BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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REPORT ON A FEASIBILITY STUDY FOR A JOINT SINO-AUSTRALIAN COMPREHENSIVE GEOLOGICAL AND GEOPHYSICAL STUDY OF THE EASTERN JUNGGAR REGION, XINJIANG, CHINA

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SUMMARY

On the basis of a feasibility study carried out by a joint Australian-Chinese team during 24 May to 24 June 1987, a proposal for a 3-year comprehensive geological and geophysical study of the eastern Junggar region, Xinjiang Autonomous Region, China, has been formulated. The area of the proposed study covers about 30,000 square kilometers. The proposal takes into account constraints imposed by the Chinese government regarding availability of geological and geophysical information and air photos to a foreign country.

The main aims of the comprehensive study are: 1) to provide a comprehensive geological and geophysical framework for the eastern Junggar region; 2) to gain a better understanding of the tectonic setting and mineral potential; 3) to assist in the selection of areas which appear to be the most prospective for detailed mineral exploration; 4) to introduce methods and techniques used in Australia in the search for mineral deposits and, 5) to help in training scientific and technical personnel.

It is recommended that the comprehensive study be completed within three years, and should involve four Australian geologists, including two with expertise in mineral exploration, and four or more Australian geophysicists working in teams with Chinese counterparts. Geophysical work should include, as a matter of urgency, a low-level airborne geophysical survey, including magnetics, radiometrics and possibly EM, to be carried out by the Aero Geophysical Survey (AGS) of China; a regional gravity survey should also be carried out by China. The Australian contribution should include planning and initiation of a SIROTEM field program; training of Chinese field teams in the use and interpretation of SIROTEM and IP; assistance in processing airborne data, in organizing training courses for geophysicists in China, in interpreting airborne survey data, and in selecting targets for ground geophysics; and provision of experts, as required, to advise on specialist topics. Several Chinese geologists and geophysicists should visit Australia to gain experience from Australian mineral exploration companies and research institutes.

The recommendations would require in the order of three million Australian dollars from technical cooperation funding (AIDAB) to cover salaries, allowances, contracts and airfares for the Australian participants, costs for Chinese geoscientists visiting Australia, and necessary equipment for the 3-year period of the study. The costs of the airborne geophysical survey of eastern Junggar, accommodation and transport for the Australian participants within Xinjiang, and computer services in Xinjiang and Beijing should be borne by China.

OBJECTIVES

The Objectives of the Feasibility Study were to define the requirements for a co-operative comprehensive geological and geophysical study of the eastern Junggar region, Xinjiang Autonomous Region, which if carried out will provide a geological, geophysical and geochemical framework within which exploration and prospecting for base metal mineral deposits can be conducted.

FEASIBILITY STUDY TEAM

(1) Australian members and their credentials

Dr D.H. Blake, Principal Research Scientist, Bureau of Mineral Resources, Geology & Geophysics (BMR): 23 years experience in carrying out regional geological studies and leading research teams; been involved in fieldwork in Papua New Guinea, Canada, Iceland, Norway, Britain, New Zealand, and South Africa, as well as in various parts of Australia; author of more than a hundred published geological papers, maps, and reports; Leader of the Australian team.

R.J. Smith, Chief Geophysicist, CRA Exploration Pty Ltd: spent 8 years in the Metalliferous Section, Geophysical Division, BMR, conducting geophysical surveys in Australia, USA, and Canada, followed by 6 years with McPhar Geophysics Pty Ltd, contracting and consulting in mining geophysics in Australia, Canada, USA, New Zealand, Papua New Guinea, Indonesia, Malaysia, Thailand, India, and South Africa, 4 years as private consultant in mining geophysics in Australia and North America, and 10 years as Chief Geophysicist with CRA Exploration Pty Ltd working in Australasia, southeast Asia, North America, Brazil, Ireland, South Africa, and China; advisor to several Australian organisations including CSIRO, BMR, AMIRA, AMF, and University of Adelaide.

Dr S-S Sun, Principal Research Scientist, BMR: 4 years with BMR and 4 years with CSIRO carrying out geochemical, isotope, and petrological research; an international authority on the application of trace elements and isotopes to igneous and metamorphic petrology, and has lectured widely on this subject in Australia, China, USA, Japan, and Europe; author of more than 30 international scientific publications; bilingual in English and Chinese (Mandarin).

(2) Chinese members

All members are from the Bureau of Geology and Mineral Resources (BGMR), Xinjiang.
Mr Bai Guangqun, Deputy Director, No. 2 Geological Brigade; geologist; co-Leader of Chinese team.
Mr Chen Yirong, Associate Chief Engineer, Geophysical and Geochemical Exploration Brigade; geophysicist; co-Leader of Chinese team.
Mr Feng Qi, Geologist; credited with discovery of the Kalatongke Cu-Ni orebody.
Mr Zhang Chengjing, Geologist; specialist in remote sensing.
Mr Li Zhiyan, Geochemist.
Mr Li Henghai, Associate Geologist.

BACKGROUND TO THE FEASIBILITY STUDY

April 1983. A Memorandum of Understanding (MOU) on geoscientific co-operation between Australia and the People's Republic of China was signed in Canberra. Areas for co-operation under the MOU include geology, geotectonics, geophysics, and geochemistry.

March/April 1984. A group of five geophysicists from the Chinese Ministry of Geology and Mineral Resources (MGMR) visited Australia under the MOU.

September 1984. A return mission of five Australian geophysicists (including R.J. Smith of CRA Exploration Pty Ltd) visited China to gain an overview of regional geophysics in China and assess opportunities for scientific co-operation. During the visit it quickly became apparent that Chinese regional geophysics, and geoscience in general, is focussed directly on searching for ore-bodies - this is quite different from the Australian understanding of regional geophysics. Early in the visit, at an informal dinner in Beijing on 4 September 1984, Mr Cheng Yuan-Xue, Deputy Director of Bureau of Geophysical and Geochemical Exploration, MGMR, expressed a desire for Australian co-operation in 'research' directed toward mineral exploration in Xinjiang. This point was reiterated by other Chinese representatives several times during the visit, and at a meeting at the conclusion of the visit, Mr Chen Yunsheng, Director of the Institute of Geophysical and Geochemical Exploration, Lang Fang, emphasized this same point and specified Fuyun and Hami as areas of specific interest.

October 1984. His Excellency, Sun Daguang, Minister of Geology and Mineral Resources of the People's Republic of China, and Senator The Hon. Peter Walsh, Minister for Resources and Energy of Australia, held discussions in Beijing with a view of possible expansion of geoscientific co-operation between Australia and China. The Ministers decided that an Australian mission would visit China to hold discussions with officials of the Ministry of Geology and Mineral Resources in order to identify one or two areas for an initial geological study. In the Agreed Record of Discussion it was envisaged that, following the 1985 mission, an initial study of a short term nature would aim to identify requirements for a comprehensive study of a specific region, with the emphasis on non-ferrous metal prospecting. Officials of the two Ministries would subsequently determine the details of any proposed comprehensive study. Cost of the mission and initial study in China would be borne by the Chinese Government under the MOU, but thereafter consideration would need to be given to meeting the costs for the comprehensive study from funds under the Australia/China Technical Co-operation for Development Program administered by the Australian Development Assistance Bureau (AIDAB).

August/September 1985. An Australian mission, comprising Professor R.W.R. Rutland and Dr D.H. Blake of BMR, Dr D.H. Mackenzie of CRA Exploration Pty Ltd, and Mr P.G. Harman of BHP Pty Ltd visited Beijing and areas in Liaoning Province and Xinjiang Autonomous Region. The mission recommended in a written report that the initial geological study envisaged in the Ministerial agreement be carried out in the area east of the

Junggar Basin in Xinjiang 1-2 months to determine the scope, logistic requirements, probable duration, and indicative budget for a possible comprehensive geological study. The initial study corresponds to the Feasibility Study which is the subject of this report.

It is clear, from a letter dated 22.5.87 and a telex dated 21.5.87, both from Professor Rutland, Director, BMR, Australia, to Mr Yang Zhiling, Director, Bureau of Foreign Affairs, Ministry of Geology and Mineral Resources, China, and also from a document reporting on the Chinese Government's geological mission to Australia in November-December 1986, that Professor Rutland excluded exploration and prospecting for base metals from the objectives of the proposed comprehensive study. However, it is also clear that prospecting for non-ferrous metals was not excluded in other documents (e.g., the Agreed Record of Discussion of the October 1984 meeting),and is regarded by the Chinese as the most important aspect of the proposed comprehensive study.

SUMMARY OF ITINERARY

The Australian team arrived in Beijing in the early morning of May 24, 1987. The following day the team met with Mr Yang Zhiling, Director of Bureau of Foreign Affairs, Ministry of Geology and Mineral Resources (MGMR) to clarify the aims of the planned comprehensive study. On May 26 and 27, the team were briefed on the geology of Xinjiang, and visited various organizations in Beijing to collect relevant information for work in Xinjiang. On May 28, the team flew from Beijing to Urumqi, Xinjiang, and from May 29 to June 1 were briefed in Urumqi on the geology and geophysics of the eastern Junggar region. Visits were made to the Central Laboratory in Urumqi and the Geophysical and Geochemical Exploration Brigade in Changji. From June 2 to 11 the Australian team and their Chinese counterparts went on a field trip in the eastern Junggar region. During this field trip extensive discussion were held to formulate a joint proposal for a comprehensive study of the eastern Junggar region. Further discussion and debate on the details of a joint proposal took place in Urumqi from June 15 to June 17. The Australian team returned to Beijing on June 18, and from June 19 to June 23, together with three representatives from Xinjiang and a senior geologist from the Ministry of Geology and Mineral Resources, finalized a draft proposal for a comprehensive study agreeable to both Australian and Chinese representatives. On June 26, the Australian team left Beijing for Australia.

OUTLINE OF THE GEOLOGY OF XINJIANG AUTONOMOUR REGION

(Based on information provided by Mr Huang Chongke, Chief Geologist, Department of Regional Geology and Mineral Resources, MGMR, on 27 May 1987, at Beijing).

The Xinjiang Autonomous Region of western China (Fig.1) has an area of about 1 260 000 sq km, 30 percent of which is mountainous. It ranges in altitude from over 8000 m in the Karakoram Range in the southwest to 154 m below sea level in the Turfan Basin southeast of Urumqi. Xinjiang is considered to belong to the Euroasian plate, and is separated from the Indian plate to the south by a broad suture zone represented by the Tibetan Plateau. Five major tectonic units are recognised within Xinjiang; these are from north to south, the Altai Shan Geosyncline, Junggar Basin and Fold Belts, Tien Shan Chain, Tarim Basin, and Kunlun Belt (Fig. 2).

Altai Shan Geosyncline

This unit extends northwest into USSR and southwest into Mongolia. It consists of Ordovician to Carboniferous sediments and intermediate to felsic volcanics which have been metamorphosed to schist, gneiss, and migmatite and intruded by Variscan granites (270-300 Ma). It is bounded to the south by the northwest-trending Ertix Fault zone. Several deposits of rare metals (beryllium, tantalum, niobium, etc) are associated with pegmatites related to the granites, and important deposits of copper, lead, zinc and gold are known in this unit in USSR.

Junggar Basin and Fold Belts

The Junggar Basin consists of non-marine Mesozoic sediments containing major oil and coal deposits. It is flanked to the east, in eastern Junggar, by northwest-trending fold belts, and to the west by northeast-trending fold belts. These fold belts are formed of little metamorphosed Palaeozoic sedimentary, volcanic, and intrusive rocks containing deposits of chromite, gold, and copper-nickel. They also include small Mesozoic basins, some containing Jurassic coal.

Tien Shan Chain

This east-west trending chain crosses the central part of Xinjiang and extends east into Mongolia. It is a series of belts formed largely of early Palaeozoic carbonates, clastic sediments, and andesitic volcanics, but it also includes some Archaean in the far southwest as well as some late Proterozoic marine sediments and numerous Variscan (late Palaeozoic) intrusives. Some minor Cu-Ni mineralisation is known. Folded coal-bearing Jurassic strata and Permian oil shale are present along the north side of the belt east of Urumqi.

Tarim Basin

The Tarim Basin is a desert covering about 390 000 sq km. It has a Proterozoic basement (1.7-0.9 Ma) formed of metamorphosed clastic sediments and younger magnesite marble, clastic sediments, granite, ultramafics, and andesite. Overlying cover consists of late Proterozoic sandstone, glacials, and carbonates, Cambrian and Ordovician carbonates, Silurian and Devonian

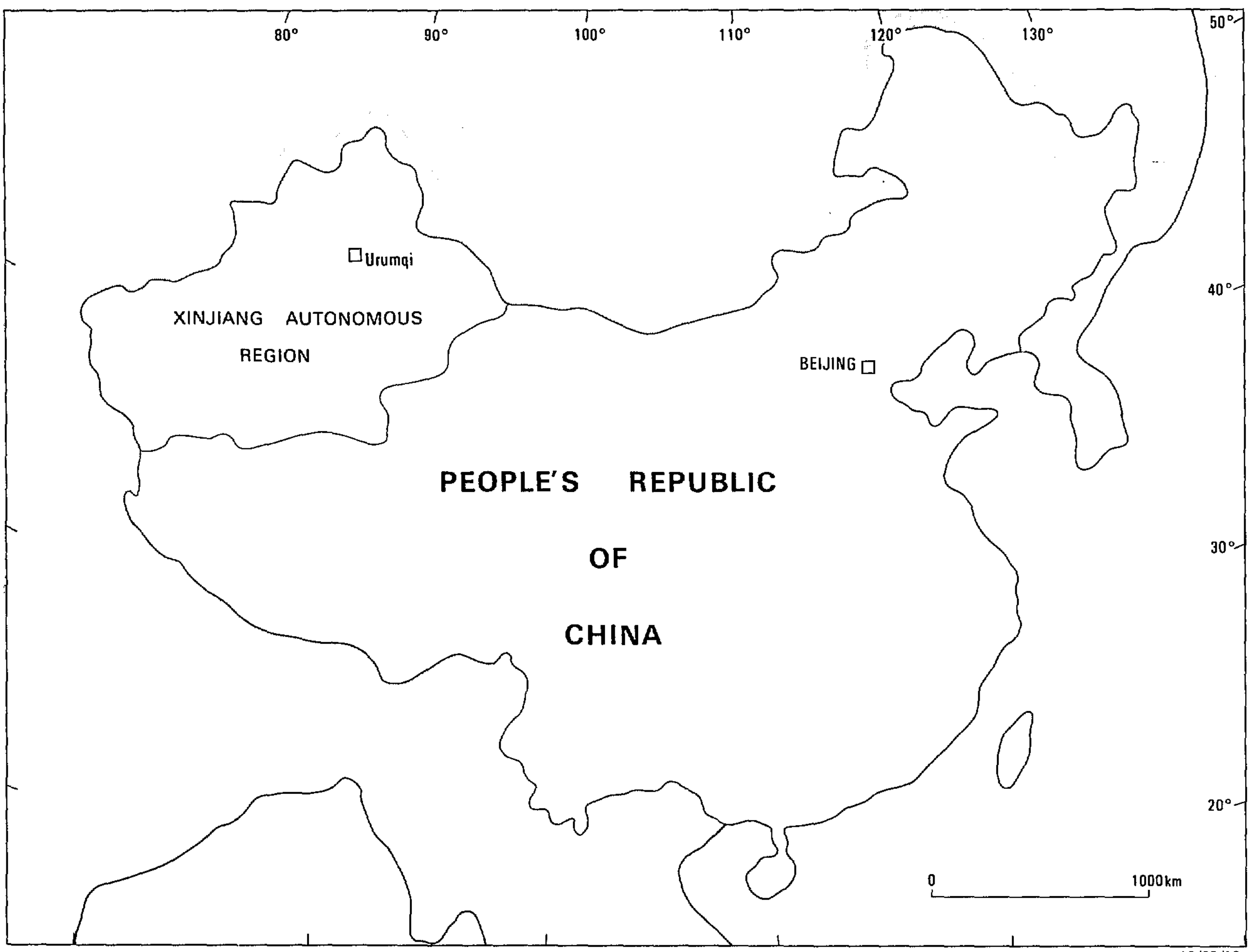

Fig. 1 Map of China

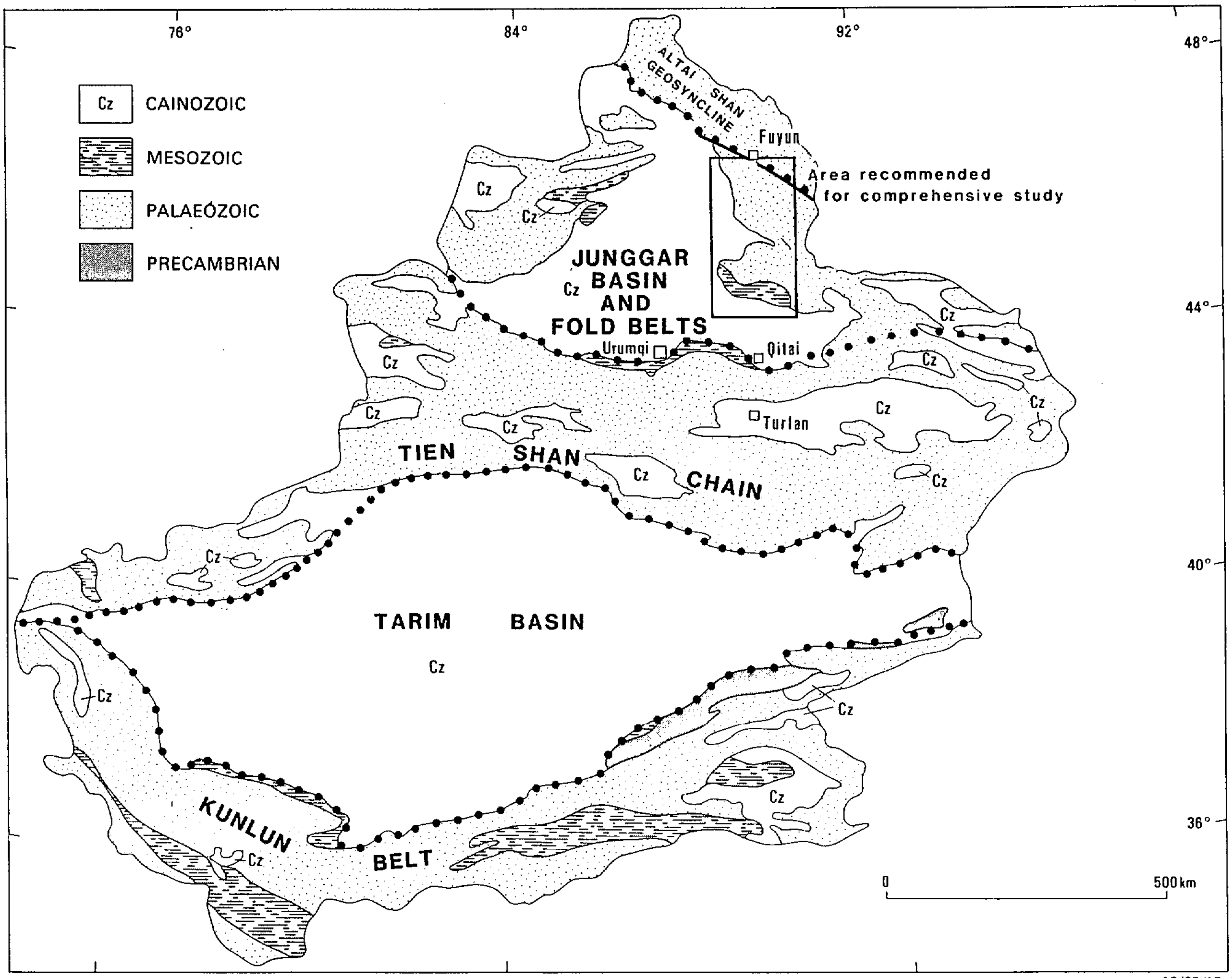

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Fig. 2 Geological map, Xinjiang Autonomous Region sandstone, Carboniferous and Permian carbonates and clastic sediments, Mesozoic sediments (around the margins of the basin), and up to 2000 m of Cainozoic terrestrial deposits. Oil has been found in the northwest.

Kunlun Belt

This is the western part of a mountain chain that extends east across most of the central China. It is formed mainly of Palaeozoic sedimentary, volcanic and intrusive rocks.

Igneous intrusions

The oldest known igneous intrions are of Proterozoic age, in the Kunlun Belt. The second oldest are intermediate and felsic intrusions of Caledonian age (around 400 Ma); some granite of this age is exposed in eastern Junggar.

The majority of the intrusive rocks are Variscan. Four main phases are present:

1, at around 350 Ma - mafic intrusions in the southwest of the Tien Shan Chain; also some quartz diorite bodies.
2, the dominant phase, between about 300 and 250 Ma - includes large granitic plutons in the Tien Shan, smaller bodies in the Altai, most granite in eastern Junggar, and also many small mafic and ultramafic intrusions, including several in eastern Junggar.
3, at around 230 Ma - some syenite and other alkaline felsic intrusions, also a few small granite plutons.
4, minor younger quartz and pegmatite veins.

A small amount of felsic intrusive activity took place in the Mesozoic, between 100 and 200 Ma. However, this was a much more important period for granitic intrusions in eastern China.

Cainozoic intrusions appear to be restricted to sparse alkaline mafic bodies in the southern part of the Tien Shan.

Mineral deposits

Xinjiang is a major producer of petroleum and gas, which come from reservoirs in the western part of the Junggar Basin, and extensive drilling for oil is taking place in other parts of the Junggar Basin and in the Tarim Basin. However, the main mineral resource of Xinjiang is coal. Most of the coal occurs along the northern margin of the Tien Shan, where it represents Mesozoic lake and swamp deposits. Reserves are estimated at 10^9 tonnes, amounting to about one third of China's total coal reserves.

There are no major mines for metallic minerals in Xinjiang. Iron is only produced from a small mine in skarn in the Hami area. Several chromite occurrences are known in mafic and ultramafic rocks, including some in eastern Junggar, but there are no economic deposits. Large Pb-Zn deposits are being mined in nearby USSR, but only a few Pb-Zn occurrences are known in similar rocks just to the east, in Xinjiang. Some mines are being developed to exploit Cu-Ni deposits associated with mafic and ultramafic intrusions; one of these, Kalatongke, is in the eastern Junggar region. Beryllium and rare metal pegmatites have been mined in the Altai Shan of northern Xinjiang, but are no longer considered to be of economic significance; however, a large deposit is known in the Altai Shan in Mongolia to the east. A small amount of alluvial gold has been recovered near Urumqi.

Geological setting of the eastern Junggar region

The eastern Junggar region includes part of the Altai Geosyncline in the far north, but mostly lies within the eastern Junggar Fold Belts. Bedrock ranges in age from Upper Ordovician to Jurassic, with folded Carboniferous and Devonian sedimentary and volcanic rocks being the most extensive, Most intrusions are Variscan (Upper Carboniferous and Permian): they include granites and numerous ultramafic and mafic bodies.

The region is crossed by three major northwest-trending fault zones: the Ertix Fault in the north, which forms the southern boundary of the Altai Shan Geosyncline, and separates high-grade metamorphic rocks, including migmatites, in the north from low to very low grade rocks to the south; the Ulungu Fault zone crossing the central part of the region, and the Kalameily Fault zone in the south.

THE EASTERN JUNGGAR REGION

General geography

The area selected for the comprehensive study, the eastern Junggar region (Figs. 2 and 3), is situated in the northeast of Xinjiang Autonomous Region, close to the international border with Mongolia. It extends from latitude 44°40′ N to latitude 47°00′N (257 km), and from longitudes 88°30′E to 90°33′E (150 km), covering about 30 000 sq km and lying between the Altai Shan range in the north and the Tien Shan range in the south, with the sandy desert of the Junggar Basin to the west; the southernmost part of the region is regarded as part of the Gobi Desert.

The eastern Junggar region is sparsely populated, especially in the southern half. The largest town is Fuyun, population about 10 000, in the far north. The main supply centre is Qitai, which has a population of about 50 000 and is situated about 80 km south of the region. Qitai is about 210 km by sealed highway east from Urumqi, population more than 1 million, the capital of Xinjiang Autonomous Region. Fuyun has a regular air service with Urumqi. Two unsealed roads cross the eastern Junggar region from south to north, connecting Fuyun with Qitai. Other unsealed roads lead from Fuyun north to Kekatohai in the Altai Shan and west to Beitun and other towns outside the eastern Junggar region. Several vehicle tracks branch off from the unsealed roads. Travel across country by 4-wheel-drive vehicle is generally easy along flat-floored depressions between mountain ridges, although care has to be taken in crossing hummocky salt flats in many parts of the region, and in negotiating sand dunes and unexpectedly soft surfaces on apparently firm undulating terrain in southern areas.

The two main rivers in the region, the westerly flowing Ertix river in the far north and the Ulungu river in the northern central part, can only be crossed by bridges in the summer. The eastern unsealed road between Qitai and Fuyun is reasonably

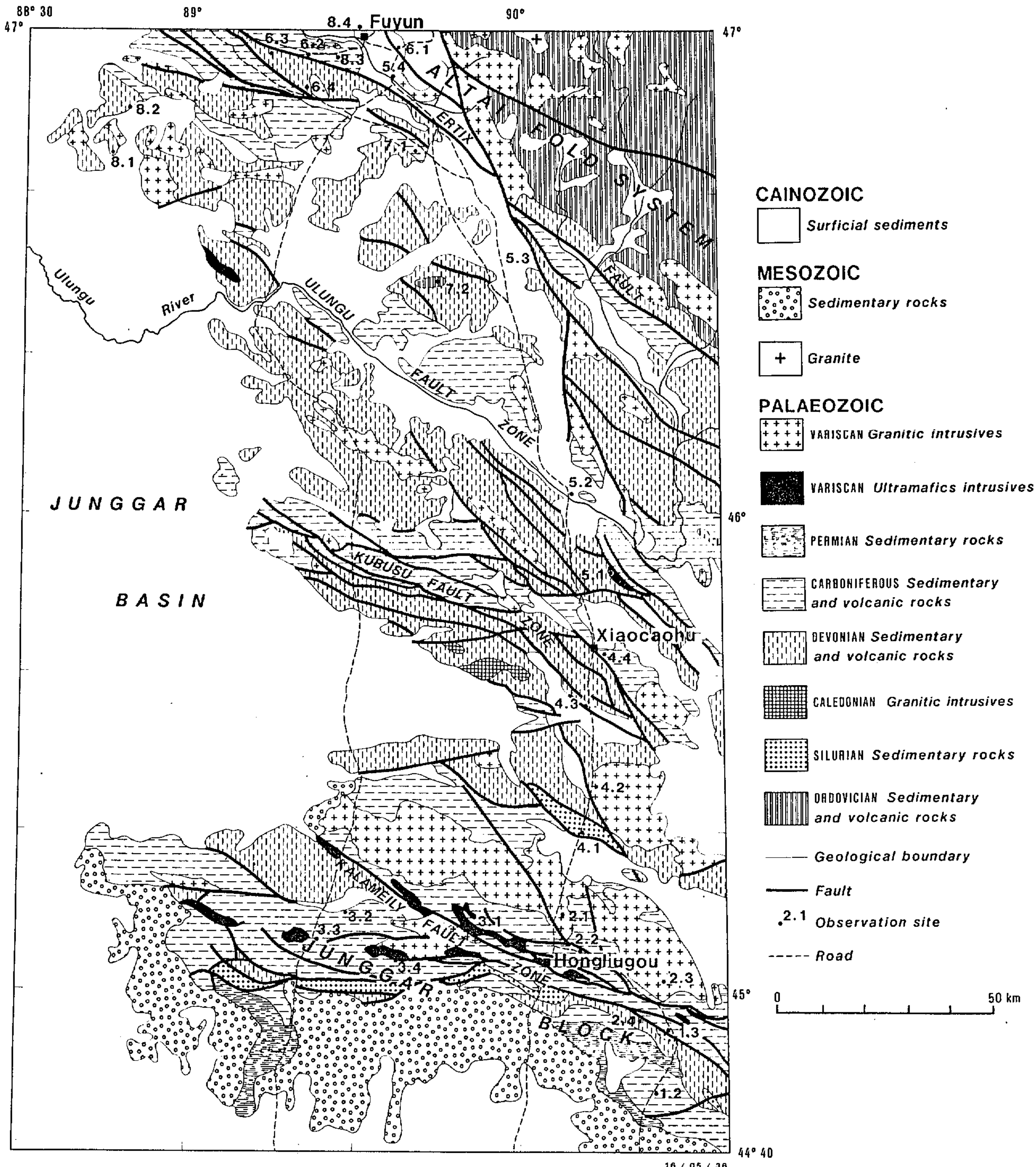


Fig. 3 Geological sketch map, eastern Junggar region

smooth in the north but has a very rough surface south from the Ulungu river. The western unsealed road was not seen.

The climate of eastern Junggar is temperature desert and semi desert, with rainfall increasing northwards. Two wet spells, each lasting several hours, occurred during the period 2-11 June 1987, but this was unusual, and rain does not normally affect field work. Winters are very cold, but summers are warm to hot, with surprisingly small diurnal temperature ranges (commonly around 5°C). Spring and autumn are windy seasons.

Eastern Junggar rises in altitude northwards, from maxima of about 1500 m a.s.l. in the south to 2300 m in the centre and 3200 m in the north. Local relief is generally less than 500 m. The main ranges trend northwest-southeast. They are the Kalameily hills in the south, Armantai and Beitashan ranges in the centre, and the Altai Shan in the north. Soil cover is almost non existent in the ranges, where there are extensive exposures of fresh bedrock. Away from the ranges, and locally within them, bedrock is commonly concealed beneath a cover, less than a metre to many metres thick, of unconsolidated alluvial and colluvial deposits.

The Altai Shan ranges are partly drained by the Ertix river, the only river rising in China which flows northwards through USSR to enter the Arctic Ocean. The Ulungu river to the south has headwaters in both the Altai Shan and Beitashan; it flows into a lake in the north of the Junggar Basin. Both rivers freeze over in the winter, but carry large volumes of cold melt water in summer. In the southern part of the region, there is no surface flowing water in summer, and water from the few springs present is of poor quality, so drinking water has to be transported either from Qitai or from the two rivers to the north.

Vegetation is very sparse in the south, where it is largely restricted to scattered low shrubs along water courses. In the northern half of the region, flat and undulating terrain are grass-covered in summer, and there are local patches of low shrubs (up to about 1 m high). Except along the Ertix and Ulungu rivers, the region is devoid of trees: only one tree not planted by man is reputed to be present in eastern Junggar.

Previous geological investigations and availability of published data

The earliest recorded geological observations in the eastern Junggar region were made by a group of Swedish and Chinese geologists in the 1930s. Formation names given at this time are still being used. In the 1960s and 1970s the entire region was mapped by geologists from the Xinjiang BGMR using 1:60 000 black-and-white airphotos and contoured topographic maps based on these airphotos. This survey resulted in the publication of 1:200 000 geological maps and accompanying reports. More detailed geological mapping, at a scale of 1:50 000, has subsequently carried out around some of the mineral prospects by the Xinjiang BGMR. In 1982 the Fuyun Sheet in the north was covered by 1:20 000 airphotos; these were probably taken with colour film, although only black-and-white prints are held by the Xinjiang BGMR.

The availability of 1:200 000 and 1:50 000 geological and topographic maps, geological reports, and airphotos is restricted by the Chinese Government. Consequently, the Australian team were unable to obtain official permission to examine any of them during the Feasibility Study. Landsat scenes of eastern Junggar at 1:500 000 scale were also regarded as restricted in Xinjiang. The only maps the Australian team were permitted to use during the Feasibility Study were an unpublished 1:500 000 hand-coloured geological map compiled from the 1:200 000 maps and 'updated', and a 1:500 000 contoured aeromagnetic map showing the results of an airborne geophysical survey in 1962. The Australian team had to sign declarations stating that they would not show these maps to any unauthorised person.

However, the Australian team have been assured, both in Xinjiang and in Beijing, that once the proposed comprehensive study of eastern Junggar begins all maps, reports, and airphotos considered necessary would be available to the Australian scientists concerned. It is unlikely, though, that any large-scale published maps or airphotos, will be allowed out of China. This situation needs to be clarified before a joint study goes ahead.

The Australian team were unable to assess library facilities at the Xinjiang BGMR.

Assessment of available geological information

Because of the restricted availability of maps and reports, the geological work that has already been done in eastern Junggar could not be fully assessed, and hence what additional work needs to be done could not be determined satisfactorily. However, from the information gathered during the Feasibility Study, it appears that the 1:200 000 geological maps of eastern Junggar are closely comparable in detail and reliability to most of the 1:250 000 geological maps produced in Australia, during the 1960s and 1970s. They are not as detailed as the more recent 1:100 000 maps produced by the BMR. Little work appears to have been done in the region on detailed or regional structural analysis, sedimentology, volcanology, and rock geochemistry, and on the application of modern concepts to tectonic setting, crustal evolution, and metallogenesis.

Outline of geology

The following account of the geology of the eastern Junggar region is based on an unpublished 1:500 000 geological map and accompanying notes given to the Australian team, on information presented by Mr Bai Guangqun in Urumqi on 29.5.1987, and on observations made during the 2-11 June field trip.

Under the scheme of Mr Huang Chongke, the eastern Junggar region (Figs 2 and 3) covers part of the Altai Shan Geosyncline in the far north and part of the East Junggar Fold Belts to the south. However, following Mr Bai Gangqun, in this section the Altai Shan Geosyncline is termed the Altai fold system and the East Junggar Fold Belts correspond to the Junggar fold system north of the major west-northwest-trending Kalameily Fault zone and the Junggar block south of this zone. The Ertix Fault in the north forms the boundary between the Altai and Junggar fold systems; it separates high-grade gneisses to the north from little metamorphosed rocks to the south. Two other systems of northwest-trending faults, the Ulungu-Armentai and Kubusu zones, cut the Junggar fold system.

Stratigraphy

The Stratigraphy of the Altai and Junggar fold systems and Junggar block is summarised in Table 1. the oldest rocks exposed are Ordovician, and the youngest are Mesozoic, except for unconsolidated Cainozoic sediments. The Paleozoic seguence includes abundant volcanics, especially andesitic rocks of apparently orogenic type, some felsic ignimbrites (which have been regarded as volcaniclastics) and minor basaltic pillow lavas; fossiliferous limestones are common.

Igneous intrusions

Altai fold system. Numerous intrusions of Variscan age are present in this tectonic unit. They include gabbro, diorite, microdiorite, tonalite, granite, pegmatite, and quartz-feldspar porphyry. A net-veined complex representing a mixture of felsic and mafic magma at Wuqiagou Pass east of Fuyun (locality 6.1 in Fig. 3 and Appendix B). This complex, which was described as migmatite, is formed of unmetamorphosed pink granite (230-250 Ma), dolerite-gabbro, and heterogenous hybrids, cut by pegmatite veins; the complex intrudes migmatitic banded gneisses. West of Fuyun (locality 6.2), banded gneisses are intruded by dykes of unmetamorphosed quartz-feldspar posphyry which may be Variscan. There are also some intrusions of Mesozoic potassic granite, 2 mica granite (160 Ma) and porphyritic granite (100 Ma).

Junggar fold system. Minor Caledonian granodiorite is present; e.g., at locality 4.2, where it is overlain by Devonian sedimentary rocks. Variscan intrusions are widespread. They include a large batholith in the south, formed of pale pinkish porphyritic biotite granite and slightly younger red K-granite; several other granitic plutons (Fig. 3); and numerous ultramafic and mafic bodies located along major fault zones. The ultramafic bodies consist predominantly of dunite and harzburgite with serpentinised olivine, and commonly contain small chromite deposits. A differentiated mafic body, ranging in composition from olivine gabbro (?) to diorite, hosts the Kalatongke Cu-Ni deposit in the north, about 5 Km southwest of the Ertix Fault.
Junggar Block. Intrusions are said to be less common in this unit. However, several Variscan ultramafic bodies are present along the Kalameily Fault zone in the north, and circular granite plutons, numerous mafic, intermediate and felsic dykes, and some felsic plugs occur to the south.

TABLE 1. STRATIGRAPHY OF THE EASTERN JUNGGAR REGION

Tectonic	Age	Lithology (thickness in metres)	Remarks
Altai fold system	Mesozoic	Sandstone, shale; some coal	Subvertical near Fuyun; unmetamorphosed?
	Carboniferous	Upper part: clastic sediments Lower part: intermediate to felsic volcanics intercalated with marine sediments	Regionally metamorphosed to schist, gneiss, and migmatite, index minerals include andalusite, sillimanite, kyanite and staurolite
	Devonian	Clastic sediments and andesitic to basaltic volcanics	
	Silurian	Sandstone and siltstone (flysch)	
Junggar fold system	Permian	Upper part: conglomerate, sandstone, mudstone; some coal and plant fossils Lower part: conglomerate, breccia, sandstone; some plant fossils. (<500m)	Exposed along faults and in small graben Shallow marine and coastal
	Carboniferous	Middle and upper parts: andesitic and basaltic volcanics of orogenic type - lavas and pyroclastics; dacitic ignimbrite; bedded and nonbedded volcaniclastic rocks (100-3000m) Lower part: shale and mudstone overlying sandstone, conglomeate, felsic to mafic volcanics, and fossiliferous limestone with corals, brachiopods and crinoids. ($\sim$2000m)	 Shallow marine
	Devonian	Upper part: tuffaceous sandstone and siltstone. ($\sim$1000m) Middle part: tuff, sandstone and fossiliferous limestone (1700) overlying dacitic to basaltic lava, ignimbrite, tuff, pillow lava, radiolarian chert, and fossiliferous limestone(1000m)	Shallow marine Shallow marine to coastal
	U. Silurian	Thinly bedded grey siliceous siltstone, carbonaceous slate, sandstone, and fossiliferous limestone (>400m)	Shallow marine
	U. Ordovician	Andesitic to basaltic pillow lava, radiolarian chert, ferruginous sandstone, limestone with corals, brachiopods and crinoids	Marine
Junggar block	Mesozoic	Some middle Jurassic coal measures (e.g. near Jinshangou)	Lacustrine
	Permian	Sandstone, conglomerate, mudstone; some plant fossils. (>2000m in S)	Unconformity at base
	Carboniferous	Upper part: sandstone with rhyolite band a few metres thick (300m) overlying sandstone, mudstone, fossiliferous limestone-brachiopods, corals and crinoids (400m) overlying clastics with plant fossils (200-400m) Lower part: porphyritic andesitic lava of orogenic type, dacitic ignimbrite, and basalt (1000-4000m) overlying volcanoclastic sandstone and conglomerate and some carbonaceous shale	Shallow marine facies overlying continental facies Marine and coastal; low angle unconformity at base
	M.Devonian	Thin-bedded grey sandstone (greywacke?) and siltstone, limestone with brachiopods and corals (200-300m)	Marine
	M.Silurian	Feldspathic sandstone, conglomerate, marl, and limestone with brachiopods (500-800m)	Marine; previously mapped as Lower Devonian

Structure

Folding. The Palaeozoic rocks were moderately to tightly folded during the Variscan orogeny; dips are commonly steep and are locally subvertical. The older Palaeozoic rocks may also show the effects of a Caledonian deformation. No regional or local structural analysis of the folding appears to have been attempted in the region.

Faulting. The major faults identified clearly postdate the folding, so are Variscan or younger. Three major northwest-trending fault zones are present - the Ertix Fault in the north, which dips 65-70°N, the largely concealed Ulungu zone to the south, which is reported to be vertical and tensional, and the Kalameily Fault zone in the south, which dips 65-90°S. The Ertix and Kalameily faults are mainly compressional, but show significant lateral displacements, and are marked by phyllitic to mylonitic rocks. In the NE the Ertix Fault is displaced several kilometres by a right lateral NNW-trending fault dipping steeply NE. A major earthquake took place on this fault in 1931, and resulted in the death of 10000 people. Another fault system, the west-northwest trending Kubusu zone, crosses the central part of eastern Junggar.

Metamorphism

In the Altai fold system the Variscan intrusions are weakly or non-metamorphosed, but the rocks they intrude are high-grade gneisses and migmatites. The gneisses are separated from little metamorphosed rocks of the Junggar fold system to the south by the Ertix Fault. Within the Junggar fold system the metamorphic grade decreases southwards, and the Paleozoic rocks of the Junggar block to the do not appear to be regionally metamorphosed.

Mineral Resources

Three metallogenic zones are distinguished by the Xinjiang geologists. These coincide with the three major fault zones - the Ertix zone in the north, with mainly Cu-Ni mineralisation, the Ulungu zone in the centre, with mainly Cu, Mo and Cr mineralisation, and the Kalameily zone in the south, with Au, polymetal, Cr and Sn mineralisation. However, none of those zones appears to be strongly mineralised, and the main known mineral deposits (Suorkuduk Cu-Mo, Kalatongke Cu-Ni, Qingsui Au and Jinshangou Au) other than Cr are located close to, rather than within, the zones.

Assessment of geological knowledge

The eastern Junggar region has been mapped geologically in relative detail, and the general stratigraphy and distribution of rock types should be reasonably well established. However, little work has been done on sedimentology (e.g., depositional environments and sediment sources), volcanology, igneous petrology (no chemical data available ?), or structural analysis. Hence there is insufficient information available on which to base satisfactory models for tectonic setting, crustal evolution, geological history, and metallogenesis.

Detailed field investigations in carefully selected areas, rather than another region-wide geological survey, need to be carried out to establish a satisfactory geological framework. Such investigations should focus on sedimentological and volcanic stratigraphy and intrusive and structural history of the Altai and Junggar fold systems and the Junggar block, be backed up by igneous rock chemical analyses (major and trace elements), and make full use of information obtained during concurrent mineral exploration and regional geophysical investigations. Areas selected for the detailed geological study should be readily accessible and well exposed, should include transects across the three major fault/metallogenic zones, and should be covered by 1:25 000 colour airphotos. As suggested by Mr Bai Guangqun, the selected areas could be two north to south transects, about 10 Km wide, one along the main Fuyun-Qitai road in the east, and the other along a parallel road or track about 50 km to the west. The geology of the remaining parts of the regions could be updated by extrapolating from these two transects by airphoto interpretation and some ground checking.

Geophysical investigations

Gravity

Although the BGMR in Beijing advised that some regional gravity was available for eastern Junggar, no regional gravity maps of the area were sighted, and it was eventually disclosed that 1:200,000 gravity maps are restricted and could not be made available to Australians. Hence no regional gravity data will be available for a joint comprehensive study of eastern Junggar.

Some detailed gravity on isolated profiles over mineral prospects (e.g., Kalatongke, Suorkuduk) was sighted, but is not relevant to the regional program.

Airborne Magnetics and EM

Most of eastern Junggar was surveyed with aeromagnetics at a scale of 1:100,000 (1km and 2km line spacing) in 1962. Line direction was NE-SW. The results were presented as stacked profiles (1:200,000 and 1cm=250nT) by the Aero Geophysical Survey. Later, a contour map was prepared by the staff at Changji at 1:500,000, with 100nT contour interval, and a copy of this map was supplied to the Australian team (Fig.4). The 1962 survey used only analogue recording with a magnetometer sensitivity of 10nT or 30nT, and there appear to have been some severe errors in navigation. The results showed significant magnetic relief, mainly in NW to WNW-trending zones coincident with major fault zones.

The main magnetic anomalies in eastern Junggar are due to mafic and ultramafic rocks associated with four main linear fault zones. These are:

新疆东准噶尔地区ΔT等值线平面图

Aeromagnetic Contour Map — eastern Junggar

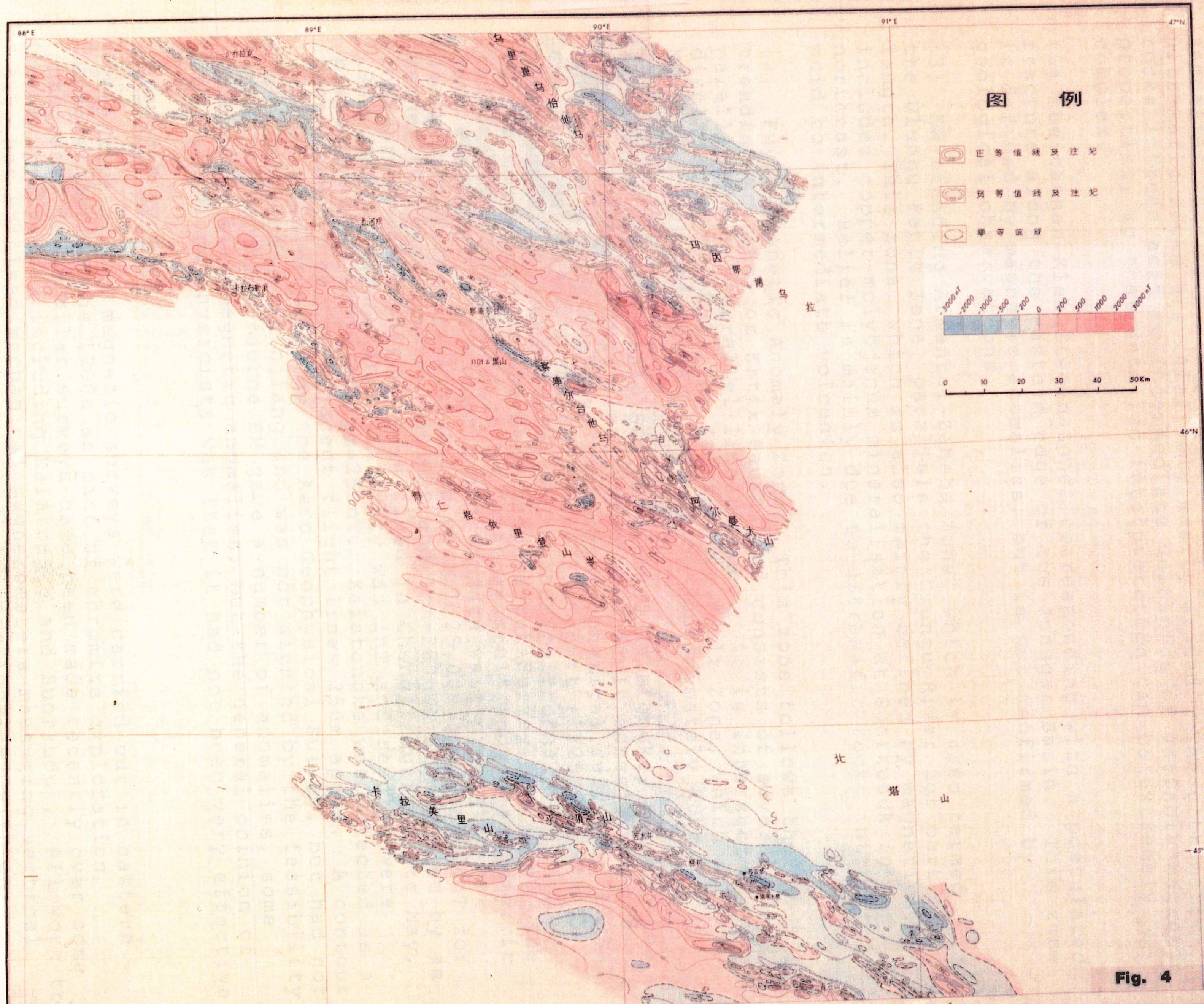


Fig. 4

(1) Kalameily Fault Zone in the south, trending WNW-ESE. Most anomalies in this zone are associated with ultramafic rock bodies with magnetic relief often exceeding 1000nT. In the east, dipolar anomalies are common. In the west there are more negative anomalies, suggesting significant remanence. Magnetic anomalies usually correspond with topographic depressions, as the ultramafic rocks are relatively easily eroded. The ultramafic rocks intrude acid to intermediate volcanics of variable magnetic properties, so that detailed interpretation can be extremely complex.

(2) Beitashan-Klabuliegen Zone, corresponding with a postulated fracture along the eastern edge of the Junggar Basin. This zone is defined by magnetic anomalies, but is not confirmed by geological observations.

(3) NW-trending Armantai-Zaheba Zone, which is also termed the Ulungu Fault Zone. parallels the Ulungu River for part of its length. This zone, which is also mainly defined by magnetics, includes copper-molybdenum mineralisation at Suorkuduk in the northeast. Relief is mainly due to ultramafic rocks intruding acid to intermediate volcanics.

(4) Fuyun Magnetic Anomaly Zone. This zone follows the NW-trending Ererqisi or Ertix Fault, and consists of several parallel and sub-parallel linear zones. It is intersected and displaced by the Ertai or Kalaxianger Fault Zone, which strikes NNW and displaces the Ertix Fault by approximately 20km.

An area of approximately 5000km^2 around Kalatongke, between the Ertix and Ulungu Rivers (and associated fault zones), was the subject of a comprehensive airborne geophysical survey in 1982-3. The area was flown on NE-SW lines 250m apart (1:25,000 scale) with magnetics, radiometrics and TRIDEM (airborne electromagnetics) by the Aero geophysical Survey, Beijing. The radiometrics was stated to be "unsuccessful" and no radiometric data was seen. The magnetic and EM data were presented as stacked profiles (preliminaries were 1:25,000 and 1cm=250nT for magnetics, finals were 1:50,000 and 1cm=250nT) accompanied by an interpretation report which arrived in Changji during late May, 1987. The magnetometer sensitivity was 1nT and results were presented at a scale of 1cm=250nT. Kalatongke was detected as a 250nT anomaly on two adjacent flight lines 250m apart. A contour map has been prepared by the Aero Geophysical Survey, but had not been delivered to Xinjiang and was not sighted by the feasibility study team. The airborne EM gave a number of anomalies, some coincident with magnetic anomalies, but the general opinion of the Changji geophysicists was that it had not been very effective.

Ground Magnetics

Extensive ground magnetic surveys were carried out in eastern Junggar during the 1960s as part of chromite exploration programs, and similar surveys have been made recently over some other prospects, including Kalatongke and Suorkuduk. All work to date has utilised mechanical magnetometers measuring vertical field (and perhaps horizontal field occasionally) with an accuracy of approximately 10nT. No total field measurements with proton precession magnetometers have yet been made in eastern Junggar. Kalatongke was stated to give an anomaly of approximately 500nT - presumably from intrusive diorite rather than sulphide mineralisation.

Induced polarisation (IP)

Several IP surveys have been conducted over prospects in eastern Junggar (e.g., Kalatongke and Suorkuduk) using gradient array for profiling and Schlumberger array for soundings. Equipment used was time domain, manufactured in China. Results have been presented as contours and profiles (and sounding curves where appropriate). Anomalies were detected over known mineralisation at Kalatongke, probably due to shallow disseminated sulphides and a carbonaceous (graphitic?) halo, and at also Suorkuduk. More interpretable results would probably have been achieved if dipole-dipole array had been used.

Some Spectral IP measurements (probably using Phoenix equipment and dipole-dipole array) have been made by the Chinese Academy of Science, but results were not available in Xinjiang and were not sighted by the feasibility study team.

Sundry

Various tests with EM (thought to be MAX-MIN) and other electrical or electromagnetic methods had been made at Kalatongke by staff from IGGE at Lang Fang; no details were available.

No geophysical logging or borehole measurements have been carried out, although numerous drill holes are available for such work (e.g., at Kalatongke).

Mineral Deposits

The rock types exposed, and the structure, tectonic setting, and geological history, indicate that eastern Junggar has considerable potential for deposits of non-ferrous metals. However, few such deposits have so far been found in the area, and there are no mines currently in production. Of the known mineral deposits, the most promising is the Kalatongke Cu-Ni deposit, which is being developed at present. Of the other mineral deposits visited by the Feasibility Study team, only the Qingsui No.48 Au deposit and the Suorkuduk Cu-Mo deposit, both of which are currently being evaluated, appear to be of potential economic significance, as the several chromite deposits in the area, all associated with ultramafic intrusions, and graphite (at Sujiquan) and tin (at Beilekuduk) associated with Variscan granite are unlikely to be of sufficient size to be of economic interest.

Kalatongke copper-nickel deposits

The Kalatongke area (locality 7.1 in Figure 3) lies in the Junggar fold system, on the south-east side the Ertix Fault. It is crossed in the east by the active NNW-trending Ertai Fault, which has a dextral displacement of 20km and was the site of a major earthquake in 1931. The area consists of poorly exposed Carboniferous tuff, shale, sandstone, conglomerate, and graphitic slaty mudstone, flanked by Devonian volcaniclastics to the north and south (Fig.5). Ordovician rocks are present in the core of an anticline to the south, and Cretaceous (80 Ma) granite crops out

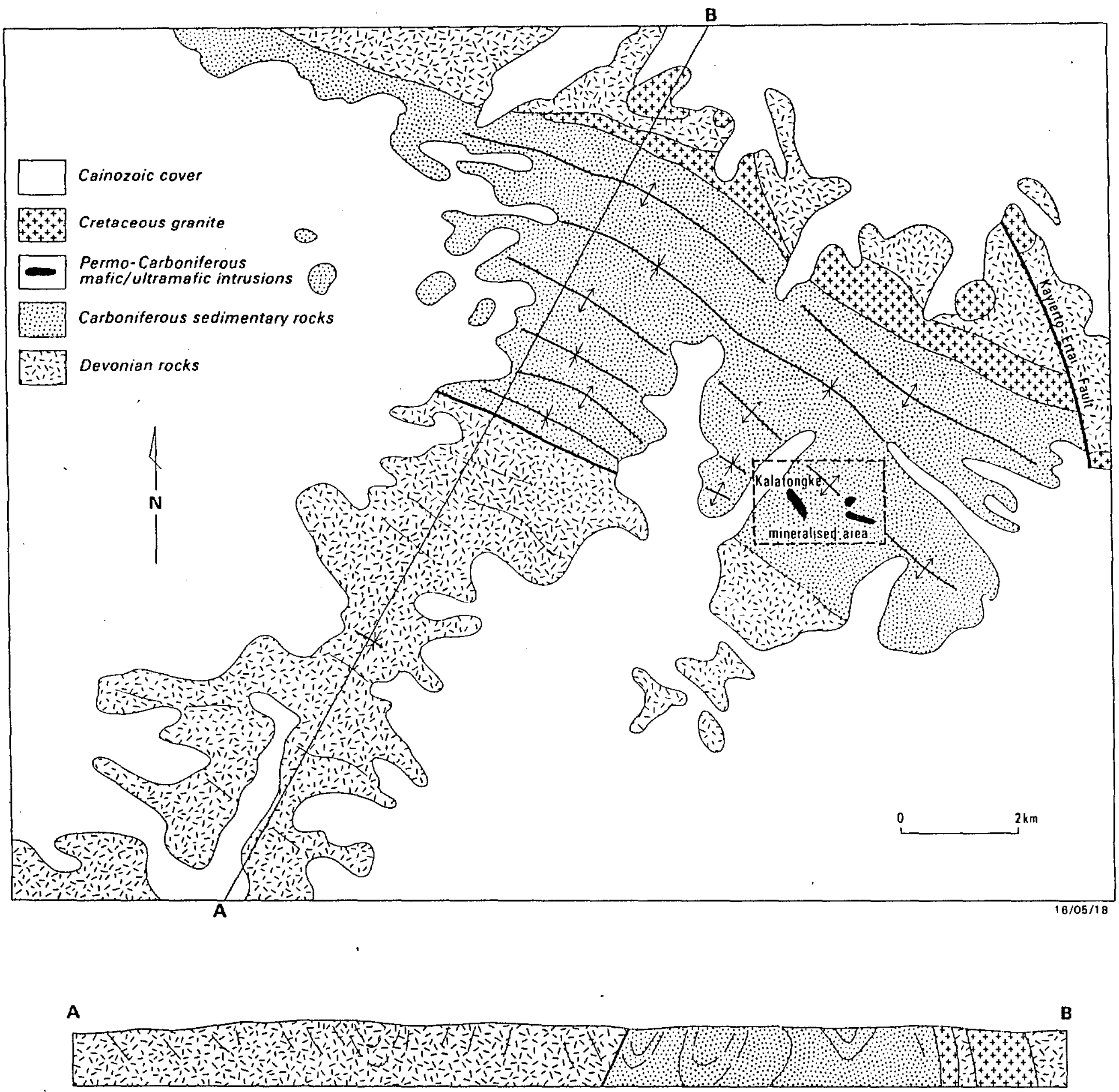


Fig. 5 Geological map, Kalatongke area

in the north. The Carboniferous sediments form small anticlines and synclines with northwesterly trends, and are intruded by Carboniferous or Permian mafic and ultramafic bodies (K-Ar ages 250-295 Ma) which contain the Kalatongke Cu-Ni deposits. Four sets of fractures, with northwest, north-northwest, close to east-west, and northeast trends, are present. The mafic intrusions occur along fractures close to anticlinal axes, and give rise magnetic and gravity anomalies.

Four of the mafic intrusions, three along the southern anticline and one on the northern anticline, are mineralised. The most mineralised intrusion crops out poorly (largely covered by up to 1m of superficial deposits) over a length of 700m and a width of 30-300m in the western part of the southern anticline, and extends to a depth of at least 500m. It dips north, and has a steeply-dipping northern contact and a gently dipping southern contact. With increasing depth the intrusion becomes more mafic, with hornblende gabbro and gabbro (100m thick) passing down into norite (100-200m thick) and then olivine gabbro (more than 50m thick). Dolerite and gabbro occur at the margins. Sulphides are common throughout the intrusion, but orebodies are concentrated in the middle and lower parts, below 200m. Three types of ore are recognised - disseminated, massive, and hydrothermal breccia. Main ore minerals are pyrite, pyrrhotite, chalcopyrite, pentlandite, and complex sulphides. Proved reserves are 270,000t Cu and 175,000t Ni, average grades being 1.17% Cu and 0.74% Ni. The ore also contains Co, Ag, Pb, Pd, Sb and Se.

The two mineralised intrusions to the east are concealed beneath an overburden 150-200m thick. They are zoned mafic bodies similar in overall size, shape and composition to the main mineralised intrusion, but are less rich in sulphides. The mineralised intrusion to the north (rock body no. 7) is smaller, but may be an erosional remnant of a larger intrusion; it is exposed at the surface as a gossan.

The Kalatongke deposit was found by local workers who, when collecting mushrooms while on holiday, picked up a sample of heavy rock, expecting it to be magnetite like that known to the north. The sample was subsequently identified as sulphide gossan, so some drilling and ground magnetics and geochemistry were carried out, resulting in the locating of the main Cu-Ni deposit in 1978.

Geological mapping was carried out in the area in 1983, when 5000km^2 was covered at 1:200 000 scale, and in 1984, when 1500km^2 was covered at 1:50 000 scale. No maps have been published. Stacked profiles of airborne magnetic data are available as preliminaries (1:25 000 and 1cm=250nT) and final published maps (1:50 000 and 1cm=250nT) from the 1982-83 comprehensive survey conducted by Aero Geophysical Survey, Beijing. This survey identified additional magnetic anomalies, many of which, as shown by drilling, indicate similar basic intrusions. To date, however, no additional significant mineralisation has been discovered. At one of the anomalies tested, Kalatongke airborne magnetic anomaly, 16-1, five drillholes to a maximum depth of 130m showed that pyroxenite with some cobalt is present at a depth of 30-80m in the east, gabbro occurs in the west, and there is some pyrite mineralisation in the north. Country rocks include graphitic shale, so there is a strong IP anomaly around the magnetic anomaly.

Other geophysical methods used at Kalatongke include ground magnetics, detailed gravity, and gradient array IP. All methods were apparently successful over the known mineralisation. Gravity and magnetics detected the mafic intrusions, but could not be expected to differentiate between mineralised and unmineralised bodies. Gradient array IP anomalies were clearly responding to near surface disseminated mineralisation and carbonaceous alteration; the massive mineralisation at depth may have contributed to the overall response, but it could not be specifically recognised.

Although there was great interest in using TEM methods, in general the massive mineralisation is too deep for detection by any surface geophysical methods. Borehole TEM, with a surface transmitter and a receiver at depth in a borehole, should be effective, however, and the use of such a system was recommended.

A great deal of meticulous geological, geophysical and geochemical work has contributed to an excellent case history at Kalatongke. It is an impressive discovery and there is potential for additional ore in the region. The depth to massive mineralisation, however, is too great for direct detection by most surface methods, and future exploration in the area will be difficult.

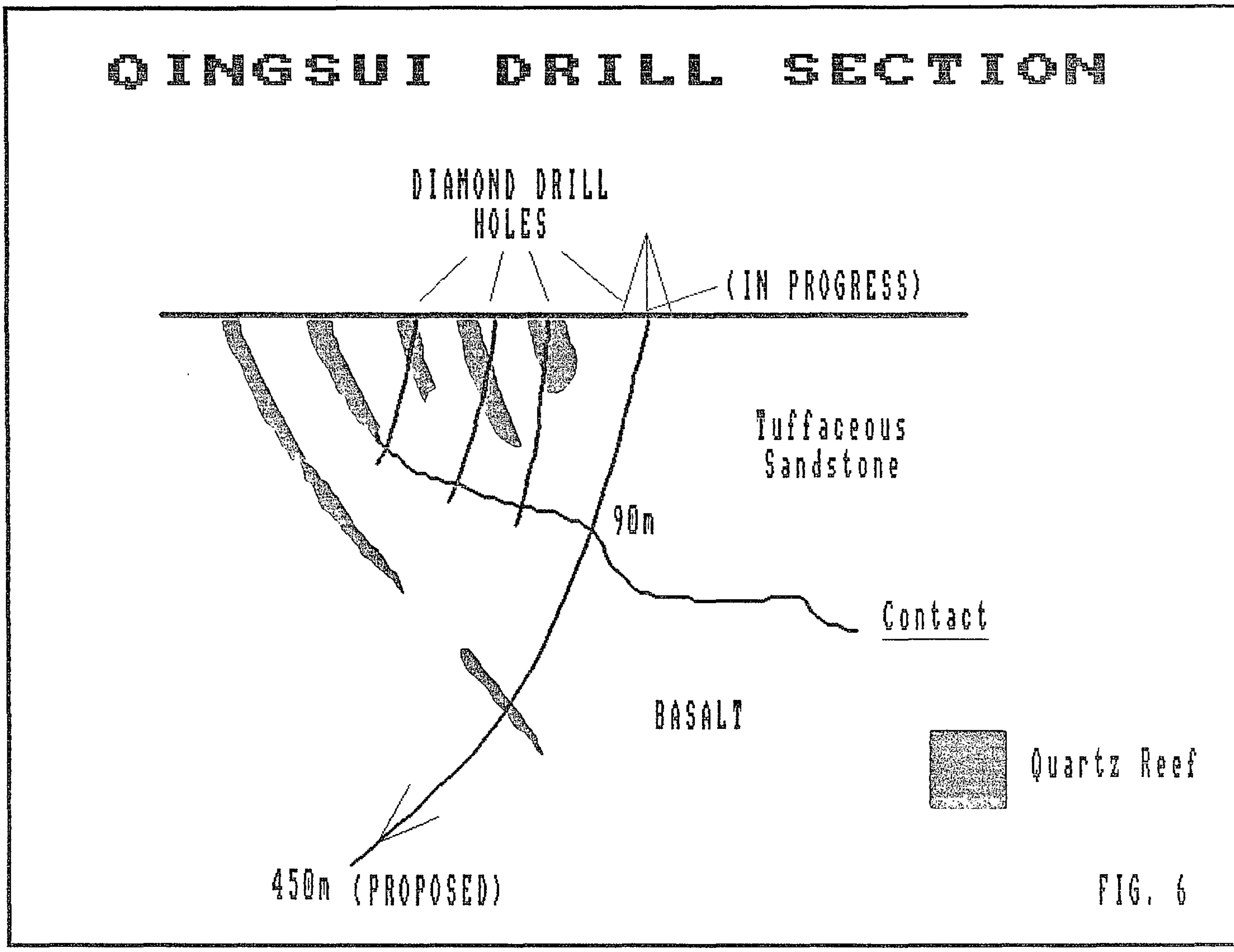
Qingsui No. 48 gold deposit

The feasibility study team visited Qingsui No. 48 gold deposit on June 5 (locality 3.2, Fig.3). The deposit is located in middle Carboniferous volcaniclastics near 45°10'N, 89°30'E, in the Kalameily Fault Zone. It was being actively explored at the time of the visit: a large geological field camp was established on site and drilling was in progress.

At the time of the visit six separate "ore bodies" had been defined. The gold occurs mainly in pyrite associated with calcite-quartz veins and crush breccia zones near a contact between basalt and tuffaceous sandstone (see Figure 6). The largest vein was approximately 350m long and 1-2m wide. Other zones were often shorter but wider (up to 10m wide). The quartz veins generally dip at 50°-70°, roughly parallel to the contact, and are present both in the basalt and the tuffaceous sandstone.

Reserves down to a depth of 70m were estimated at 417kgms of gold at an average grade of 7.44gm/tonne. Grades vary from 33.35gm/tonne down to a cut off of 4.35gm/tonne. Obviously, mineralisation extends to much greater depths, and the drill hole in progress (see Figure 6) had a planned depth of 450m. Very little deep drilling has been done so far and reserves were not estimated beyond a depth of 70m.

No geophysical work was discussed at Qingsui and presumably none had been done. Ground magnetics could assist with mapping the contact and possibly outlining alteration. IP should easily detect the disseminated pyrite; however, barren pyrite may extend well beyond the area of gold mineralisation.



QINGSUI DRILL SECTION
DIAMOND DRILL HOLES
(IN PROGRESS)
Tuffaceous Sandstone
90m
Contact
BASALT
Quartz Reef
450m (PROPOSED)

FIG. 6

Suorkuduk copper-molybdenum deposit

The feasibility study team visited Suorkuduk copper-molybdenum deposit on June 10 (locality 8.1, Fig.3). It is located near 46°45'N, 88°45'E in a probable northwest extension of the Ulungu Fault Zone (defined by aeromagnetics), in intermediate to basic volcaniclastics of the middle Devonian. The Suorkuduk deposit was discovered in 1984 by a geological survey team, and is currently being explored and evaluated.

The main country rocks are tuffaceous sandstone, tuff and andesite, with pink biotite granite (to the east) and concealed diorite. There are also numerous dykes of granite and porphyritic dacite. Mineralisation is described as skarn type, but no carbonates have been identified in the area.

The area of mineralisation defined to date is approximately 2km^2, but additional mineralisation has been found nearby and exploration is continuing. Mineralisation consists of chalcopyrite and pyrrhotite (with malachite, azurite, etc.) and some molybdenite in extensive garnetiferous "skarns". Twelve vertical drill holes, have been completed to depths ranging from 70m to 450m, but no drill sections or estimates of grade and tonnage were seen. It appears likely that the mineralisation is patchy, with sporadic high grades, and limited in extent. Detailed geological mapping (1:2 000) and geophysical work are in progress.

A geophysical team was operating about 3km from the main Suorkuduk deposit testing apparently similar mineralisation. The main methods being used were ground magnetics and gradient array IP. Although these have been quite successful at Suorkuduk in outlining mineralisation, only a coarse interpretation was possible. Dipole-dipole IP and/or TEM might give more interpretable results.

Chromite deposits

Chromite mineralisation occurs sporadically in numerous serpentinised "ophiolitic" ultramafic bodies along the Kalameily and Ulungu fault zones. The ultramafic bodies generally have steep dips and faulted contacts with lower Carboniferous (in the Kalameily fault zone) or Devonian (Ulungu fault zone) mafic-intermediate volcanics, tuffaceous sandstone, and radiolian chert. Extensive ground exploration (geological, geophysical, geochemical, drilling, and trenching) was carried out in those zones during 1960. All known chromite ore bodies are of small size, and occur in the form of lenses and veins in dunite. Smaller but more numerous chromite deposits are present in harzburgite. Currently, no chromite ore is being mined in the eastern Junggar.

Sujiquan graphite deposit

Globular crystalline graphite aggregates , some having cores of sedimentary rock, occur in a mid-Variscan biotite granite pluton (@340 m.y.) near the contact with a reddish K-granite of slightly younger, though similar, age, in the south of the Junggar fold system (locality 2.3, Fig.3). The graphite deposit was probably formed through assimilation of carbonaceous Carboniferous country rock. It has been mined, but is now abandoned due to transportation problems.

Beilekuduk stannite deposit

This deposit (locality 2.1, Fig.3) occurs within a greisenised and albitised porphyritic biotite granite pluton which is a part of a large middle Variscan (340 m.y.) granite batholith 250 km long (E-W) and 30-40 km wide, in the south of the Junggar fold system. There are two phases of granite present: an early biotite granite intruded into Devonian andesitic volcanics and pyroclastic rocks, and later small bodies and dykes of reddish potassium granite. Tin mineralisation, mainly stannite and other sulfides but including some cassiterite, occurs in two parallel belts, about 500 m apart, of vertically dipping greisenised veins trending 020-30^{o}. The tin mineralisation is discontinuous. Individual veins measure ten to several tens of meters in length and up to several meters in width.

A tin anomaly was first noticed in the area in 1960 during a heavy mineral reconnaisance survey. Vein type mineralization was identified later. In 1986 the Geophysical and Geochemical Prospecting Brigade from Xaanxi province began an extensive geochemical survey and trenching in this area, as part of Xinjiang 305 project.

Geochemical aspects

An extensive program of geochemical prospecting involving regolith sampling and analysis has been carried out in eastern Junggar by the Geophysical and Geochemical Prospecting Brigade, Xinjiang BGMR. The program has not been very successful, apparently because of the problem of wind-blown material. Australia could help in this field by contributing an experienced exploration geochemist to the proposed co-operative comprehensive project. The analytical work should be carried out by the Xinjiang BGMR.

Whole rock geochemical and isotopic (mainly Sr and Nd) studies of igneous and meta-sedimentary rocks of eastern Junggar, integrated with geological and petrological studies, are required to help answer questions relevant to:

1. Source character and differentiation processes of the major granite bodies. Major magmatic-hydrothermal ores may be associated with highly fractionated granite.

2. The tectonic environment and processes involved in the formation of the mafic-ultramafic ("ophiolitic") bodies and their associated chromite mineralisation.

3. The tectonic affinity and crustal environments (e.g., island arc, continental margins, etc) of the mafic igneous rocks.

4. The cause of magmatic sulfide mineralisation associated with mafic igneous rocks.

5. The crustal evolution history of the region.

Whole-rock analyses for major and trace elements can be done in Xinjiang (BGMR), but some duplicate analysis should be carried out, to test precision and accuracy, elsewhere in China (e.g. Lang Fang) and also in Australia (BMR or ANU, Canberra). Isotope analysis could be done at the Chinese Academy of Geological Sciences and ANU, Canberra.

Some geochronological work using Rb-Sr,K-Ar,U-Pb and possibly other dating methods, may need to be done, preferably in China, e.g., at the Chinese Academy of Geological Sciences.

Analytical facilities

. Central Laboratory for chemical and mineralogical analysis in Urumqi, Xinjiang (BGMR). This laboratory has 140 members, including 60 professional analysts with engineer qualification. It is well equipped with modern facilities for sample preparation, mineral separation and chemical analysis, and is operated on a contract basis. Major equipment includes XRF (1986), AA (1985), emission spectrometer (1986), ICP (1986), laser probe trace element spectrometer (1983), and X-ray defractormeter (1985), all imported from overseas. An electron microprobe will be installed by the end of the year. In our opinion, it is as well, if not better, equipped as most Australian research organisations. However, no facility for isotope analysis is available in Xinjiang.

Institute of Geophysical and Geochemical Exploration at Lang Fang, Hebei Province, a major analytical institute under the Ministry of Geology and Mineral Resources.

Institute of Geology, Chinese Academy of Geological Sciences, also under the Ministry of Geology and Mineral Resources, has first class modern equipment and personnel well-qualified to carry out isotope anaysis. Many of the scientists have received training in western countries.

BMR and ANU, Canberra, Australia. Whole rock major and trace element analysis is routinely carried out by XRF and AA at BMR. Dr Chappell, at the Australian National University, is an internationally renowned XRF analyst, and also has an neutron activation facility designed for high quality trace element analysis. The Research School of Earth Sciences, ANU, has first class facilities for isotope analysis. Contracts for analytical services could be arranged with these organisations.

Factors considered in making recomendations for a co-operative study of eastern Junggar

1. The availability of published topographic, geological, and geophysical maps at 1:200 000 scale and larger scales (e.g., 1:50 000), all gravity data, and all airphotos is restricted by the Chinese government. Under guidelines currently enforced, none of these data are allowed out of China, and the Australian Feasibility Study team were unable to get official permission to examine them. However, ready access to such information is vital both for successful mineral exploration and for scientific communication.

2. The maximum period during which geological fieldwork can be carried out in eastern Junggar is about 4 months, from mid-May to mid-September. Four months is also about the maximum length of time most Australian geoscientists would be able to work in Xinjiang in any one year because of family reasons, business commitments, and other factors.

3. The main objective of the proposed co-operative study, according to the Australian guidelines, is to establish a comprehensive regional geological and geophysical framework for the eastern Junggar region, but the Xinjiang Bureau of Geology and Mineral Resources regard mineral prospecting as the dominant subject for any joint work.

4. Australia's role in mineral exploration in eastern Junggar should be advisory, providing consulting services to the Chinese geoscientists who will do the bulk of the prospecting work and retain ownership of any discovery resulting from it.

5. A new geological survey of the entire eastern Junggar region, as at one time envisaged, is considered unwarranted: the region is already covered by high standard 1:200 000 geological maps published in the 1960s and 1970s, and parts are also covered by 1:50 000 geological maps produced during the 1980s. These maps show stratigraphy in comparable detail to that shown on Australian 1:250 000 geological maps. They result from fieldwork by the Xinjiang Bureau of Geology and Mineral Resources using 1:60 000 black-and-white airphotos taken in the 1960s (comparable to the Australian RC9 1:80 000 airphotos) and contoured topographic maps compiled from these airphotos.

6. Eastern Junggar is ideally suited, because of sparse vegetation, moderate relief, extensive exposures, and variety of rock types, to detailed geological mapping using colour airphotos at about 1:25 000 scale for interpretation and accurate positioning. Australian expertise involves the extensive use of colour airphotos in detailed geological mapping and mineral exploration.

7. Little work has been done in eastern Junggar on detailed structural analysis, sedimentology, volcanic geology, igneous rock geochemistry, and hence on tectonic setting, crustal evolution, and metallogenesis. These aspects are especially suitable for study by Australian geoscientists. In particular, they form a major part of current research by BMR in its role of providing an integrated, comprehensive, scientific understanding

of the Australian continent as a basis for mineral exploration.

8. Eastern Junggar was covered in the 1960s with aeromagnetic surveys at 1: 200 000 scale, but more detail is required now. In 1982 an area of about 5000 km^2 in the northern part of the region was surveyed at 1:25 000 scale with airborne magnetics, radiometrics, and EM. The EM was of limited use and the radiometrics was 'unsuccessful'; however, the magnetics has proved very useful. The extent of exposed bedrock in eastern Junggar is comparable to that of the Mount Isa region in northwest Queensland, where radiometrics has been spectacularly successful in mapping lithology, so radiometrics can be expected to be equally useful in eastern Junggar.

9. Airborne operations in Chinese air space can only be carried out by China, and hence should be paid for by China. The Aero Geophysical Survey, based in Beijing, are capable of doing the airborne geophysics. They are also well equipped to process and interpret the data, but to speed up this stage and justify some sharing of costs, Australia could contribute technically to the data processing and interpretation.

10. The Australian team were most impressed by the enthusiasm and co-operative attitudes of the Geophysical and Geochemical Brigade of the Xinjiang BGMR at Changji, Xinjiang, and the Aero Geophysical Survey, Beijing: this augurs well for any joint scientific study. The Brigade at Changji have done good systematic work (ground magnetics, gravity, and gradient IP) at the Kalatongke and Suorkuduk deposits in eastern Junggar. They have reasonable computer facilities and many kinds of software, and will soon be getting new magnetometers.

11. A significant Australian contribution, at low cost and with potential commercial spin-offs, would be Australia-made equipment, such as SIROTEM and Australian software, and the training of Chinese geophysicists and technicians at Changji in their use.

12. Training courses in geophysical methods and techniques, like those given at AMF, Adelaide, could be adapted for presentation in Chinese by Chinese geophysicists in Xinjiang and other parts of China.

13. A remote sensing study of much of Xinjiang, including at least part of the eastern Junggar region, is currently being undertaken by the Chinese Academy of Sciences in Beijing, funded through Xinjiang Project 305.

14. Regional exploration geochemistry has been carried out in eastern Junggar, but has failed to identify many anomalies, perhaps because of problems in collecting suitable samples. Some research and evaluation are probably needed to determine the most suitable sampling techniques for different parts of the area.

15. An important objective of an Australian contribution should be to demonstrate the advantages of close co-operation between geologists, geophysicists and geochemists. For mineral exploration, and geological work in general, to be successful in eastern Junggar it is essential that all available information is shared between geoscientists within the Xinjiang BGMR and also

between the Xinjiang BGMR and other groups, such as those working on Xinjiang Project 305.

16. Possible involvement by Australian companies: several times in correspondence between Australia and China, it has been stated that if any significant mineral deposits are located in eastern Junggar and if the Chinese Government decides to allow foreign participation in their development, then Australian companies may be invited to participate. Eastern Junggar does not seem to offer any major unusual technical problems, but no Australian company would be likely to involve itself in exploration in an area where existing maps of geology, airborne geophysics, and gravity at 1:200 000 and 1:50 000 are withheld. If other explorers with access to these maps, have been unsuccessful in the region, why should an Australian company hope to do better without them? Australian company participation in the evaluation and development of deposits that may be discovered with Australian help will depend on policies and conditions which apply at the time; although difficult to envisage under present conditions, such participation could be both viable and desirable in the future.

BASIS FOR RECOMMENDATIONS FOR A CO-OPERATIVE GEOLOGICAL AND GEOPHYSICAL STUDY IN EASTERN JUNGGAR, XINJIANG, CHINA

1. The area selected for a proposed co-operative study is the eastern Junggar region, an area of about 30 000 km^2.

2. Eastern Junggar is regarded as having considerable mineral potential, but few significant mineral deposits have been found in the area to date.

3. The proposed co-operative study would result in a wide range of new information on the area, thereby providing a much better basis for effective mineral exploration. It would not duplicate any information already in existence.

4. The Bureau of Geology and Mineral Resources, Xinjiang, wish to focus the proposed study on mineral exploration; consequently, the study should include experts in mineral exploration companies to assist in targetting areas for mineral prospecting.

5. No Australian companies have yet shown interest in becoming involved in mineral exploration or development in the area.

6. Both Australia and China would have major, and comparable, input to the proposed study; e.g., Australia would provide geological and geophysical expertise for the term of the study, and would take part in ground operations; China would conduct the necessary airborne operations.

7. When formal agreement is reached to carry out the study, it should be on the understanding that all existing maps and data would be made available to the joint study team. Otherwise the project would not be practicable.

8. Training of Chinese geoscientists would be an integral part of the project.

9. The proposed study would be planned around the 4-month field

season in eastern Junggar. It would be most efficient for the Australian participants to spend most of the rest of the year in Australia.

RECOMMENDATION FOR A CO-OPERATIVE GEOLOGICAL AND GEOPHYSICAL STUDY OF THE EASTERN JUNGGAR REGION, XINJIANG, CHINA

1. The aims of the study should be to provide a comprehensive geological and geophysical framework for the eastern Junggar region, gain a better understanding of the mineral potential, assist in the selection of areas which appear to be the most prospective for detailed mineral exploration, introduce methods and techniques used in Australia in the search for mineral deposits, and help in training scientific and technical personnel.

2. The study to be completed within a three-year period, preferably from May 1988 to April 1991, by a team of Australian and Chinese geoscientists. Fieldwork to be carried out between mid May and mid September each year.

3. The co-ordinating authorities for the joint study be the Bureau of Mineral Resources, Australia, and the Xinjiang Bureau of Geology and Mineral Resources, China.

4. All geoscientists involved in the co-operative study should together review the geology and geophysics of the entire eastern Junggar region from information currently available and from data obtained during the course of the study. Results of this review should be published as synthesis reports and accompanying small-scale (e.g., 1:500 000) maps.

5. The Australian contributions to the study should include the following Personnel:

- A senior geologist as Project Manager, full time, to supervise and co-ordinate all aspects of the study, together with two or three support accounting and secretarial staff, part time.

- One or two senior geologists full time, to concentrate on regional framework studies. They should spend 3-4 months each year in Xinjiang, including the field season, and the remainder of the time on office and laboratory work in Australia.

- Two geologists with wide experience (15 year minimum) in Australian mineral exploration techniques and philosophies (part time) to concentrate on assessment of the non-ferrous mineral potential of eastern Junggar. These geologists should spend 5-6 months a year on the project, partly or entirely in Xinjiang, carrying out field work and completing reports each year. One of the geologists, at least for the first field season, should be an expert geochemist.

- Consultant geologists as required, on a short term basis (up 2 months in any one year) to advise on specialist topics.

- Geophysicist and technical assistant experienced in the use of SIROTEM for field surveys; part time (2-3 visits to Xinjiang, during field seasons).

- Senior geophysicist to plan and initiate a SIROTEM field program and assist interpretations of IP and TEM data; part time (2-3 visits).

- Two data-processing experts with Australian software to assist with processing of airborne data at AGS, Beijing; part time (2-3 visits).

- Senior consultant geophysicist and assistant to help organise training courses for geophysicists in China, to aid interpretation of airborne survey data, and to advise on selections of targets for ground geophysics; part time (1-2 visits).

6. A low-level detailed airborne geophysical survey of the eastern Junggar region should be carried out as a matter urgency to help in the understanding of the regional geology and setting of the known mineral deposits, and to establish a framework for future mineral exploration. Principal methods should be magnetics and radiometrics; EM could also be flown if it does not significantly increase the cost, but is of secondary importance. Such airborne surveys are used extensively in Australia in areas not unlike eastern Junggar, and have proved invaluable as an aid to geological understanding, as well as directly detecting some significant mineral deposits.

7. The airborne survey should be carried out by the Aero Geophysical Survey (AGS) of the Ministry of Geology and Mineral Resources, Beijing, and should be paid for by China. However, Australia could contribute technically to the data processing and interpretation, and hence share with China the total cost of the survey.

8. The Australian geologists should work in the field with Chinese counterparts in one or two field teams.

9. Detailed geological mapping of selected key areas in the eastern Junggar region should be carried out during the study, preferably using colour airphotos at 1:20 000 - 1:25 000 scale. At present only a small part of the region appears to be covered by such photos - the Fuyun Sheet in the north, flown in 1982. Alternatively, 1:60 000 black-and-white airphotos taken in the 1960s could be used if enlarged to 1:30 000. Detailed mapping of areas in Australia comparable to eastern Junggar would not be contemplated until 1:25 000 colour airphotos became available.

10. During the 3-year project, as part of the framework study, integrated petrological, geochemical, and isotopic (mainly Sr and Nd) research should be carried out on igneous and metasedimentary rocks to investigate the origin and differentiation processes of the major granite bodies, the tectonic signatures of the mafic igneous rocks, and the crustal evolution of the region. Whole-rock analyses for major and trace elements should be done mainly in Xinjiang (BGMR), but some duplicate analyses should be carried out, to test precision and consistency, elsewhere in China (e.g., LangFang) and also in Australia (ANU or BMR, Canberra). Isotopic work could be done at the Chinese Academy of Geological Sciences, Beijing, or at ANU, Canberra.

11. Research should be carried out to establish a suitable sampling methodology for regional geochemical exploration in

eastern Junggar.

12. Some geochronological work, using Rb-Sr, K-Ar, U-Pb zircon and possibly other methods, may need to be done, preferably in China (e.g., at the Chinese Academy of Geological Sciences).

13. To complement the airborne survey and enable the full aims of the geophysical study to be achieved, a regional gravity survey of eastern Junggar should be undertaken. As regional gravity data are restricted (none were sighted during the Feasibility Study), this survey has a lower priority than the airborne survey, and it would have to be carried out and paid for by China.

14. Australia should contribute to ground geophysics by introducing a SIROTEM electromagnetic system and appropriate training for its use and interpretation of results.

15. In the period February - April of each year of the joint study, 2-4 Chinese geologists and assistant geologists (including an interpreter) should visit Australia for about 3 months to work with their Australian counterparts on maps and reports and also with Australian mineral exploration companies to gain experience in Australian prospecting philosophy and techniques.

16. Australia should assist in the training of Chinese geophysicists in China in different methods of ground geophysics (e.g., dipole-dipole IP) and computer-aided interpretation.

17. China should send 2-4 geophysicists (including interpreter) to Australia each year to assess geophysical methods used by Australian mineral exploration companies, BMR, and CSIRO, help prepare training courses in Chinese to be held in China, and work on the interpretation of field data from eastern Junggar. It is also recommended that a Chinese expert in image processing from the AGS visit Australia to exchange methods and techniques with BMR, CSIRO, and mineral exploration companies.

18. Australian personnel should take courses in Mandarin, and their Chinese counterparts should take courses in English language. However, it is essential that a proficient English speaker be included in any party of Chinese geoscientists visiting Australia.

19. Output should include 1:500 000 scale geological and geophysical maps and accompanying reports for publication; larger scale maps, including some at photo-scale of key areas, in unpublished form (unless official Chinese policy is changed to allow unrestricted distribution of maps at scales between 1:200 00 and 1:10 000); and scientific papers in international and local journals. Geological and geophysical maps should be at the same scales and use the same topographic bases, to enable ready comparison and facilitate interpretation.
Authorship: as a matter of principle, all publications should have joint Chinese and Australian authorship, except in exceptional circumstances. The major contributor should be the senior author, whether Chinese or Australian; if there is doubt, preference should be given to the Chinese author.

20. Costing It is recommended that sharing of costs for the study be on the basis:

A. Australia pay salaries, allowances, and contracts for the Australian geologists and geophysicists, and their fares between Australia and Xinjiang (or between Australia and Beijing if working in Beijing, e.g., at the AGS); China pay for fares, accommodation, and meals in Xinjiang (and in Beijing if working in Beijing). Australia also pay for fares, accommodation, and meals for Chinese geologists visiting Australia from the time they leave Xinjiang until they return to Xinjiang, but China pay their salaries and also all their costs in Xinjiang.

B. China pay for services carried out by China in China and for China, and also for equipment that is not considered essential for the study and has no Australia-made components.

21. Periodic evaluation and review of the project should be carried out twice each year: in China, at the end of each field season (August-September), and in Australia before the beginning of the field season (April-May). Results of the reviews should be presented as reports for circulation by the Co-ordinating Authorities.

22. An MOU for the co-operative study should allow for amendments to be made at any time, as required, following agreement and Letters of Exchange between the Co-operative Authorities and ADIAB.

Perceived mutual benefits

1. Strenthening of ties between major trading partners.
2. Exchange of scientific ideas and expertise, and establishment of personal contacts.

Perceived benefits to Australia

1. Publicity for Australian expertise and equipment, and propagation of their wider application.
2. Possible new opportunities for the Australian mineral industry.
3. First hand knowledge of a little known area which is of major international geological interest.

B. Perceived benefits China

1. Introduction to Xinjiang of current Australian ideas and concepts on topics such as basin development, tectonic evolution, plate tectonics, and metallogenesis.
2. A sound geological and geophysical framework for mineral exploration.
3. Introduction of Australian techniques, methodology, and philosophy in mineral exploration to Xinjiang.
4. Promotion of successful integration of geology, geophysics, and geochemistry to mineral exploration.
5. Possible discovery of new ore bodies.
6. Training of young Chinese geologists and geophysicists.
7. National and international recognition of the work of the Xinjiang BGMR.

8. Updating of present geological and geophysical maps.

APPENDIX A:
RECOMMENDED PROVISION OF SERVICES AND OUTLINE OF BUDGET

Services to be provided by Australia

1. Professional advice and assistance
2. Fares to and from Xinjiang (or Beijing) for all Australian geoscientists and their Chines counterparts.
3. Some processing of airborne geophysical data.
4. Training courses and study tours in Australia for Chinese geoscientists.
5. Preparation of some maps, reports, and scientific papers for publication.
6. Chinese language courses for Australian geoscientists.
7. Other services as may be agreed.

Services to be provided by China

1. Professional counterparts for the Australian geoscientists.
2. Service staff for field operations in Xinjiang: drivers, field assitants, interpreters, etc.
3. 1:25 000 colour airphotos, at least of key areas selected for detailed study (could be partly paid for by Australia).
4. Interpreting and translation facilities in China.
5. All geological and geophysical maps and reports, and airphotos, as required by the Australian and Chinese geoscientists in China.
6. Provision and payment of all accommodation and transport within Xinjiang (or within China, where no foreign exchange is involved).
7. Medical support for Australian personnel, if required.
8. Computer services in Xinjiang and Beijing (e.g., at AGS).
9. Airborne geophysical survey of eastern Junggar.

General Services

It is expected that China will facilitate all aspects of the joint study in China, including expeditious customs clearance, internal transportation of supplies and personnel, provision of all necessary assistance to Australia personnel, and security clearances for the Australian geoscientists to examine and use relevant maps, reports, computer tapes, and other data, and that Australia will reciprocate in Australia.

Equipment to be provided by Australia for use by Australians in China

Photocopier with paper and toner
Portable typewriter for field use
Word processor for office
2 microcomputers (one for geophysical fieldwork)
Overhead projector, slide projector, and screen
Dyeline printing machine and paper
10 swags for fieldwork
Bushtoilets for field camps
6 35mm cameras and film
Geological hammers, compasses, stereoscopes
FAX machine (Doubtful but desirable)
Drafting supplies
Miscellaneous stationery

Selected medical supplies
Textbooks
Radio receiver for field camps
?2 Tents for field camps
?2 Toyota Landcruiser station wagons
Etc.

<u>Equipment to be provided by China</u>

Vehicles for fieldwork in Xinjiang
All necessary camp equipment for fieldwork in Xinjiang
Office space in Xinjiang (Urumqi and Changji)
Office furniture in Xinjiang
Telephones, and FAX line in Xinjiang
Typewriter/word processor with Chinese characters
Etc.

<u>Estimated costs to be borne by Australia</u> ('ball-park' figures)

	A$
Fares for Australian geologists (27) and Chinese counterparts (13) @ $5000	200 000
Consultancy fees for Australian geologists, 2600 days @ $500	1 300 000
Accommodation costs in Australia for Chinese geologists, 1000 days @ $100	100 000
Publications costs of maps and reports prepared and printed in Australia, perhaps	100 000
Possible purchase of colour airphotos of key areas	100 000
Possible purchase of 2 Toyota Landcruiser station-wagons (one for the Australian geologists, the other for the Australian geophysicists)	100 00
Office machines (photocopier; dyeline printing machine; slide projector, overhead projector, and screens; 2 microcomputers, FAX machine, word processor, etc.)	50 000
Geological field equipment (hammers, compasses, stereoscopes, cameras and film, 2 tents?, 10 swags, bush toilets, portable typewriter, etc.)	50 000
Miscellaneous geological items/contingency fund (e.g. Landsat scenes, drafting supplies, language courses, medical supplies, ?rent of office space in Urumqi, chemical analyses in Australia, stationery, freight and postage charges, contract typing and drafting, etc.)	100 000
TOTAL GEOLOGICAL COSTS OVER 3 YEARS	<u>$2100 000</u>
Fares for Australian and Chinese geophysicists (25) @ $5000	125 000
Consultancy fees for Australian geophysicists 800 days @ $500	400 000
Accomodation costs in Australia for Chinese geophysicists, 800 days @ $100	80 000
Purchase of SIROTEM, complete with 'Stand alone', Tx, 'Roving Vector Rx', and borehole Rx,	100 000
Other geophysical equipment - gamma-ray spectrometer, portable magnetic susceptibility meter, etc.	50 000
Software fees or purchasing costs	50 000

Possible AMF fees	100 000
Computer costs in Australia	50 000
Contingency fund for geophysics	55 000
TOTAL GEOPHYSICAL COSTS OVER 3 YEARS	$1 000 000

TOTAL COST ABOUT $3 000 000 OVER 3 YEARS

Costs to be borne by China

1. Salaries for Chinese
2. Allowances for Chinese in China
3. Accommodation and meals for Australians in Xingiang (hotels and field camps)
4. Computer charges in Xinjiang and Beijing
5. Travel within Xinjiang for Australians and their Chinese counterparts
6. Camping equipment and field vehicles
7. Interpreters and translators
8. Winch and cable for borehole SIROTEM
9. Diamond drilling
10. Airborne geophysical survey
11. Regional gravity survey
12. 1:25 000 colour airphotos (Australia might help by paying part of cost for selected key areas)
13. Office space in Changji for Australian geophyicisits
14. Office space in Urumqi for Australian geologists
15. General office furniture
16. Typewriter with Chinese characters
17. Preparations and publication of maps, reports and papers in China.

APPENDIX B: GEOPHYSICAL RESOURCES IN CHINA

In general, China is well equipped with modern geophysical equipment - or has the capacity to manufacture such equipment in China - and has many highly skilled geophysicists. There are some deficiencies, however, and the purchase of foreign manufactured equipment is difficult where foreign exchange currency is needed. In addition, not all the existing resources are used efficiently.

China has been and is extremely active in the acquisition of regional geophysical data. Aeromagnetic coverage has been completed over most of China, as has regional gravity, albeit at various scales. The Aero Geophysical Survey of MGMR, Beijing, are well equipped with modern instrumentation for airborne magnetics, radiometrics, and electromagnetics, and they process data to final maps and prepare interpretation reports competently and efficiently.

With the exception of TEM, China should be relatively self sufficient in ground geophysical instrumentation, as Magnetometers (MP4 proton precession), gravimeters (Worden type) and IP equipment are manufactured at the Beijing Geological Instrument Factory.

Reasonable computer facilities are available to most geophysical teams; however, they are not being fully utilised.

The feasibility study team visited several organisations in Beijing and in Xinjiang in order to assess the level of geophysical resources in China. These are discussed separately below.

Aero Geophysical Survey, Beijing

The Aero Geophysical Survey (AGS) is one of the arms of the Bureau of Geophysical and Geochemical Exploration, part of the Ministry of Geology and Mineral Resources (see Figure 7). It is based in Beijing, but operates throughout China conducting regional and detailed airborne geophysical surveys. The AGS has facilities to process data through to final maps, to interpret and prepare reports on the results, and also to conduct research into new methods.

In the past, the AGS has conducted surveys as directed (and paid for) by the Ministry of Geology and Mineral Resources. They are currently trying to introduce a cost recovery system and function as contractors (for example to provincial bureaux), but the system does not appear to be fully functional.

The AGS operates two main aircraft installations.

1. Twin Otter aircraft equipped with a TRIDEM airborne electromagnetic system, a helium vapour magnetometer (sensitivity 0.02nT), and a gamma ray spectrometer (32 litre crystal volume).

2. Y12 (Chinese aircraft) equipped with helium vapour magnetometer (sensitivity 0.02nT), and a gamma ray spectrometer (48 litre crystal volume) which includes an upward facing crystal and is said to be fully calibrated.

Both aircraft use a new electronic navigation system of the Doppler type which is claimed to be very reliable.

The magnetic and radiometric instrumentation appears to be at least equal to that currently in use in Australia, although data quality could not be assessed. The TRIDEM airborne electro magnetic system (manufactured by Scintrex in Canada) operates at three frequencies (520Hz, 2020Hz, 8020Hz) and records both in phase and quadrature components continuously. Although it has been effective in Canada, the frequencies are rather high to be effective in a deeply weathered environment, and it has not been used in Australia. Results available in China were of mixed quality and the value of the system for eastern Junggar is questionable.

In practise, flight path recovery and preliminary data checks (using an IB PC XT) are done in the field. The data is then returned to Beijing for flight path digitization, further checks, and processing through to final maps. Processing is done on an SEL computer, using software marketed by Dataplotting of Toronto and some Chinese software. Additional software is available for filtering, reduction to the pole, etc., and interpretation (including packages marketed by Paterson, Grant and Watson of Toronto). Processing and interpretation software has also been developed in China at the Beijing Computer Centre and at Chang Chun Geological College.

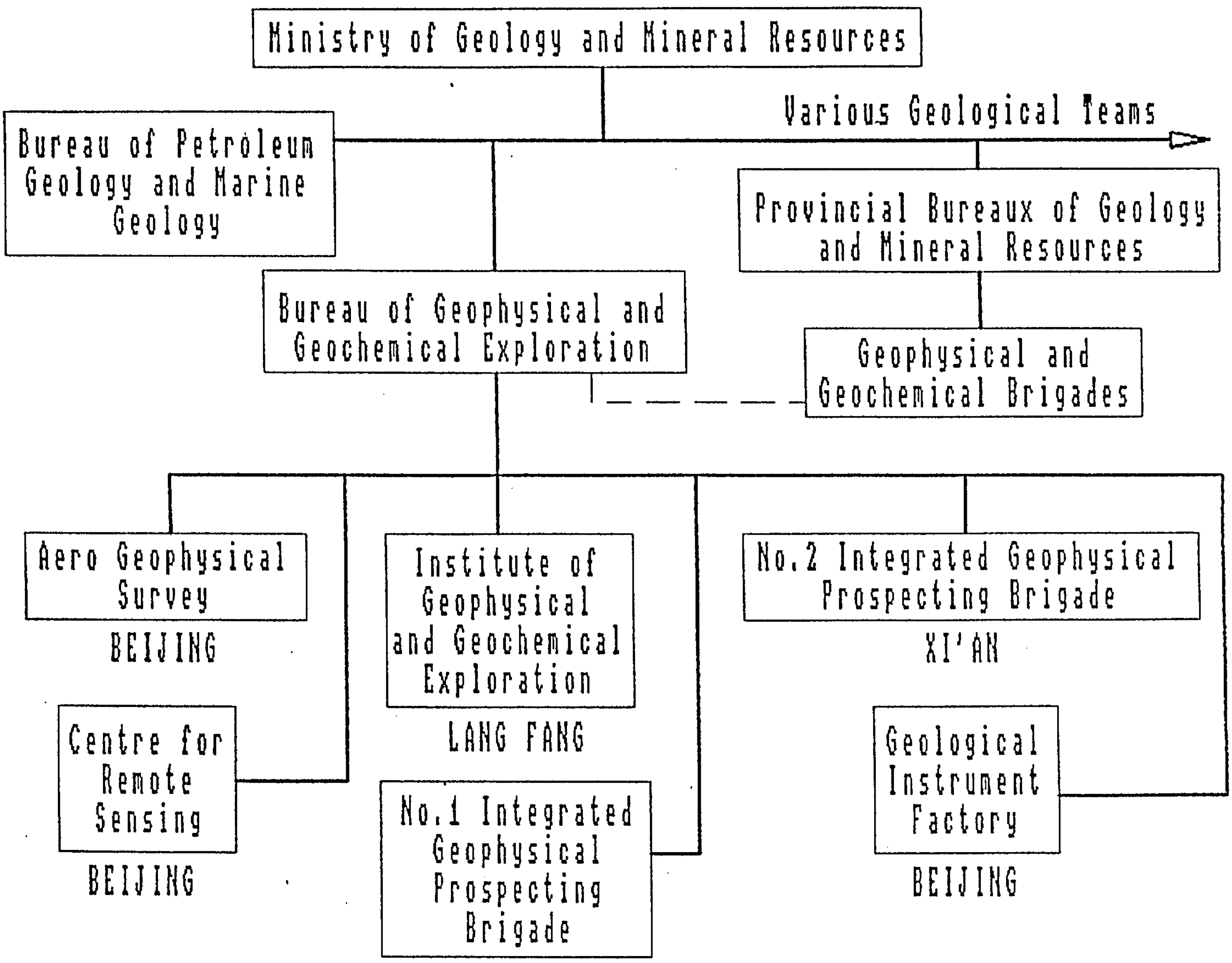


Fig. 7. Structure of the Ministry of Geology and Mineral Resources Peoples' Republic of China

The Research Institute of the AGS has an I^2S System 600 image processor powered by a MICROVAX II. The researchers are very active in image processing of geophysical data and were able to show some impressive results.

In conclusion, the AGS impressed as a dynamic, progressive and professional organisation which was happy to cooperate with any ADAB project in eastern Junggar. For example, discussions with the Director of AGS, Mr Zhuo Song-Nian, indicated that they would be pleased to have an Australian data-processing group work in AGS, on AGS computers, processing data from eastern Junggar with Australian software. It is considered that some exchange of ideas and methods (not necessarily software) would be mutually beneficial.

The Centre for Remote Sensing in Geology, located nearby, is due to be absorbed into AGS in the near future.

Institute of Geophysical and Geochemical Exploration, Lang Fang

The feasibility study team did not visit Lang Fang but Mr. Jiang Bangyuan of IGGE attended discussions In Beijing. The IGGE is another arm of BGGE (see Figure 6). It is essentially an organisation devoted to researching and developing geophysical and geochemical exploration methods. The Institute is currently conducting experiments to evaluate the geoelectrochemical extraction method, partly in eastern Junggar, but no results are available.

Second Integrated Geophysical Prospecting Brigade, Xi'an

The Second Integrated Geophysical Prospecting Brigade is a third arm of the BGGE (Fig.6) with the responsibility for regional gravity mapping of China. They are based near Xi'an but coordinate regional gravity surveys throughout China. These surveys are often carried out by Provincial Bureaux on contract, but methods, standards,etc.,are supervised by the Second Geophysical Brigade. Most of China has been surveyed with gravity at a scale of 1:1 000 000 (approx. 9km by 9km grid), but there are some gaps not yet surveyed around eastern Junggar. Gravity surveys are currently in progress in Xinjiang at a scale of 1:200 000 (sample density 3km by 3km).

Apparently gravity data is regarded as extremely sensitive in China, and it is protected by strict security regulations. No regional gravity maps were shown to the feasibility study team.

Beijing Geological Instrument Factory

The Beijing Geological Instrument Factory, which is also part of the BGGE (Fig.6), was established in 1959, and manufactures a range of geological, geophysical and geochemical equipment. During a brief visit the feasibility study team were able to inspect a range of products, including:

1. **Gravimeters:** Three different models were available, all "Worden type", but claimed to have improved drift characteristics. They are basically similar to the Scintrex or Sharpe range of instruments.

2. **Magnetometers:** An old mechanical magnetometer was on display, but most of the current effort is directed towards manufacture of Scintrex MP4 proton precession magnetometers under licence to Scintrex.

3. **IP Systems:** The factory currently produces time domain equipment, similar to the Scintrex IPR-8 and with both 1.5 and 3kW transmitters. A new IP receiver with built-in memory is under development.

4. **Atomic Absorption Spectrometers:** Three models are currently produced - GGX2, GGX4 and GGX5. GGX2 with direct reading and automatic zero adjustment is for general use. GGX4 and 5 are new 1987 products. They are interfaced with micro computers. Calibrations for 40 common elements in geology have been done for GGX4.

5. **LXG-4 Digital Mercury Analyzer:** It can handle both dry (heated by electric furnance) and wet (with solution) samples over a wide range of concentrations. The detection limit and sensitivity are better than 0.01 nanogram Hg.

6. **XYD-1 Two Channel Fluorescence Spectrometer:** A 1984 design, copy of a Perkins product. It is designed for analyzing Sb, As, Bi, Hg, Se, Te, Sn and Ge with detection limits better than 0.1 nanogram for As, Sb, Bi.

Although little modern geophysical equipment (e.g. proton precession magnetometers) was evident in Xinjiang, that manufactured in China should be obtainable without foreign exchange problems.

Geophysical and Geochemical Prospecting Brigade, Bureau of Geology and Mineral Resources, Changji, Xinjiang

This Brigade, located at Changji, about 20km from Urumqi, is responsible for geophysical and geochemical exploration in Xinjiang. Members of the Brigade were extremely open and cooperative. They are skilled at gravity surveys (probably under contract to the "Second Integrated Geophysical Prospecting Brigade") and also routinely conduct magnetic and IP surveys, particularly as follow up to airborne surveys.

Ground magnetic surveys are currently restricted to mechanical magnetometers, measuring vertical field intensity. Late in 1987 they expect to take delivery of two MP4 proton precession magnetometers, but this will be a new experience and may take some time to catch on.

IP surveys use a variety of equipment, including at least one modern digital instrument. All equipment is time domain, and gradient array is used exclusively, except for some soundings using Schlumberger array. Dipole-dipole array would certainly be more appropriate in some circumstances, but the Brigade have no experience with it and seem hesitant to try something new.

The Brigade has no electromagnetic, radiometric, seismic or borehole logging equipment.

A well equipped computer centre was established in 1985 with a range of equipment, including the following.

DUAL 6800 CPU with 2MB memory and UNIX operating system.
1 x 8 inch floppy disk drive
1 x 8 inch Winchester disk (80MB)
4 x CRT terminals
1 x VIS550 monochrome graphic terminal
1 x dual speed, dual density tape drive (800, 1600 BPI)
2 x Epson Printers
1 x Digitizer
1 x Calcomp 945A plotter
1 x HP300 desktop computer
1 x COMPAQ PLUS portable wit 10MB hard disk

An extensive range of software was also available, including geophysical and geochemical data processing and various plotting routines. In general, however, the computer facilities were only lightly used, and a great deal of "available" software had never been implemented. There were nine specialist staff members in the computer centre, and only they could use the computer.

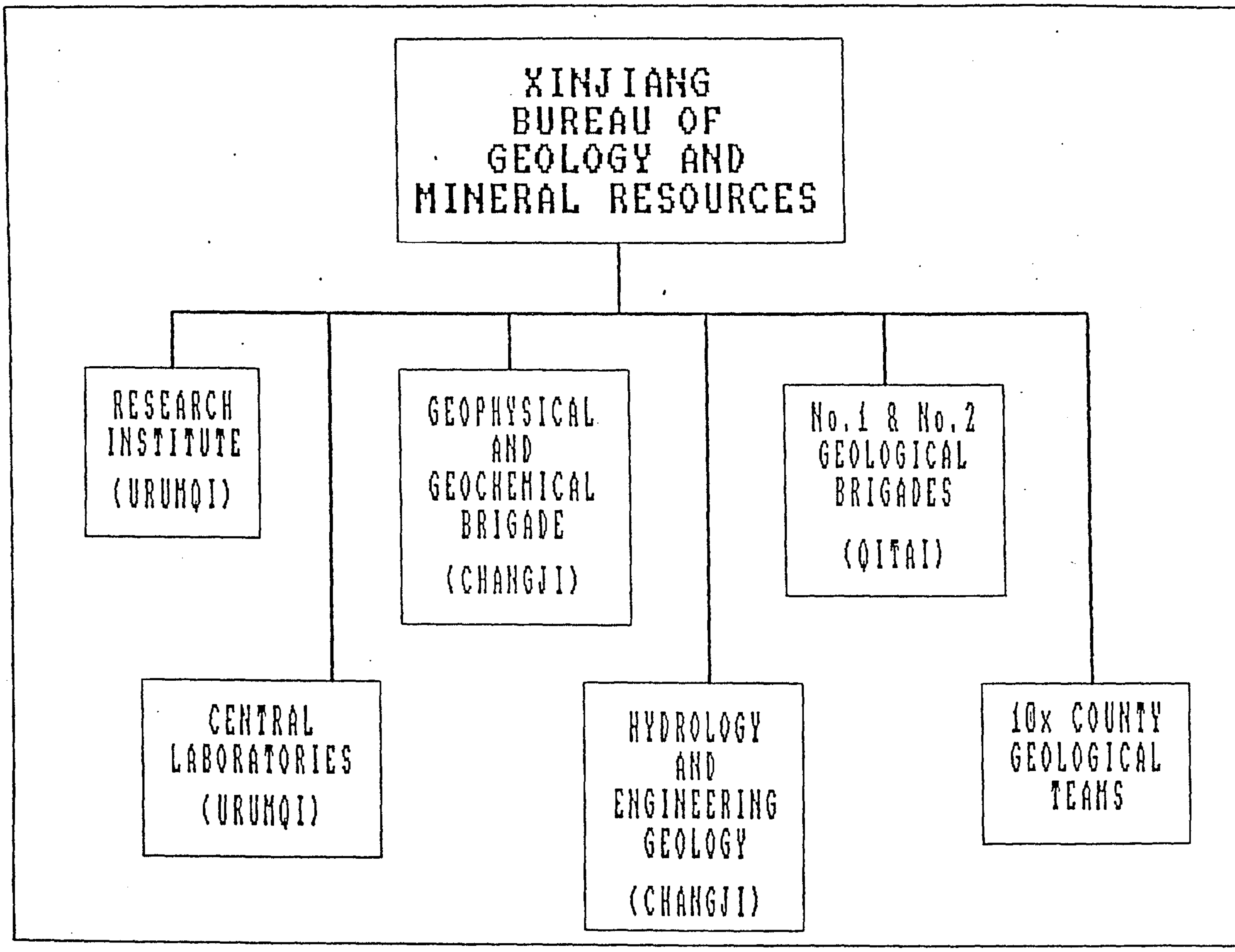


Fig. 8 Structure of the Xinjiang Bureau of Geology and Mineral Resources

APPENDIX C: DETAILS OF ITINERARY

May 23 (Saturday). Flew from Australia to Beijing, China

24 (Sunday). Arrived at Beijing airport 0:50 am. Met by Mr Qiu Xianghua and Mr Wu Aisu, Bureau of Foreign Affairs, Ministry of Geology and Mineral Resources (MGMR) PRC. Driven to Xi Yuan Hotel.

25 (Monday). Morning, met Mr Yang Zhiling, Director, Bureau of Foreign Affairs; Mr Jian Xueyan, his deputy Division chief; Mrs Zhou Weiping, (Deputy Director, Department of Regional Geology and Mineral Resources (MGMR), and Mr Liu Jian Hua (program officer of MOFERT), for general discussions of the feasibility study and itinerary. Visited Mr Kevin Conlan, Counsellor (ADAB), Australian Embassy.

Visited Aero Geophysical Survey (AGS) of MGMR in the afternoon. Held discussions with Mr Shi Qing-Yun (Chief Geophysist of AGS) and several of his associates. Shown the results of a comprehensive geophysical survey of Fuyun area, Xinjiang, carried out 1982. Also visited Research Institute, AGS, and Center for Remote Sensing in Geology, MGMR.

26 (Tues). Morning: Afternon: Mr Song Baochun, Division Chief of Bureau of Geophysical and Geochemical Exploration, MGMR, explained the structure, organization and personnel of MGMR related to geophysical and geochemical exploration. He also introduced in very general terms the geophysical and geochemical exploration in Xinjiang.

27 (Wed) Morning: Mr Huang Chongke, Chief Geologist of Department of Regional Geology and Mineral Resources, MGMR introduced regional Geology of Xinjiang. Afternoon: visited AGS to inspect drafting facilities and Institute of Geography to check availability of Landsat scenes.

28 (Thurs) Morning: visited Beijing Geological Instrument Factory, where Chief Engineer Mr Wu Tian-Biao and Deputy Chief Engineer Mr Zhou Ji-guang led a quick tour of the factory.

Left Beijing airport 2:00pm for Urumqi, Xinjiang. Arrived at 5:40 pm and met by a group from Bureau of Geology and Mineral Resources (BGMR) of Xinjiang Uygur Autonomous Region. Banquet in evening at the Kulun Hotel hosted by Mr Chen Zhefu, Vice Director of BGMR.

29 (Fri)	Morning: at BGMR museum, Mr Bai Guangqun introduced the general geological and geographical conditions of the eastern Junggar region. Afternoon: Mr Chen Yirong described the main geophysical features of the eastern Junggar region.
30 (Sat)	Morning: Mr Chen Yirong continued description of geophysical features of the eastern Junggar with emphasis on Kalatongke and adjacent area. Afternoon: tour of Urumqui.
31 (Sun)	Visited Heavenly Lake (Tianshi) east of Urumqi.
1st June (Mon).	Visited the Geological Exhibition Hall of BGMR and the Central Laboratory for chemical and mineralogical analysis in Urumqi (Blake and Sun). Dr Blake gave a talk on the geology of Mt. Isa. Mr R. Smith visited the Geophysical and Geochemical prospecting Brigade in Changji and gave a talk on mineral exploration in Australia. Met the new Director of BGMR, Xinjiang, Mr Jiang Chengsong (Geophysicist), in evening.
2nd (Tues)	Travelled from Urumqi to Qitai (210 km), where No.2 Regional Surveying Brigade is located. Met director of the No.2 Regional Surveying Team. Drs Blake and Sun gave talks on Australian geology and Mr R Smith gave a lecture on geophysical exploration and some Australian case studies.
3rd (Wed)	Travelled from Qitai to Jinshangou to visit the Jinshangou gold mineralisation (quartz veins and greisen) associated with Permian acid volcanism. Stationed at Hongluigou Inn.
4th (Thurs)	Visited Beilekuduk tin mineralisation in a mid-Variscan granite pluton; observed No. 46 ultramafic body (with chromite mineralisation) of the Kalameily ophiolite suite; visited the Sujiquan graphite deposit at the contact of two granite bodies; observed geology near the Kalameily fault.
5th (Fri)	visited Qingsui ultramafic bodies with chromite mineralisation and Qingsui No. 48 gold deposit.
6th (Sat)	Travelled from Hongluigou to Xiaocaohu (80 km). Made some geological observation along the road.
7th (Sun)	Travelled from Xiaocaohu to Fuyun. Observed No. 108 ultramafic body associated with the Armantai fault. Visited the Ertai Fault which was active in 1931.
8th (Mon)	Stationed at Fuyun. Mr Feng Qi led a tour of geological features in the Fuyun area.

9th (Tues) Visited the exhibition of the Kalatongke Cu-Ni ore district. Mr Feng-Qi described the regional geology and Ni-Cu sulfide mineralisation associated with differentiated mafic intrusions. In the afternoon Dr Blake visited a few localities in the ore district; while Mr Smith and Dr Sun visited the team from Changji Geophysical and Geochemical Prospecting Brigade working in this area.

10th (Wed) Visited Suorkuduk copper-molybdenum "skarn" deposit (porphyry copper?).

11th (Thur) Travelled from Fuyun back to Qitai (450 km)

12 (Fri) Visited map drawing and production facilities of No.2 Regional Surveying Brigade in Qitai. Left Qitai to return to Urumqi.

13th (Sat) Visited Geophysical and Geochemical Prospecting Brigade at Changji. Mr Smith gave a talk on IP methods.

14th (Sun) Visited Turfan, the 'Barossa Valley' of Xinjiang.

15th (Mon) On the basis of numerous discussions with their Chinese counterparts, the Australian team presented a proposal for an integrated geological, geophysical and geochemical comprehensive study of the eastern Junggar region. Mr Wang Youbiao, who chaired the meeting, presented a counter-proposal emphasizing mineral exploration and Australian financial aid.

16th (Tues) - 17th (Wed). Continued discussions aiming for a joint proposal agreeable to both sides.

18th June (Thurs). Left Urumqi at 9:10 am and arrived in Beijing at 12:50. In the afternoon visited Mr Kevin Conlan, ADAB representative in Beijing. Stayed in Xi Yuan Hotel.

19th (Fri) Meeting in the Negotiation Building close to the Xiyuan Hotel with Mr Yang Zhiling and his assistants as well as three representatives from the Xijiang BGMR (Mr Deng Zhenqiu, Mr Bai Guangqun and Mr Chen Yirong). The purpose of this meeting was to further define the aims of the joint proposal.

20th (Sat) Meeting with Mr Huang Chongke and the three Xinjiang BGMR representatives on for further discussions on the joint proposal.

21st (Sun) Toured the Summer Palace in the morning.

22nd (Mon) Morning, further discussion with Xinjiang BGMR representatives on the joint proposal. Afternoon: visited the Aero Geophysical Survey (AGS) to discuss the possibility of Australian involvement in processing and interpretation of any airborne geophysical data to be collected by AGS in the eastern Junggar.

23rd (Tues) Visited Professor Gu Gongxu, President of the Chinese Geophysical Society, in the morning. Lunch time banquet hosted by Professor Sun Honglie, Vice President, Chinese Academy of Science. Worked on report in afternoon and evening.

24th (Wed) Visited Mr Kevin Conlan, ADAB, and Dr Jocelyn Chey, Senior Trade Commissioner at the Australian Embassy in the morning. Banquet lunch hosted by Mr Yang Zhiling, Director, Bureau of Foreign Affairs, MGMR. Finalised proposed recommendations with Chinese counterparts at Xi Yuan Hotel in evening.

25th (Thurs). Left Beijing at 0850 for Sydney.

APPENDIX D: DESCRIPTION OF SITES VISITED DURING FIELD TRIP TO EASTERN JUNGGAR. (Locations shown in Fig. 3)

Wednesday, 3 June

Stop 1.1. Jinshangou, Junngar block. A group of gold-bearing quartz veins 3 km long and up to 600 m wide cut across hills formed of Carboniferous orogenic-type porphyritic andesite lava and felsic eutaxitic ignimbrite. Individual veins are less than 20 cm thick, generally dip 45-90°NW, and are bordered by alteration zones up to 5 m thick. Gold was mined here before 1911, but production is unknown. Workings consist of open cuts and open stopes. Nearby amygdaloidal porphyritic basaltic andesite is cut by irregular pink felsic dykes containing albite phenocrysts.

Stop 1.2. 23 km north of Jinshangou, Junggar block. Hills of Carboniferous pink and grey volcanic conglomerate. The 'only tree in eastern Junggar' is located here, at a small permanent spring.

Stop 1.3. 25 km north of Jinshangou, Junggar block. Strike ridges of Carboniferous, well-bedded friable limestone, with abundant coral, crinoid, and brachiopod fossils, conformably overlying volcaniclastic conglomerate and sandstone dipping 20-40° west.

Stop 1.4. North side of Junggar block, within the Kalameily Fault zone. Steep-sided knolls of subvertical grey slate and phyllite show slump folds probably related to recent fault movements.

Thursday, 4 June

Stop 2.1. Beilekuduk stannite locality, Junggar fold system. Stannite, cassiterite, secondary copper minerals, and arsenopyrite occur in greisen and albitised porphyritic biotite granite forming low rounded hills with extensive smooth rock faces. This granite is the main phase of a large middle Variscan batholith (Rb-Sr age 340 Ma, initial ratio 0.7047 - 0.7077), 250 km long from east to west and 30-40 km wide, intruding Devonian andesitic volcanics. In addition to the main granite phase there are small bodies and dykes of later reddish potassic granite. The tin mineralisation is in two parallel belts, about 500 m apart, of vertical NE-trending greisen veins (020-030°). Individual veins range up to several tens of metres long and up to several metres wide. Anomalous Sn was reported during a heavy mineral survey in the 1960's. Vein mineralisation was found recently. A program of geochemical samplying along trenches was begun in 1986 by the Geophysical and Geochemical prospecting Brigade of Xaanxi Province as part of Xinjiang 305 project.

Stop 2.2 No 46 ultramafic body, Junggar fold system/Kalameily Fault zone. The body consists of poorly exposed dunite in the centre and harzburgite around the margins. It intrudes hill-forming lower Carboniferous altered basaltic and andesitic lava, tuffaceous sandstone, and radiolarian chert. Trenching and drilling shows that chromite forms irregular lenses, some more than 10 km long, at the contact between harzburgite and dunite, and is also disseminated in dunite. The intrusives and country rocks show a pronounced vertical cleavage parallel to the WNW-trending Kalamely Fault.

Stop 2.3. Sujiquan graphite deposit, Junggar fold system. Globular aggregates of crystalline graphite, some with cores of hornfelsed sedimentary rock, and also disseminated graphite, occur in middle Variscan biotite granite (about 340 Ma) near the contact with slightly younger reddish potassic granite. The granites mainly form smoothly rounded hills. The graphite deposit has been mined by open cut methods, but is now abandoned. It was probably formed through assimilation of Carboniferous carbonaceous country rocks. Some secondary copper minerals, sulphur staining, and selenitic gypsum are associated with the graphite.

Stop 2.4. Tamugang, Junggar block/Kalameily Fault zone. Vertically dipping Devonian grey sandstone (?greywacke) and siltstone exposed on the steep southern side of a broad flat alluvial plain are overlain to the south with slight angular unconformity by Carboniferous conglomerate containing some granitic clasts. About 3 km to the southeast, columnar-jointed Carboniferous andesite lava is exposed in a gorge.

Friday, 5 June

Stop 3.1. Pingdingshan (Flat-top mountain), Junggar fold system/Kalameily Fault zone. Three ultramafic bodies, elongated WNW and dipping steeply south, intrude and metamorphose lower Carboniferous basaltic to andesitic lavas and pyroclastics and jaspery radiolarian chert. The largest ultramafic body is 15 km long, up to 1.2 km wide, and consists mainly of harzburgite. Several small chromite deposits have been found within the ultramafic bodies by trenching and drilling. The ultramafic bodies form general depressions flanked by steep-sided ridges of country rock.

Stop 3.2. Qingsui No. 48 gold deposit, Junggar fold system. Native gold occurs in quartz veins cutting Carboniferous basaltic and andesitic volcanics, tuffaceous sandstone, and thin-bedded siltstone. The auriferous veins are in breccia zones up to 315 m long and 2 m wide, in gently undulating terrain. Gold was discovered here in 1960. Drilling being carried out at present has reached a depth of about 450 m. Estimated reserves to a depth of 70 m are 50 000 t ore at 7.44 g/t Au.

Stop 3.3. Kalameily Fault zone. Dykes of fine-grained pink leucogranite intrude Carboniferous thinly bedded and poorly sorted grey volcaniclastic sandstone forming low hummocks. The rocks here are not markedly sheared or brecciated.

Stop 3.3. Qingsui no. 5 ultramafic body, Junggar fold system/Kalameily Fault zone. The ultramafic body contains the biggest chromite deposit in eastern Junggar. The country rocks are ridge-forming lower Carboniferous andesitic to basaltic volcanics. The chromite is mainly disseminated in dunite, but

also occurs in thinly banded ore which in places shows tight folds. The deposit was extensively tested by diamond drill holes and trenches in the 1960's.

Saturday, 6 June

Stop 4.1. Silurian outcrop north of Hongliugou, Junggar fold system. Subvertical thin-bedded grey siliceous siltstone and dark grey to black carbonaceous slate, cut by numerous quartz veins, form hills and strike ridges. No fossils have been found at this locality.

Stop 4.2. Yemaquan (Wild Horse Spring), Junggar fold system. Low rolling hills here are formed of Variscan granite intruding and metamorphosing grey Devonian sedimentary rocks. The main intrusive phase is a medium-grained, pale pink, granite containing sparse biotite; it is cut by irregular vein-like bodies of finer grained and more potassic granite.

Stop 4.3. Junggar fold system. Undulating terrain formed of Caledonian granodiorite (Rb-Sr age about 410 Ma) and overlying Devonian arkose, tuffaceous sandstone, and dark grey limestone. The granodiorite is cut by mafic dykes (?Devonian) and irregular vein-like bodies of fine-grained pink biotite granite (?Variscan).

Stop 4.4. Xiaocaohu, Junggar fold system. Low rolling hills east of the road are formed of Carboniferous volcanics: massive andesitic sandy tuff (?ignimbrite) and lava, dacitic ignimbrite showing good eutaxitic textures, and minor bedded tuff, intruded by pink felsic dykes containing small phenocrysts of feldspar and altered biotite. The rocks are brecciated and sheared in the vicinity of a northwest-trending fault marked by a recent fault scarp about 1.5 m high indicating northeast-side-up.

Sunday, 7 June

Stop 5.1. No. 108 ultramafic body, Armantai Range, Junggar fold system. This is one of 8 ultramafic bodies in this area intruding ridge-forming Devonian volcanics: mainly andesitic volcanoclastics but also including dacitic ignimbrite, basalt, and ?feldspathic quartzite. These are cut by veins of quartz, aplite and pegmatite, and by bodies of altered dolerite. Apart from the dolerite, all rocks, including ultramafics, show a prominent vertical cleavage. The ultramafic body is X-shape in plan, and contains massive, disseminated, and banded chromite ore, mainly in dunite. Exploration has been by numerous trenches and several drill holes.

Stop 5.2. Bridge across the Ulungu river. The river here flows northwest, along a major fault zone within the Junggar fold system. It is flanked by river terraces which conceal the bedrock.

Stop 5.3. Kalaxianger (Ertai) Fault. This major active NNW-trending reverse fault was the site of an earthquake in 1931 which measured 8 on the Richter scale, and resulted in the formation of a fault scarp, about 2 m high, facing west. Movements along this fault have caused up to 20 km right-lateral displacement of the Ertix Fault, the boundary between the Altai and Junggar fold systems.

Stop 5.4. Kalatunk coal mine, Altai fold system. At this small open cut mine SE of Fuyun, a seam of coal a few metres thick occurs within subvertical Jurassic strata overlying Variscan granite exposed immediately to the east.

Monday, 8 June

Stop 6.1. Wuqiagou pass E of Fuyun, Altai fold system. The entrance to the pass is on the major fault forming the southwestern edge of the Altai Shan. This fault is parallel to the Ertix Fault 10 km to the southwest. Highly sheared Variscan granite at the entrance to the pass passes northeast into a massive net-veined complex, well exposed on the sides of the gorge, formed of pink granite, dark grey dolerite and gabbro, and heterogeneous hybrid rocks, all cut by quartz-feldspar pegmatite veins. The mafic rocks form pillow-like inclusions enclosed in and veined by granite. The pillows have highly intricate cumulose contacts with granite, indicating an original liquid-to-liquid relationship. The granite, dated at 230-250 Ma, intrudes grey gneissic and migmatitic metasediments (?Devonian) exposed in the gorge to the northeast.

Stop 6.2. Ertix Fault west of Fuyun. Banded amphibolitic and quartzitic gneiss and migmatitic gneiss of the Altai fold system on the northeast side of the fault are cut by numerous dykes of unmetamorphosed quartz-feldspar porphyry which terminate at the fault. Higher ridge-forming Devonian andesitic sandstone, siltstone, and possibly ignimbrite are exposed on the southwest side of fault; these rocks are sheared and phyllitic alongside the fault, but appear little deformed or metamorphosed 100 m away. The foliation in the gneisses to the northeast is generally subvertical, parallel to the fault, but in places shows tight minor folds plunging 20-30° southeast.

6.3. Copper prospect southwest of the Ertix Fault, Junggar fold system. Small trenches have been dug here at sites of Cu-staining in middle Devonian ridge-forming massive to brecciated basalt and subordinate jasper.

6.4. Junggar fold system. Exposures of Devonian volcanics and jaspery radiolarian chert and ?Variscan gabbro. The gabbro contains traces of gold and has been drilled to a depth of at least 100 m.

Thursday, 9 June

Stop 7.1. Kalatongke Cu-Ni deposit, Junggar fold system.

Stop 7.2. Ordovician outcrops, Junggar fold system. Amygdaloidal basaltic pillow lava is well exposed a low ridge, highly magnetic sedimentary ironstone (sandstone) crops out in a depression to the west, and pink and grey limestone with coral and crinoid fossils occurs further west.

Friday, 10 June

Stop 8.1. Suorkuduk copper-molybdenum dejposit, Ulungu fault zone.

Stop 8.2. Devonian porphyrite andesite lava, orogenic type, Junggar fold system.

Stop 8.3. Altai fold system near Ertix Fault. Banded amphibolite and felsic gneiss are cut by veins of pegmatite.

Stop 8.4. Altai fold system at Fuyun. Irregularly folded Devonian?, migmatitic rocks - amphibolite and meta-arenite with leucosomes, gneissic pink leucogiarite - cut by pegmatite veins and granite dykes are exposed on mountainside.