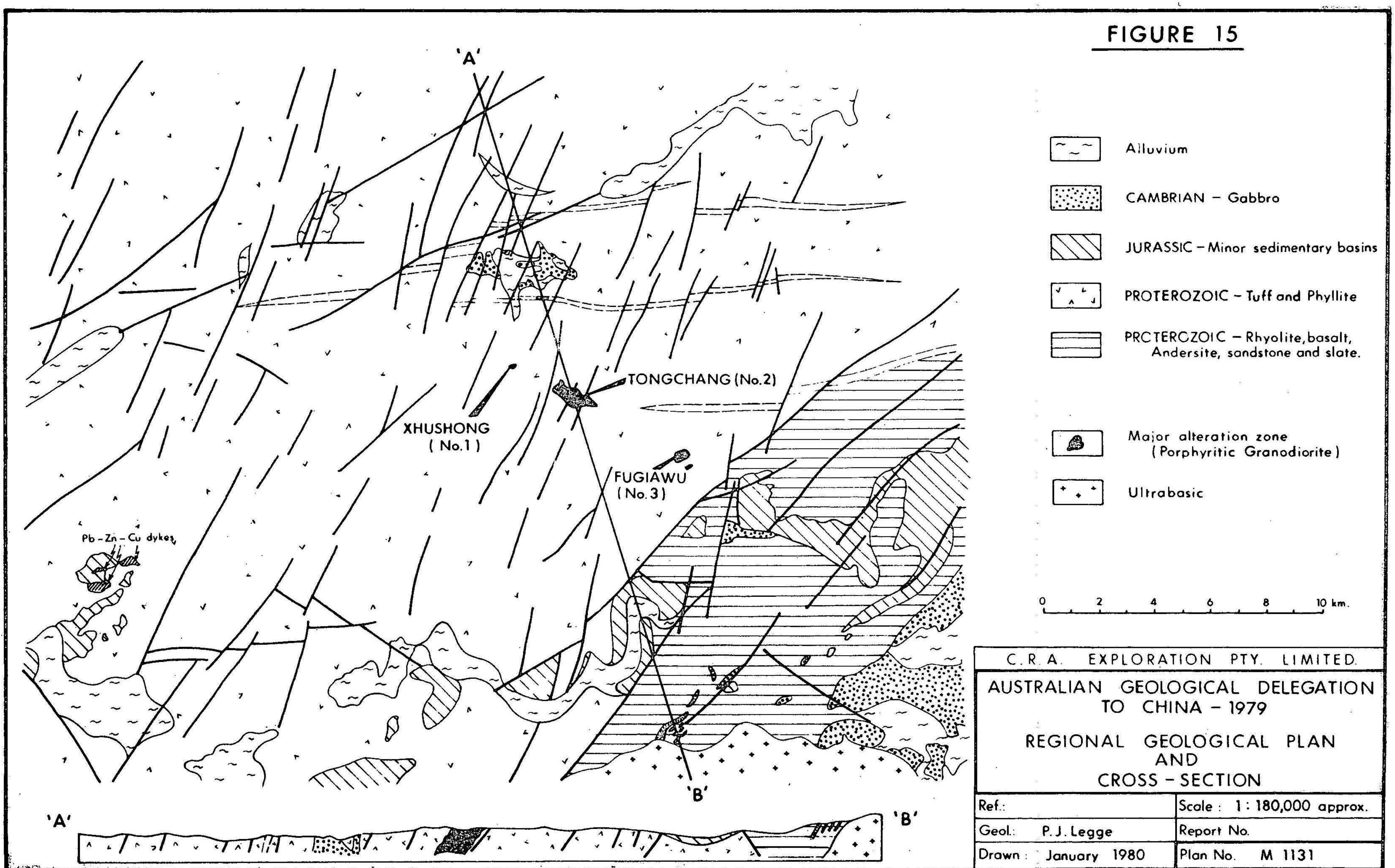


FIGURE 15
'A'
'B'
TONGCHANG (No.2)
XHUSHONG (No.1)
FUGIAWU (No.3)
Pb - Zn - Cu dykes
Alluvium
CAMBRIAN – Gabbro
JURASSIC – Minor sedimentary basins
PROTEROZOIC – Tuff and Phyllite
PROTEROZOIC – Rhyolite, basalt, Andersite, sandstone and slate.
Major alteration zone (Porphyritic Granodiorite)
Ultrabasic
0 2 4 6 8 10 km.
C.R.A. EXPLORATION PTY. LIMITED.
AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA – 1979
REGIONAL GEOLOGICAL PLAN AND CROSS – SECTION
Ref.:
Scale : 1 : 180,000 approx.
Geol.: P. J. Legge
Report No.
Drawn : January 1980
Plan No. M 1131

TABLE 1

DEXING PORPHYRY COPPER DEPOSIT

REGIONAL MAGMATIC SEQUENCE

K	Cretaceous - Late Yenshan Period		
			intermediate, basic dykes Radiometric Age 104 My BP
J	Jurassic - Early Yenshan Period		
		5.	dacite porphyrite dyke with associated lead zinc, copper in minor quantities
		4.	coarse grained diorite porphyrite nearby and cutting granodiorite porphyry
		3.	granodiorite porphyry with principal copper, gold and molybdenum mineralisation. Radiometric age 161-170 My BP
		2.	granite in batholithic proportions mainly of coarse to medium grained porphyrite biotite granite, outcrops SE of Dexing mine. Radiometric age 183- My BP
		1.	ultramafic rocks including pyroxenites (hartzburgite and peridotite), chromium bearing.
T-D	Ordovician to Devonian - Hercynian		
			metamorphosed basic intrusives, mainly fine grained - radiometric age approximately 269 My BP.
E	Cambrian - Caledonian		
			Gabbro and diorite stocks. Age 503 My BP
Z	Sinian - Upper Proterozoic		
			Metamorphosed basalt andesite rhyolite porphyry. Metamorphosed amphibolite, gabbro and oceanic magnatism.

The tuff lacks observable bedding planes and the geometry of detailed structure is by inference based on orientation foliation and fractures only.

The granodiorite has a uniform texture and similar composition throughout the area; composite bodies, according to the Chinese, are not present. Outcrop area exposed was given as No. 1 granodiorite 0.06 km^2, No. 2 granodiorite 0.72 km^2, No. 3 granodiorite 0.2 km^2. The three stocks plunge to the northwest at about 50^o and are distributed as shown on Fig. 16.

Composition of the No. 2 granodiorite was given as:-

plagioclase (49.0%) mainly occurs as zoned phenocrysts with a composition and An_{46-36} and also in the groundmass with composition An_{15}.

potash feldspar (14.5%) mainly occurs as orthoclase in the groundmass but alteration microclinisation is also present.

quartz (20.5%) occurs as corroded phenocrysts and in the groundmass.

hornblende (8.5%) occurs as phenocrysts.

biotite (4.0%) occurs as idiomorphic pseudohexagonal crystals.

accessories magnetite, apatite, zircon and sphene.

Analysis for trace elements of a very weakly altered, unmineralised sample gave Cu 180 ppm, Mo 4 ppm, Au 0.04 ppm, Co 10 ppm.

Whole rock analyses are given in Table 3. The No. 3 granodiorite is reportedly more acidic than the No. 2 granodiorite. Acid dykes mapped at surface have been found to indicate concealed stocks at depth, and small scale explosion breccias have been located outside the main granodiorite body. The marked change in orientation of foliation of the host sequence in the vicinity of the granodiorite is not believed to be related to intrusion.

TABLE 2

DEXING PORPHYRY COPPER DEPOSITS

TONGCHAND (No. 2) MINE

DIAMOND DRILL HOLE INTERSECTIONS ON SECTION 11.

Note: Details tabulated below are taken from section 11 displayed on site at Dexing. The intersections listed are those which grade equal to or in excess of 0.4% Cu on average.

Hole No.	Termination Length	Intersection m	Assay % Cu.
ZK 1109	507.72 m	4.0	0.4
		36.4	0.55
ZK 1103	551.35	10.33	0.41
		2.71	0.46
		2.65	0.40
		15.24	0.40
		23.58	0.41
		2.7	0.4
		105.08	0.4
		16.92	0.4
ZK 1115	393.37	13.30	0.41
		13.5	0.42
		5.13	0.4
		17.46	0.41
		37.16	0.4
		4.71	0.4
		32.67	0.4
		2.18	0.44
		22.74	0.4
ZK 1114	373.12	28.01	0.4
		198.08	0.41
ZK 1113	302.26	16.63	0.4
		63.39	0.41
		161.81	0.48
ZK 1112	260.04	59.06	0.43
		4.57	0.41
		Balance	0.3 - 0.4

Hole No.	Termination Length	Intersection m	Assay % Cu.
ZK 1111	293.96	16.36	0.53
		22.48	0.4
		4.8	0.53
		10.56	0.4
		Many barren zones	
ZK 1104	370	298.61	0.51
ZK 1107	430.52	285.27	0.47
ZK 1101	663.11	413.8	0.45
		5.26	0.47
		3.73	0.40
ZK 1110	473.52	209.21	0.49
		bottom in ore	
ZK 1105	656.95	53.52	0.4
		121.43	0.52

Attempts by the Chinese to systematize the nature and sequence of fracturing have been detailed. Strain ellipsoid concepts of failure under shear and tension have been used to explain fracture relationships, but this work does not seem to have been translated into practical criteria to assist exploration. Fracture patterns in the Dexing area are shown in Fig. 16. There was no evidence that the Chinese have measured fracture intensity (eg. ROD); at the locations inspected, fracture intensity in the porphyry was highly variable. Centimetric scale irregular tension fractures were observed together with more widely spaced decimetric joint sets in the open pit. There are no obvious controls by major fracture setson the distribution of mineralisation, but the bulk of the chalcopyrite observed lies along short irregular fractures in veinlet form.

DISCOVERY AND DEVELOPMENT OF THE DEXING PORPHYRY COPPER

Historical records indicate that Dexing was gouged by local inhabitants in the period 618 - 1279 A.D. but only in 1959 were reports of copper systematically investigated by geologists. Geological work at the Tongchand occurrence was followed by mining in 1967. Initially the northern part of the Tongchand area was developed using a caving method with railed haulage on two adit levels. The surface subsidence area seen by the delegation is reminiscent of that induced by block caving (Fig. 22); underground workings were not inspected. This caving operation was suspended when the north wall/north hill threatened to collapse onto the working area; minor landslip scars are evident on the northern hill and a major collapse may have already occurred. The operation was then transferred to an open cut in the southern part of the deposit where mining is current. Plans to enlarge the entire operation are now in hand.

Exploration in the region during the period 1959 to present has resulted in the discovery of two new copper occurrences - Xushong lying to the northwest of Tongchand, and Fugiawu to the southwest. These deposits are now numbered sequentially from the northwest to the southeast No. 1, No. 2, No. 3 (Fig. 14).

TABLE 3

Chemical and Mineral Composition of Rocks at Tongchan No. 2 Mine

Component / Content / Rock Type	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MnO %	CaO %	MgO %	K_2O %	Na_2O %	P_2O_5 %	H_2O %	Loss on heating	Pre-paratory Notes
Sericite phyllite	64.94	0.62	15.53	3.98	3.95	0.11	1.95	2.68	3.80	1.18	0.14	0.03	1.47	
Crystal tuff phyllite	65.56	0.64	16.45	1.47	3.28	0.15	0.41	1.55	3.32	3.22	0.20	4.02	1.50	
Sabulous phyllite	73.31	0.46	13.62	1.98	0.70	0.008	0.12	0.62	0.32	0.32	0.06	3.58	3.22	

Granodiorite Porphyry Mineral Composition

Mineral Type	Important Minerals %					Secondary Minerals (g/T)					
	Plagioclase	Quartz	Orthoclase	Hornblende	Biotite	Magnetite	Phosphorite	Zircon	Castellite	Orthite	Titanium Iron Minerals
Average Mineral Content	49	20.5	14.5	8.5	4	5260.5	350.5	194	145	71	Small Amounts

Chemical Composition of Granodiorite Porphyry

Analytical Component	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	H_2O	Loss on Heating
Average Content %	65.56	0.401	15.51	1.81	2.40	0.136	3.25	1.61	3.043	3.918	0.189	1.70	1.47

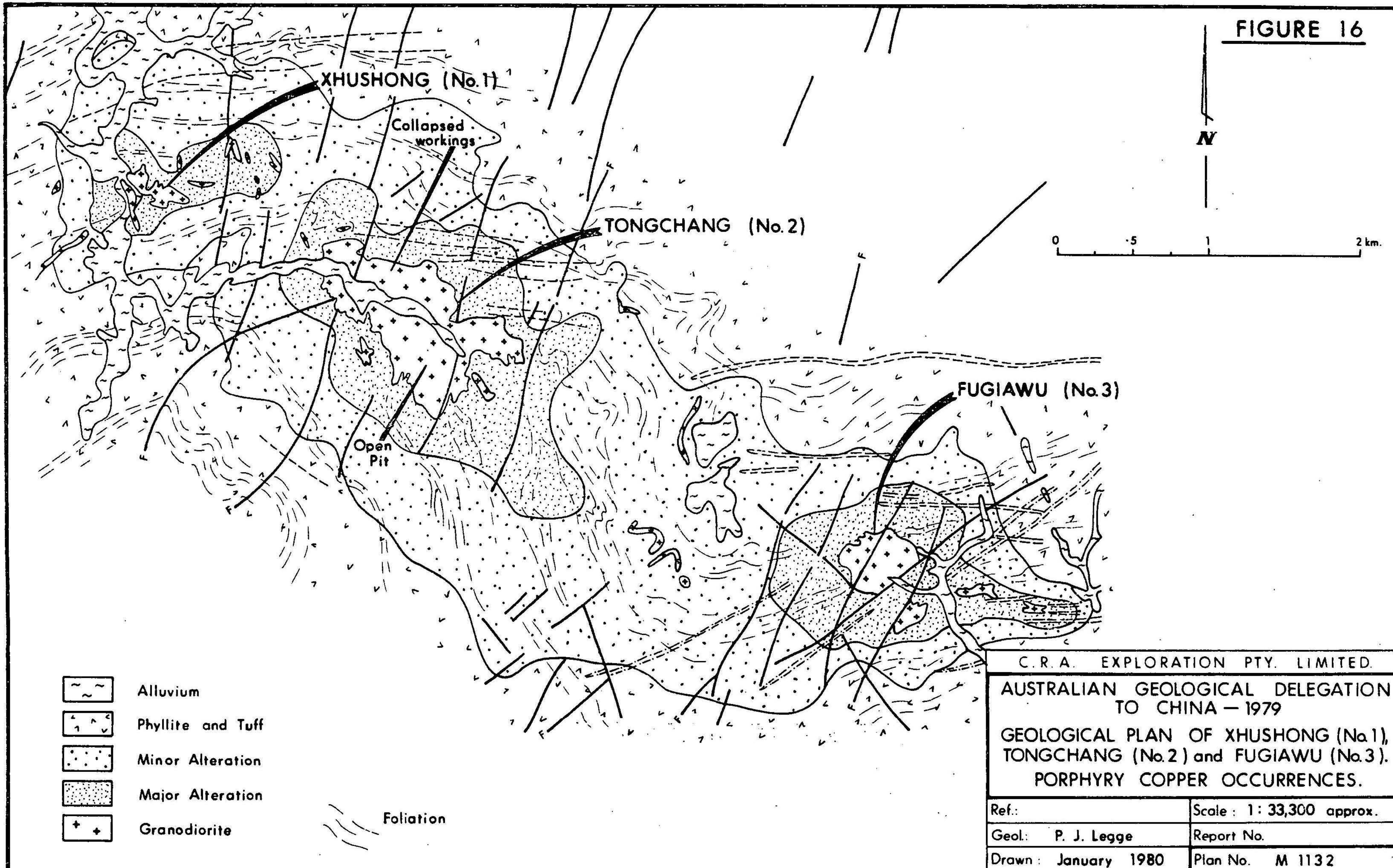


FIGURE 16
N
0
·5
1
2 km.
XHUSHONG (No. 1)
Collapsed workings
TONGCHANG (No. 2)
Open Pit
FUGIAWU (No. 3)
Alluvium
Phyllite and Tuff
Minor Alteration
Major Alteration
Granodiorite
Foliation
C.R.A. EXPLORATION PTY. LIMITED.
AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA — 1979
GEOLOGICAL PLAN OF XHUSHONG (No. 1), TONGCHANG (No. 2) and FUGIAWU (No. 3). PORPHYRY COPPER OCCURRENCES.
Ref.:
Scale: 1: 33,300 approx.
Geol.: P. J. Legge
Report No.
Drawn: January 1980
Plan No. M 1132

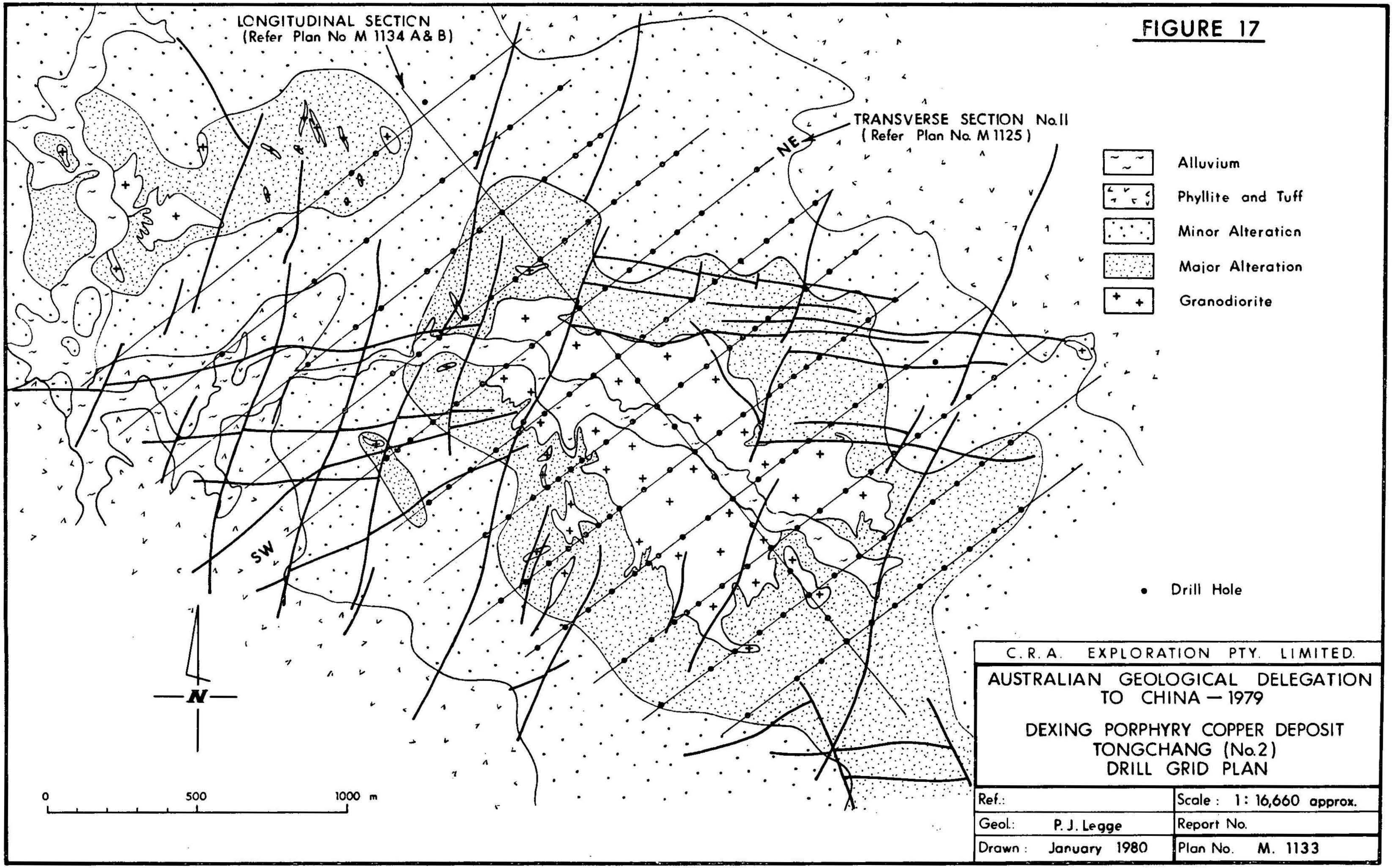


FIGURE 17
LONGITUDINAL SECTION
(Refer Plan No M 1134 A& B)
TRANSVERSE SECTION No.II
(Refer Plan No. M 1125)
NE
SW
Alluvium
Phyllite and Tuff
Minor Alteration
Major Alteration
Granodiorite
Drill Hole
N
0
500
1000 m
C. R. A. EXPLORATION PTY. LIMITED.
AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA — 1979
DEXING PORPHYRY COPPER DEPOSIT
TONGCHANG (No.2)
DRILL GRID PLAN
Ref.:
Scale : 1: 16,660 approx.
Geol.: P. J. Legge
Report No.
Drawn : January 1980
Plan No. M. 1133

MINERALISATION - COPPER SULPHIDE AND ASSOCIATED MINERALS AND ELEMENTS

In the Dexing area sulphides have been discovered in the Proterozoic country rock only in the vicinity of the Jurassic granodiorite. The geometric distribution of copper for the No. 2 deposit as illustrated in Figs. 18, 19, 20 and 21 also reflects the distribution of chalcopyrite. The central core of the granodiorite stock is barren of significant mineralisation. No illustrations of grade distribution were available for the No. 1 and No. 3 deposits.

Surface leaching of sulphide minerals is generally less than 20 m and no supergene enrichment of copper sulphide or copper oxide zone is developed. Total sulphide content was stated to be about 5% with the ratio of pyrite:chalcopyrite:molybdenite being 300:33:1 in the No. 2 deposit. (These figures appear to be incompatible).

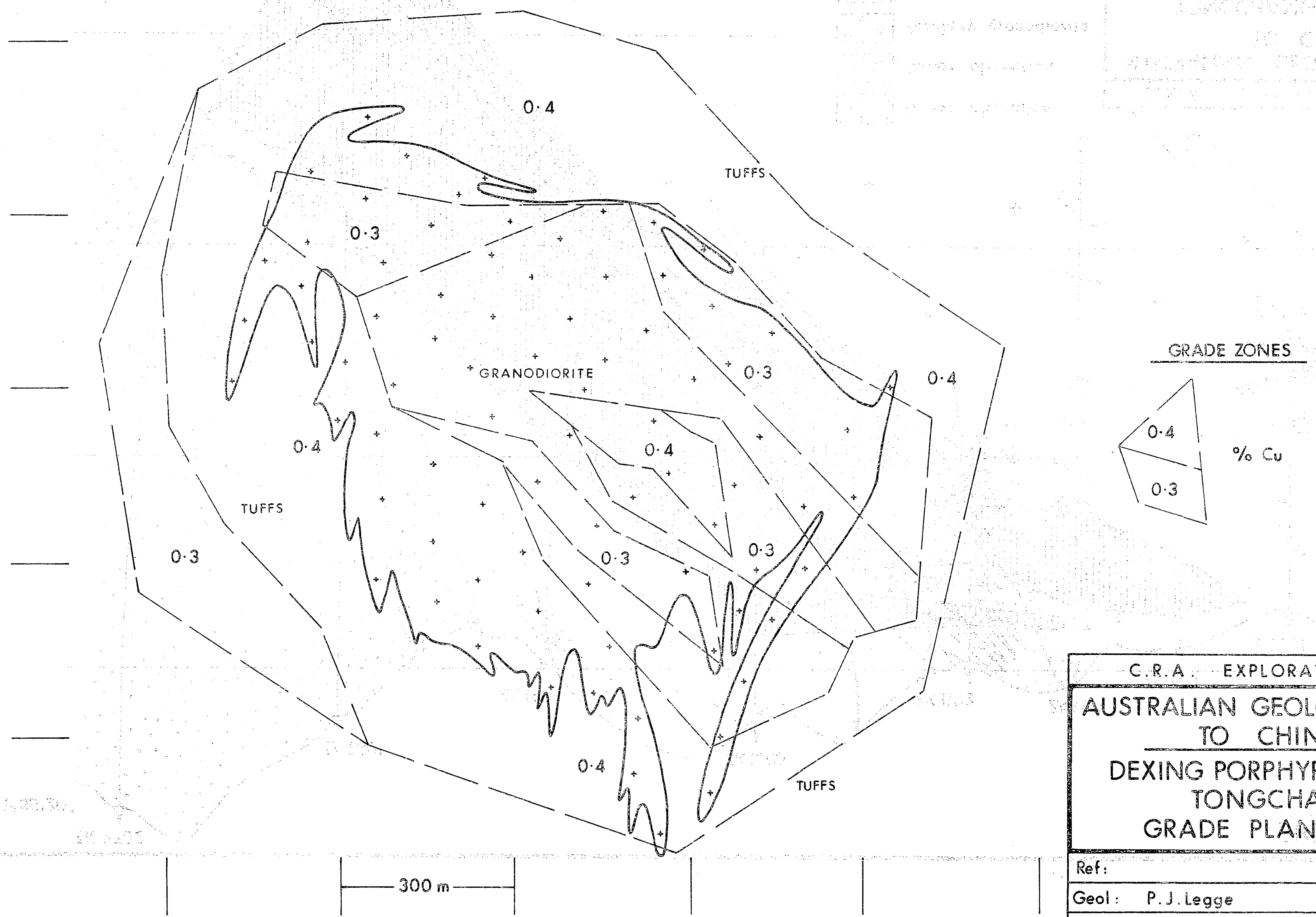
The association of sulphide, particularly chalcopyrite, with secondary alteration is marked. Principal alteration zones coextensive with chalcopyrite are zones of silicification, carbonitisation and chloritisation with subsidiary zones of albitisation, microclinisation/sericitisation and biotitisation; anhydrite is common in the cupriferous zone. Alteration is most intense along zones of fracture but shows an overall pervasive character in both the granodiorite and tuffaceous host rock.

The alteration contact zone designated H_2 in the tuff sequence is defined on the basis of the presence of more than 20% secondary quartz; relict quartz phenocrysts are generally destroyed in the granodiorite porphyry.

Table 4 gives the changes in the chemical composition across alteration zones.

Ore textures are generally xenomorphic and fine grained with pyrite and chalcopyrite occurring mainly as veinlets (along small fractures) with some blebby dissemination. Massive sulphide is unknown in the area. The sequence

FIGURE 18



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AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA – 1979

DEXING PORPHYRY COPPER DEPOSIT TONGCHANG MINE GRADE PLAN : 00m LEVEL

Ref:	Scale: 1 : 10,000 approx.
Geol: P. J. Legge	Report No:
Drawn: November 1979	Plan No: M 1126

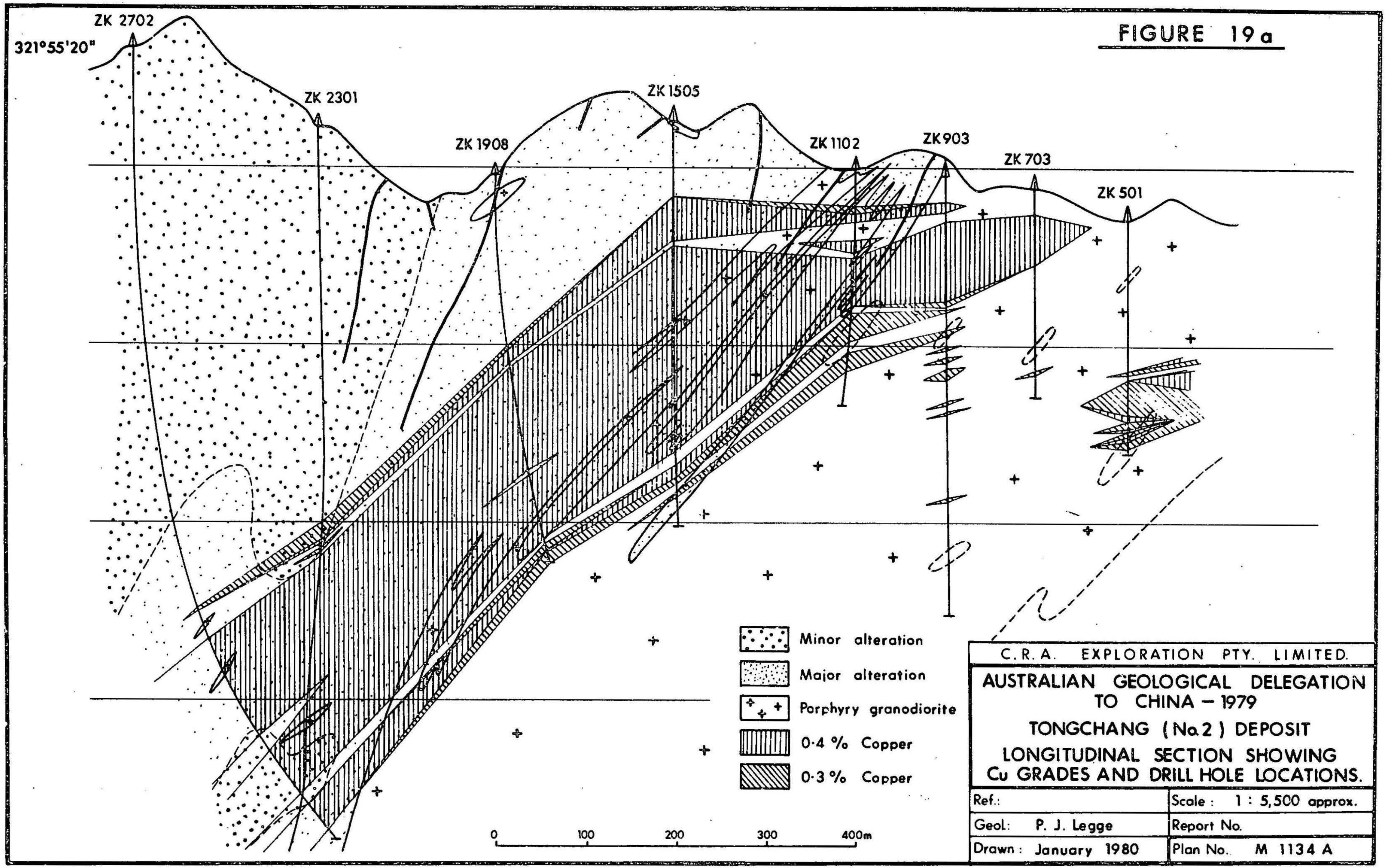
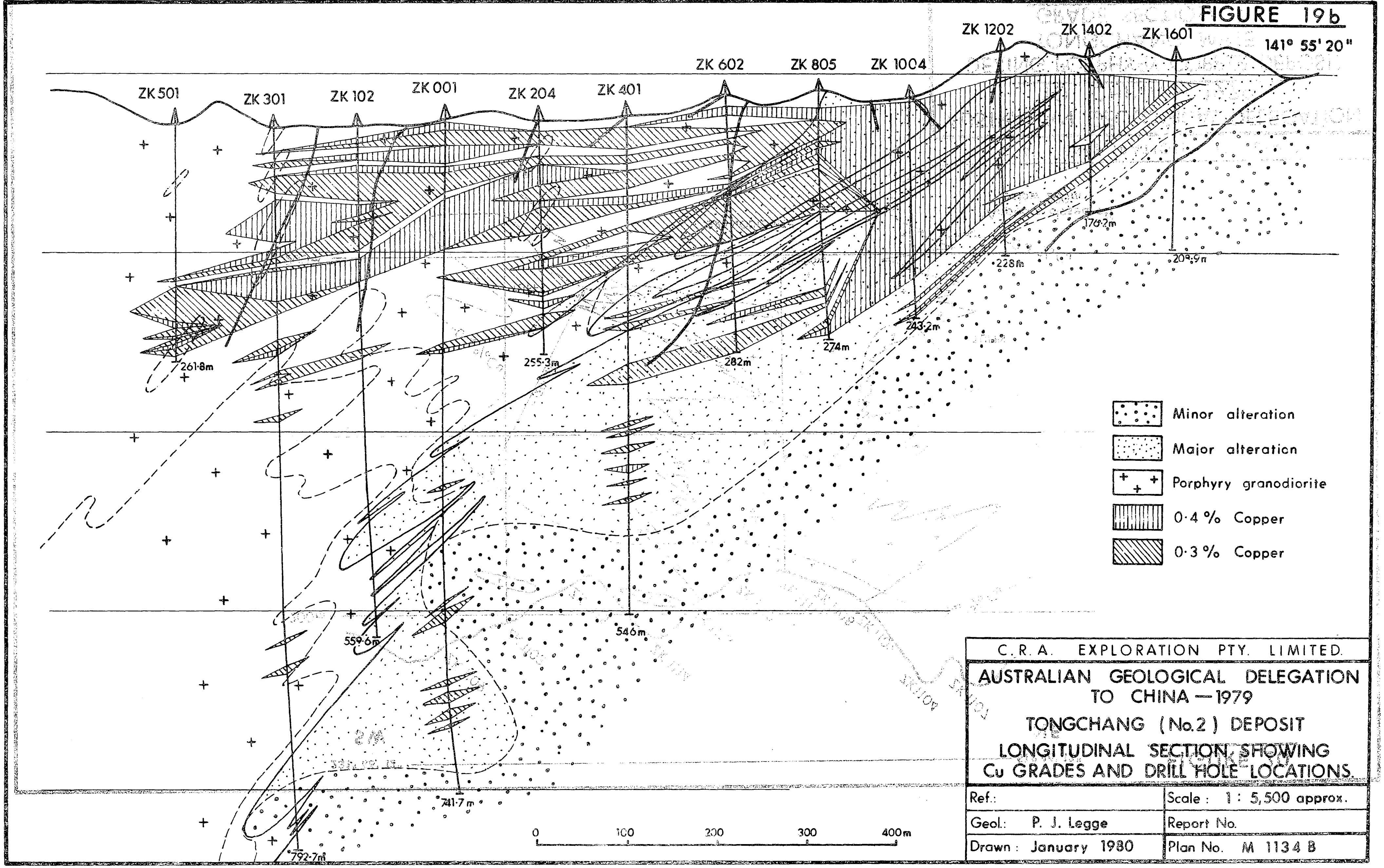


FIGURE 19a
321°55'20"
ZK 2702
ZK 2301
ZK 1908
ZK 1505
ZK 1102
ZK 903
ZK 703
ZK 501
Minor alteration
Major alteration
Porphyry granodiorite
0·4 % Copper
0·3 % Copper
0 100 200 300 400m
C.R.A. EXPLORATION PTY. LIMITED.
AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA – 1979
TONGCHANG (No.2) DEPOSIT
LONGITUDINAL SECTION SHOWING Cu GRADES AND DRILL HOLE LOCATIONS.
Ref.:
Scale: 1 : 5,500 approx.
Geol: P. J. Legge
Report No.
Drawn: January 1980
Plan No. M 1134 A



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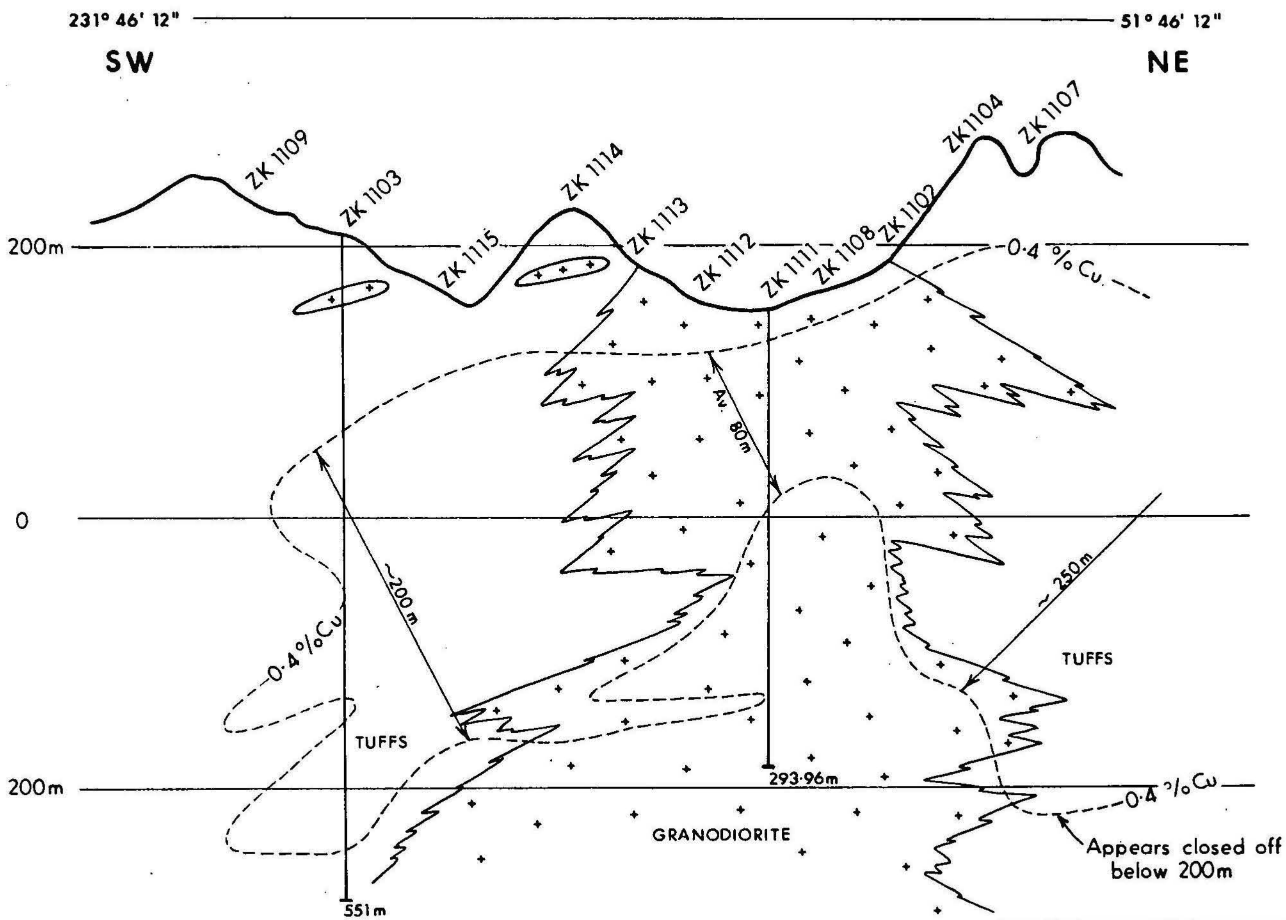
AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA — 1979

TONGCHANG (No.2) DEPOSIT

LONGITUDINAL SECTION SHOWING Cu GRADES AND DRILL HOLE LOCATIONS.

Ref.:	Scale : 1 : 5,500 approx.
Geol.: P. J. Legge	Report No.
Drawn : January 1980	Plan No. M 1134 B

FIGURE 20



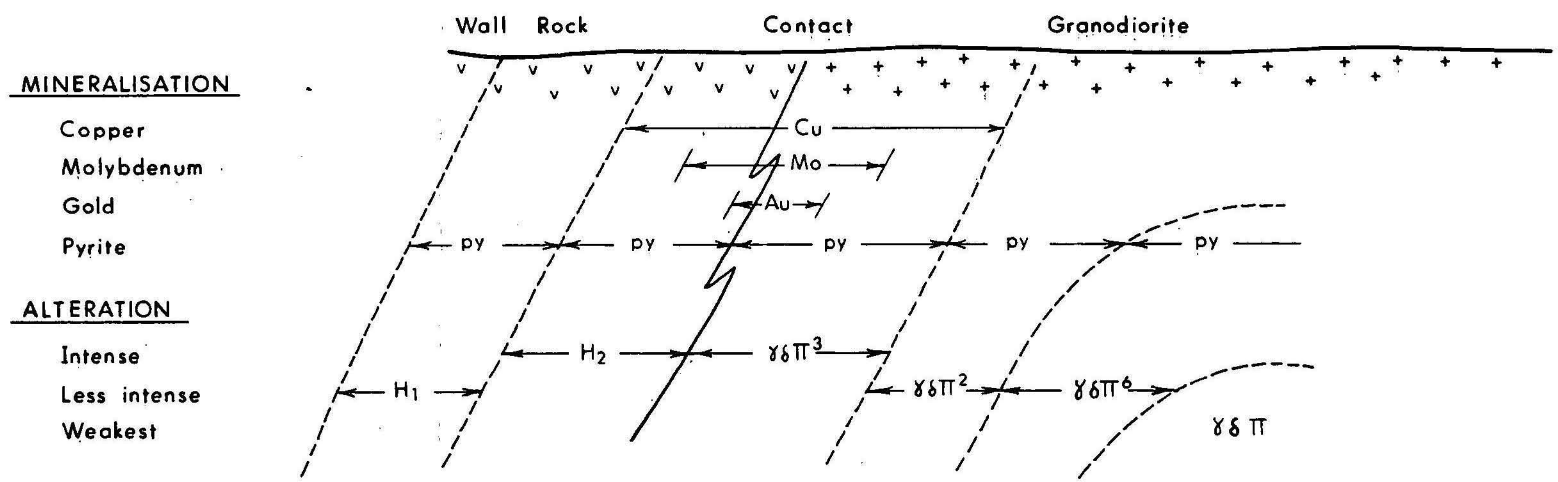
C.R.A. EXPLORATION PTY. LIMITED

AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA – 1979

DEXING PORPHYRY COPPER DEPOSIT
TONGCHANG MINE
GRADE SECTION 11

Ref:	Scale: 1 : 5,500 approx.
Geol: P. J. Legge	Report No:
Drawn: November 1979	Plan No: M 1125

FIGURE 21



C.R.A. EXPLORATION PTY. LIMITED.

AUSTRALIAN GEOLOGICAL DELEGATION TO CHINA – 1979

TONGCHANG (No 2) ZONING OF CONTACT ALTERATION AND MINERALISATION

Ref:	Scale :
Geol: P.J.Legge	Report No:
Drawn: November 1979	Plan No: M 1127

of formation of mineral phases is shown on Table 4. The formation of quartz-sulphide and carbonate-sulphide association is thought to have been important, and an evolutionary carbonate development from siderite to ankerite to dolomite to calcite is indicated, with ankerite showing strong relationship to maximum chalcopyrite formation. Sulphur isotope work gives the typically narrow range of similar porphyries. Liquid inclusion studies on fluorite indicate that weakly alkaline reducing briny solutions were present during mineralisation.

ORE GRADING

The Dexing geological staff provided the following metal grade details -

a) Currently recovered metals

	geological grade	Comment
Cu	0.41 - 0.53%	No. 2 mine 0.46%, mainly chalcopyrite
Au	0.2 g/t	90% in native state enclosed in pyrite, chalcopyrite, enargite and quartz.
Ag	0.8 - 1.0 g/t	as antimony sulphide, gold alloy, native gold, and in galena.
Mo	0.01%	No. 2 mine, molybdenite mainly as
S	n.a.	pyrite/chalcopyrite.

b) Metals proposed for recovery

Ni Co	n.a.	contained in pyrite
Re Os	n.a.	contained in molybdenite
Mo	0.06%	No. 3 deposit, siliceous granodiorite.

TABLE 4

Sequence of Mineral Phases

Ore Formation Period	Late Mesozoic Period - Late Gas-forming Hydrothermal Period	Hydrothermal Period								
Stage of Ore Formation	Potash-feldspar - Sulphide Stage	Quartz - Sericite - Sulphide Stage			Hydromuscovite - Illite - Sulphide Stage	Chlorite - Sulphide		Carbonate Salts - Fluorite		Gypsum Stage
Order of Genesis / Main Minerals		Quartz - Sericite Sulphides	Quartz Potash-feldspar - Sulphide	Anhydrite - Sulphide		Chlorite - Sulphide	Chlorite - Iron glance - Sulphide	Carbonate salts - Fluorite - Sulphide	Calcite - Sulphide	
Potash-feldspar	▬▬		▬▬							
Biotite	—		—							
Albite	—		—			—				
Magnetite	—						—			
Quartz	▬ ▪	▬▬	▬▬	- -	- -	- -	- -	- -		
Sericite	▬▬	▬▬	▬ - -		- -					
Hydromuscovite - illite	—	- -	- -		▬▬	- -				
Pyrite	▬▬	▬▬	▬▬	▬▬	▬▬	▬▬	▬▬	- -	—	
Chalcopyrite	▬▬	▬▬	▬▬	▬▬	▬▬	▬▬	▬▬	—		
Molybdenite	- -	▬▬	▬▬	▬▬	- -					
Pyrrhotite		—								
Anhydrite				▬▬						
Variegated pyrite		—								
Carrollite plessite		—								
Natural gold		- -								
Chlorite		- -			- -	- -				
Epidote					- -	▬▬	▬▬	- -	- -	
Iron glance					—	▬▬	▬▬	—		
Calcite							▬▬			
Siderite	—			- -		- -	- -	▬▬	▬▬	
Dolomite						- -	- -	▬▬ —		
Fluorite							- -	▬▬ ▪	—	
Sphalerite								▬ - -		
Tetrahedrite							—	▬▬		
Lomonite							—	▬▬		
Gypsum								—		

Drill hole copper grades taken from the illustration of Section II at the north west end of the No. 2 mine are shown in Table 2.

Composite grades rarely exceed 0.5% Cu and the mineralized zone appears to be uniformly mineralized at grades between about 0.3 - 0.5% Cu. A reserve grade figure of 0.46% Cu was given for the No. 2 Tongchand deposit. Gold assays are probably not routinely taken and the figure given above is suspect. Molybdenum is of very low grade; the problems of obtaining a representative sample coupled with the problems of assaying suggests the grade figure must be taken with caution. The No. 3 deposit which is associated with a more acidic stock has a higher molybdenum content. It is thought that No. 2 mine molybdenum grade increases with depth with a sympathetic decrease in copper grade. Sampling and assay procedures were not available for discussion with the Chinese. Core recovery was stated to be 90%. Core is stored in strong wooden boxes stacked under cover in a derelict building near the main road which crosses the No. 2 deposit; core was not examined during the visit.

ORE TONNAGE OF THE NO. 2 (TONGCHAND) DEPOSIT

Copper is distributed as an asymmetric north plunge elliptical annulus and cap shape around the margin of and draping over the centre of a granodiorite stock (Fig. 19). Grade zones of 0.3 - 0.4% Cu and +0.4% Cu for the horizontal section at MSL are illustrated in Fig. 18. A total of 177 diamond drill holes on 13 Section lines have tested the No. 2 deposit on grid of 100 m x 200 m, narrowing to 50 m in places.

In the contact annulus zone ore grading more than 0.3% Cu is persistent to depths in excess of 600 m in the north west half of the elliptical shape. Copper tends to cap the granodiorite in the south east zone and lacks depth persistence below about 200 m depth. Based on rough estimates from the data supplied and using a 0.3% cut off, tonnages are indicated as follows-

north western half elliptical annulus = 800 million tonnes

south eastern annulus/cap = 300 million tonnes.

GRADE AND TONNAGE OF THE NO. 1 AND NO. 3 DEPOSITS

Few details were provided on these deposits. Copper grades are reportedly similar to No. 2 but the molybdenum grade is higher in No. 3. The No. 1 deposit is pyritic at surface and although a weak soil copper geochemical anomaly is present chalcopyrite occurs below 200 m depth in a porphyry which has increasing horizontal dimensions with increasing depth. No category C (inferred) reserves have been established on the No. 1 occurrence but a total of 57 holes to a maximum depth of 1020 m have been completed for 40 000 m of drilling on a 280 m x 140 m grid.

EXPLORATION

Stream sediment geochemistry has been completed on a regional basis and stream water geochemistry on a local basis. Airborne magnetic surveys, undertaken by the airborne geophysics section of Jiangxi Province and Beijing Airborne geophysical team failed to show anomalies. (The mine geologists do not hold the data). Ground magnetic surveys show a 20 - 200 gamma anomaly directly over the No. 2 granodiorite porphyry. Electrical or electromagnetic surveys do not appear to have been used.

No other porphyry copper prospects or geochemical anomalies indicative of porphyry copper are known in the region.

There are no facilities for atomic absorption assaying on site at Dexing. Although copper assays on site are routine, the repeatedly mentioned high cost of gold assaying suggests that gold is not routinely assayed in core and rarely used as a guide in prospecting. No gold workings are known in the area.

Regional fracture patterns are being interpreted using aerial photography. The suggestion of using aerial photos and Landsat to detect major alteration patterns appeared to be received with interest.

Exploratory diamond drilling is current in the southern part of No. 2 and on the No. 1 orebodies.

TABLE 5

Consolidated table of orebed Zoning at Tongchand (No. 2) Mine

Lithological Characters	Position	Alteration Zone	Composition of Ore Minerals	Composition of Mineralized Elements	Ore Type	Vein Content Density bands/metre	Vein Content Ratio	Constitution of Sulphur Isotopes	
								S^{34} 0/00 Range of Change	S^{34} 0/00 Arithmetic Mean
Granodiorite Metamorphic; Porphyry	Inner ↑	Potash feldsparised Zones	Pyrite Chalcopyrite	Cu Ba	Veinlet Dissemination	23.9	3.74	2.2-0.5	1.34
		Quartz ↑ Sericite	Predominantly Pyrite, Chalcopyrite ↑ Predominantly Pyrite, Molybdenite	Cu, Mo (Ag)	Predominantly Disseminated	26	5.1	3.5-1.2	2.67
	Contact	↓ Hydromuscovitised Zones	↓ Predominantly Pyrite, Chalcopyrite			25.2	4.04	3.2-1.2	2.66
		Hydromuscovite Illite (-ised) Zones	Pyrite Chalcopyrite	Cu (Mo)	Predominantly Veinlets	34.7	5.53	3.2-2.5	2.82
	↓ Outer	Chlorite-epidotized Zones	Pyrite	S Pb Zn	Veinlets & Large Veins	20.3	6.48	4.9-3.3	4.29

MINING

A very brief review of the mining activities was provided by Xie Tong Ke, mining engineer. Current activity centres on the open cut benching in the southeast part of the No. 2 deposit. Seven benches are being worked using a 12 m bench height slotted into the crest of a steep sloped spur. Two benches are fired each day. Grade control is by sampling 50 m spaced blast and exploratory drill holes and wet chemical assaying. Ore and waste is loaded from 8 m^3 buckets into 32 trucks each of 27t capacity. Ore is dumped into one of three ore passes (each about 5 x 3 m) which have been raised from the rail haulage level. Ore is then railed for 5.3 km west along twin lines contouring the hills and bridging valleys to the concentrator near the town area.

In a 24 hour period two shifts produce some 7,000 tpd ore and 20,000 tpd waste. Current ore:waste ratio is 1:2.7. An enlarged pit is planned to produce 130,000 tpd with an overall ore:waste ratio of 1:2.43 which includes a south pit ore:waste of 1:1.84. Completion depth of the expanded pit was stated to be 175 m below MSL which does not agree with the given vertical depth of the pit from edge to base of 600 m. The pit length will be 2,700 m and a 42^o pit slope is planned. Current working area on the southeast open cut is 1500 m x 700m.

On the north area, mining of copper has just ceased after 15 years of activity. Two principal adit haulage levels were developed at 125 m and 185 m above MSL using an undescribed caving method to draw ore. Surface subsidence clearly led to landslips from the steep hill to the northeast and may have led to an unreported underground disaster. The area will be re-mined as part of the expanded open-cut operation.

METALLURGY

(contributed by R.E. Wilmshurst)

At present 7 000 tonnes of ore with an average grade of 0.5% Cu is being treated daily. The ore, untreated at the mine except for some significant breakage in ore passes, is transported by electric railway to the mill some 5 km away. Each ore train consists of 16 trucks of 3.6 m^3 capacity.

Fig. 22. Caved workings at surface north part of No. 2 deposit.

Fig. 23. Open cut operation at south east No. 2 deposit.

In the mill the ore is first broken in a 1.2 by 1.5 m jaw crusher to around 250 mm, then crushed to around 50 mm in a secondary gyratory crusher 2.1 m in diameter. A third stage, again using a gyratory crusher of 2.1 m diameter reduced the ore to minus 15 mm.

Grinding is carried out in eight ball mills operating in parallel. Each mill is 3.2 m in diameter and 3.1 m long, and operates in closed circuit with a twin screw classifier. Power and steel consumption are 16 kwhr/t and 1.2 - 1.4 kg/t respectively to give a ground product of which 65% is -74 μm in size.

Flotation is used in a plant which is conventional except that the rougher cells are each of 50 m^3 capacity (3.2 x 2.4 x 6.8m) and both agitated and aerated by compressed air. Pine oil and xanthate are used to give a rougher concentrate of 8 - 10% grade, the principal diluent being pyrite.

The rougher concentrate is reground to 90 - 95% passing 44 μm and refloated with the pyrite depressed. The finished concentrate contains:-

Cu	24 - 26%	at 84 - 86%	recovery
Mo	0.2 - 0.3%	at 60 - 70%	recovery
Au	5 - 8 g/t	at 50 - 60%	recovery

The flotation concentrate is thickened and filtered in 3 rotary disc filters each of 34 m^2 area. No dryer is used, the moist cake being shipped in bulk.

A limited amount of pyrite is produced as a by-product. The grade of this product is low at 35% (cf FeS_2, 53.1%S) and recovery is around 30%. This material is used for sulphuric acid manufacture, a purpose for which it would be unacceptable in most countries.

The milling operation is well under control. Samples of feed concentrate and tailing are taken for analysis at 20 minute intervals. Assay turnaround time is 8 hours. Mineralogical back-up service is available and is used frequently. Plans are in hand to produce a separate molybdenum concentrate, and plant trials of a copper/molybdenum separation have shown that 80 -90% recovery of molybdenum into the rougher concentrate can be achieved.

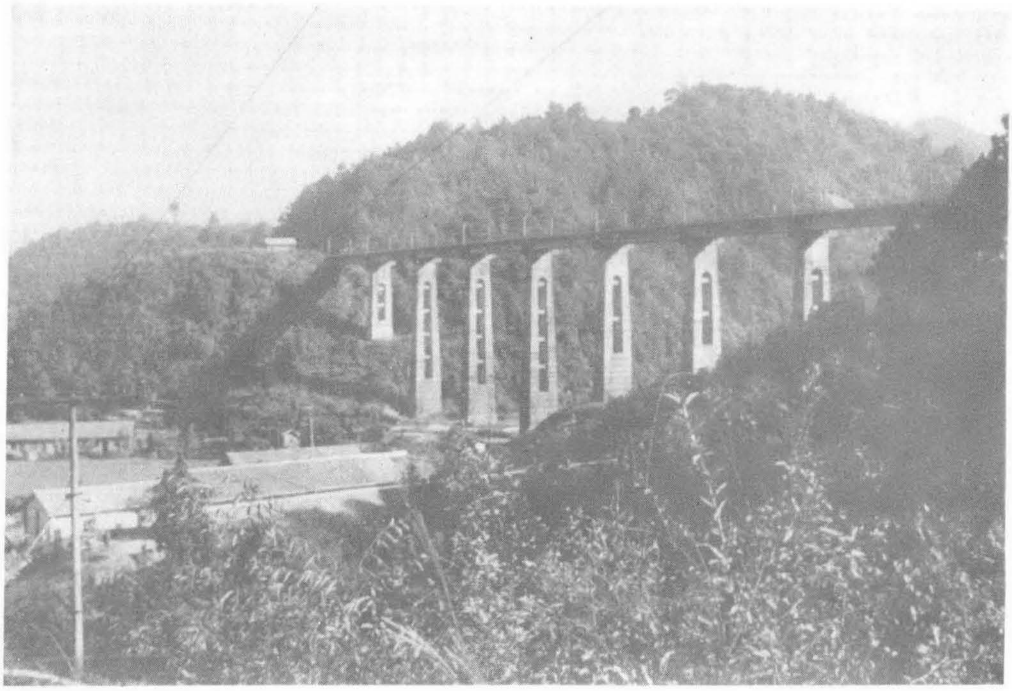


Fig. 24. Rail haulage to concentrator.

Fig, 25, Typical alteration and mineralization in chloritic tuff - north subsidence area.

By far the biggest problem facing the operators of the Dexing mine will be that of environmental pollution. These are already two obvious problem areas:-

(a) drainage water from the mining area is quite strongly acidic and heavily polluted with iron.

(b) loss of tailing pulp from the mill and tailings disposal system into the local watercourses is obvious to the eye.

It can be expected that, with development of the mine proceeding apace, at least the first of these problems will intensify very rapidly. Rainfall in the area is in excess of 1 m annually, and with large amounts of sulphide in the huge waste rock dumps which are being established, the local river - already obviously and heavily polluted - will become much worse than at present. The pollution will propagate downstream and unless remedial measures are adopted deleterious effects can be expected for probably at least 50 - 100 km from the mine.

FOREIGN INVOLVEMENT

According to World Mining, October 1979, Fluor Mining and Metals Inc. of California was awarded a $400 000 contract in March 1979 for a study of the copper area with a $3 000 m concept of an integrated mine and plant to produce 400 000 annual tonnes of copper. The China National Technical Import Corporation has signed a separate specific Phase 1 and Phase 2 contract with Fluor Mining and Metals valued at $10 000 000 for basic engineering on the 192 500 ton per day mill and mine development. Completion target is later 1983. Much new crated equipment is already on site at Dexing.

Additional smelting capacity is planned for Jiangxi Province and it is understood that in early 1979 three Japanese companies headed by Sumotomo Metal Mining were awarded a contract to construct a 90 000 tonne per year blister copper smelter valued at $115 M. In January 1979 Euclid Inc. received a US$7 million order for ten 170 tonne trucks which may be destined for Dexing.

ANSHAN IRON ORE DEPOSITS

by W.J.S. Howell

ABSTRACT

The Anshan iron-ore deposits in Liaoning Province of northeast China supply the raw material for 25% of China's steel output. The deposits are contained within discreet horizons in a basement complex assigned to Archaean age. Most of the ore is low-grade banded hematite-magnetite-quartzite of Algoma-type but with some similarities to Lake Superior-type deposits. Total annual production of the Anshan district is currently 26 million tonnes of iron-ore at an average grade of 30-35% Fe In-ground ore reserves are quoted at 8000 million tonnes, and major production increases are planned.

All but 7% of Anshan's iron-ore production is from open-pit mining. One of these open-cut mines, at Dagushan, was visited by the Delegation. The Dagushan ore-body measures 970-1000 m in length and 230-270 m in width. Mineable reserves are 200 million tonnes at an average grade of 33.64% Fe, with less than 0.1% S and 0.035% P. Ore cut-off grade is believed to be 20% Fe. Annual ore production from the mine is 4.4 million tonnes of ore and presently consists mainly of magnetite-quartzite which is beneficiated by magnetic separation. Current waste: ore ratio is of the order of 3.5 : 1. Transportation of most of the ore and waste is by rail pit haulage, but plans to increase ore production to 6 million tonnes per annum will require more flexible transportation modes.

INTRODUCTION

The Delegation visited the iron-ore district of Anshan in Liaoning Province, north-east China on 24th and 25th October, 1979. Anshan city is approximately 80 km SSW of the provincial capital Shenyang by rail and sealed road, and is the centre of China's presently largest iron and steel complex. Annual production at Anshan is approximately 7 million tonnes of steel ingots, representing about 25% of the nation's output.

Low-grade iron-ore for the iron and steel works is supplied from five operating open-cut mines within a radius of 15 km of Anshan city. These are the Qidashan, Xianshan, Donganshan, Dagushan and Yienqianshan mines (Fig. 26). The open-cut at Guangmenshan is reportedly not working at present. A major new operation is being developed at Hujiamiaozi and may have commenced mining. Some high-grade iron-ore is supplied to Anshan from an underground mine at Guangqanlin (or Huqanlin), 60 km ENE of Anshan city.

During the first morning of the Anshan visit, members of the Delegation were given a presentation on regional geology of the Anshan district by personnel of the Geological Exploration Company of the Anshan Mining Corporation. This was followed in the afternoon by field visits to view geological outcrops in the Hujiamiao and Tiejiashan areas. The Dagushan open-cut mine was inspected next morning. No visits were made to ore treatment or steel making plants.

This chapter describes the regional geology of the Anshan district and operations at the Dagushan open-cut mine.

ANSHAN DISTRICT

REGIONAL GEOLOGY

The geological setting of the Anshan district is essentially one of a remnant metamorphic-migmatite-migmatic basement complex assigned to Archaean age, on which has been deposited Proterozoic miogeosynclinal sediments and Phanerozoic platform cover.

A generalised plan of the distribution of rock-types and iro-ore deposits in the Anshan district is shown in Figure 26. A column of their stratigraphic relationship, rock-type descriptions and horizons of iron ore deposition is contained in Table 1. Some liberty has been taken in compiling these data to attempt to reconcile a number of apparent inconsistencies, errors and omissions in the maps and information presented by the Anshan geologists.

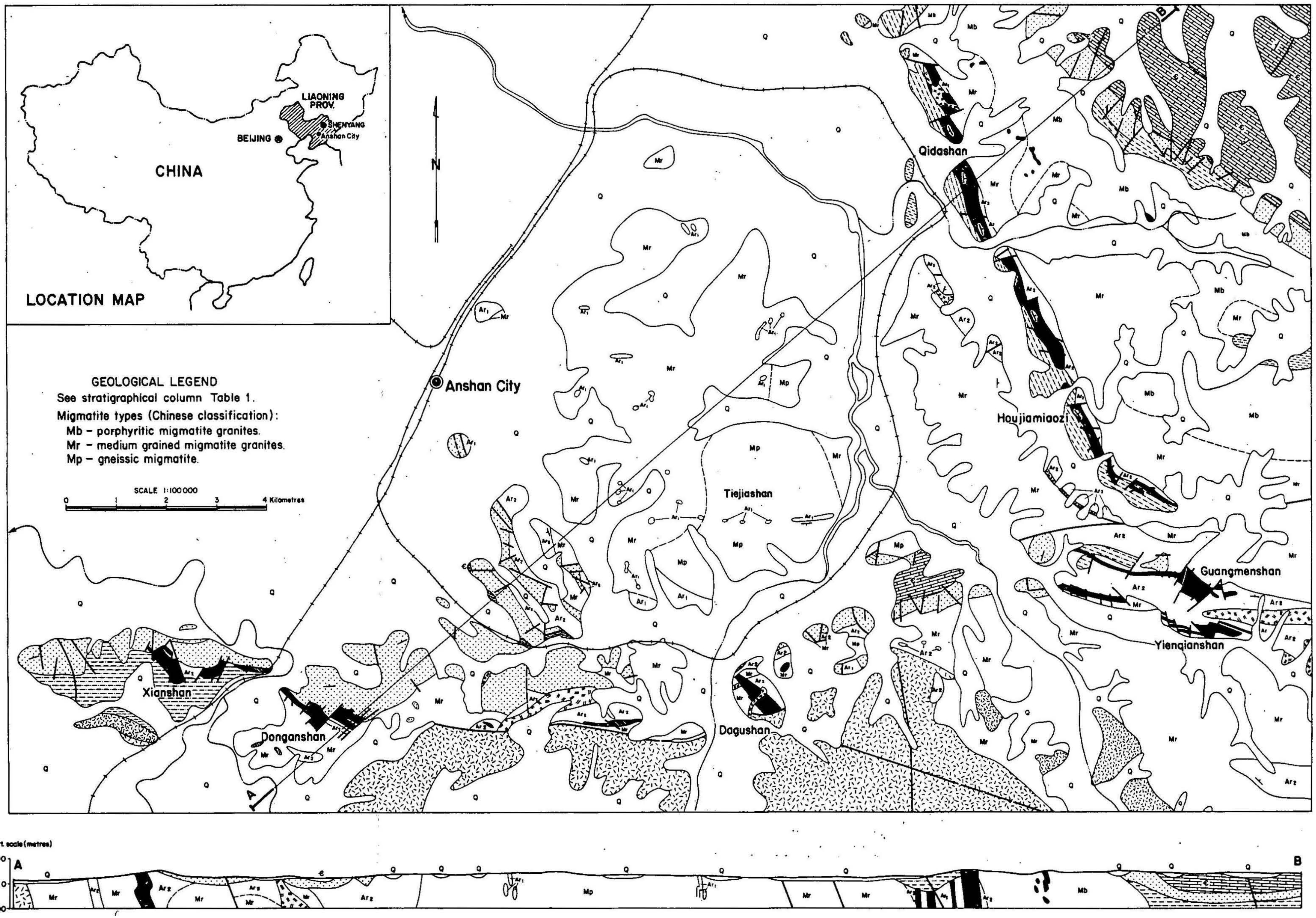


Figure 26.
Generalised plan of geology and location of iron-ore deposits, Anshan district.

EON/ERA	SYSTEM	SERIES	GROUP	FORMATION		COLUMN	THICKNESS IN METRES	ROCK - TYPE DESCRIPTION		MINERALISATION
					Q	Q Q	<70	Alluvial Sands, gravels, clays, sub-clays (loam). Area of loess and proluvial cover		
PALEOZOIC	CAMBRIAN	UPPER			$Є_3$		350	Lithologically constant cherty limestones, dolomitic limestones, limestones, "bamboo leaf" (vermiculated) intra-formational limestone conglomerates, thick-bedded shales, thin-bedded sandstones. Intrusive: Qianshan Granite γ_5 and granite porphyry (Yenshanian, late Jurassic)		
		MIDDLE			$Є_2$		300			
		LOWER			$Є_1$		350			
								disconformity		
PROTEROZOIC	SINIAN			Qiontou	Z_3		120	Thick-bedded, fine-grained quartzites siliceous shales, marls		
				Nanfen	Z_2		150	Marls, siliceous shales, intercalated grey limestones		"Iron bearing horizon"
				Diaoyutai	Z_1		70	Intercalated medium grained quartzites, thin-bedded sandy shales and glauconitic sandstones Basal conglomerate		
				Panjialu	Pt_2		>200	angular unconformity Tuffs and tuffaceous sandstones, tuffaceous agglomerates and breccias, phyllites, intercalated dolomite		
			Liaoho	Langzishan	Pt_1		700	Chlorite-sericite phyllites, limey siltstones, thin-bedded quartzites. Poorly-sorted basal conglomerate (Paotaisnan) Intrusives: diorite δ quartz porphyry		
								angular unconformity		
ARCHEAN			Anshan	Qijiagou	Ar_3		>1000	Biotite-granulites, tremolite-actinolite-schists biotite-granulites, tremolite-schists, actinolite-tremolite-albite-biotite-schists	MIGMATIZATION	Thin-bedded lenticular magnetite-quartzite bodies approx. 10 iron-ore beds total 270m 4-10 iron bed total 90m (Type 2)
				Yingtaoyuan	Ar_2		>1000	Plagioclase-amphibolites, biotite-granites, quartz-chlorite-schists sericite-quartz-schists siliceous shales, chlorite-schists, tremolite-actinolite-muscovite-schists		Thick-bedded, uniform magnetite-hematite-quartzite max. thickness 300 m (? Type 2) Thin-bedded magnetite-hematite quartzite Lenticular discontinuous magnetite-hematite-quartzite max. thickness 300 m (? Type 1)
				Tiejiashan	Ar_1		>2000	Quartzites, biotites-schists granulites, plagioclase-amphibolites		Thin-bedded iron-bearing quartzite

Table 1.
Stratigraphic column rock-type and mineralization description, Anshan district.

Archaean basement - Anshan Group

The Anshan Group is a plus-4000 m thick complex of metavolcanic-metasedimentary rocks and granitoids which have undergone two and possibly three episodes of metamorphism and intensive migmatization. Isotopic age datings of rocks of the earliest stage of migmatization have returned age determinations of up to 3600 million years. The Anshan Group has been likened by the Anshan geologists to the Keewatin-Timiskaming Supergroup of the Canadian Shield and the Pilbara Block of Australia. The economic iron ore horizons at Anshan are contained within the Anshan Group basement rocks.

Sub-division of the Anshan Group into three formations (Tiejiashan, Yingtaoyuan and Qidjiagou Formations) has been made on the basis of "primary rock mineralization characteristics" microfossils, physical and chemical variations of the stages of migmatization, physical characteristics of zircon and radiometric age dating. Some of these parameters have received very detailed attention, and are presented in Table 2 to illustrate the style of approach and kind of emphasis placed by the Chinese geologists in their investigations.

Proterozoic - Liaoho Group

The Liaoho Group is composed of (mio)-geosynclinal clastics and volcanoclastics which rest unconformably on the Anshan Group Archaean basement. The Liaoho Group has undergone medium to low-grade metamorphism, local migmatisation and broad folding on mainly E-W structures. The basal Paotaishan conglomerate of the Liaoho Group is described as being a "littoral collapse facies" type, with poorly sorted and angular fragments (Fig. 30). The conglomerate has yielded plant microfossils including *Leiominuscula, Myxococoides,* plus large numbers o bacteria-like micro-organisms similar to those described from the Yintaoyuan Formation of the Anshan Group (Table 2).

The Anshan geologists also report that the content of amino acid in the Liaoho Group phyllites may reach 23-29 micrograms of acid per gram of phyllite, considerably higher than that of the Anshan Group phyllites.

Table 2. Characteristics used to subdivide Anshan Group rocks into the Tiejiashan, Yingtaoyuan and Qijiagou Formations.

	ANSHAN GROUP		
	TIEJIANSHAN FORMATION	YINGTAOYUAN FORMATION	QIJIAGOU FORMATION
<u>MIGMATIZATION</u>			
Type:	<u>Gneissic migmatite (Mp)</u>	<u>Migmatite and migmatite granite (Mr)</u>	<u>Porphyritic migmatite granite (Mb)</u>
Description:	Dominantly dark grey in colour, fine grained texture, gneissic lineation	Light grey to mid-grey in colour, fine to medium grained granitic texture	Contains relics of (Mr) stage migmatite. Medium to coarse grained porphyritic texture
Accessory minerals:	Sphene, ?perovskite, apatite	Pyrite, chalcopyrite, sphalerite, molybdenite, chalcocite, also leucoxene, rutile. Low sphene content.	As for (Mr) stage migmatization. Some Anshan geologists believe (Mb) stage is same as (Mr) stage, but belonging to different sub-stages. (applies to rows from Accessory minerals to Extinction coefficient)
Titanium:	High relative to (Mr) and (Mb) stages of migmatization. Contained in sphene, no titanium oxides discovered.	Low relative to (Mp) stage migmatization	
Other oxides:	High	Low	
<u>ZIRCON CHARACTERISTICS</u>			
Description:	Light grey, rarely rose-coloured, mostly transparent, rare opaque		
Specific gravity:	High		
Extinction coefficient	2.0 - 2.5	2.0 - 3.0	
Temperature of formation:	600 degrees C.	800 - 850 degrees C.	Discovery of secondary zircon crystals with rounded core of earlier zircon may indicate high temperature of formation
<u>RADIOMETRIC AGE DATING</u>			
U - Pb method	On zircon 2570 million years On sphene 2848 million years	On zircon 2400 - 2300 million years	On zircon 2100 - 1900 million years
K - Ar method		On muscovite from chlorite schist 2428 million years	
<u>MICROFOSSILS</u>			
Plants:		Huroniospora compacta sp. nov. Palaeoanacystis antiquus sp. nov. Leiominuscula minuta Naum. Trachysphaeridium sp. Trematosphaeridium cf. Palaeolungbya anshanensis sp. nov.	
Algae:		"Chinese triangle form" cells, new genus, new species. Triangulophycus sinansisgen et. sp. nov.	
Micro-organisms:		Plankton fibre-like bodies. Iron-bacteria: Gallionella ferrugineidps sp. nov. Thiobacillus sp. Leptothrix microsiphonia sp. nov. Siderococcus archilimoniticus sp. nov. Non-iron bacteria: Clostridium sporulosum sp. nov. Clostridium anshanense sp. nov. Vibris anshanensis	

K-Ar datings of muscovite from phyllite in the Liaoho Group have given metamorphic age determinations ranging from 1803 million years to 1675 million years.

Sinian

Beds of the upper part of China's Sinian suberathem (of upper Proterozoic age) rest with angular unconformity on both the Archaean and earlier Proterozoic rocks. The beds are composed of (transgressive) platform sediments comprising quartzites, shales and marls, with intercalations of thinly-bedded littoral glauconitic sandstones. Quartzite grains are well rounded and sorted, and the Anshan geologists have recorded ripple marks and mud-cracks in the sediments. The sediments are only slightly metamorphosed and exhibit broad sub-horizontal folds, although subsequent regional fractures have resulted in block faulting and locally complex fold structures with some apparent overturning of beds.

Cambrian

Mainly chemical with minor clastic sediments of Cambrian age disconformably follow the Sinian rocks. They have yielded trilobite *Redlichia*. The sediments are un-metamorphosed and lithologically uniform, reaching a total thickness of about 1000 m. The Chinese geologists have likened these rocks to the lowest Palaeozoic limestones and dolostones of the Appalachians of eastern U.S.A.

Quaternary

Quaternary sediments cover most of the flat plain around Anshan city. They are composed mainly of loose alluvial sand, gravel, clay and "sub-clay" (nearest equivalent loam). Areas of loess are also reported, as well as proluvium. Maximum thickness of the Quaternary cover is about 70 m.

REGIONAL TECTONICS

The Anshan district lies in the area of the intersection of the east-west Yinshan-Tienshan tectonic belt and the NNE trending (Songhuanyang-Liaoho) depression and (Laodong Peninsula) uplift belts of the Neo-Cathaysian shear tectonic system.

The Yinshan-Tienshan tectonic belt is the northernmost of China's three major latitudinal tectonic systems of compressive fold and fracture zones, active since Palaeozoic with maximum acitivity since Mesozoic times. The Neo-Cathaysian system is the largest of China's so-called xi-type NNE-SSW tectonic systems, generated in Meso-Cainozoic times by "counter-clockwise N-S shearing movements."

These major tectonic belts have imposed a number of fault sets on the rocks of the Anshan district. Anshan geologists have recognised the following five sets:

*NE-SE faults, late Archaean onwards
*E-W faults, late Archaean and early Proterozoic influencing deposition of Liaoho Group
*NE-SW faults, cutting earlier NW-SE and E-W faults
*NNE-SSW faults post-dating NE-SW faults
*N-S faults, locally occurring, detected only by satellite imagery and geophysical data.

MINERALISATION

Mining of iron ore in the Anshan district is based on banded magnetite-hematite-quartzite sedimentary horizons of the Yingtaoyuan Formation of the Anshan Group. The grade of iron-ore beds is low with average mining grade being 30-35% Fe. The apparent Archaean age, volcano-sedimentary setting, lenticular nature and dimensions (1-10 km long by less than 300 m thick) of the iron-ore bodies suggest that they are dominantly Algoma-type but with some similarities to Lake Superior-type deposits. The Anshan geologists compared the Anshan ores with both world types during the course of the Delegation's visit. All the iron ore horizons dip steeply at an average angle of about 80°. Down-dip extent of ore is believed to average about 500 m.

The classifications of iron ore are recognised locally at Anshan, based mainly on enclosing country rock lithologies. Descriptions of the two local ore types as given by the Anshan geologists are detailed in Table 3.

	TYPE 1	TYPE 2
Anshan classification:	Phyllite-schist-(with minor granulite)-hematite-(magnetite)-quartzite	Plagioclase-amphibolite-granulite-schist magnetite-(hematite)-quartzite
Anshan Type name:	Metamorphic or argillaceous type	Volcano-sedimentary or semi-argillaceous type
Physical characteristics:	Thickness of individual beds 100-260 m, discontinuous, lenticular, extending up to several km along strike lateral facies change to chlorite schist	Variable thickness of beds maximum 300 m more continuous, often extending more than 10 km along strike Down-dip facies change to plagioclase-amphibolite
Minerals:	Hematite, magnetite, "hydro-morphous hematite" (goethite, limonite ochres) hydrohematite (turgite), down-dip increase in banded and stockwork primary iron-rich carbonates (siderite, ankerite).	Hematite and hydro-hematite (turgite) dominant to 300-400 m depth, grading into martite, magnetite, with tremolite, actinolite increasing.
"Chemical analysis":	* >n x 10%: 0.n% to n x 10%: 0.0n% to 0.n% : 0.00n% to 0.0n%: <0.00n%:	Fe_2O_3, SiO_2 FeO, Al_2O_3, CaO K_2O, Na_2O, H_2O MgO, TiO_2, MnO_2, CO_2 S, P_2O_5 Cu, Ni, GeO_2 V_2O_5
Anshan deposits:	Xianshan Donganshan Dagushan Yinqianshan	Qidashan Hujiamaouzi Guangmenshan
Type deposits:	? Superior-type (Messabi Range, Minnesota)	Algoma-type (Timigami, Canada)

* System adopted by the Chinese for indicating relative range of values where n is any number from 1 to 9.
Probably Russian origin

Table 3. Classification of iron-ore types, Anshan District

Both types of iron-ore are of similar grade. Type 1 occurs mainly in the W-E Xianshan-Yienqianshan iron-deposit belt. Type 2 dominates in the NNW-SSE Qidashan-Guangmenshan belt. The iron-bearing horizons of the Qijiagou Formation parallel to the northeast of the Qidnshan-Guangmenshan belt also belong to Type 2.

Magnetic anomalies occur in a NNW-SSE belt 2 km west of and parallel to Qidashan-Guangmenshan belt and in a NW-SE trend under Anshan city. Almost certainly these anomalies represent non-outcropping magnetite-bearing horizons. In fact, members of the 1978 Australian Iron and Steel Mission were told that a rich deposit occurs at depth below Anshan city.

PRODUCTION

Organized iron mining and smelting is reported to have been carried out in the Anshan district as early as 100 BC, but modern development began in the early 1900s when the Japanese worked the iron ore deposits. The Japanese added the first open-hearth furnaces at Anshan in 1935.

Total known reserves of low-grade iron ore in the Anshan district are reported to be approximately 8000 million tonnes of ore.

Total annual production is currently running at 26 million tonnes of 30-35% Fe compared with installed capacity of 35 million tonnes. In addition to ore mined from the five operating open pits at Qidashan, Xianshan, Donganshan, Dagushan and Yienqianshan, current total production includes about 2 million tonnes per annum of high-grade magnetite with average 62% Fe content from underground operations at the Guangqanlin (or Huqanlin) mine, 60 km ENE of Anshan city.

DAGUSHAN MINE

LOCATION

The Dagushan pit is one of five open-cut mines presently producing iron-ore in the Anshan district. It is located approximately 12 km SE of Anshan city in the W-E Xianshan-Yienqianshan Type 1 iron-bearing belt.

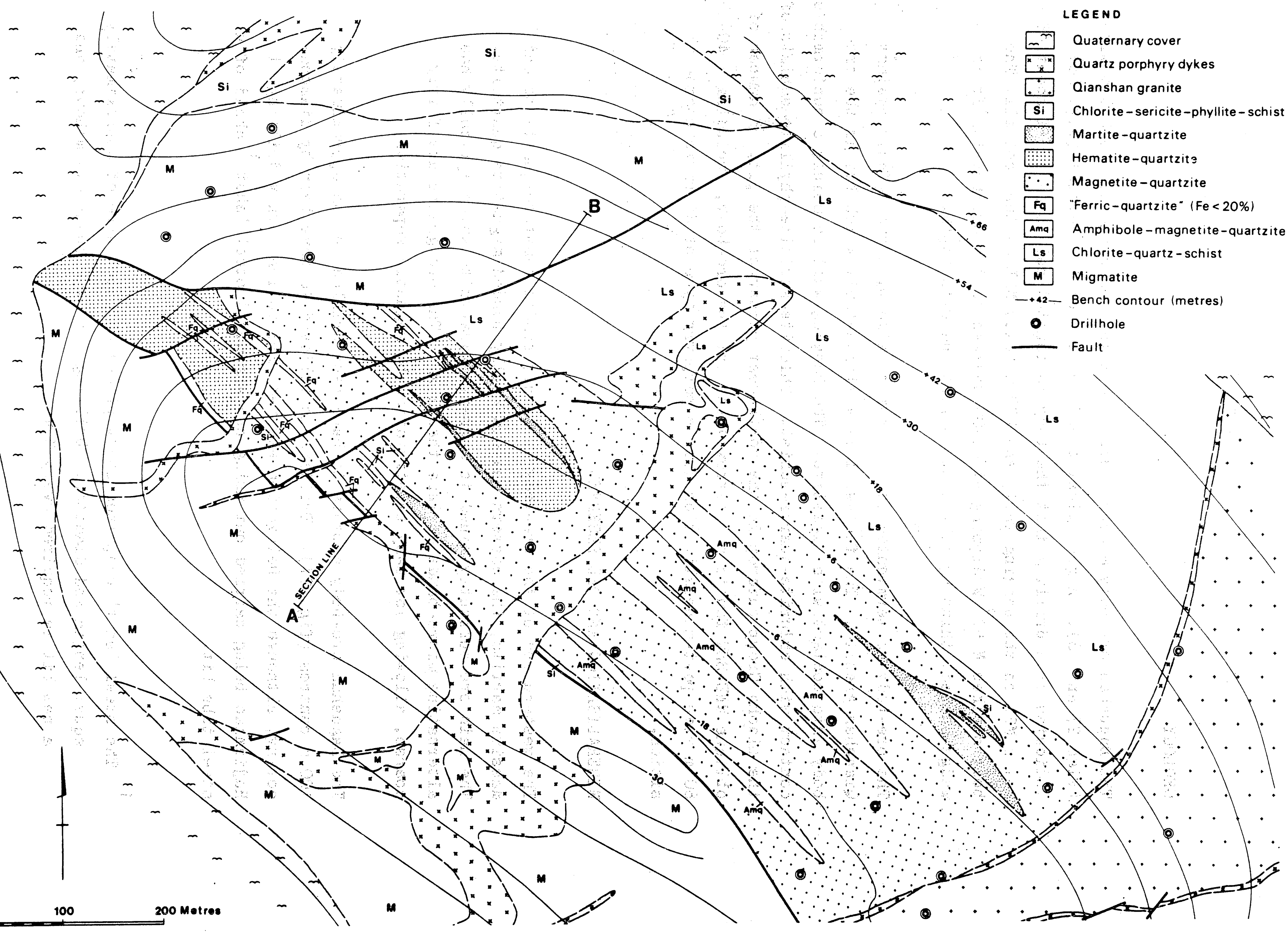


Fig 27. Geological plan of Dagushan iron-ore deposit, Anshan, China. (Drafted from photograph of Chinese plan shown to Delegation)

GEOLOGY

The Dagushan ore-body measures 970-1000 m in length and is 230-270 m wide (Figs 27 and 28). A geological cross section of the deposit (Fig. 28) indicates from drilling that the body is faulted out down-dip at about 48 m below MSL on the hanging wall, and 200 m below MSL on the footwall. The body strikes N 60^{o} W dipping at 60-80 degrees to the northeast. It is wedge-shaped, thinning from east to west and with depth.

The ore-body is terminated on its eastern side by a cross-fault against Qianshan granite. The foot-wall is a strike-fault which brings the ore-body into contact with migmatite. The hanging-wall is mainly a conformable contact with chlorite-quartz-schist. Chlorite-sericite-phyllite-schists of the Liaoho Group outcrop in the north-west corner of the pit. A number of oblique NNE-SSW faults and narrow dykes cut the ore-body, including a 40-60 m wide post-mineralization quartz porphyry dyke of dioritic composition.

MINERALISATION AND ORE RESERVES

The western end of the ore-body is mainly banded hematite-quartzite and massive martite, the eastern end dominantly banded magnetite-quartzite. The main ore currently mined is magnetite-quartzite which typically has alternating micro-bands of less than 2 mm. The ore grains are fairly coarse, allowing for easy beneficiation by magnetic separation.

The Dagushan ore-body appears to have been drilled out on approximately 100 m centres (fig. 27). Drilling is believed to have been by diamond-coring, although the Delegation watched exploration rotary drilling at Hujiamiao being carried out using heat-hardened steel 'shot'[1] ahead of a steel tube bit.

[1] The steel 'shot' comprises short pieces of steel wire of approximately equal length and diameter. Drilling rate was about 0.5 m/hour, and a new bit is required every 3 m.

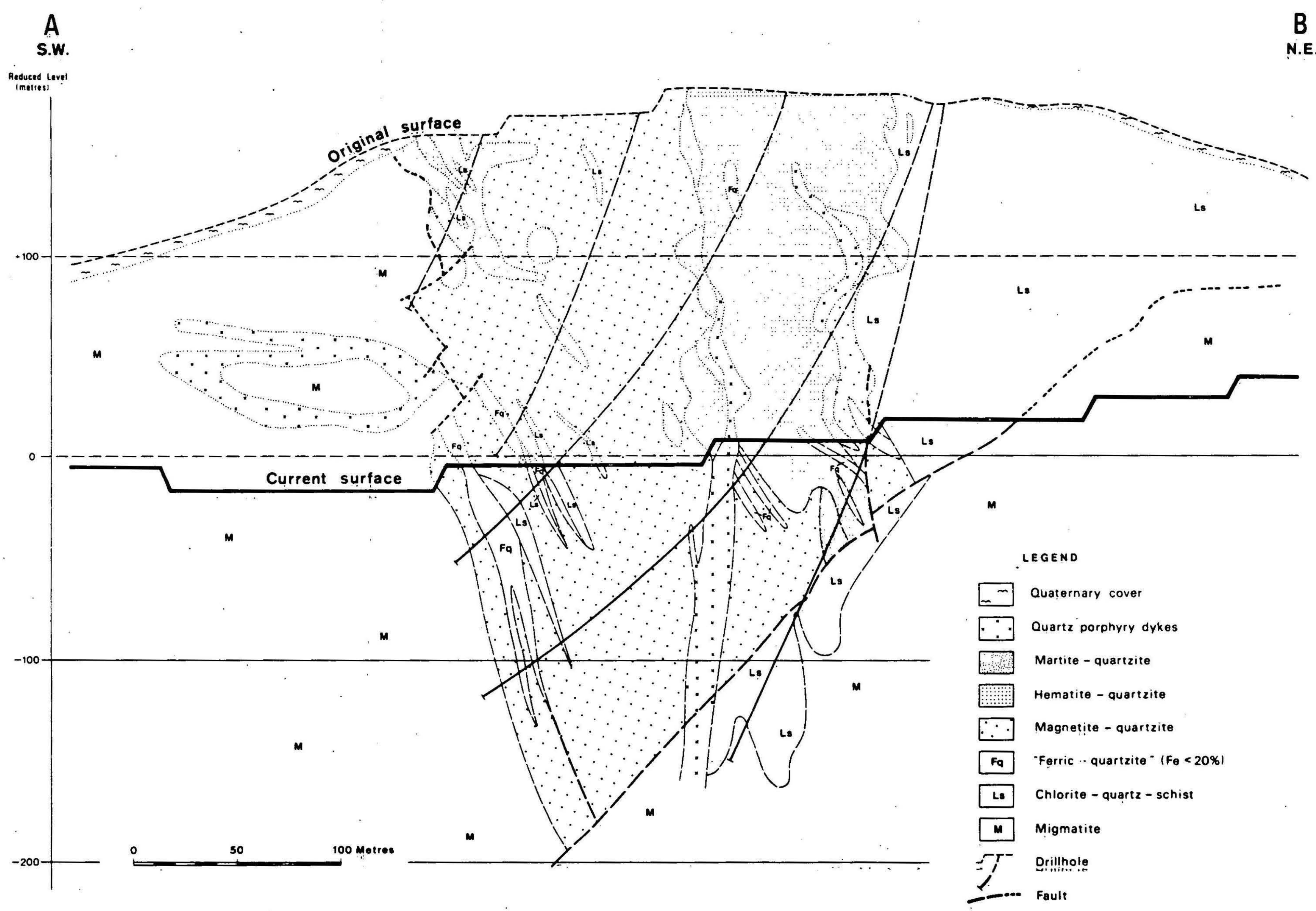


Fig. 28. Geological section, Dagushan iron-ore deposit, Anshan, China.
(Drafted from photograph of Chinese plan shown to Delegation)

Mineable reserves in the ore-body were quoted to be 200 million tonnes with an average grade of ore of 33.64% Fe, with less than 0.1% S and 0.03% P. These reserves include 3.2 million tonnes of high-grade ore averaging 45% Fe along the foot-wall contact, but this ore is mined as run-of-mill with no attempted high-grading. The Anshan geologists regard material containing less than 20% Fe as being ferruginous quartzite, and this figure probably constitutes the effective mining cut-off grade.

HISTORY OF PRODUCTION

Dagushan started in 1916 as a hill cut (Dagushan means big isolated hill) at an elevation of 80 m above MSL. Prior to "liberation' in 1949, the Chinese claim that production was a few hundred thousand tonnes (believed to be around 450,000 tonnes) per annum, achieved by hand shovels and horse-drawn cart transportation. However, other sources indicate that during the war years 1940-1945, the Japanese mined Dagushan at an ore rate of 2 million tonnes per annum. Much of the Anshan plant was reportedly dismantled and removed by the Russian occupation forces in 1945, and the Chinese presumably mean that hand-mining was carried out in the years between 1945 and 1949.

In 1954, the mine was restructured for rail transportation, and production by 1958 was quoted at 4.5 million tonnes of ore per annum, about the present production rate. Further expansion was disrupted by the Cultural Revolution which ended in late 1976.

Total production at Dagushan from 1916 to 1979 is put at 300 million tonnes of rock, of which 140 million tonnes were ore. Historical overall waste to ore ratio is thus 2.1 : 1.

MINING

The Dagushan pit measures approximately 1.8 km by 1 km (Fig. 32). There are 12 benches of which 10 are being worked. Bench height is 12 m and final pit slope design is 41 degrees. The pit floor is currently at 30 m below MSL.

Present production is 4.4 million tonnes of ore per annum. Total rock being moved is up to 19 to 20 million tonnes per annum giving waste to ore ration of about 3.5 : 1, well above the historical average for the mine. Plans are underway to increase ore production to 6 million tonnes per annum.

Ore is mined by a variety of electric shovels totalling 15 in all. Most are Chinese-made 3 cubic metre and 4 cubic metre units, but the mine also has two Bucyrus Eerie shovels purchased from the US in 1975 - 195B 7.5 cubic metre and a 280 BCL 6 cubic metre shovel. The mine is also believed to have two Russian-built EKT-8 8 cubic metre shovels. The mine has 5 drilling machines, two being 45R BE units, two 60R BE units and the fifth a Chinese-made model. Details of grade control and drill patterns were not obtained.

Transportation of ore from all but the higher, older benches is by rail pit haulage. 90% of ore and more than 50% of waste is moved by rail. Each ore train consists of eight side-dump type wagons pulled by electric locomotives of 80 tonnes, 100 tonnes and 150 tonnes weight. Each wagon has a capacity of 27 cubic metres or approximately 60 tonnes. Rail gradient averages 2%.

Rail distance from the pit to the nearest ore dressing plant was stated variously as 1.5 km, 7 km and 10 km, and to the waste dump 12.5 km. It could not be clarified whether or not the larger figures included part of the considerable in-pit rail distances.

Road haulage of ore and waste on higher benches is carried out mainly by Italian-made Perlini 20 tonne trucks, of which Dagushan has about 40. For the last year, the mine has been testing a new Chinese-built "Shaofeng" 100 tonne electric wheel haul-truck which is very similar to the Wabco 120 B unit. Also being tested was a WD 1200 12 cubic metre electric shovel built in Fushun in 1977 (Fig. 31).

DISCUSSION

STRUCTURE OF THE ANSHAN GROUP

The Anshan geologists believe that the main deformation and folding of the Anshan Group as observed today was complete before sedimentation of the overlying Liaoho Group. Subsequent movements of the Anshan Group have been due to vertical faulting. However, there are at least two schools of thought on the interpretation of the structure of the Anshan Group basement rocks themselves.

Anticlinorium "broken dome" structure

This structure, favoured by the geologists presenting the Anshan geology to the Delegation, assumes a simple anticlinorium with long axis NW-SE plunging SE, in which the oldest Tiejiashan Formation is exposed in the core. (Fig. 29a).

Synclinorium structure

The proposal for a dominantly synclinal structure plunging NW is based on the interpretation that the distribution of the two main iron-ore belts reflects the outline of the original sedimentary basin. However, to retain the core of the oldest Tiejianshan Formation, this interpretation necessitates placing the Qijiangou Formation below the Yingtaoyuan Formation (Fig. 29b).

Another viewpoint expressed at Anshan, confirmed in part by the apparently similar micro-fossil evidence of the Yingtaoyuan and Liaoho Groups, is that the W-E Xianshan-Yianqianshan iron-ore belt of the Yingtaoyuan Formation should as assigned to the base of the Proterozoic. This viewpoint would tend to support the synclinal structure proposal which makes the Yingtaoyuan Formation the youngest formation of the Anshan Group.

There therefore seems to be some real doubt not only on the structure of the iron-ore bearing Anshan Group but on whether some or all of main iron-ore formations are of Archaean or early Proterozoic age.

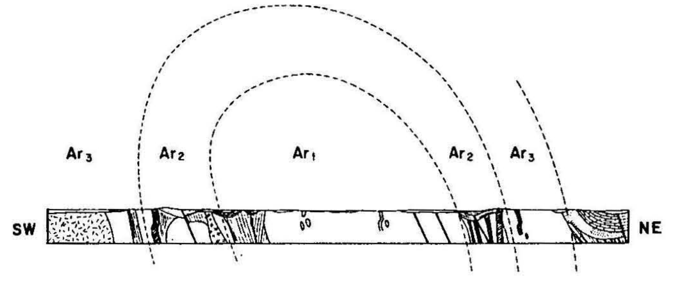


Fig 29A Anticlinorium "broken dome" structural interpretation of Anshan Group rocks.

Ar_3 Qijiagou Formation
Ar_2 Yingtaoyuan Formation
Ar_1 Tiejiashan Formation

Note – Diagrammatic section based on geological section in Fig. 1.

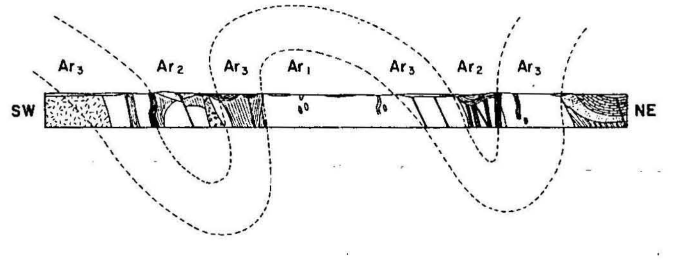


Fig 29B Synclinorium structural interpretation of Anshan Group rocks.

FUTURE INCREASES IN PRODUCTION

Major ore production increases are planned for the Anshan deposits. Apart from the immediate planned expansion of Dagushan from 4.4 million tonnes per annum to 6 million tonnes per annum, it was learnt that production from the 4.7 km NNW-SSE trending section which includes Qidashan (current production 8 million tonnes per annum) and Hujiamiaozi (being developed) is planned to be 45 million tonnes per annum by 1985.

The Chinese are fully aware that the key to increased production in the Anshan district will be their ability to upgrade ore and waste transportation.

The existing rail haulage system is inadequate for increased production. High in-pit rail distances mean that, as observed at Dagushan, a large number of shovels remain idle for too long a time. No in-pit rail switch-back or by-pass systems were observed. Most of the present truck haulage fleet has too small a capacity.

The Chinese talk of using ore conveyor systems, in-pit crushers and ore passes and more flexible large-scale haulage trucks. The experimental use at Dagushan of the Chinese-built 12 cubic metre electric shovel and 100 tonne haulage truck reflects their awareness of the problems involved.

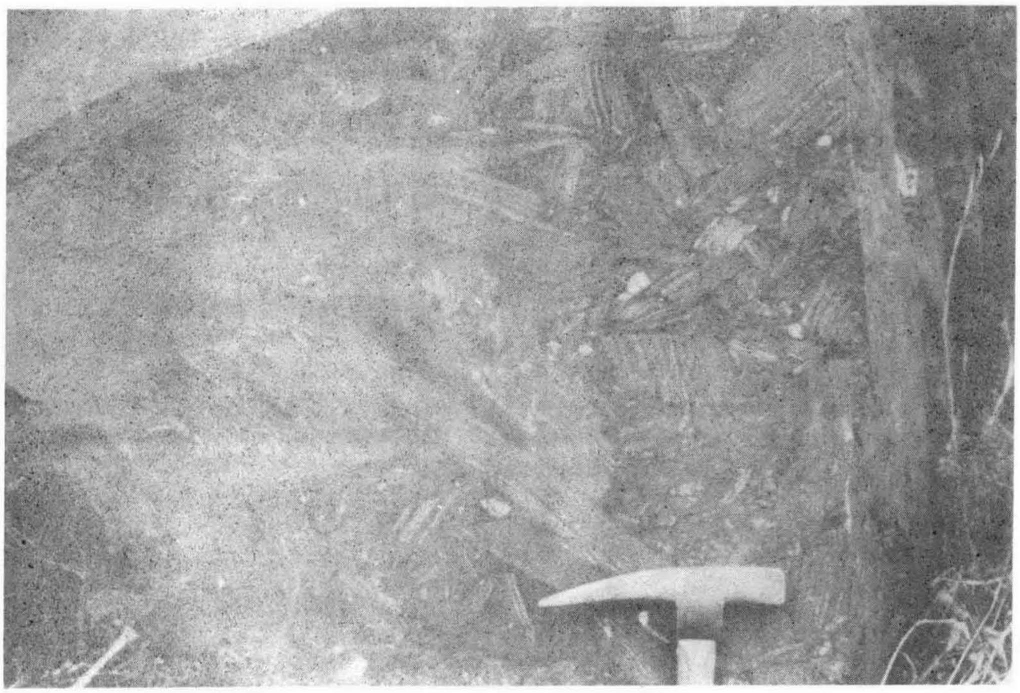
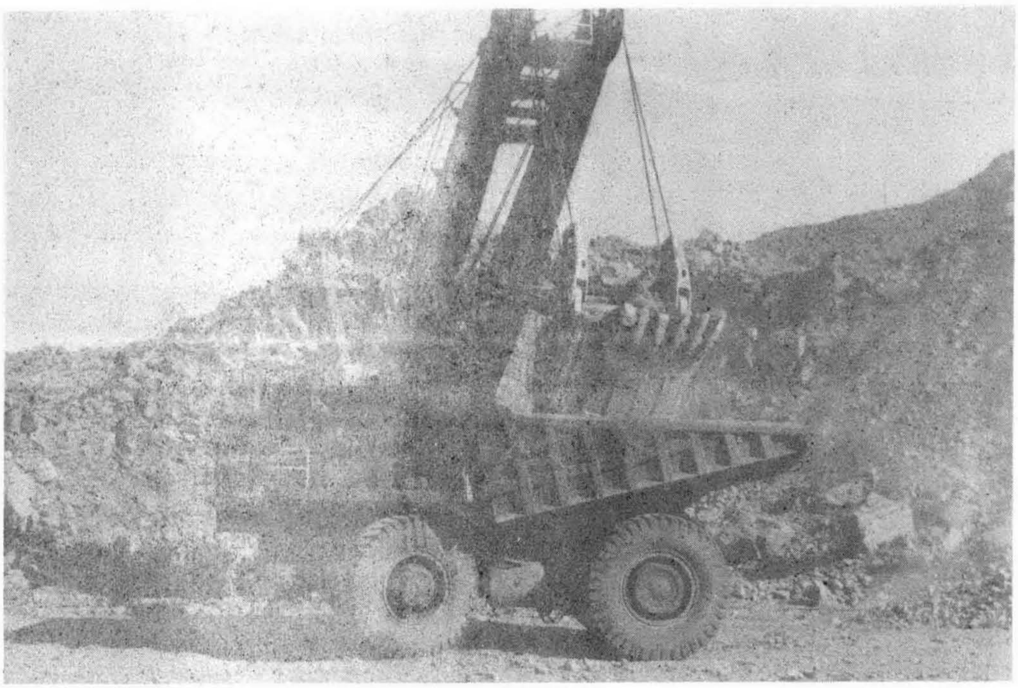
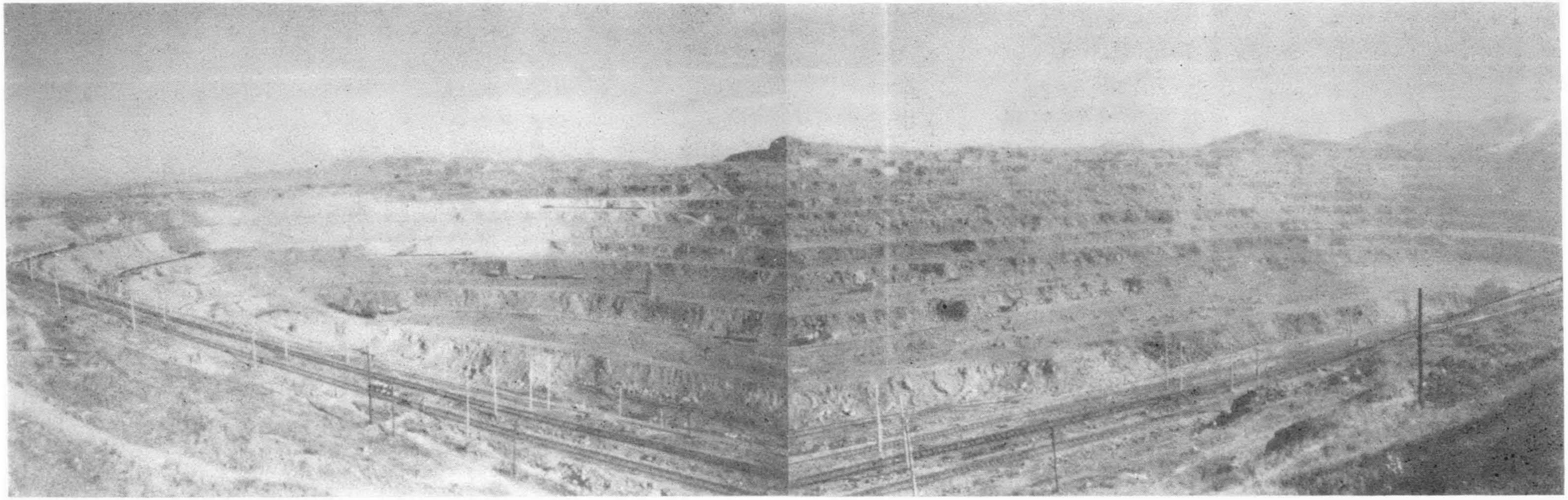


Fig. 30. Basal Paotaishan conglomerate of Liaoho Group, Hujiamiao area containing angular fragments of Type 2 banded hematite-quartzite.



Fig, 31, Mining operations Dagushan pit WD 1200 $12m^3$ electric shovel loading Shaofeng 100t haulage truck. Both units are Chinese-built.



NW SE

Fig. 32. Dagushan iron-ore mine, Liaoning Province, China.
Panoramic view of open pit operations looking NE. Note colour -
cut-off between ore and waste. At eastern end of pit dark-coloured ore is faulted out against light-coloured Qianshan granite. Note number of train rakes visible in the pit, but also number of idle shovels.

DASHIQIAO MAGNESITE DISTRICT

by G.C. Hall

ABSTRACT

There are many large size high quality magnesite deposits in the Dashiqiao district of southern Liaoning Province, China.

The magnesite deposits occur in dolomitic marble of the Dashiqiao Formation, Liaoho Group of Lower Proterozoic age. The Dashiqiao Formation extends ENE for a distance of 30.5 km and with a width of 2.2 to 4.0 km. In this area there are more than ten magnesite deposits, of which six large size deposits have reserves of more than 100 million tonnes each. The operating mines include Xiafangshung, Jinjiapuz, Huaziyu and Qingshanhuei. The ore bodies are of large size with constant thickness, length and quality.

The Dashiqiao Formation extends for a further 70 km outside of this district. Within this area, reserves of 2300 million tonnes are proven and more reserves can be expected.

INTRODUCTION

Magnesite was discovered near Dashiqiao in 1913, and the mines are operated by two subsidiaries of the Anshan Metallurgical Mining Company.

The Huaziyu mine was visited on the afternoon of 25th October 1979. The trip by bus from Anshan took less than 2 hours to cover the 80 km. En route the party travelled through Heichung, a town which has been rebuilt after a 1975 earthquake destroyed 75% of buildings.

On the return journey the delegation visited the Tang Gangze hot springs 8 km south of Anshan. This locality is a scenic tourist spot and its use dates from the Tang dynasty. Some 3000 people per annum make use of the 1300 bed sanatorium on site. The hot springs contain beneficial mineral salts for both drinking and bathing. The water contains S, K, CO_2 and radon. Water temperature is $72^{o}C$.

GEOLOGY

REGIONAL GEOLOGY

The Dashiqiao magnesite district is located in southern Liaoning Province, China (refer Fig. 33). The regional geology of the district is shown in Fig. 35.

Stratigraphy

The pre-Cambrian metasediments in this area include the Archaean Anshan Group, Lower Proterozoic Liaoho Group and the rocks of the Sinian System. In addition there are Quaternary deposits.

The Archaean *Anshan Group* is isotopically dated at 3000 m.y. (Pb-Pb). It is distributed in the NW of this area in the form of relicts of different size within the migmatite mass. The main rock types are plagioclase amphibolite, plagioclase amphibolite gneiss, biotite granulite, mica schist and locally magnetite quartzite. The unit is greater than 3000 m thick. A K-Ar date of 2400 ± 500 m.y. represents the age of metamorphism.

The *Liaoho Group* is distributed in the eastern and southern parts of this area and includes from top to bottom,

Gaixian Formation
Dashiqiao Formation
Langzhishan Formation

The Langzhishan Formation is composed of argillaceous and clastic sedimentary rocks and volcaniclastic units. It is subdivided into three Members.

The lowest member is composed of mica schist, biotite granulite, biotite gneiss intercalated with quartzite, marble and plagioclase amphibolite. The unit has a thickness 148 m to 1302 m.

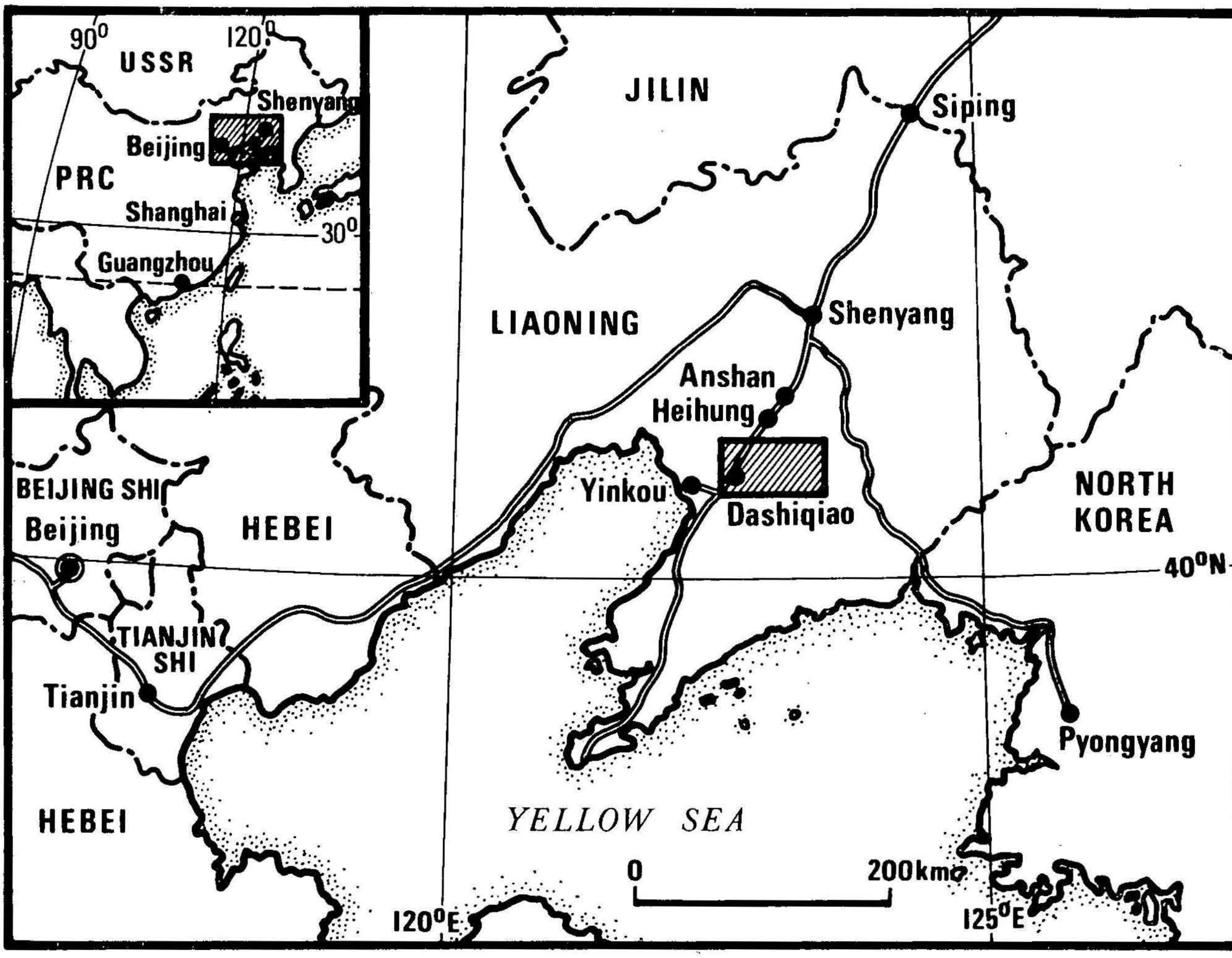


FIG.33. LOCATION OF DASHIQIAO MAGNESITE PROVINCE

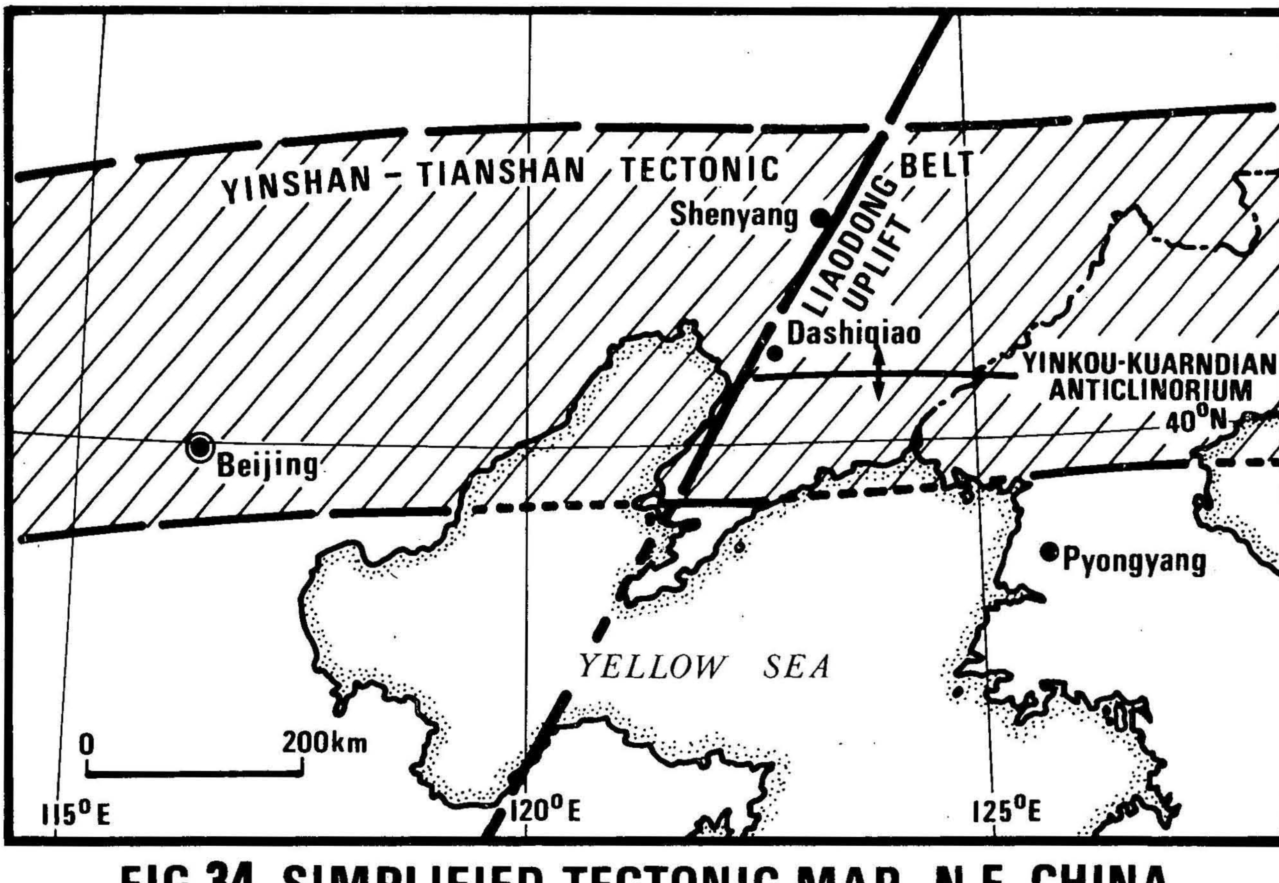


FIG.34. SIMPLIFIED TECTONIC MAP, N.E. CHINA

The middle member consists mainly of metamorphosed tuff, rhyolite tuff, rhyolite lava, breccia, tuffaceous lava, tuffaceous slate, leucogranulite, tourmaline granulite, biotite granulite, amphibolite granulite and two mica schist, intercalated with marble and plagioclase amphibolite schist. The unit ranges in thickness from 456 to 1807 metres.

The upper member consists of sillimanite biotite-muscovite schist, sericite phyllite and calcareous slate intercalated with scapolite marble and carbonaceous slate. The unit ranges in thickness from 656 m to 694 m.

The *Dashiqiao Formation* is composed of carbonaceous argillaceous rocks and carbonate. It is subdivided into three members.

The lower member consists of scapolite marble intercalated with tremolite, tremolite-diopside, amphibolite, granulite and stromatolites (Pseudogymnosolen minor, Gruneria f., Kussiella cf. vittata, Omachtenia f, Colonnella f., Surdia f., Doshigioaella dashigiaensis, Nanlouella homalosa). The unit is 1298 m thick.

The middle member consists of sillimanite garnet mica schist, biotite schist, staurolite-muscovite-biotite schist intercalated with marble, tremolite, actinolite-diopside and quartzite. The unit is 842 m thick.

The upper member consists mainly of dolomitic marble and tremolite dolomitic marble intercalated with sericite mica schist, tourmaline chlorite schist and phyllite. This member is the magnesite-bearing unit and is 1647 metres thick.

The *Gaxian Formation* is composed of argillaceous rocks and includes two members.

The lower member consists of staurolite-biotite-muscovite schist and staurolite-garnet schist intercalated locally with dolomitic marble. This unit has a thickness of 3400 metres.

The upper member is mica-quartz schist and phyllite, intercalated with metamorphosed sandstone and slate. This unit has a thickness of 3250 metres. An isotopic date of 1800 $\pm$ 500 m.y. (K-Ar) has been obtained for this Formation.

The Sinian System occurs as scattered outcrops of Diaoyutai Formation. It consists of white, grey-white quartzite and has a thickness of 30 to 100 metres. K-Ar dating of glauconite gives ages of 604 m.y. on samples taken from outside this area. It rests unconformably on Dashiqiao and Gaixian Formations.

Quaternary sediments are distributed in the north west as valley fill. They consist mainly of sand, gravel, clay and loess which form alluvium. Thickness of these sediments is normally 4 to 6 metres with a maximum of 14 metres.

Structure

The main structure is the Yingkou synclinorium and an associated fracture system.

The Yingkou synclinorium is located in the central and southeast parts of this area. The core contains Gaixian Formation, with Dashiqiao and Langzhishan Formation on the limbs. The axis is located to the north of Yinglo commune, plunging north east at 065^{o}. The north limb strikes 065^{o} to 080^{o} dipping SE in the SW of this area (around Beizhai) while in the central part of this area it dips SE at 35 - 60^{o} (around Huaziyu). In the Huaziyu mine the rocks are overturned dipping NW at steep angles (45 - 60^{o}, locally 70 - 80^{o}). On the south limb the rocks dip NNW at 24 - 60^{o}. To the west of Huangziabuzi, in the central part of the area there are second order anticlines in the lower member of the Gaxian Formation. The axis of this second order syncline strikes parallel to that of the Yingkou Synclinorium and dips at 55 - 65^{o} NE.

The fractures in the area are well developed. They are often the site of acid and basic intrusions. The main fractures often have second order folds or fractures on both sides. Strikes of these fractures are either parallel or normal to the fold trend.

There are two major strike faults in the area; one is located along the footwall of the upper member of the Dashiqiao Formation, dying out in the vicinity of the Shengshuisi, Qingshanhuai and Huaziyu mines. This fault strikes parallel to the bedding and the fault plane dips SE at 30 - 58^{o}, and thought to be a thrust fault. The other strike fault is called Dongyangshugou fault and is located in the central part of the area, north of Huagziabuzi. The fault plane strikes 070^{o} and dips NW at about 50^{o}. It is also a thrust fault. Its NW hanging wall is composed of Dashiqiao Formation while the SE footwall is composed of Gaixian Formation.

Cross fractures are well developed and locally concentrated, often intruded by intermediate or basic dykes or carbonate (dolomite).

Magmatic Rocks and Migmatite

Magmatic rocks are mainly two mica granites, plagioclase granites, granite porphyry and pegmatite dykes. These units are distributed mainly in the west and north west of the area and intrude plagioclase amphibolite, plagioclase amphibole gneiss, biotite granulite of the Anshan Group and Liaoho Group. In addition, in the area of Pailou commune there is dark green metamorphosed gabbro intruding metamorphosed volcanics of middle member of Langzishan Formation, and also intruding into granulite and mica gneiss. This gabbro body is 10 km long and 1 km wide and strikes NE extending outside the area.

The migmatite is mainly homogeneous migmatitic granite and is extensively distributed in the west and northwest parts of the area. It includes relicts of plagioclase amphibolite, plagioclase-amphibole gneiss, biotite-plagioclase gneiss, biotite granulite, mica schist, and magnetite quartzite.

Tectonics

The area lies on the junction of two major uplift zones at the north west end of the Yinkou-Kuarndian anticlinorium that formed in the Liaodong uplift and within the Jiaolo Block of the North China Platform. The area lies on the eastern end of the north-east trending Yunshan-Tianshan tectonic belt. The former uplift is of Mesozoic to Recent age and the latter of Palaeozoic age (Fig. 34).

PEOPLES REPUBLIC OF CHINA

REGIONAL GEOLOGY OF DASHIQIAO - HAICHENG DISTRICT

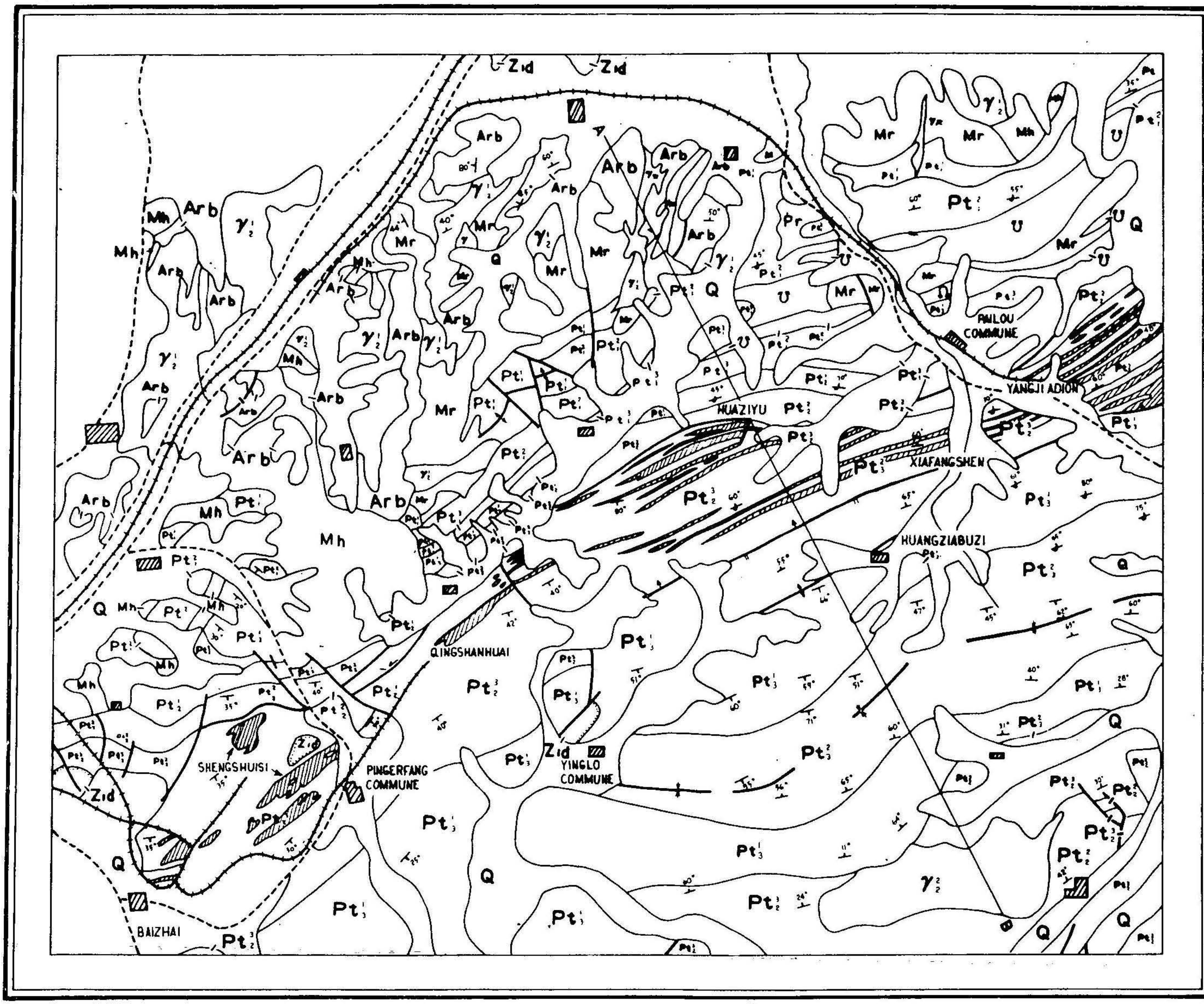
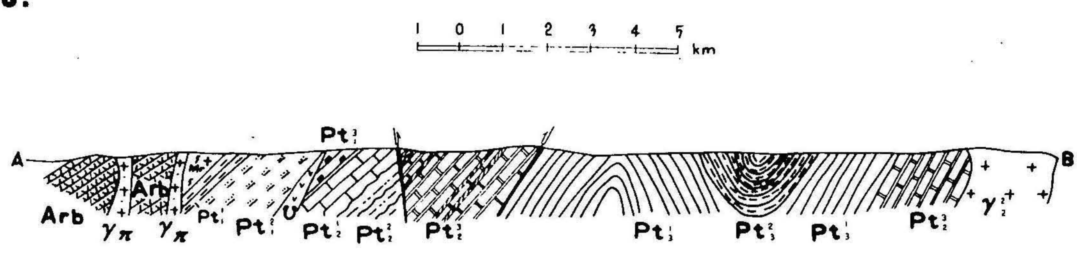


FIG.35.



To accompany report of the
Australian Delegation to China, 1979

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MAGNESITE DEPOSITS

Magnesite in the area occurs in dolomitic marble of the upper member of the Dashiqiao Formation, Liaoho Group. In the NE of this area, Yangjiadian, the magnesite has many layers with comparatively large thickness but poor quality. Better quality magnesite occurs locally. Southwest of Sungjiabuzi magnesite has been divided into upper and lower zones.

The lower zone is predominantly high quality magnesite, e.g. Shengshuisi, Qingshanhuai, Huaziyu, Jingiabuzi and Xiagangsheng deposits. The thickness of this zone ranges from 480 to 850 metres.

The upper zone has much impurity with local high quality ore; e.g. Pingerfang and Beidaling deposits. The thickness of this zone ranges from 560 to 803 metres.

Country rocks are predominantly dolomitic marble, tremolite-dolomitic marble, phyllite, and sericite schists. Sometimes intercalations of magnesite are seen.

Magnesite occurs as multi-layer deposits, with 10-293 m thickness of ore interspersed with 10 to 15 m thickness of country rock. Magnesite occurs as lenses 1,000 to 2,000 m in length and extends 500 to 800 m down dip. The magnesite/dolomite contact is usually gradational, but where sharp it interfingers. The magnesite rocks are predominantly thick layered (100 mm), rarely thin layered; and in addition radiating, spotted, banded and massive textures are seen. Grain size of magnesite can be subdivided into extremely coarse ($>$50 mm), coarse ($>$5 mm), medium (2-5 mm) and fine ($<$2 mm). The coarse class predominates followed by extremely coarse. Magnesite ores are mostly magnesite containing a small amount of dolomite, tremolite, talc, clinochlore and quartz. Associated metallic minerals include pyrite, chalcopyrite, haematite, etc.

Chemical assays of ore grade material show,

COMPOSITE GEOLOGICAL COLUMN

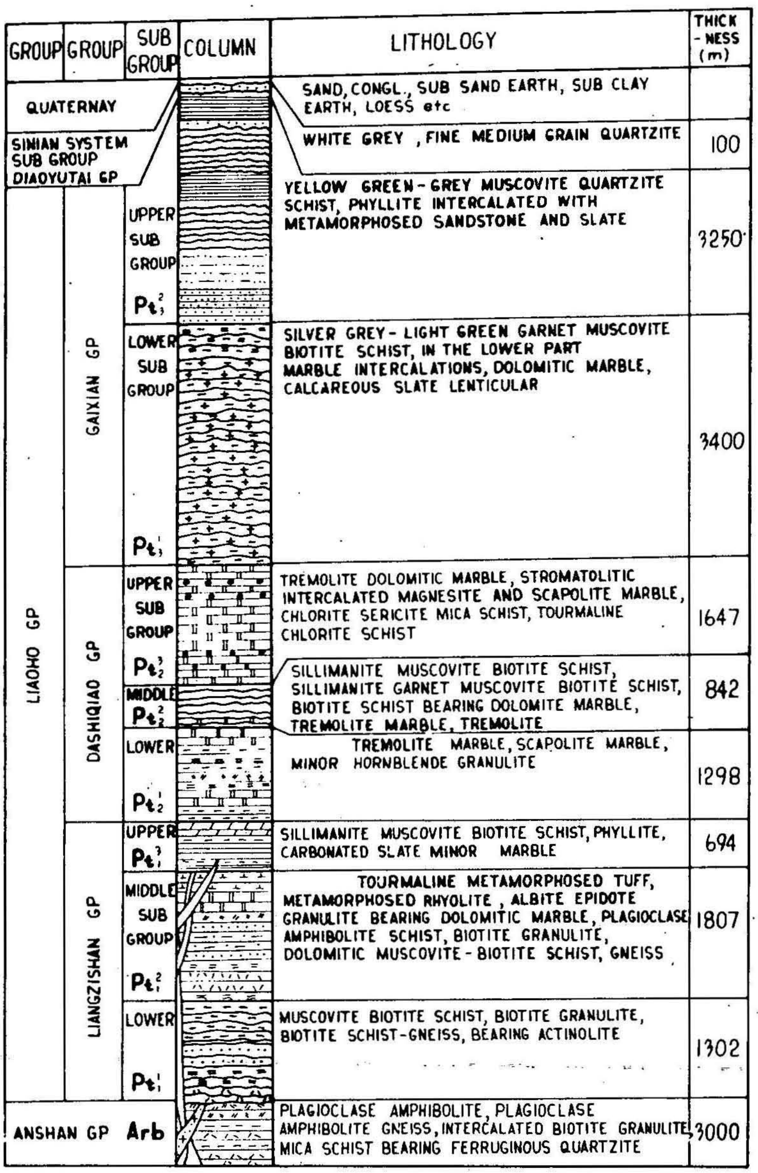
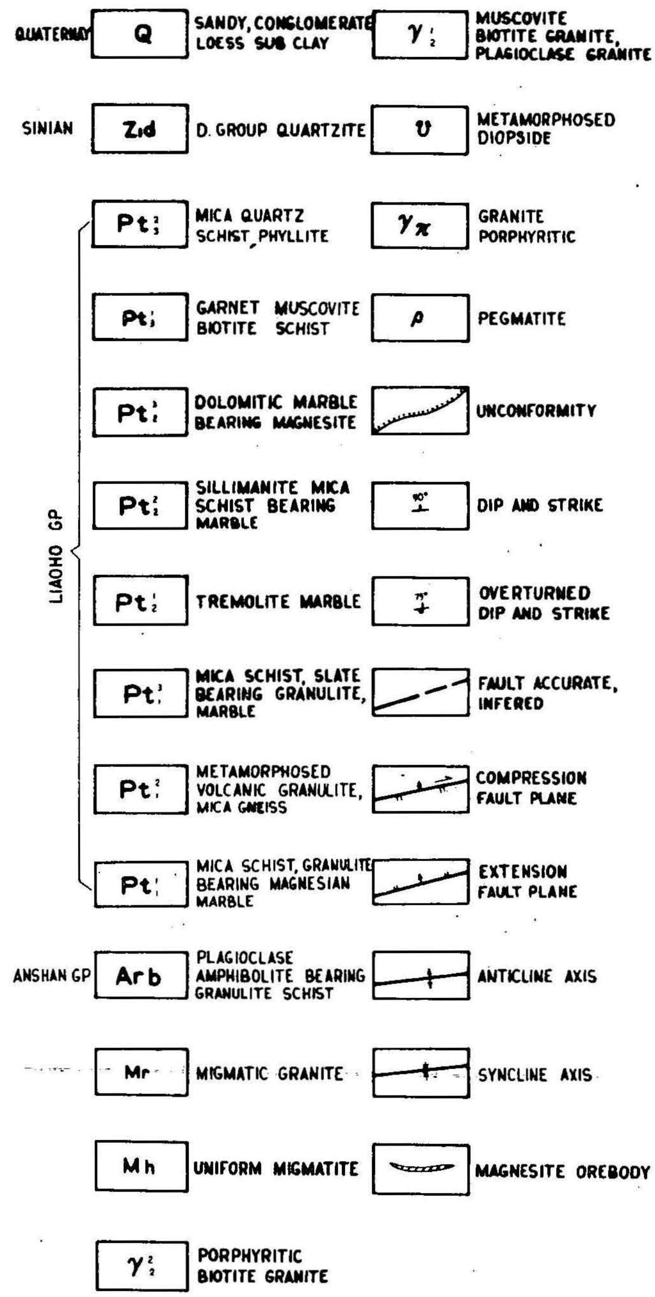


FIG. 36.

LEGEND



To accompany report of the
Australian Delegation to China, 1979

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$MgO+CO_2$	95-98%
MgO	44.4-46.8%
CO_2	50.18-51.94%
SiO_2	0.6-2.5%
$CaO+Fe_2O_3+Al_2O_3$	1% with few other impurities

Proven ore reserves within the magnesite province total 2300 million tonnes and 1.5 million tonnes ore mined annually.

HUAZIYU MINE

The Huaziyu mine is located in the centre of the Dashiqiao district (Fig. 35).

The orebody has a 6000 metre strike length which is subdivided into 22 mining blocks. The eastern orebody contains mining blocks numbers 1 to 11 inclusive and covers 3200 m strike length; the western orebody contains blocks 12 to 22 extending over 2750 m strike length. The orebody has a constant thickness of 190 m.

At the time of inspection mining was being undertaken in mining blocks 1 to 6 (2,000 m) at the 125 m level. The mining face was located on the third of the 6 magnesite beds which comprise the orebody. In this area (mining blocks 1 to 8) the strata are overturned and dip NW at 60°. In the remainder of the mine the strata dip SE. Faults conceal the hanging wall and footwall lithologies in this area.

The mine geologist maps four grades (I to IV) on the basis of visually estimating magnesite content in rock samples, and wet chemical assays of the silica content. Only one grade is mined, grade I, while grades II to IV are stockpiled in bulk.

	Grade I	Grade IV
SiO_2	1.2%	3.5%
CaO	0.75%	1.2%
MgO	46.3%	44%

Annual production is 500 000 tonnes of grade I which is sold on both the domestic and export market (main importer : Japan).

By-product talc is hand picked by women from local communes on contract. Two products are sorted, high and low grade. Both products are exported to Japan.

The mining technique involves drill and blast, with secondary breaking. Bulldozers (3 x D5 size) stockpile ore, and $4M^3$ electric shovels (6) load 27 ton dump trucks (20) of Russian construction which haul 2 km downhill to primary crusher and rail-head loader. The crushed ore is railed 20 km to a central mill.

MILLING

The mills were not visited. Samples of the final products were available. These have specifications as follows:

	Granule	Granule	Dust	Lump
Size	1-10 mm	0.5 mm	0.1 mm	0.90 mm
MgO	90	90	90	90
SiO_2	4.5	4.5	4	4.5
CaO	1.6	1.6	2	1.6

	Brick	Brick
MgO	80	88
Al_2O_3	5-10%	
CaO		3
Temp	1580 ^oC	1500 ^oC
Kg/cm^2	350	400

One mill produces 400 000 t/year "sand" (calcinied magnesite) and 120 - 130 000 t/year bricks. The other produces 200 000 t/year sand and magnesia for chemical, veterinary and paper making purposes.

CHANGCHUN COLLEGE OF GEOLOGY

by A. Renwick

SUMMARY

The Changchun College of Geology was established in 1952 and is the first of six such colleges now operating in China. It was visited by the Delegation on 26 and 27 October.

The College is divided into four Departments: Geology; Geophysics; Hydrogeology and Engineering Geology; and Geophysical Prospecting Instrumentation. There are also classes in basic sciences, English and other languages, and physical training. 13 specialities are represented within the four departments.

The staff: student ratio is about 1:7, or 1:4 if junior teaching assistants are included in the staff figures. The standard undergraduate course is four years, two or three of which are spent on general courses, and the remainder on specialist courses.

A three-year postgraduate course was started last year - the present enrolment being 52 students - compared to 3000 undergraduate students.

Equipment and facilities are, for the most part, out-of date and less than adequate for the numbers of staff and students served. The need for new and expanded facilities is appreciated and, for instance, a new computer - approximating in capacity to a standard mini-computer - is to be installed next March.

The Delegation visited a number of laboratories and other work areas; heard presentations on current research projects in a number of fields; and had a general discussion meeting with staff members.

ORGANISATION

INTRODUCTION

The Changchun Geological College was established in 1952 in response to a perceived need for a large number of geologists to implement the program of 'socialist construction' which followed the 'liberation'. At the time there were only 200 geologists in China, but since that time 13 000 have graduated from Changchun alone. It operates under the Ministry of Geology.

There are now five other such colleges established or being built in China, situated at: Wuhan; Changdu; in Hebei Province; Xian; and in Anhui Province (under construction). In addition, some universities such as Beijing and Nanching have geological schools.

The President, Professor Dong Shinpao, promised to send a list of senior staff of the College since the number of staff members introduced to the Delegation was too large for a reliable record to be compiled during the visit.

ADMINISTRATION

The College is divided into four main Departments:

Geology
Geophysics
Hydrology & Engineering Geology
Geophysical Prospecting Instrumentation

There are also classes in basic sciences such as mathematics, physics, and chemistry; as well as in English and other languages (principally Russian and Japanese), and in physical training.

Within the Departments, 13 specialities are represented:

1. *Geology* - geological survey, mineral prospecting, geomechanics, seismic geology, geochemical survey, rock and mineral analysis.

2. *Geophysics* - geophysics of metallic and non-metallic deposits, petroleum geophysics, airborne geophysics.

3. *Hydrogeology and Engineering Geology* - Hydrogeology, engineering geology, engineering prospecting.

4. *Geophysical Prospecting Instrumentation* - instrumentation design, modification and methodology.

Staff comprises: 71 professors and associate professors; 353 lecturers; and more than 300 teaching assistants.

Students comprise : more than 3000 undergraduates; 52 postgraduates; 11 foreign students (from Africa and Asia).

Undergraduate students enter the College at the age of 17 or 18 (owing to the suspension of State examinations during the 'lost' years of the cultural revolution, the average age of present students is higher). About 15% of total undergraduate students are female. Education, food and accommodation are all provided free of charge.

COURSE STRUCTURES

The undergraduate course takes four years to complete. Great stress is laid on basic subjects and two to three years of the course are devoted to their study, the remainder being spent on specialist subjects, each course lasting a half or one year.

Geology is not taught as a subject in Chinese schools, although some is included in general science classes.

Courses are programmed on the semester system and the special courses are elective. It is proposed to introduce the elective system to some basic courses, each course unit having a credit rating.

Basic courses

These can be grouped as follows:

1. Politics, economics, history of the Chinese communist party
2. Physics, mathematics, chemistry (number of courses and levels depend on main discipline selected).
3. Foreign languages: English is the principal foreign language taught, but some study Japanese or Russian as their first foreign language. The object is to be able to read references. Senior students may study a second language.
4. Geological processes: Petrology, mineralogy, palaeontology, structural geology, stratigraphy, dynamic geology.

The study of electronics will shortly increase, and mathematical geology is developing in importance.

Special courses

The selection of special courses is primarily made by the students themselves although the broad overall weighting of places on courses is determined by the State.

Fieldwork courses

Fieldwork is undertaken by students in three periods spread over three years, and totalling six months. Students are attached to parties doing productive work as part of the Ministry of Geology or Ministry of Metallurgical Industry programs. Practice in lecturing (public presentation of work) is included in the fieldwork periods.

Postgraduate courses

Postgraduate courses (started in 1978) last three years. Students prepare a thesis based on a piece of assigned research in special research sections established in each of the College's four Departments.

Topics for research are, for the most part, designated by the State, but some are generated by the College. Research may be into basic processes or may be oriented towards solving specific problems thrown up during work programs - sometimes involving collaboration with other bodies such as the Chinese Academy of Science, the Ministry of Geology, or the Ministry of Metallurgical Industry. Postgraduate students are also expected to lecture.

China has an immense need for specialist capability, and the College is responding to this.

The level of postgraduate attainment is claimed to be a little higher than a Masters' degree.

Employment opportunities

These arise mostly within the two ministries, and choice of assignment is made jointly to meet, as far as is practicable, individual preference and the needs of the State.

FACILITIES AND WORK AREAS

MUSEUM

A large area with many good specimens and displays housed in old-fashioned cases. Exhibits include fossils, minerals, economic minerals, and displays illustrating stratigraphy and dynamic geology. Some specimens are labelled in English as well as Chinese, and it was suggested during the visit that this practice should be extended to all exhibits as an aid to language teaching. The museum is said to be extensively used by the students.

LIBRARY

A large, but obviously inadequate, room which was crowded with students reading textbooks and lecture notes, and working on exercises and problems. One got the impression that this was the only place available for private study - we did not see the students' living quarters.

Books, not a large collection, were shelved in two rooms, with English and Russian texts held separately. Russian texts outnumbered English ones by three to four times. English texts were mostly old classics. The books did not appear to be much used, and no foreign texts were seen on the library desks.

The establishment of exchange arrangements with BMR was suggested during the visit and warmly welcomed by the College.

LABORATORIES

Introduction

Laboratory equipment is almost entirely old and not technologically advanced.

Optical laboratory

Equipped with standard petrological microscopes and usual supplementary equipment. Mostly Zeiss equipment from German Democratic Republic (East Germany).

Mineral Separation laboratory

Equipment was, for the most part, locally made versions of conventional equipment such as the Franz 'isodynamic' separator and electrostatic separators. Dielectric separation has been developed, and the equipment does seem to have had some original design input.

X-ray laboratory

X-ray diffraction equipment in use was of Chinese manufacture and had a 3KW generator.

Infra-red spectroscopy laboratory

Zeiss-Jena (DDR) equipment (model SPECORD 751 R) was in use for infra-red spectroscopic studies of zeolite and clay minerals.

Isotope dating laboratory

A 7 year old Chinese manufactured mass spectrometer was being used for age determination and stable lead isotope studies on ore deposits to determine whether the deposits are of metamorphic or metasomatic origin. Determination of K:Ar ages were also being made in this laboratory.

SERVICE FACILITIES

These include a chemical analysis laboratory; a printery; and a machine shop for making, modifying, and repairing equipment. A new computer is to be installed in March 1980. Designed by the University of Beijing and manufactured in northeast China, it will have a memory of 60 000 bytes and be capable of 150 000 additions a second.

GEOLOGY DEPARTMENT

INTRODUCTION

In a four-hour visit to the Department in the afternoon of 26 October, one group from the Delegation heard a number of presentations, and saw practical demonstrations of research being carried out.

The research programs are devised largely in response to needs perceived by the Ministries (Geology and Metallurgical Industries), although sometimes they are developed within the College itself. Typical programs involve staff, post-graduate and undergraduate students, and where appropriate field teams from Provincial Bureaux.

There was an enthusiasm evident in all the presentations of the program being described, and a strong impression was gained that senior students exposed to such enthusiasm would be stimulated to develop an attitude of dedication to their work.

The activities described to the Delegation are by no means exhaustive of the Department's research program and, for this reason they are recorded here only in broad outline without inclusion of the detailed results and conclusions which were sometimes presented. They will serve as examples of the sorts of problems being tackled.

ORE MINERAL SECTION

The first presentation was on the regional economic geology of East Tsinling. Since 1973, 30 staff and 300 students have worked on the project whose object is a study of the basic geology and mineralisation of a mobile metamorphic belt covering an area of some three 1:250 000 sheets. Fieldwork has been conducted on various scales, i.e. 1:20 000; 1:50 000; and a general coverage at 1:200 000 to produce a map at scale 1:500 000. The program has involved geochemistry and geophysics.

The overall impression was that the approach to the problem and the results are comparable to those of BMR regional projects.

Other projects described were:

1. a study of bauxite in the Tertiary volcanics of Hunan Province.
2. studies of ophiolite suites and comparison with those of Cyprus.
3. research on a major mesozoic gold deposit at Linglongtu (Liaoning)
4. a re-interpretation of the Dexing porphyry copper deposit at variance with that of the prospecting teams, and more in accord with the Delegation's views.

EXPERIMENTAL PETROLOGY AND ORE GENESIS LABORATORY

Extensive work has been done on the synthesis of crystals under high temperatures (700-800^{o}C) and pressures (up to 2000 atmospheres) as a basis for mineralogical research, including interpretation of genetic implications of crystal inclusions. The emphasis at present is on artificial skarn minerals such as garnet, sillimanite and wollastonite, in relation to metamorphism, hydrothermal alterations, and metasomatism.

Spectacular piezoelectric quartz crystals were shown. These take 55 days to make under a pressure of 1500 atmospheres and a temperature of 352^{o}C. Each crystal was approximately 150 mm long. At the end of the visit to the College, the Principal presented one of these crystals to the Delegation.

PRECAMBRIAN RESEARCH GROUP

A group comprising staff, postgraduate and undergraduate students has been working since 1975 with a geological team from the Provincial Bureau on an investigation of the regional setting and on the exploration of a low-grade Precambrian iron ore deposit at Gei Dong in Hubei Province. Total reserves are estimated at several billion tonnes.

A seond presentation dealt with a high grade lead - zinc deposit at Guangmenshan, 60 km north-east of Shenyang (Liaoning).

SEDIMENTARY ROCK GROUP

Work of the group is concentrated on late Precambrian rocks because strata of that age are well developed in China and because the principal sedimentary ores occur in them. The group consists of five staff members and two postgraduate students who have projects in Hubei, Liaoning, Jilin and adjacent Provinces. Main thrusts are the study of composition and sedimentary profiles in the field, and analysis of rock associations. Studies of sedimentary mechanisms, facies changes, and origin of structures have led to the discovery of sedimentary phosphate, iron and manganese deposits. Some of the research on phosphate deposition appears to be highly original. A paper has been published entitled 'Formation of Phosphorites' in which the deposition of phosphorite is attributed to a critical dynamic environmental balance rather than to chemical precipitation.

GEOMECHANICS EXPERIMENTAL LABORATORY

The work of the laboratory is concentrated on experimental modelling with a strong leaning to classical themes originated by J.S. Li, and a rejection of the plate tectonic theory.

GEOPHYSICAL DEPARTMENT

(contributed by L.W. Williams)

INTRODUCTION

A second group from the Delegation visited the Geophysical Department on the afternoon of 26 October.

The Department has several laboratories and extensive use is made of physical modelling for teaching and research in the electrical and magnetic laboratories. Equipment is modern but frequently is not latest generation.

METALLIC LOGGING

The instruments exhibited were a 3-component magnetic down-hole tool, a signal detector and a down-hole EM tool.

The magnetic tool was designed in 1968, used in exploration in 1972 and further developed in 1978. The instrument measures X, Y and Z components and is oriented by gravity with Y always in the direction of the hole. It is a flux-gate type of instrument, and is a modification of a Swedish design, made in China. The outside diameter of the tool has been reduced and is now 44 mm. The control panel on display had a manual balance system. An example was shown where logging of drill holes on an iron ore prospect showed 19 layers of iron against the 8 logged in the core, which added 10 m of iron rich material to the intercept.
The signal detector can be used for IP, SP and apparent resistivity recording and can also be used with radiometric probes.

The down-hole EM tool has separate units for the transmitter and receiver, with outside diameter of 30 mm; the diameter will be greater on the next version to be produced. The equipment can be used either with the transmitter and receiver in one hole or in separate holes. An example was shown of the detection of a copper ore body using holes 62 m apart.

ALTERNATING CURRENT LABORATORY

A model was in use using equipment to measure in-phase and out-of-phase components of the magnetic fields.

Another model was being employed with airborne EM equipment operating in time domain. The model used a copper sheet lying on graphite bars. The equipment produced results at six different decay times to a maximum of 2.6 m.

The survey is normally carried out at a height of 150 m. Horizontal positioning is done by vertical photographs with the aircraft position being transferred directly to printed maps - photo-mosaics are not used. Examples of orientation surveys over sulphide veins and iron deposits were inspected. These prospects gave anomalous responses into the fourth and third channels respectively and were not considered good anomalies by our Chinese hosts.

GRAVITY

The laboratory was set up in 1954 and is now using the fourth generation of equipment. An old Askania gravity meter and two Russian types are used for teaching and a torsion balance is also on display.

The gravity meter currently being used on surveys has a quartz-system and is made in Beijing. It was described as having some parts based on another design. Characteristics quoted for the meter were a reading accuracy of 20-30 microgals, drift 50 microgal per hour and a temperature coefficient of 30 microgal per ^{o}C. The instrument has a temperature compensator but no temperature control.

China has been surveyed gravimetrically, except for a few mountainous regions, at a scale of 1:1000 000 or 1:500 000. One station has been measured each 100 km^2 for the 1:1000 000 map and one station each 20 km^2 (approx.) for the 1:500 000 map.

DIRECT CURRENT LABORATORY

This laboratory has 5 baths, 4 for teaching and 1 for research.

1. Graphite model in water (horizontal cylinder) and profiling method to simulate low resistivity orebodies e.g. iron deposits. They also have a topographic model to measure resistivity and deduce a terrain correction (not sighted).

2. Water/insulator model, profiling and sounding techniques using a Schlumberger arrangement in order to deduce a 2 layer curve - simulating coal or water applications.

3. Time domain IP model, using semi automatic measurement.

4. The frequency domain IP equipment had automatic adjustment of the range of frequencies of the transmitter, and the receiver can measure the frequency effects for 3 pairs of frequencies and gives % frequency effect.

5. Larger bath for research work, set up with time domain IP and automatic measuring.

PETROLEUM BORE LOGGING LABORATORY

The instruments displayed were a velocity logging tool, a general recorder for other logs and an induction tool.

The velocity logging tool was first made in China in 1966. It operates with a fundamental transmitter frequency of 20 kHz and a pulse frequency of 20 Hz.

For teaching purposes the electronics of the down-hole tool are set out on a board to illustrate the operation.

The general recorder and induction tool appeared to be conventional.

MATHEMATICAL GEOLOGICAL LABORATORY

This is currently part of the geophysical Department but soon to become a separate department. Two examples of the application of mathematics to geology were illustrated.

The first example involved the use of the Markov method of correlation analysis to unravel a structural problem in an iron ore province where there was little outcrop. The problem consisted of two possibilities

- one iron bed and two sub parallel synclines

or - two iron beds in one syncline.

The analysis showed the sequence above and below each iron bed to be different and highlighted which sequences were similar and hence the facing of the bed.

The second example involved the application of the multivariate statistical analysis of Hsu to a metallic region. This analysis highlights which areas are most prospective for ore deposits of the type already identified within the region.

Most of the mathematical analysis is done by hand as the computing facility is not yet completed.

The analyses being applied are very modern and approach "the state of the art": certainly as far as applied mathematical geology goes within Australia.

APPENDIX I
NAMES OF OFFICIALS MET BY THE DELEGATION

GUANGZHOU

Mrs Cai Wenyan - Chinese Academy of Geological Sciences, Ministry of Geology, Foreign Affairs Section.

Mrs Zhang Andi - Institute of Mineral Deposits, CAGS, Ministry of Geology (Geologist).

Prof. Zhang Bingxi - Chief Geologist Engineer, Ministry of Geology.

Mr Liang Xianlun - Dy Director, Bureau of Geology, Kwantung Province.

Mr Hu Ming - Head of Administration Office, Provincial B of G.

Mr She Dingchang - Deputy Head of Administration Office, P B of G.

Mr Chen Qunming - Interpreter, P B of G.

SHAOGUAN

Miss Wang Yaping - Foreign Affairs Section, Jiangxi Provincial Government.

Mr Bao Jiabao - Head of Scientific Technical Section, Bureau of Geology Jiangxi Province.

XIHUASHAN

Mr Li Qingyan - Director, Xihuashan Mine.

Mr Wang Zehua - Head Geological Section, Xihuashan Mine.

Mr Deng Kunxing - Head Geological Bureau, Jianxi Province.

Mr Han Zhujiu - Geologist/Engineer, Geological Team 908 Jiangxi Geological Bureau.

Mr Guan Xuli - Foreign Affairs Office, Ganzhou District.

Mr Su Yongzhi - " " " " "

Mr Wang Shiwei - Head Admin. Office, Xihuashan Mine.

TAOLIN

Xiao Hesheng - Deputy Head, Taolin Mine.
Chen Baohua - Geologist/Engineer, Taolin Mine.
Li Yixun - Admin. Office, Taolin Mine.
Li Shuguan - Deputy Chief Engineer.
Dan Dechi - FAO Hunan Provincial Rev. C'ee.
Luo Shikand - Geologist, Provincial Geol. Bureau.
Fang Chuangu - Geol. Section of Taolin Mine.

XI KUANGSHAN - (XKS) (Tin Mine Mt).

Cui Zhenjiang - Director, Mining Bureau XKS.
Yi Chengwu - Geol/Eng. XKS
Liu Guangmo - " " "
Chen Miaozhang - Geol/Eng. XKS
Zhang Xiankuei - Deputy Head, Geol. Section XKS.
Zhang Ximing - Chief Engineer, Deputy Director of XKS Mining Bureau.
Liu Guozao - Deputy Chief Mining Engineer.
Sun Suilong - Deputy Head, Ore Dressing Plant.

YINGTAN

Uranium Prospect No. 60
Zhang Guangyi - Head, Geological Exploration Team.
Bao Shirong - Geologist Engineer.
Fan Chuanbi - " " (gave presentation).

DEXING

Xu Jisheng - Head of NE Jianxi Geological Brigade.
Hu Kuei - Geologist Engineer (gave presentation).
Fan Meisheng - " "
Xue Tongke - Mining Engineer.
Chen Shipong - Ore dressing engineer.

ANSHAN

Wang Zhifu - Vice President and Chief Engineer, Anshan Mining Corpn.
Li Hongye - Vice Engineer in charge of geology, " " "
Bao Jinlin - Vice Department Leader " " "
Yin Chingjun - Geological Engineer, Geological Exploration Co of Anshan Mining Corpn.
Qin Dazhong - Geologist, Anshan Mining Corpn.
Xu Anlin - Vice Department Leader, Anshan City Foreign Affairs Office.
Wei Subin - Staff member " " " " "
Fu Dachun - " " " " " " "
Ji Jinchuan - Interpreter " " " " "
Chi Wenzhang - Geologist Engineer, Geological Exploration Co of AMC.
Zhou Minghao - " " " " " " "

(Presentation on iron ore geology by Yin Chingjun)
(" " " " " " Chi Wenzhang)

BEIJING

Airborne Geophysical Team

Ji Zhuping - Head of Airborne Geophysical Team, Ministry of Geology.
Fang Yinjao - Chief Engineer.

Computer Centre

Liu Zhenqan - Head of Administration - Institute of computation technology applications.
Zhu Yunqing - Head of Science and Technology.
Miss Ho Chunzchu - Head of Technical Work.
Hou Zhengchu - Geophysicist in charge of machinery.
Lun Xueli - Administrator.

National Geological Museum

Pan Jiang - Permanent Head of the Museum.

Academy of Geological Science

Zou Jiayou - President Chinese Academy.

Meng Disheng - Vice President Academy.

Miss Zhang Juin - F.A. Section.

Liu Ying - Director Inst. Lab. Determinations.

Sung Shuhe - Director Inst. Min. Deposits.

Miss Zhang Ruyu - Scientist Inst. Min. Deposits.

Sung Xiexin - Geologist.

Zhang Ronghua - Geochemist.

Lu Yushan - Experimental petrologist.

Rui Zengyo - Geologist.

Institute of Uranium Geology
(Beijing Uranium Geology Research Institute)

Wang Wenshan - Vice Director of Uranium Geology Research Institute
POB 764 Beijing China.

Prof. Gao Zhidi - Dy Chief of Bureau of Uranium Geology.

Hu Shaokang - Geologist.

Zhu Leitung - Geophysicist (interpreter)

Ministry of Geology - Bureau of Foreign Affairs

Yang Zheling - Deputy Chief (Mrs Zhang's husband).

Jiang Xueyan

Zhang Jiajiun

GENERAL OBSERVATIONS

INTRODUCTION

The Delegation was fortunate in being a small group with a variety of experience but with a common interest, most ably guided by Professor Zhang Bingzi and assisted by Mrs Zhang Andi and Mrs Cai Wenyan. It was able, as a result, to gain more in-depth impressions of aspects of Chinese life and work relevant to its interests than would be possible for the ordinary visitor. At the same time, members of the Delegation were very conscious of the superficiality of many of their impressions of social and cultural conditions; and observations on these aspects are therefore, kept to a minimum.

GEOSCIENCE TRAINING AND RESEARCH

The effects of the Cultural Revolution (often referred to as the lost ten years) were evident everywhere. They include dilapidated laboratories and classrooms, out-of-date and poorly maintained equipment, a general scarcity of resources, and a missing generation of professional workers.

These effects are being countered with a sense of urgency by the acquisition of new equipment from overseas, by the design and construction of equipment in China, and by according a high priority nationally to the development of all branches of geoscience.

Members of the Delegation agreed that facilities in Beijing were generally very superior to those in the Provinces, but that even there, much of the equipment was a decade or more behind western standards. In spite of this, several examples of original thought and of careful research were seen, and it must also be borne in mind that the visits were confined to research institutions within three ministries; those of Geology, Metallurgical Industries, and the Second Ministry of Machine Building: and that many institutions within these ministries could not be visited in the time available. To these must be added the considerable geoscientific research activities in institutions under the aegis of Academia Sinica. More detailed observations on the institutions visited are contained elsewhere in this report.

The members of the Delegation were impressed by what they saw at the Geological College at Changchun. (Again, more detail is contained in the relevant chapter in the report). Even allowing for the fact that this is the oldest, and therefore possibly best developed, of such colleges in China, the overall achievement in undergraduate training reflects a high level of governmental understanding of the importance of geoscience in developing national resources.

It was difficult in a short visit to assess the overall level of attainment of the students at Changchun, but the dedication, enthusiasm, and ability displayed by the staff suggest that the level of attainment is reasonably high and will, with improved conditions, equipment, and facilities, improve in the future.

MINING PRACTICE

It is difficult to compare mining practice in China to that in the West; and in many ways such a comparison is irrelevant. For instance, the labour-intensive methods in all the mines and treatment plants visited were immediately noticeable. But such methods are probably appropriate to a country with vast human resources, limited technology, and intense demand for machinery and other fabricated products from other fields of national development.

Apart from the highly labour-intensive methods, such as hand-picking of ore on slow-moving conveyors, the utilisation of machinery and the application of technology were often inefficient. Examples of this were seen at Anshan where electric shovels were idle for a large part of the time owing to the slow-moving rail system used to convey ore from the face to the treatment plant; and in the poorly controlled flotation cells and thickeners at Taolin. Certainly in the first of these examples, mine management was aware of the problem and a new haulage system using 100-tonne trucks is planned, and a prototype truck of Chinese manufacture was already on trial.

Again, in contrast to Western practice, dust control is taken very seriously whilst other health hazards are given scant regard. Face masks of gauze are worn by most workers, and all mine walls and roofs are washed monthly, whilst feed through treatment plants is so wet as to make concrete floors and steel ladders dangerously slippery, and to improve the efficient handling of the material itself. On the other hand, ill-fitting gumboots are standard footwear underground, and no eye protectors were seen.

Electrical installations are primitive - conductor wires for underground tramways are, statutorily, 1800 mm above the floor, and carry up to 250 volts. In places the clearance is inevitably less, and with safety helmets usually constructed of open wickerwork and tarred paper and with the amount of water everywhere, it is surprising that accidents are not more frequent than they apparently are. Perhaps the gumboots help.

Possibly again related to the concern with respiratory problems, ventilation was excellent in all the mines visited.

EXPLORATION METHODS

These are, for the most part, also labour-intensive, and rely in large measure on extensive drilling programs using fairly primitive equipment which, however difficult the terrain, seem to be positioned with minimal mechanical aid.

Dated theories of ore genesis, and a lack of interchange of experience and ideas between exploration staff at different mines inhibit the estimation of future ore reserves in operating mines and the discovery of related deposits in a region.

It was noticeable that the Provinces were not equipped for geophysical exploration and that surveys were conducted by groups from organisations in Beijing. The local geologists had little knowledge of geophysical methods.

COMMUNICATION BETWEEN SCIENTISTS

Probably the most noticeable problem confronting geoscientists in China is the lack of communication.

Even in Beijing there was a marked lack of interchange between workers in different institutions, and it was obvious that this lack was far more serious in the Provinces.

For instance, the field staff conducting uranium exploration near Yingtan were completely unaware of the experience gained by their colleagues in the same Ministry who had attended the Pine Creek Symposium in Sydney, and it is doubtful if any widely available report by the Chinese Delegation on Exploration Geoscience to Australia in 1978 had been written, or was even planned.

Language is certainly a barrier to communication between many Chinese geoscientists and their overseas colleagues, but the lack of copying machines and the complexity of Chinese typewriters also place grave limitations on the communication of ideas.

No mention was made of central or regional symposia or seminars, and questions on such meetings were usually answered by pointing out the difficulties imposed by distance and travel restrictions, although there was an understanding of the usefulness of such meethings 'when they are again possible'.

The enthusiasm for 'debriefing' sessions which followed each mine visit gave an indication of the desire, especially in the Provinces, for the opportunity to exchange views and ideas; just as the lack of handout material and of printed maps at initial briefings emphasised the basic problems in communication.

LASTING IMPRESSIONS

The sincere friendliness and generosity with which the Delegation was met on every occasion and in each situation made a lasting impression on its members.

The outstanding effort made on behalf of the Delegation by Professor Zhang Bingxi, Mrs Zhang Andi and Mrs Cai Wenyan has already been refferred to. The representatives of Provincial Bureaus of Geology, of research institutes, of Ministries and of mine management also contributed greatly to the success of the visit; and the staff of hotels, guest houses and others with whom the Delegation had contact helped to make the visit enjoyable and memorable.