BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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REPORT ON A VISIT TO CHINA
9-26 APRIL 1980

by

D. Denham

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SUMMARY

In a country where nearly two million people have been killed by earthquakes in the last two thousand years, it is not surprising that earthquake prediction rates high in the scientific priorities of China. Even so, I did not expect to see the size of the effort currently being devoted to this aspect of the earth sciences, and I estimate that at least 3000 people are employed directly on this problem.

The big push started in 1966 when the then Premier Chou En-Lai, after visiting the area devastated by the Hsing-Tai earthquakes, gave instructions to initiate an expanded program aimed at their prediction. Since then, apart from some temporary interruptions, there has been a rapidly expanding program in this field and large growth is still taking place.

Several methods are used to try and predict earthquakes. In fact it seems that the Chinese are prepared to monitor almost everything in an effort to discover parameters that can be used in the future to make successful predictions.

For example in a 300 x 400 km area round Beijing, data from 21 seismic stations and 8 magnetic stations are telemetered by land line into a central office where they are recorded on visual recorders and magnetic tapes. There are always at least two people on duty 24 hours per day, alarm bells ring when an earthquake of magnitude 4 or greater takes place in the region, and epicentres are calculated within 17 minutes of the earthquake taking place.

The telemetry centre for the Yunnan Province at Kunming, will be even more impressive when it is fully operational. Not only will it record 34 channels of seismic data from 15 stations but also 25 channels of precursory data monitoring the geomagnetic field, resistivity, tilt, radon counts, stress, temperatures, and water-well levels. Thus data from a formidable array of detectors will spew forth on to 40 pen recorders and 16 tape recorders, with a dedicated digital computer hooked up to assist with the analysis. The cost of the equipment will be about $A2 million the annual telemetry rental is $A600 000, and the complex employs over 300 people housed in a brand-new five storey building about half the size of the one currently used by BMR in Canberra. Five other similar installations are planned throughout China, so the national effort is very large indeed.

The question is, of course, will all the work being dedicated to earthquake prediction lead to an improved success rate ? To date there have been some spectacular failures (e.g. the 1976 Tangshan earthquake in which over half a million people were killed) and remarkable successes (e.g. the Haicheng earthquake of 1975, which was predicted to the day). The Chinese seem to think that the best plan is to try and detect anomalies in several parameters. They argue that unusual radon counts or water levels in wells will not, by themselves, lead to any reliable predictions. However, if several parameters such as the geomagnetic field, patterns of foreshocks, stress, electrical resistivity, and radon counts all exhibit unusual behaviour then there is a good chance of predicting an earthquake.

During my three-week stay in China I visited several geophysical institutes and the main geophysical observatories at Beijing, Kunming, and Kwangchou. All these institutes and observatories were affiliated either with the State Seismological Bureau or the Academia Sinica. I also visited the Hsinfengchiang reservoir in Kwangtung Province, where in 1962 a large destructive earthquake was triggered when the dam was being filled.

At each centre I presented lectures on 'Stresses in the Australian Crust' and 'Explosion Seismology in Australia'. These seemed to be well received judging by the vigorous discussions that usually followed.

I was impressed by the willingness of all workers to discuss their research programs with me. They were also keen to discuss some of my own suggestions and ideas. In some cases they readily admitted that what they were doing may not result in the required answer but they insisted that the problem was so important that they should look at everything. For example one group at Beijing is working on the changes in spectral components of microseisms before and after major earthquakes - this seems to have a very long-shot chance of success but nevertheless a major program has been mounted on this particular problem.

One thing that did surprise me was how the simple plate tectonic models, involving the interactions of the Indian/Australian and Pacific Plates on the Asian Plate, explain the patterns of active faulting in China and also the directions of the pressure axes for all major Chinese earthquakes. This is all the more remarkable because in an apparently much simpler situation like continental Australia no such patterns are evident.

One major shortcoming in the Chinese prediction effort is the woeful lack of up-to-date computers. Most earthquakes are still located by manually striking arcs with compasses on maps; the Jeffreys-Bullen travel-times are still used (improved crustal models have not been generated); and the depth control for the earthquakes is therefore not good. However, when there is no shortage of people the need for computers is perhaps not so acute.

I was entertained with generous hospitality during my visit and the presence of Professor Zeng Rong-sheng throughout my stay provided invaluable translation and scientific 'expertise'.

A reciprocal visit in the fields of interpretation methods used in explosion seismology, the use of computers to locate earthquakes, the earthquake prediction work being done at Brisbane and Canberra, and for a general review of Australian geophysics and seismology, would be of value to the Chinese.

INTRODUCTION

From 9-26 April 1980 I visited the Peoples' Republic of China under the auspices of the Scientific and Technical Exchange Program sponsored by the Academia Sinica and the Australian Academy of Science.

The original proposal was to visit five places in China (Beijing, Kwangchou, Wuhan, Tangshan, and Kunming or Langchou) and to discuss a wide range of geophysical programs. However, this was cut down to three places (Beijing, Kwangchou, and Kunming) and the subject matter of the visit was concentrated on earthquake prediction.

The itinerary presented to me in Beijing by the Chinese was very sparse, with far too many tourist-type visits and not enough packed into each day. While I was able to extend my stay in Beijing by one day and visit institutes there not originally on my schedule, I was not able to visit the Institute of Geomechanics, the Beijing University, the main Earthquake Prediction Centre, or any institutes working mainly in gravity and/or geodesy. The main problem seemed to be a lack of communication betweenthe Chinese institutes at Beijing. They seemed not to have read (or translated) my proposal properly and certainly had not advised the Kunming Bureau of my main interests.

However, impromptu changes proved not only possible but very successful, and even where these were organised at half a day's notice I was able to visit laboratories and offices to discuss various research programs.

Appendixes 1 and 2 give a complete list of the personnel met, and the full itinerary.

The bureaucratic structure in China is very complicated, and it is essential to understand this if one is to find one's way successfully through the maze of institutes and bureaus. Figures 1 and 2 give some indication of the relations between the Academia Sinica, various Government Ministries, and the State Seismological Bureau. The relation between the State Seismological Bureau and the Academia Sinica was not entirely clear either to me or, I suggest, my Chinese hosts. Apparently the head of the Bureau is a member the Academia Sinica but the SSB obtains its finances directly from the State Scientific and Technical Commission, so the links between the AS and the SSB may not be strong in a formal sense. Appendix 2 gives a translation of the history of the Academia providedby C. Donovan of the Royal Society, London.

BEIJING, 10-15 APRIL

Thursday 10 April

On the first day I was briefed by the Director of the Institute of Geophysics of the SSB, Professor Kuo. The Institute comprises six main sections:

1. Seismological instruments (45 people)
2. Theoretical Physics of the earthquake source (30 people)
3. Beijing seismic network (50 people)
4. National Seismicity Section - focal mechanisms and ancient seismicity (40 people)
5. Regional Seismicity Section - change of 'b' factor, Vp/Vs (40 people)
6. High Pressure laboratories.

The function of the SSB is to predict earthquakes, and this was hammered home throughout my entire visit.

At present there are about 400 short-period stations in China, of which 17 are standard stations reporting to World Data Centres. Most are run by regional bureaus or brigades.

After the briefing I visited the high-pressure laboratories. The first was examining the changes in electrical and magnetic properties of rock due to changes in pressure. For dry rock I was told that pressure changes of 200 MPa produce a 30 percent change in conductivity - unfortunately experiments with saturated rock were not carried out. The magnetic experiments measure changes in magnetic susceptibility caused by pressure changes. Pressures of up to 400 MPa can be introduced and susceptibility changes of 2.8×10^{-3} per MPa were observed.

These measurements seemed rather basic and routine, but in the second high-pressure laboratory, where studies of acoustic noises in rock during the elastic, plastic, and fracturing processes are carried out, the work seemed more advanced. Here they used a variety of confining pressures and then applied uniaxial loading until the rock fractured. Most of the acoustic noise appeared to come when the rock was deforming elastically, and they were optimistic that this fact could be used in earthquake prediction.

Friday 11 April

In the morning I visited the office of the Beijing array, where 21 seismic stations in a 300 x 400 km area are telemetered in by land-line. The data are recorded on magnetic tape and drum recorders using pen on paper. The drum recorders are changed every 4-8 hours depending on speeds etc., and 2 people are always on duty in the office for 24 hours per day. Most of the SP instruments have magnifications of about 25k and only two stations have three-component recorders - the rest just monitor the vertical component.

They are charged Y 440 000 (about $A300 000) per annum for the telephone links - but since it is Government paying Government they don't worry too much about it. The magnetic tapes store all the information from 4 key stations - the other stations use event detecting facilities but I was not able to ascertain what criteria were being used to select the signals.

In addition to the seismological recorders the outputs from 8 proton magnetometers which are sampled at intervals from 15 minutes to every 20 s if necessary are also telemetered in to the main office. Again someone is on call 24 hours of the day. I was surprised that the ΔFs between the magnetometers were not monitored and was not given a satisfactory explanation for this not being done.

A major experiment using microseisms as a possible earthquake predictor was also being carried out there. This experiment has only just started, and no results were available because large earthquakes had not yet occurred near the detectors. The data came in on the same land-lines used for the conventional records, and selected stations were sampled on a 15-minute continuous loop. These werethen filtered with a set of four analogue filters in the range 2-20 Hz and the amplitudes of each component were plotted against time.

The theory is that the frequency characteristics of the microseisms may change before and after a major earthquake because the change in stress alters the Q factors in the crust and hence boosts the higher-frequency components when the stress increases. I was shown large changes in amplitude which I was told were not caused by weather or wind, but it was difficult to check this and I remain sceptical of the application of this method to prediction of earthquakes.

There was also a primitive computer which determined epicentres, but it was not very sophisticated because it did not determine the depths of the earthquakes.

Most of the electronic recorders, amplifiers etc. were made in Shanghai though they had some old British tape recorders which were still being used. Their computing facilities were very limited. However, if you can calculate a reasonable epicentre 17 minutes after the earthquake, who needs computers?

In the afternoon I visited the Beijing Observatory - Pai Chia-tang. I met five of the staff of 16 (including Ghin Ping-chou, the leader of the observatory). The observatory is operated by the Institute of Geophysics of the SSB, and the buildings now occupied were completed in 1954.

The vaults are entered down 3 flights of 12 stairs with a set of doors at the bottom of each set of stairs. There are a bewildering number of seismometers and recorders ranging in magnification from 70 to 25k. The station is sited on loess in spite of the fact that solid rock crops out only about 200 m away.

The magnetic observatory was impressive, even though all the equipment was old. It had a set of 12 piers in the absolute building. They use a Schmidt declinometer, a QHM, a proton magnetometer for F and Z, and an induction coil fo calibrations. The photographic record produced by the variograph was of high quality on glossy paper. An experimental proton for F and Z is being developed with an accuracy of 2 nT.

They also monitor radon levels from water at depths of 150-300 m in several wells near Beijing. However, none of the wells have been close enough to large earthquakes for any changes to be correlated. Data have been monitored since 1975, and the main changes occur in August and September of each year, when the rains come.

Saturday 12 April

In the morning I visited the Institute of Geophysics of the Academia Sinica, where I met three groups working on the structure of the crust in Tibet. They were all preparing frantically for the International Conference on Tibet scheduled for May 1980 in Beijing.

The first group I visited was concerned with explosion seismology. The recent program in Tibet consisted of recording on a north-south traverse using 25 FM tape recorders with 3-component (0.5-5 Hz) seismometers (LS1 type). The recorders have an endurance of only 3 hours, and the complete recording station is quite cumbersome with the amplifiers, radios, and clock all housed in separate boxes. Seismic sources were charges of 5 to 16 tonnes detonated in lakes.

The seismic interpretation seemed quite primitive, only travel-times bein used to determine simple horizontal-layer models. The record sections were compiled from analogue records and were of poor quality with none of the secondary arrivals showing up well. A digital system is being developed but I was not able to see how far this had advanced.

The other two groups I inspected had used gravity and magnetotelluric methods respectively to study the crust in Tibet. There seemed to be little communication between the different groups, and no attempt had been made to reconcile differences between the MT and seismic models. The MT interpretation used only one-dimensional models and was quite simplistic. The gravity work was limited by the elevation control in Tibet, where most of the heights were simply taken from published maps.

Both the gravity and the seismic methods produced similar models with a 40-50 km thick crust under the Himalayas, thickening to 70 km about 30 km to the north of the main range. There was also a group looking at heat flow in Tibet, but they were only using data from hot springs, and no special purpose holes had been logged to determine the regional heat flow. The other section in the Institute was that concerned with palaeomagnetism but I was not able to visit this.

In the afternoon I tried to arrange a visit to the Institutes of Geology and Geomechanics but was unsuccessful. Instead I was taken to the Museum of Geology, which was a well laid out modern museum and very interesting, but not really what I wanted to see.

Sunday 13 April

Visit to Great Wall, Ming Tombs, and Beijing Zoo.

Monday 14 April

I gave my lecture on the stress measurements in the morning to about 100 scientists, and in the afternoon visited the Beijing Seismograph Factory and the Academia Sinica Institute of Geology.

The seismograph factory employs 300 or more people and manufactures most of the mechanical devices used by the State Seismological Bureau. They have manufactured the SQ-70 tiltmeter, the DK-1 (13 sec) and DD-1 (about 1 sec) seismographs, and the LS-1 seismometers. During my visit they were making DD-1 seismographs and SQ-70 tiltmeters. They plan to install 40 to 50 stations with tiltmeters throughout China. The accuracy is about 0.001" of arc and it has an optical recorder situated about 5 m from the tiltmeter. The LS1 is a compact, easy-to-handle seismometer with sensitivity 600V/m/s, and costs about $A800. It weighs 3 kg and is easily modified for horizontal operation.

At the Institute of Geology of the Academia Sinica I visited the geothermal group. They have a very good experimental set-up with 3 conducting bridges operating in parallel and a very solid-looking probe capable of going to depths of 3 km. The sensitivity of the probe was claimed to be about 0.02°C. It is rather large, with a diameter of 6 cm, but has a very clever device to keep out the water. This consists of a thick rubber sleeve with brass flanges at each end which is screwed down tight onto the cable to seal off the water.

I was impressed with the mechanical workmanship of their apparatus and their obvious mastery of the pitfalls of geothermal measurement techniques.

Tuesday 15 April

In the morning I gave my lecture on explosion seismology studies in Australia, and in the afternoon visited the Institute of Geology of the State Seismological Bureau. This Institute has six sections dealing with the following topics:

1. Structure of China
2. Geomechanics
3. Deep structure of the Earth's crust
4. Tectonophysics
5. Geochemistry
6. Induced seismicity

Because the visit was arranged at half a day's notice it was possible to discuss only the program carried out by the section on deep structure of the Earth's crust. However I visited two groups with this section.

The first was carrying out a program on P to S conversion in the crust and upper mantle from teleseisms. They had deployed an array of 20 three-component DD1 seismographs at 20 km intervals at about latitude 40°N to study these waves, and identified between 8 and 10 interfaces in the top 100 km of the Earth. They claimed to be able to correlate these interfaces across the continent and also to correlate them with interfaces found from explosion seismology work.

The second was the geothermal group. It seemed to be doing the same work as the group visited the day before, namely, studying heat flow in the sedimentary basins of northeast China. However, instead of using the data for oil maturation studies they were trying to use the heat flow results to determine crustal structure. This approach is fraught with problems. I was not impressed by their instrumentation, which consisted of a rather frail-looking probe for down hole measurements and a Shotherm QTM-D2 quick-thermal-conductivity meter, which was designed for measuring conductivities of large flat objects like bricks rather than small cores from boreholes. I suspect they had been sold something they did not really want by some energetic Japanese salesman.

KUNMING, 16 - 21 APRIL

Wednesday 16 April

Travelled by plane from Beijing to Kunming with Professor Zeng Rong-sheng. Held preliminary discussions on my Kunming program and visited the Buddhist temples at Kunming.

Thursday 17 April

In the morning I visited the Kunming Seismological Bureau. It is situated about 12 km from the city centre in a large complex of offices. It employs 950 people of which 300 work at the telemetry centre in the main city. Sixty seismic stations are operated in Yunnan province. Thirty 3D short-period stations are operated by professional operators, 15 others are telemetered into the telemetry centre by land-line and radio-link, and 15 short-period vertical component seismographs are operated by volunteers. In addition there are 250 volunteer observation stations monitoring such parameters as radon counts, geomagnetic changes, and water levels in wells.

The Bureau also employs 62 geologists, 80 people working in geodesy, and 40 engaged in geophysical prospecting. There is a seismological institute of 35 people undertaking research on the physics of the earthquake source, an engineering seismology group, and a high-pressure measurement section. Their seismograph factory, which employs 120 workers, builds medium/strong motion seismographs and the transport brigade includes about 90 people. The main office is so large that a primary school operates within the compound solely for the children of the Bureau workers.

The main observatory at Kunming is most impressive and has been aptly named a 'super-station'. It is operated by a staff of 20 people. It was founded in 1957 and considerably enlarged in 1974. All the instruments are sited in a 70 m tunnel, which has been built into the hill at the back of the Bureau's compound and extends 30 m below the surface.

Continuous recordings are made of earthquakes and changes in the gravity and geomagnetic fields, stress, and tilt. Like the Beijing observatory Kunming boasts a bewildering array of seismographs. There are four sets of three component instruments with periods of 1.0, 1.1, 3, and 15 seconds and magnifications ranging from 80k downwards. In addition there is a set of accelerographs with a triggering level of 0.001 g (or so I was told), a sensitivity of 0.0005 g/mm, and a recording speed of 5 cm/s. These strong motion instruments were made at the Equipment Factory of the State Seismological Bureau's Institute of Geology, and twelve sets operate in Yunnan Province.

The Earth's gravity field is monitored by three Askania gravity meters and one LaCoste & Romberg gravity meter. Melchior's earth tide recorder was also operating while I was there, as part of his global program of measuring solid-earth tides.

The magnetic field is monitored by a three-component photographic recorder; the tilt is monitored by two quartz tilt meters (manufactured by the Beijing seismograph factory), and the stress is measured by four Hast-type borehole strain gauges. These gauges measure the change in magnetic susceptibility of a material that occurs with change of pressure. The workers claimed a sensitivity of about 100 μH per 0.1 MPa and a threshold of about 0.01 MPa.

After visiting the observatory I discussed the research programs of Tang Posh-ong on 'The isostatic gravitational anomalies of the Mount Jolmo Lungma areas' and of Kan Rong-ju on 'The stress field of southwest China'. Kan Rong-ju's work showed that, by applying finite element analysis to the simple plate tectonic model of China being squeezed by the Pacific and Indian/ Australian Plates, then the major pattern of faulting and the principal axes of compression from earthquake focal mechanisms can be deduced.

Apparently 85 percent of earthquakes occur along faults, and surface fractures are usually caused by earthquakes larger than magnitude 7. Since the year 1500 about 15 earthquakes greater than magnitude eight have occurred in China.

Friday 18 April

In the morning I gave my talk on explosion seismology in Australia, and in the afternoon discussed the 'Seismicity and Geology of Yunnan Province' with Han Yuan. This was a similar discussion to the one held on 17th with Kan Rong-ju.

Saturday 19 April

I gave my talk on stress in the Australian crust in the morning and visited the telemetry network centre in the afternoon. This centre was by far the most impressive part of the Kunming visit. It is housed in a new five storey office in the centre of Kunming and contains a whole range of recorders monitoring both seismic and other precursory data that are telemetered into Kunming by radio and land-line links. The diagram below indicates the extent of the system when it is fully operational.

Normal Seismic Recorders

Type	short period (3 comp)	med. long period (3 comp)	medium strong 3 comp	long period 3 comp	100 dB dynamic range
Magnification	10k - 100k	100 - 1000	1 - 10	1500	
				0.3-200s	0.05-20s
Number of channels	15	7	6	2	4

Precursory Recorders

Type	geomagnetic	resistivity	tilt	radon	stress	temp., well levels etc.
Number of channels	5	3-5	5	4	1?	6

The outputs are recorded on 16 tape and 40 pen recorders, officers are on duty 24 hours every day, and alarm bells ring whenever an earthquake of magnitude three or more takes place within the province.

They aim to locate an earthquake three minutes after it has occurred, and within ten minutes all the basic parameters are usually determined.

The pen recorders (DD1) were made at the seismograph factory in Beijing and the tape recorders and other electronic components come from Shanghai. Data from six of the stations are transmitted by radio and nine receivers for each station are required to detect all the signals. There is also a dedicated computer worth about $A300 000. I estimated that the total cost of the equipment in the centre would be about $2.0 million.

Sunday 20 April

Visit to the Stone Forest in Karst country near Kunming.

Monday 21 April

In the morning discussions were held with Chen Li-de on precursory anomalies of the Long Ling earthquakes. These two earthquakes took place in 1976 and had magnitudes of 7.3 and 7.4. They were expected because of the following factors: (1) sudden increase in earthquake activity in 1973 surrounding an area of 70 x 200 km where no earthquakes had recently occurred; (2) sudden change in Vp/Vs from 1.65 to 1.74 close to the epicentral area; (3) drop in radon counts by 18 percent near the epicentral area and 5 percent 400 km away; (4) changes in the water levels in wells; and (5) changes in well-water temperatures. However, although the earthquakes were expected no short-term prediction was made.

In the afternoon I travelled to Kwangchou.

KWANGTUNG PROVINCE, 22-26 APRIL

Tuesday 22 and Wednesday 23 April

I visited the Hsinfengchiang reservoir at Hoyuan. This is about 190 km north east of Kwangchou. It was constructed in 1958 and by 1960, when it was almost full, earthquakes started to take place beneath the reservoir. The dam wall is 105 m high, and when the earthquakes persisted the wall was strengthened to resist MM VIII shaking. In October 1960 a network of eleven seismograph stations were set up around the dam, and in December 1962 the main earthquake of magnitude 6.1 took place beneath the deepest part of the reservoir. Considerable damage was done to the town of Hoyuan and several people were killed; the dam was strengthened again. However, that was the last of the damaging earthquakes. The largest aftershock since then took place in 1964 (magnitude 5.3), and although over 12 000 events with magnitude greater than one have occurred since 1960 it looks as though the dangers from earthquakes in that region are now over. The seismic network has been reduced to three three-component stations, and although geodetic and geological observations are still being made these seem to be mainly caretaker activities.

The network of eleven stations that operated for at least ten years provided excellent data on the earthquake activity associated with the water level in the reservoir. One interesting result was that the number of earthquakes with depths less than 5 km correlated positively with the water depth while those occurring deeper showed a strong negative correlation.

At present there is a staff of 13 operating the seismic array - and the 24 accelerographs scattered around the dam - and 8 people operating the geodetic station. At the latter a 24 m distance across the fault thought to be associated with the 1962 earthquake is measured twice per day and tilt is measured four times per day. While there is obvious value in the presence of a small seismic array near the dam the geodetic program seems to me to be of doubtful value. All the measurements correlate so strongly with temperature and rainfall that it is impossible to extract any meaningful secular movement and in any case it was not certain that they were looking at the main fault.

Thursday 24 April

In the morning I gave both my talks and in the afternoon visited the Kwangchou observatory. This is situated on the outskirts of the city and is one of the network of 28 seismic stations operated within the Province. It was established in 1955; magnetic recording commenced in 1957 and seismic in 1959. There are 21 staff members who all live on the premises.

While the station is not as comprehensive as the Kunming observatory it has two sets of three component short-period seismographs and two sets of medium-period seismographs. There are also two sets of strong motion accelerographs.

The maximum magnification of the short-period instruments is about 20k, and all seismographs record on either photographic recorders or pen recorders.

The magnetic recorder is a conventional three-component variograph and calibration observations are made to measure I, D, F, and H.

Friday 25 April

I was given a run-down of the operations of the Kuangtung Province Seismological Bureau and had detailed discussions with the staff of the Prediction Centre. The province has a population of about 45 million people and although not a highly seismic area several earthquakes in the magnitude range 5 to 7 have taken place close to the coast in the last 100 years. Staff numbers are shown below:

Prediction Centre		40
Institute	Induced seismicity)	
	Geology)	100
	Earthquake engineering)	
	Computing)	
Geodetic Brigade		70
Geophysical Brigade		50
Station operations		190
Seismograph factory (for micro-earthquake recorders and strong-motion equipment)		100
Administration and Transport		140
	Total	690

In addition to the 28 seismograph stations there are 9 radon stations, 6 volunteer deformation stations, 8 stress stations, 3 magnetic stations, and 1 gravity station. All earthquakes larger than magnitude three that occur within the Province are located.

One interesting magnetic method of earthquake prediction was to determine the constants in the equation:

$$\Delta H = a\Delta Z + b\Delta D$$

where ΔH, ΔZ, and ΔD are the sudden commencement amplitudes of magnetic storms and to see how they change in relation to the occurrence of large earthquakes. The workers claimed a correlation between these constants and major earthquakes, but I remained sceptical.

Other discussions with prediction workers dealt with the usual radon counts, stress measurements (using the Hast instrument in boreholes), and studies of foreshocks.

I was surprised at how much effort was put into earthquake analysis considering this is one of the most aseismic provinces in China.

Saturday 26 April

I said farewell to my hosts, caught the train to Hong Kong, and the plane back to Australia.

ACKNOWLEDGEMENTS

I would like to express my appreciation to the Australian Academy of Science and the Academia Sinica for enabling me to undertake this visit to China. Professor Zeng Rong-sheng, who accompanied me throughout and assisted with translations, contributed greatly to the success of my visit. I would also like to thank those officials at Beijing, Kunming, and Kuangchou whose names are listed in Appendix 1, and Wen Ta-tsun (Kwangchou), Hsia Wen-yi and Ding yun (Kunming), and Wu Ming-yun (Beijing), who acted as interpreters.

APPENDIX 1

Personnel met in China

Beijing

State Seismological Bureau

Institute of Geophysics

Director, Professor Kuo K.S.

Deputy Director Chung Jan-liu

Professor Zeng Rong-sheng

Gao Long-sheng - high pressure laboratories

Professor Qin Xin-ling - in charge of Beijing telemetry centre

Chon Ghin-ping	leader and geomagnetic expert)	
Bau Nai-ji	seismologist)	
Ni Wha-san	geomagnetic expert)	Main Beijing
Hu Dwing-guang	radon)	observeratory
Wang Yu-shien	radon)	

Seismograph Factory

Zhon Hon - designer of SQ-70 tiltmeter - engineer

Institute of Geology

Ma Jin	tectonophysics
Shao Xou-zun	converted waves
Chan Ry-xy	geothermal
Chan Ga-xy	converted waves
Wu Gen-ven	geothermal
Can yun	administration

Academia Sinica

Institute of Geophysics

Teng Ti-wen	explosion seismology

Institute of Geology

Professor Chang Wen-yu	Director

Kunming

Seismological Bureau of Yunnan Province

Tang Chen-yei	Director operations
Tang Posh-eng	isostatic anomalies in Tibet
Kan Rong-ju	focal mechanisms and stress
Han Yuan	seismicity and geology
Tong Wang-lian	leader of Kunming telemetry centre
Chen Li-de	earthquake precursors

Kwangchou

Seismological Bureau of Kwangtung Province

Ding Yun	administrator
Lon Yuan-lang	seismic station at Hsinfengchiang
Shou Zhe-wei	geodetic station at Hsinfengchiang
Zhou Kei-jing	leader of Kwangchou observatory
Wen Kuan-li	Earth tides
Pong Zhou-hsin	head of prediction centre

APPENDIX 2

Itinerary

Day Date	Morning	Afternoon	Evening
Wednesday 09	In Hongkong	Left Hong Kong by train (13.00) Arrived Kwangchou (16.00)	Left Kwangchou by plane (23.00)
Thursday 10	Arrived Beijing (03.00)	Visited Institute of Geophysics of State Seismological Bureau - high pressure laboratories and briefing	Dinner as guests of Institute of Geophysics
Friday 11	Visited Beijing telemetry network centre	Visited Beijing Observatory (Pai Chia-tang)	
Saturday 12	Visited Institute of Geophysics of Academia Sinica	Visited Beijing Museum of Geology	Visited Theatre.
Sunday 13	Visited Great Wall	Visited Ming Tombs and Beijing Zoo	
Monday 14	Presented lecture on Stress in Australian crust	Visited Beijing Seismograph factory and Academia Sinica Institute of Geology	Entertained four of my hosts to dinner
Tuesday 15	Presented lecture on Explosion Seismology	Visited Institute of Geology of State Seismological Bureau	
Wednesday 16	Travelled by plane from Beijing to Kunming	Visited Buddhist Temples at Kunming	Visited Theatre
Thursday 17	Visited Kunming Seismological Bureau at Kunming Observatory	Discussed Stress field in China and isostatic anomalies	Visited Theatre
Friday 18	Gave lecture on explosion seismology	Had discussions on Seismicity of Yunnan Province	Visited Theatre
Saturday 19	Gave lecture on Stress	Visited Kunming telemetry centre	Visited Theatre
Sunday 20	Travelled to Stone Forest by road	Visited Stone Forest in Karst country	Banquet given by Kunming officers
Monday 21	Discussed earthquake prediction at Kunming	Travelled to Kwangchou by plane (13.00)	
Tuesday 22	Travelled to Hoyuan by car	Travelled to Hoyuan by car	
Wednesday 23	Visited Hsinfengchiang reservoir and observatories	Travelled to Kwangchou	
Thursday 24	Gave lectures on Stress and explosion seismology	Visited Kwangchou observatory	Visited Theatre
Friday 25	Visit to Kwangchou Trade Fair	Discussion on earthquake prediction	Banquet given by Kwangtung Bureau
Saturday 26	Travelled by train to Hong Kong (08.30 - 11.30)	In Hong Kong	Travelled by plane to Sydney (23.00)

Appendix 3

A Short Account of the Chinese Academy of Sciences

translated by Catherine Donovan, Royal Society, London, UK

1. An Outline of the History of the Chinese Academy of Sciences (CAS)

The CAS was established on 1 November 1949. In the thirty years since then with the care and support of the Party and the State, there have been great developments in the scale of work of the CAS. Before the creation of the new China, the predecessors of the CAS - the old Central Research Academy and the Beiping Research Academy - had altogether only 21 scientific research institutions, including three in the social sciences. There were only just over 200 scientific and research workers, many academic and scientific disciplines were not covered, and there were almost no groups closely related to production or to newly emerging subjects in science. Now there are 113 institutions engaged in scientific research in the Academy with over 36 000 scientific and technical workers. The total number of people employed by the CAS amounts to 80 000. The research institutes carrying out social science research are now under the direction of the Chinese Academy of Social Sciences.

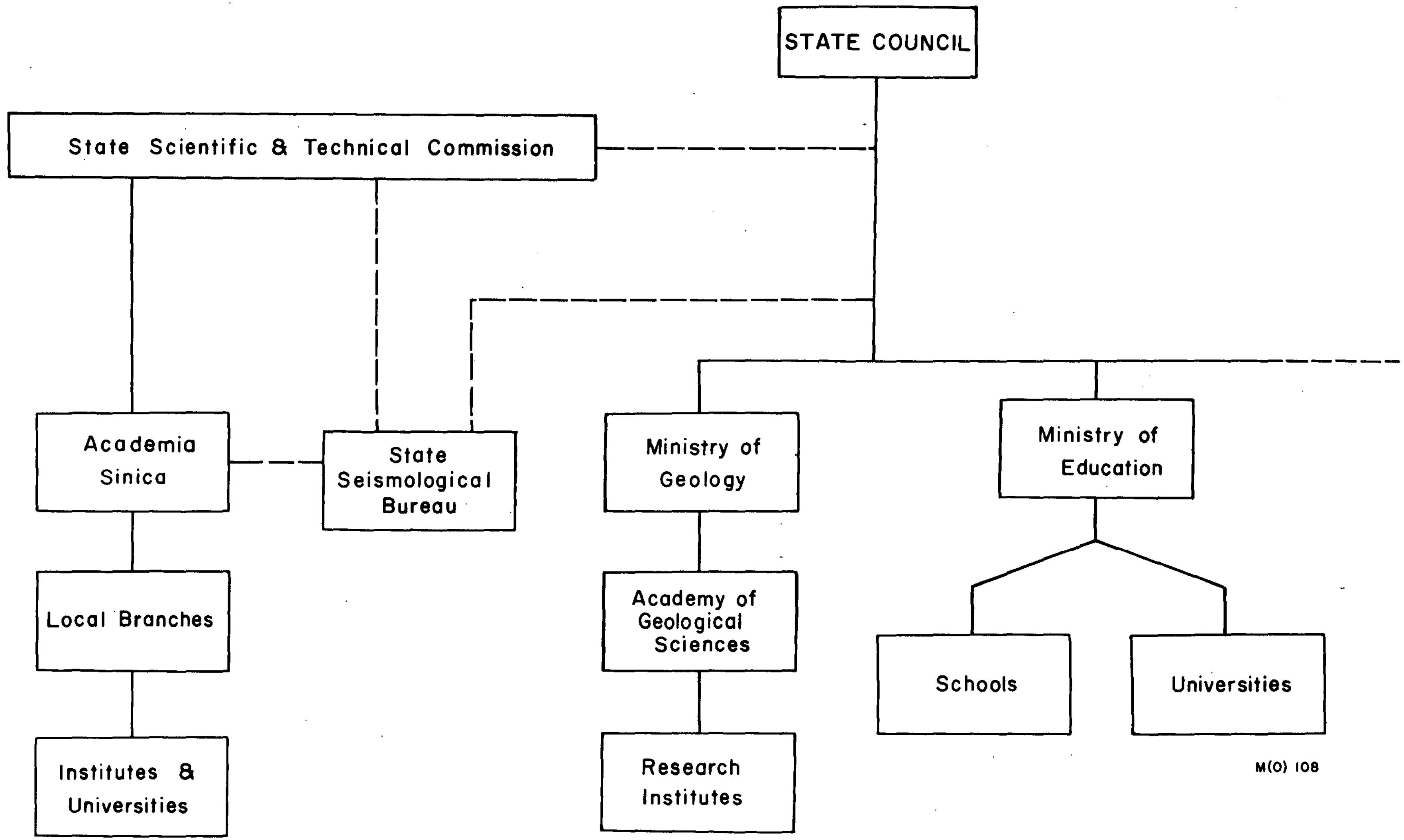
After its establishment the CAS continued to strengthen and expand and methodically broadened research into fundamental science, applied science and new technology, contributing many of its successes in science and technology to the development of the national economy. In 1956 China drew up its first long term plan for the development of science and technology (i.e. the 12 year plan from 1956-1967), and the CAS began to establish research institutes of semi-conductors, computing technology, automation, electronics and others, which had the effect of spearheading the development in China of new science and technology, at the same time raising the level of scientific research. In 1962 China completed the main tasks of the first 12 year plan five years ahead of time and drew up the second long term plan (i.e. the ten years from 1963-1972) to guide the further development of science and technology in our country. By 1965 CAS research institutes numbered 106 and there were over 22 000 scientific and technical personnel. In fundamental science and in the fields of some new technologies, the gap had narrowed between us and the advanced international levels. In fact some had nearly caught up with or actually did catch up with the international standards of the time.

However, in the ten years of upheaval caused by Lin Biao and the Gang of Four, the CAS suffered great damage and destruction. In 1973, there were only 53 research units left and only 13 000 scientific and technological workers. After the smashing of the Gang of Four a National Science Conference was convened. The Party and State proclaimed the glorious slogan 'Raise the Scientific and Cultural Level of the Whole Chinese People', thereby determining the correct policy for China's scientific and technological development, and drew up the third plan for the development of science and technology (i.e. the 8 year plan from 1978-1985). There emerged at the CAS a new situation of vigorous growth. In the last three years, the research institutes of the Academy have been revived and enlarged and have taken the first steps towards the formation of fundamental scientific and technological research programmes. Outstanding research personnel and advanced scientific results have continued to emerge.

2. The Organisation and Structure of the Chinese Academy of Sciences

The work of the CAS is directed by the President and Vice-Presidents. The President and Vice-Presidents are nominated by the Premier of the State Council and then each of them is separately appointed by the National People's Congress (NPC) and the Standing Committee of the NPC. Important decisions to be made by the President and Vice-Presidents of the Academy are first discussed at a meeting of the Council of the Academy. Persons attending the Council meetings are the President, Vice-Presidents, consultants to the Academy, the Secretary General, the Deputy Secretary General, the heads of each academic department, the heads of the Academy's branches, heads of the specialised committees, and the responsible persons of the chief administrative departments of the Academy.

The academic departments are the leading organs in academic subjects and are formed from the best scientists in the country. In 1955 the CAS established departments of mathematics, physics, chemistry; biological and earth sciences; technical sciences and philosophy and social sciences (the predecessor of the Chinese Academy of Social Sciences). The activities of these departments were curtailed during the Cultural Revolution, but are now renewing their work and adding to their members to further promote the academic leadership of the departments.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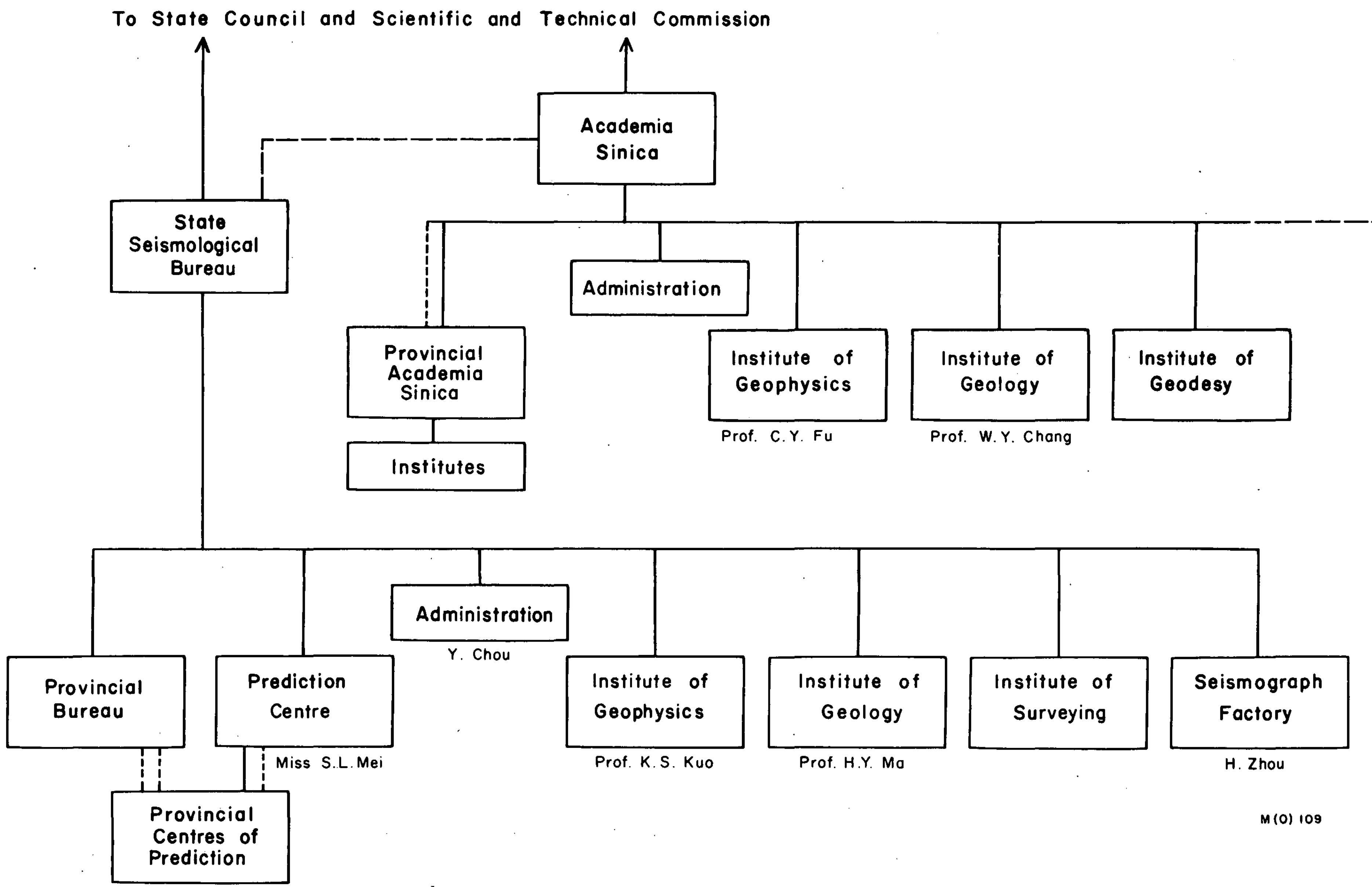
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Under the leadership of the President and Vice-Presidents, the Secretary General and the Deputy Secretary General have individual responsibility for the day-to-day organisation and administration of scientific research.

The administrative organisation of scientific research in the Academy is as follows:

Five special subject bureaux: (i) Biology, (ii) Mathematics, Physics and Astronomy, (iii) New Technology, (iv) Chemistry, (v) Geography and other scientific subjects. And also:

Planning Bureau
Basic Construction Bureau
Material Resources Bureau
Factories Bureau
Office for the Support of Agriculture
General Offices
Office of Policy Research
Bureau of Foreign Affairs
Education Bureau
Office in charge of cadres and other sections.

The research institute is the basic unit of the CAS, and is the primary organisation at which scientific research is carried out. Professional and administrative work of the institute is led by the Directors and Deputy Directors. The Director presides at meetings to discuss institute affairs and settles through discussion important questions affecting the institute. An academic committee has responsibility for academic work. Within the institute are the research laboratories and research discussion groups.

There are at present 113 research institutions under the CAS, divided according to subjects as follows:

Mathematics and Mechanics	5
Physics	12
Chemistry	15
Astronomy	8
Earth Sciences	20
Biological sciences	26
New Technology	23
Modernisation of Agriculture	3
History of Science and Technology	1

There are also ten scientific instrument factories, four universities and a postgraduate school associated with the China University of Science and Technology and the research institutes in Beijing. Apart from the above there are also libraries, publishing houses, etc.

The research institutions of the CAS are distributed among 21 provincial, municipal, and autonomous regions. In order to strengthen the leadership of the research institutions in each area and to improve the scientific and technological cooperation in the various places, the CAS has established branch academies in the provinces, municipalities, and autonomous regions where units are more concentrated.

3. The Main Research Tasks of the Chinese Academy of Sciences

The CAS is the country's national academic research organisation. It was determined at the National Science Conference that 'The CAS is the comprehensive centre of the nation's research into natural sciences. Its main task is to conduct research into and develop new theories and techniques in the natural sciences, and coordinate efforts made by various departments concerned in solving the important problems encountered in the course of economic construction. It must emphasise the laying of foundations and the raising of standards'.

Our country's scientific and technical bodies include the CAS, the higher education institutions, the production departments, the defence departments, and local scientific research establishments, each with their own work, yet cooperating and coordinating their efforts. The CAS is mainly engaged in research into basic science and the various newly emerging technologies. The subjects include the six big basic sciences of mathematics, physics, chemistry, astronomy, earth sciences, and biological sciences. They also include mechanics, computing technology, optics, material science, energy resources, mechanisation, high temperature physics, metal corrosion and protection, and other fields of science.

Under the guiding principles of service to the national economy and defence and the importance of laying firm foundations in science and raising scientific standards, the CAS conducts research into, and develops, new theories and techniques in order to serve the modernisation of our country.

In accordance with the plans for scientific and technological development and the division of labour within the existing scientific and technological resources, the CAS at the present time lays stress on the development of the following fields of research:

(i) In the Field of Basic Science

To develop the various branches of the following list and other research:

Pure and applied mathematics
Solid state physics
Theoretical physics
Acoustics
Organic polymer chemistry
Catalytic chemistry
Astrophysics
Solar physics
Geodynamics
Oceanography
Atmospherics
Molecular biology
Cell biology
Genetic engineering

The main task is to seek out the basic laws governing the movement of materials in the natural world, to promote knowledge of applied research and new technology and to cultivate scientific and technical personnel. For the long term development of science and technology to carry out the construction of large scale science engineering projects such as high-energy accelerators and astrophysics observation bases, and also to widen research into dialectics of nature and the history of natural science.

(ii) In the Field of New Technology

To develop comprehensive research into space science and technology.
To manufacture astronomical and earth resources satellites.
To carry out basic research, and application of, remote sensing technology.

To try to increase the rate of large-scale integrated circuits.
To carry out research into computer science and technology.
To develop new modern optical precision instruments.
To research into lasers, ultraviolet, low-temperature superconductivity and the handling of information.

(iii) <u>In the Field of Service to the Great Task of National Economic Construction</u>

To apply new theories and technology to research into plant breeding, pedology, fertilisers, and biological control.

On the basis of research into particular scientific techniques:

To carry out experimentation into the comprehensive modernisation of agriculture.
To integrate the special characteristics of China's mineral resources.
To carry out comprehensive exploitation and research into new materials.
To develop research into the formation and evolution of oil and natural gas.
To estimate long-term oil and gas resources.
To develop basic research and experimentation in harnessing solar energy, the gasification and liquefaction of coal, methane, and geothermal energy.
To undertake comprehensive interdisciplinary research into environmental protection.

(iv) <u>In the Field of Accumulating Fundamental Natural Science Materials</u>

To compile zoological and botanical encyclopedias and astronomical calendars.
To establish data banks in various subjects.
To carry out a comprehensive scientific investigation of natural conditions.

(v) <u>In the Field of Equipment for Modern Scientific Investigations and the Manufacture of Scientific Instruments</u>

Apart from the study and construction of various large-scale scientific experimental apparatus, also to study and manufacture various kinds of electron microscopes and other such instruments for precision analysis and exploration.

At the present time the CAS has 5000 subjects under research. The money allocated by the Nation towards research work increases year by year. This year 600 million renminbi was spent on research and construction.

4. <u>The Guiding Principles in Speeding up Scientific Development</u>

Acting in accordance with our country's policy in developing science and technology, the CAS is especially aware of the following points in promoting scientific and technological research:

(i) <u>To vigorously identify, nurture and utilise manpower</u>. To bring into play the beneficial aspects of scientists as academic leaders and to strive to bring up a new generation of scientists. To encourage middle-aged and young scientists to overcome the difficulties in science and strive to scale scientific heights. Establish strict examinations and promotion hierarchy, selecting and supporting the excellent and encouraging progress Adopt methods of combining work and study, of selecting postgraduates and students to study abroad and to speed up the nurture of personnel.

(ii) <u>To rely on scientists to strengthen their academic leadership</u>. To follow the advice and discussions of scientists when formulating policy for scientific development, determining important areas in science and technology, appraising important results and promoting senior scientists. Through the academic departments and academic committees of the various research institutes, to organise scientists to participate in the leadership of scientific research.

(iii) To speed up modernisation of the methods of conducting experiments. With the principle of changing our lives by our own efforts we must at the same time make positive efforts to bring in advanced instrumentation from foreign countries, systematically introduce modern laboratories in each scientific discipline, popularise the use of computers, ceaselessly renovate and utilise existing equipment, and accelerate the raising of scientific research standards.

(iv) To establish a scientific style of study. Practice is the sole criterion for the testing of scientific theories. We must increase scientific experimentation and promote research into theories. We must implement the policy of letting a hundred schools contend and encourage free discussion and different academic points of view. We must also encourage serious, rigorous, and disciplined work styles.

(v) To study earnestly advanced science and technology of foreign countries. By maintaining the policy of combining study of foreign material and our own independent discoveries, to hasten the pace of catching up with and surpassing internationally advanced standards. With regard to the import of foreign technology and methods the policy should be first to learn, second to apply, third to adapt, and fourth to invent. We must also study the advanced experience of foreign countries in scientific administration.

(vi) To deepen the study of scientific development policy. To take into account the practical situation of our country together with the developmental trends of international science. To determine scientific policy, identifying the fields for priority development, distributing manpower and resources fairly in order to give impetus to the overall development of scientific research.

(vii) To improve the method and system of the administration of scientific research. We must endeavour to administrate in accordance with the rules for scientific development, paying attention to encouraging the spirit of positive effort, initiative and innovation of the institutes in developing scientific research. We must extend the autonomy of large institutes and gradually change the administrative system where power is concentrated too much at the top and where there is excessive bureaucracy.

(viii) <u>To speed up the popularisation and application of scientific results.</u> Science and technology is a productive force and our research work is, in the last analysis, directly or indirectly, in the service of developing production, at present and in the future. We should mainly rely on the production departments of agriculture and industry to promote cooperation and to carry out the work of popularisation, but should at the same time carry out in a small way essential intermediate testing and small scale production.

(ix) <u>To be concerned for the personal lives of scientific and technical personnel</u>. The party and Nation are very concerned for the wellbeing of scientific and technical personnel. We must try our best to improve their working and living conditions so that they can carry out their work more singlemindedly and effectively.

5. <u>Academic Exchanges with Foreign Countries</u>

At present, the CAS has academic contacts with many countries and has signed bilateral agreements on cooperation with over ten of them. A few years ago there were only a few hundred people travelling to and from China on academic exchanges but now there are over a thousand. The various forms of cooperative exchange are roughly as follows.

(i) On intergovernmental scientific and technological agreements the CAS takes responsibility for those areas which directly concern their field of work.

(ii) The CAS itself enters into formal and informal agreements with the scientific academies, or equivalents, of foreign countries, and there is a mutual exchange of scientific and technological investigating teams, comprehensive delegations, or individual scientists and academic materials.

(iii) The CAS selects and sends research workers and academics to study and work in relevant institutions abroad. It invites foreign scientists to lecture or conduct joint research in China, and engages foreign scientists to take up employment as honorary research professors.

(iv) The CAS joins international academic organisations and attends international academic conferences.

(v) It organises bilateral and international symposia with foreign scientific research organisations.

(vi) It initiates the exchange of books and periodicals between CAS libraries and their counterparts abroad.

The cooperative relations between the CAS and foreign scientific and academic organisations are continually developing and together we are creating yet more forms of academic exchange and cooperation.

The CAS has contributed greatly to the development of China's science and technology since its founding thirty years ago. After surviving the destruction and complications wrought by Lin Biao and the Gang of Four, it is now once again on the path of healthy expansion.

Under our country's excellent circumstances of 'stability, solidarity and the carrying out of the four modernisations', all the scientists and administrators in the CAS are hard at work. They are studying modestly the experience of various advanced countries and we are full of hope that we shall accelerate our pace in catching up and surpassing the advanced scientific and technological levels in the world, making great sacrifices in order to make our country a thriving, prosperous and powerful modern socialist country.

November 1979